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6 GEOCHEMICAL CHARACTERIZATION OF INORGANIC RESIDUES ON
7 PLASTER FLOORS FROM A MAYA PALACE COMPLEX AT ACTUNCAN, BELIZE
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Abstract

This report describes the results of a geochemical analysis using a mild acid extraction and inductively coupled plasma-mass spectroscopy of 198 samples from plaster surfaces at the palace complex at Actuncan, a prehispanic Maya city located in a karst landscape of western Belize. Archaeologists working in the Maya region of Central America often refer to many different kinds of building complexes as “palaces” without a clear understanding of how they functioned. Often, the rooms inside these structures are devoid of features and artifacts, making it difficult to infer how they were used. Geochemical characterization of inorganic residues on plaster floors as a means of prospecting for activity areas is therefore critical for studying the function and meaning of ancient Maya palaces. At Actuncan, due to the high degree of preservation of many of the floors, overlying plaster surfaces were able to be sampled, thus informing not only how the buildings were used, but how their uses changed over time. Multivariate quantitative modeling and spatial interpolation of the chemical data demonstrate that a variety of domestic, ritual, and possibly administrative activities took place in the palace complex, a finding that challenges previous assessments of palaces as primarily royal residential compounds.

47 Keywords

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49 Sediment chemistry, Plaster technology, Household archaeology, Royal palace, Ancient Maya,

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1. Introduction

Archaeologists working in the Maya region call many different buildings and building complexes “palaces” without a clear understanding of their varied functions. As Harrison (2003:100) points out, the term “palace” is borrowed from the European lexicon and its use implies their primary function was as aristocratic residences as opposed to religious temples, meeting halls, or storage facilities. However, the real situation was more complex, as Maya palaces were multi-functional spaces where elites lived, the royal court met, and civic and ritual activities took place (Inomata and Houston 2001). While some large agglutinated structures, such as those found at Tikal or Copán (Harrison and Andrews 2004), served many functions, other constructions that Mayanists have called palaces are smaller and may have served more specialized functions (Webster and Inomata 2004).

Sorting out the functions of buildings and the rooms inside them requires an understanding of the location, size, and shape of the complex; the layout and features of its rooms; and artifacts or residues left inside them (Christie 2003). Palace rooms themselves are often devoid of features, other than benches, and their shape and location within a room block do not offer many clues as to the kinds of activities performed within them. In addition, the ancient Maya often swept clean civic-ceremonial and domestic spaces. Therefore, chemical residue analysis of floors provides essential data to reconstruct the activities that took place in palaces (Wells et al. 2000).

This report describes the results of geochemical characterization of 198 plaster samples from living surfaces in the palace complex at the ancient Maya settlement of Actuncan, Belize (Figure 1). We seek to understand the behavioral significance of the deposition and distribution of

chemical elements that can be linked through ethnoarchaeological and experimental studies to a variety of human activities involving food preparation and consumption among other activities (Barba and Ortiz Butrón 1992; Barba et al. 1995; Wells and Moreno Cortés 2010; Wells and Terry 2007).

Three areas of the palace complex were sampled for geochemical residues (LeCount 2013). Structure 19 (n=102) is a range structure, while Structures 21A/21B (n=39) and 22 (n=60) are buildings that form a patio attached to the north side of Structure 19 (Figure 2). Samples derive from sections of plaster floors and date to the Terminal Preclassic, ca. 100 B.C.-A.D. 300 and Late Classic, ca. A.D. 600-780, periods. The objective of this study is to investigate chemical patterns indicating activity loci in each area and to compare patterning between spaces and through time. The greater goal of this effort is to better understand how the palace functioned at Actuncan and the corresponding implications for sociopolitical and economic organization.

2. Geochemical residue analysis

2.1. Sediment chemistry

Recent advances in geochemical characterization of soils and sediments from archaeological contexts demonstrate that a broad range of inorganic chemical residues are preserved as insoluble oxides, sulfides, and carbonates on prepared surfaces at prehispanic settlements in southern Mesoamerica (Anderson et al. 2012; Canuto et al. 2010; Cook et al. 2006; Coronel et al. 2015; Dahlin et al. 2007; Eberl et al. 2012; Fernández et al. 2002; Fulton et

al. 2013; Hutson and Terry 2006; Inomata et al. 2001; Luzzadder-Beach et al. 2011; Parnell et al. 2002; Terry et al. 2004; Wells 2004; Wells et al. 2007). This research is possible, because different human activities result in the deposition of specific chemical compounds onto activity surfaces. Through processes of cation exchange, adsorption, and complexation, the chemical constituents of activity residues become a permanent part of the archaeological record (Wells 2006; Wells et al. 2013).

Phosphates, in particular, have long been recognized as markers of human settlement and activities involving the deposition of organic matter (Arrhenius 1931; Holliday and Gartner 2007). More recently, archaeologists have discovered that many other chemical residues, especially metals and trace elements, can be recovered from archaeological surfaces and that these residues can be associated with specific activities (Entwistle et al. 2007; Middleton and Price 1996). Several analytical techniques have been developed for the field (e.g., Eidt 1985; Terry et al. 2000) and laboratory (e.g., Abrahams et al. 2010; Middleton 2004) that allow for the extraction of anthropogenic fractions or total digestion of sediments to facilitate chemical characterization. Most recently, portable X-ray fluorescence spectrometry (see Shackley 2011) has been applied to sediments and plasters in attempts to further enhance the analytical process (Coronel et al. 2014; Johnson 2014; McCormick and Wells 2014).

2.2. Plaster surfaces

In the Maya region, plaster floors are ideal surfaces from which to extract chemical residues, since they are often composed of lime-based (calcium carbonate) plaster, a calcareous surfacing that traps and preserves a variety of chemical compounds over very long periods

(Barba 1990, 2007; Hutson and Terry 2006; Pecci et al. 2010; Wells 2004). Inorganic phosphate and potassium compounds, for example, are retained in these earthen materials by binding with complex aluminum- and iron-containing minerals, such as apatite clays (Albert 1986). The extremely small size of clay particles ($< .002$ mm) correlates with small pore sizes between clay platelets, and the relatively high surface tension in these pores can result in mechanical binding of phosphates and other chemicals (Hausenbuiller 1972:266–270).

The sediments for the present study derive from magnesium limestone substrates (containing magnetite, calcite, and dolomite), with naturally elevated concentrations of calcium, magnesium, and strontium. The clay minerals are hydrous aluminosilicates produced by the disintegration and chemical decomposition of sedimentary rocks. The three major clay groups in this region of Belize include kaolinites, illites, and montmorillonites, which contribute elevated levels of aluminum and, in the case of illites, potassium, to soils and sediments. In this study, the samples derive from two kinds of surfacings: lime plaster and a type of weathered limestone locally referred to as *sascab*.

Lime plasters consist of a binder (clay, lime, or gypsum), an aggregate (sand or crushed stone), and additives (such as plant ash or volcanic ash) combined in varying proportions according to their intended application (see Abrams et al. 2012; Hansen 2000; Littmann 1962; McVey 1998; Russell and Dahlin 2007; Villaseñor 2010). Lime is produced from the calcination of limestone (calcium carbonate, CaCO_2). When heated to approximately 800-900 °C, the calcium carbonate decomposes into carbon dioxide and quicklime (finely powdered calcium oxide). With the addition of water, a process called “slaking” or hydrating, the mixture yields a product known as slaked lime calcium hydroxide. Exposure to the air allows the evaporation of water and adsorption of carbon dioxide, eventually hardening the plaster to a solid mass.

Sascab (calcium carbonate in an unburnt state) was sometimes used instead of lime plaster on occupation surfaces. Referred to in historical accounts as “white earth” (Wells and Mihok 2010:19), *sascab* is the product of the natural weathering of limestone and is found in pockets underneath the caprock. Archaeological research has revealed that *sascab* was employed in the construction of buildings, as a protective layer for some patio and plaza floors (e.g., Barba 2007; Wells 2004), and especially for roads (*sacbe*) throughout the Maya region.

2.3. *Expectations for Maya palaces*

In the Maya region, geochemical prospection has seldom been employed to reconstruct activities in and around palaces. However, three recent projects provide insights into our research at Actuncan and help to frame testable implications for the present study. First, Wells and colleagues (2000) investigated chemical patterning on patios and interior floors of an elite residential complex on the eastern edge of the South Group Plaza at the Late Classic city of Piedras Negras in northwestern Guatemala. Using Mehlich II and DTPA extraction with ICP-AES, they identified areas of food consumption on terraces outside of rooms based on significantly higher levels of phosphorus and potassium compared to off-site (background) samples (Wells et al. 2000:456). Notably, these patterns were absent around the entryways to ancestor shrines and temple substructures in the complex, suggesting that these areas were kept clean of refuse (Wells et al. 2000:457–458). By matching the chemical record of sediments with the locations of artifacts, they were able to associate various types of craft production (chert and obsidian tools, iron pyrite mirrors, and possibly textiles) with heavy metals, such as iron and manganese (Wells et al. 2000:456). Finally, the combination and concentrations of iron,

mercury, and copper recovered from the bases of exterior building walls suggest the possibility that building facades were once painted (Wells et al. 2000:456–457).

The second project, carried out by Inomata and colleagues (2001; see also Terry et al. 2004), explored elite palace activities at the rapidly-abandoned Late Classic city of Aguateca in northern Guatemala. The team sampled interior floor spaces throughout the palace group and analyzed sediments using the same extraction and characterization procedures as Wells and colleagues. Inomata's group found evidence for high levels of iron on the floors, suggesting that the surfaces were painted red with hematite (iron [III] oxide, Fe_2O_3 ; Inomata et al. 2001:298). Low levels of phosphate undifferentiated by room suggest that food was prepared and possibly consumed elsewhere (Inomata et al. 2001:300). Adjacent to the palace group, the team also investigated a number of elite residences (Inomata et al. 2001:1243–1244). The central room of one building, argued by Inomata and colleagues to be a courtly room for political gatherings, was chemically undifferentiated from background samples. The northern room contained utilitarian ceramics, very high phosphorus concentrations, and low levels (relative to background samples) of metals, suggesting food storage or preparation activities. The southern room contained mosaic pieces of pyrite mirrors, low phosphorus, and high levels of metals (especially Fe, Cu, Mn, Pb, and Zn), indicating craft production.

Finally, Cook and colleagues (2006) examined soil chemical patterns around residences and workshops near the palace group at the Classic Maya city of Cancuén in central Guatemala. They used nitric acid with microwave digestion along with ICP-MS for characterization of heavy metals and rare earth elements. They found mercury enrichment on several occupational surfaces, indicating the presence of cinnabar (red mercury [II] sulfide, HgS). While the highest levels of mercury were found associated with special deposits, such as human burials and ritual

200 caches, broader-scale enrichment across the floors suggests that mercury was also involved in
201 other activities, possibly including craft production (Cook et al. 2006:636–637).

202 Given the findings from these prior studies, at Actuncan we might expect to find palace
203 rooms separated by function, with some rooms (e.g., the central room, as at Aguateca) reserved
204 for administrative and political activities and other rooms (such as the ancillary spaces and
205 buildings at Piedras Negras and Cancuén) used for a range of domestic activities, including food
206 preparation and craft manufacture. Moreover these and other studies (Colomban et al. 2010;
207 Holliday and Gartner 2007; Vandenabeele et al. 2005) demonstrate that activity areas can be
208 identified based on the combinations and concentrations of different extractable chemical
209 elements associated with specific types of deposits on floors, specifically: organic matter (K and
210 P), plant ash (Na, Mg, Ca, K, and P), and mineral pigments (Ti, Fe, Cu, Zn, and Hg). Since some
211 of the surfaces represent lime plaster floors, the possibility exists that plant ash or other organics
212 added to the plaster during the production process may comeingle with anthropogenic residues
213 (see Villaseñor 2010). However, based on archaeological research (Hauptmann and Yalcin 2000)
214 and experimental studies (Goodman 1998), we anticipate that those additives would only be
215 present in very low (e.g., <5 ppm) concentrations and be spread relatively evenly across the
216 surfaces. As such, we do not expect these formation processes to interfere with the detection of
217 activity areas in our study. Finally, it is important to note that the plaster floors derive from karst
218 features that largely represent magnesium limestones containing naturally occurring
219 concentrations of calcium, magnesium, and strontium. Without separate compositional study of
220 local limestones, the sources and extent of spatial variation in these elements cannot be
221 adequately predicted. As such, we suspect that these elements will be difficult to use for
222 identifying activity areas.

3. Actuncan in context

3.1. Environment

The central Belize karst (Cretaceous to Early Tertiary period limestones, dolomites, and marls) covers about 200 km² in an 85 km-long east-west belt located north and west of the Maya Mountains and south of the Belize River Valley. In western Belize, the karst extends 45 km southward toward the Vaca Plateau and the Chiquibul River. From San Ignacio eastward, the karst is about 25 km wide. Elevations within the karst range from less than 100 m amsl close to the coast to about 500 m amsl on the Vaca Plateau. Actuncan is perched on the edge of a T-3 alluvial terrace overlying karst that edges the Mopan River, which links to the Macal River a few kilometers to the north and drains into the larger Belize River. The Mopan and the Macal dissect the west-central karst into blocks of rugged upland terrain with enclosed depressions, residual hills, and valley systems (Day 1993). The intervening river valleys have broad alluvial floors with cliffed margins. The plateau, which increases in elevation from about 400 m in the north to roughly 700 m in the south, has relatively uniform summit elevations but with steep (100-150 m) local reliefs (Miller 1996).

The primary geomorphological features of the region include Quaternary alluvial and colluvial deposits, shallow closed-depressions, and seasonal swamps (Beach et al. 2008). Soils overlying the karst terrain are predominantly calcareous mollisols and vertisols (Beach et al. 2003; King et al. 1992). Soil profiles in the region tend to be less than .5 m thick, although at Actuncan our probes on the T-3 terrace reached depths of 3 m or more to the water table. In the

main valleys, alluvial soils are mostly acidic (pH 5.5-6.5) reddish-brown clays and sands. Over the limestone is a species-rich, broadleaved, deciduous seasonal forest, which contains a wide variety of wildlife (Furley and Newey 1979). During peak rainfall in July, the region receives on average 1500 mm of rain.

3.2. Culture history

Human occupation of the region stretches back to the Preclassic period (ca. 1000 B.C.-A.D. 300). By the Classic period (ca. A.D. 300-1000), the region supported at least 20 civic-ceremonial centers, including the well-known centers of Caracol and Xunantunich. Actuncan is situated 2 km north of Xunantunich, the Late Classic regional capital. The first systematic investigation of Actuncan was conducted by McGovern (2004) in the early 1990s when he mapped the 14-ha site using a total station, documented building sequences by profiling looters' trenches, and tested eight civic structures with excavation. He divided the site into two sections: Actuncan South and Actuncan North (the focus of the present study). Actuncan South is dominated by a Preclassic temple complex rising 28 m above Plaza A. It is connected to Actuncan North by a wide causeway that opens into Plaza C, a large formal space containing a ball court, range structures, and pyramids. Smaller plazas with civic monuments and elite residential compounds are located on the eastern periphery of Plaza C, and a commoner settlement is situated to the north of Plaza H.

The goal of the current Actuncan Archaeological Project is to examine the changing strategies of leadership over the site's 2000 years of occupation from the perspective of households, including that of the rulers. To date, the project has excavated all major domestic

structures including six commoner patio-focused groups, three elite residences, and the palace complex that is the focus of this study. In 2012, excavations focused on the centrally located range structure, Structure 19, and the ancillary constructions attached to the northern side of this building, which collectively form Actuncan's only palace complex, known as Group 8. Reconstructions of residential layouts, as well as household developments, are based on deep vertical excavations into each residential structure along with horizontal excavations across domestic floors.

Based on both civic and residential construction sequences, we suggest that Actuncan experienced multiple episodes of growth and diminution suggestive of shifts in regional power through time. Most households were founded in the Terminal Preclassic period, when an earlier Middle to Late Preclassic (ca. 1000-400 B.C.) settlement was buried and much of the civic core was renovated as a royal center. Sometime in the Early Classic period (ca. A.D. 300-600), authority shifted to nearby communities, first to Buenavista del Cayo and later, to Xunantunich. During this hiatus in power, Structure 19 fell into disrepair only to be renovated to form Group 8 when Xunantunich became the regional capital in the Late Classic (ca. A.D. 600-780). In the Terminal Classic period (ca A.D. 780-1000), Xunantunich, along with much of the Mopan Valley hinterland, experienced demographic decline and eventual abandonment, sparking a political resurgence at Actuncan (LeCount and Yaeger 2010:365; Mixter et al. 2014). Population decline does not appear to have occurred at the site until later, during the Postclassic period (ca. A.D. 1000-1500).

Beginning in the 1880s, the region surrounding Actuncan was occupied by subsistence farms (Leslie 1987). Completion of the major highways in the 1950s encouraged timber extraction in the region and population growth. Residential and agricultural development in the

region increased slowly from the 1960s to the present. Today, the primary ruins of Actuncan are located on a private farm intermixed with cattle pasture. Portions of the site are periodically under cultivation, including the area around the main palace complex. Most recently, much of the site including the palace complex was planted with grass nutritionally beneficial to cattle. There is evidence of possible looting on Structure 22, but these activities do not appear to have disturbed the buried occupational surfaces under investigation.

4. Sampling design and analytical methods

4.1. Field sampling

To investigate activities that took place within the palace complex, we collected point samples across all exposed occupation surfaces, following protocols described by Barba (2007) and Wells (2010). Overall, 198 samples were taken at regular .5 m intervals across floor surfaces using a staggered lattice design (see Wells 2010:213–214), unless otherwise interrupted by interior walls. Additional opportunistic samples were taken when warranted by the excavation, for example, when a discolored patch was encountered on a floor. In addition, we took eight background (“control”) samples from a range of landforms and depositional contexts within approximately 2 km from Actuncan. These samples were selected from subsurface horizons at least .25 m below current ground surface in undisturbed areas. Both sets of samples (archaeological and control) were taken with a clean trowel, placed directly into sterilized Whirlpak bags for storage, and later transported to the University of South Florida for analysis.

4.2. Laboratory Analysis

For this study, a ca. 1.00 g portion was taken from each sample, pulverized with a Coors porcelain mortar, mixed with 10 ml of .60-molar hydrochloric acid (trace metal grade) with .16-molar nitric acid (trace metal grade) in a phosphate-free polyethylene scintillation vial, and shaken vigorously on an electronic shaker at 220 rpm for 30 minutes. We decided to use a mild acid extraction (following Lewis et al. 1993) instead of total digestion of the sample, because the mineral constituents of the plaster from a digestion would overwhelm the anthropogenic contributions (see Middleton 2004). For each sample, the solution was filtered using Whatman ashless (.007 percent) filter paper and decanted into clean polyethylene vials. The extracts were then diluted with ultrapure deionized water (type I reagent grade 18 Megaohm*cm⁻¹ resistance) to bring the concentrations of the elements of interest into the optimal measurement range of the instrument. All samples were analyzed using a Perkin Elmer Elan II DRC quadrupole inductively coupled plasma-mass spectrometer (detection limits from 0.1 ppt [0.1 ng/L] to 1 ppb [ug/L] for most elements) at the Center for Geochemical Analysis at the University of South Florida. For calibration, known solution standards containing the elements of interest in concentrations bracketing the expected concentrations of the sample were processed during the analysis.

The calibrated concentrations of 21 elements were determined: sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba), titanium (Ti), vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), yttrium (Y), mercury (Hg), uranium (U), aluminum (Al), lead (Pb), and phosphorus (P). The results are reported in parts per million (ppm), or mg element / kg matrix (mg kg⁻¹). Calcium is not included in the discussion that follows, because the samples derive from limestone (calcium

carbonate, CaCO₃) plaster surfaces; as a result, it is impossible to differentiate anthropogenic impacts from natural formation processes. In addition, we do not discuss V, Cr, Co, Y, and U, since their concentrations were generally very low and their behavioral significance has not yet been established.

5. Results

A total of 198 samples were analyzed for this study, each deriving from a unique provenience at Actuncan's palace complex. The data show ≤ 5 percent variation on the NIST CRM (U.S. National Institute of Standards and Technology Certified Reference Material) for all standards and samples (including replicates), and ≤ 5 percent error on internal quality control (blanks). For the analyses discussed in this section, we converted ppm to base-10 logarithms for comparability, since natural abundances of elements tend not to have normal distributions but to be positively skewed and log-normally distributed (Burton and Simon 1993:48). Summary statistics (mg kg⁻¹) for the 21 elements appear in Table 1. As indicated in the table, the mean for each element in the archaeological samples is statistically significantly different from that in the control samples (where $p < .05$ in pairwise comparisons), except for Mg ($p = .212$), Cu ($p = .764$), and Hg ($p = .096$).

5.1. Structure 19 (range structure)

Excavations at Structure 19 encountered three phases of construction, but the project did not reach culturally sterile soil. Here we describe the last version of the building, Structure 19-1st,

and the terminal rooms on the summit, but also present limited data on 19-2nd and 19-3rd, which were found through a deep sounding excavated through the floor of the central room of the summit architecture.

The eastern half of Structure 19-1st was cleared, exposing three rooms (Figure 3). Because the Maya often built their room blocks symmetrically, we assume that there are two additional rooms to the west of the centrally placed Room 3. Structure 19-1st was occupied over many hundreds of years. It was initially built in the Terminal Preclassic period, but renovated repeatedly during the Late Classic period. Room 1, on the eastern end of the summit structure, was a small room with a bench. Its terminal floor (called “Blue”) was in good condition, located only about .35 m below the current ground surface and presented no evidence of intentional filling or disturbances of any kind. To the west of Room 1 is Room 2, which includes a bench that is preserved in the west half of the room, but destroyed, likely by a fallen tree, in the east half. Blue Floor extended into Room 2, but was resurfaced sometime later in the Late Classic period. We call this resurfacing “White” Floor. Room 3 is located on the central axis of the structure. A long bench extends across the entire back of the room, leaving a .60 m deep floor space. Before the structure’s abandonment, both Rooms 2 and 3 were filled in a similar fashion, preserving the plaster surfaces on both the bench and the floor of Room 3.

Below Structure 19-1st are two earlier versions of the range structure. These phases were investigated by excavating down 4.70 m through the central staircases and the floor of Room 3. The surface of 19-2nd is represented by a plaster floor (“Purple”) located under 2.30 m of fill below Room 3 that had three areas of burning, but with no artifact concentrations. A construction floor (“Sac”) composed of *sascab* was exposed in the fill of 19-2nd. The plaster floor (“Gray”) of Structure 19-3rd was encountered at about 2.65 m below the chert cobble fill of 19-2nd. The

surface was a fairly substantial plaster floor that replaced an eroded and slumped floor (“Tan”) about .12 m below. A charcoal sample from Tan Floor yielded a radiocarbon date of cal. 2σ A.D. 130-317 (NOSAMS-99777), and ceramics recovered from the fills of Structures 19-2nd and 19-3rd place their construction and occupation in the Terminal Preclassic period, although Purple Floor may date to the earliest phase of the Early Classic period. In sum, six surfaces from Structure 19 were found, from highest (youngest) to lowest (oldest): White, Blue, Purple, Sac, Gray, and Tan. White and Blue are associated with Str. 19-1st, Purple and Sac with Str. 19-2nd, and Gray and Tan with Str. 19-3rd. We focus our discussion on chemical patterning on the best preserved surfaces with the most exposure: Blue (which includes White Floor in Room 2) (Late Classic), Purple (Early Classic or Late Terminal Preclassic), Gray (Terminal Preclassic), and Tan (Terminal Preclassic). Sac surface appears to be devoid of anthropogenic residues.

Standardized (base-10 logarithms) distributions of all chemical data for Blue and Purple floors are normal (Kolmogorov-Smirnov test, $p > .01$) and, as expected, the variances are not homogenous between floors (Levene’s test, $p \leq .01$). The highest relative variation in the data can be seen with Ti, Hg, Al, and Pb. Aside from Al, which is a natural component of local clays, the high degree of variation in these distributions is likely caused by generally low concentrations of the elements. The distribution of P also varies to a relatively high degree, from .66-21.36 mg kg⁻¹, with coefficients of variation ranging from 48 percent (on Purple) to 92 percent (on Blue). The distributions also present a large number of outliers (cases $\geq 1.5 \times$ midspread), especially on Blue, which indicate discrete (non-overlapping) activity areas. Pearson linear coefficients between elements for Blue and Purple indicate correlations between a range of elements, although significant ($p \leq .01$) strong positive correlations ($r \geq .70$) tend to be between the transition metals Fe, Ni, Cu, Zn, and Hg.

Standardized (base-10 logarithms) distributions of all chemical data for Gray and Tan floors are normal (Kolmogorov-Smirnov test, $p > .01$), the variances are homogenous (Levene's test, $p > .01$), and the distributions lack outliers. This suggests that activities on these floors may have been somewhat homogenous and/or overlapping. As with Blue and Purple floors, Ti, Hg, Al, and Pb have the highest degree of relative variation, due to their lower concentrations compared to major elements. Phosphorus varies to a similar extent as Blue and Purple, from 1.06-18.78 mg kg⁻¹. Pearson linear coefficients for Gray and Tan indicate a large number of both strong positive ($r \geq .70$) and strong negative ($r \leq -.70$) correlations, suggesting again that activities on these surfaces likely overlapped. All of these observations, however, must be tempered with the low sample sizes from Gray ($n = 8$) and Tan ($n = 4$), which render conclusions somewhat tenuous regarding these surfaces (although Spearman's rank correlation coefficients, often used with small sample sizes, are consistent with these findings).

Given the observed differences in the use of space between Blue/Purple and Gray/Tan, we performed a one-way analysis of variance (ANOVA) on the chemical data from each floor to examine whether or not Blue and Purple could have supported the same kind of activities compared to Gray and Tan, and equally if Gray and Tan could have shared the same sets of activity residues. The results of the ANOVA and Games-Howell post-hoc test results (showing which floors may be considered similar or different with regard to their activity residues at the $\alpha = .01$ level) appear in Table 2. We chose the Games-Howell test, because it accounts for different sample sizes and variances. The ANOVA results indicate statistically significant differences among all elements ($p < .01$), except Mg ($F = 1.049$; $df = 3, 87$; $p = .375$) and Hg ($F = .506$; $df = 3, 87$; $p = .679$). As noted previously, the concentrations of Mg and Hg do not appear to differ significantly from our background samples. The post-hoc test results show that Blue and Purple

are largely similar in terms of the distributions and concentrations of chemical elements associated with human activities (including P but excluding K that may be enriched by local illite clay minerals), and that these floors are distinct from Gray and Tan, which are themselves similar to each other (except for Mg and Ca) in terms of their residue chemistry.

Given the results of the ANOVA, we performed a discriminant function analysis to evaluate the idea that Blue and Purple are chemically linked, that Gray and Tan are chemically linked, and that Blue/Purple and Gray/Tan are distinct from each other. A scatterplot of the results appears in Figure 4, with the first two canonical discriminant functions accounting for 93 percent of the variance. As displayed in the axes, Function 1 (explaining 65 percent of the variance, canonical $R^2 = .83$) is weighted most heavily by Ba (alkaline earth metal) and Fe and Hg (both transition metals), while Function 2 (explaining 28 percent of the variance, canonical $R^2 = .69$) captures mostly the variation in Na and K (alkali metals), Mg (alkaline earth metal), and Mn (transition metal). These two sets of elements are not geochemically related, and so their deposition may be anthropogenic. For example, it is well known that the Maya used ochre (hematite or ferric oxide, Fe_2O_3) and cinnabar (mercuric sulfide, HgS) in ritual practices. The presence and differential distribution of Fe and Hg on Blue/Purple may indicate the use of these minerals in activities on these surfaces. In contrast, Na and K are often associated ethnographically with the deposition of wood/plant ash (especially potash), indicating the combustion of organic matter such as through ritual burning events. Thus, it is possible that incense burning, for example, may have characterized an alternative set of activities on Blue/Purple, spatially distinct from the use of cinnabar and ochre. Table 3 displays the classification results for these two functions that correctly classified approximately 97 percent of

the samples according to the floors from which they were excavated. This strongly suggests that the two functions we identified are useful discriminants of activity residues in these spaces.

To illustrate these results, Figures 5 and 6 show boxplots of the main differences, comparing Blue and Gray. Figure 5 shows that the later Blue Floor has overall lower concentrations (and more contracted ranges) of P (.66-9.09 mg kg⁻¹) and K (1.24-7.91 mg kg⁻¹), associated with the deposition of organics, compared to the earlier Gray Floor (P: 1.70-18.78 mg kg⁻¹, K: 4.74-19.68 mg kg⁻¹). The patterns from the Terminal Preclassic floors are consistent with what we would expect to find if these areas were used for food production and consumption, such as through feasting events (LeCount 2001). Figure 6 shows that, while Blue and Gray floors share similar concentrations of transition metals (Ti, Ni, Cu, and Zn), associated with mineral-based pigments (e.g., ilmenite [FeTiO₃], millerite [NiS], malachite [Cu₂CO₃(OH)₂], sphalerite [(Zn,Fe)S]; all deriving from limestone/dolomite host rocks), the distributions for Blue Floor have numerous outliers (1.5-3.0 x midspread) and extreme values (> 3.0 x midspread). If these metals derive from mineral-based pigments, as suggested by other studies (Davis-Salazar 2003; see also Goffe 2007:62–75), then these contrasts may indicate that activity patterns on Blue Floor were discrete while those on Gray Floor were more homogenous in character. Moreover, the nature of the mineral pigments themselves suggest that these activities would have involved colors important to the Maya, including black, yellow, and green/blue (Houston et al. 2009).

Finally, we examined the horizontal distribution of the concentrations of different chemical elements to identify original activity locations. Due to the sampling design, we are only able to consider broad distributions for Blue Floor; the sampling loci of the other surfaces are too discontinuous to reasonably interpolate chemical signatures compared to Blue Floor. Figures 7 and 8 show examples of these distributions highlighting P (associated with organics) and Fe

(associated with minerals). Darker hues of red indicate higher concentrations of the element. However, higher elemental concentrations do not necessarily reflect the intensity or longevity of the activity responsible for the deposition of that element, since these characteristics are affected by numerous long-term formation processes that differentially impact elemental adsorption (see Bethell and Máté 1989; Hammond 1983). The figures show Kriged (interpolated) image maps of extractable amounts of each element in base-10 logarithms for mg kg^{-1} (kriging type = point with zero neighborhood variance and no nugget effect, based on linear semivariogram models; see Cressie 1990; Kitanidis 1997).

In these Kriged plots, one can observe the distribution of P (linked to organics, such as in food preparation and/or consumption), where there are generally very low concentrations with few specific points of deposition. This pattern is distinct when compared to earlier surfaces, such as Gray Floor, which maintains higher overall levels and discrete concentrations across its surface. Similar patterns are evident with the distribution of K (not pictured), which is often indicative of the deposition of wood/plant ash (CaCO_3 [up to 40 percent] + K_2CO_3 [about 10 percent] + PO_4 [> 1 percent] + salts and minerals). In contrast, one can observe the distinct deposition of Fe, often associated with ferric oxide (e.g., ochre). Other elements (not pictured) associated with mineral pigments, including Ti, Cu, Zn, and Hg, have contrasting depositional patterns, as described previously. While sample sizes are not the same between the floors, these observations suggest the possibility that the earlier surfaces were used in different ways: Gray involving food production/processing and consumption (such as in feasting activities) and Blue reserved for mineral-based rituals such as those using ochre and cinnabar.

5.2. Structures 21A/21B and 22 (ancillary buildings)

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499 A small multi-patio group was constructed attached to the north side of Structure 19
500 during the Samal phase of the Late Classic period (A.D. 600-670). The patio group was occupied
501 throughout the Late Classic, but was abandoned by the Terminal Classic period. Because of the
502 group's multiple patios, it has the appearance of an inchoate agglutinated palace complex similar
503 to those found at larger sites. Research focused on Patio 1, the largest and most formally
504 constructed patio. Low linear mounds that likely supported perishable superstructures line the
505 patio's north and west edges, while a low pyramidal structure dominates the eastern edge.

506 Structure 21B, the low linear structure lining the north edge of the patio, was built in a
507 single construction phase. Excavations along the structure's southern face uncovered two
508 versions of the patio surface. The earlier patio floor ("Potato," which was not sampled for this
509 study) was constructed in the Early Classic and served as the foundation for Structure 21B.
510 Sometime in the Late Classic, after the construction of Structure 21B, a new patio floor
511 ("Lettuce/Squash") replaced the older, long utilized surface. Patio surfaces were also sampled
512 west of Structure 22, the low pyramid on the group's eastern edge. This structure was originally
513 constructed on "Elmer Floor 2", which was then replaced by "Elmer Floor 1". Both floors date to
514 the Late Classic period. Elmer Floor 1 was likely occupied contemporaneously with
515 Lettuce/Squash Floor located across the patio.

516 Structure 21A was constructed in the northwest corner of Patio 1. The first two versions
517 of this building, Structures 21A-3rd and 21A-2nd, consisted of an unusual sunken room facing the
518 northwest away from Patio 1. The floors of these structures ("Onion" and "Manioc",
519 respectively) were bounded to the south by a standing masonry wall, and Manioc Floor abutted a
520 stair up to the surface of Structure 21B to the east. Later, a raised platform was constructed over

this sunken room rising above the level of Structure 21B. Low terraces were built projecting to the north and west. Samples were collected from “Chive” Floor, which covered the northern terrace. All versions of Structure 21A date to the Late Classic and post-date the construction of Lettuce/Squash Floor.

Here, we focus our discussion on two surfaces, in particular—Lettuce/Squash (Structure 21A/B) and Elmer 1 (Structure 22), which represent the best preserved and most sampled floors in this patio group. Standardized (base-10 logarithms) distributions of the elements on these three surfaces are not normal (Kolmogorov-Smirnov test, $p \leq .01$) and the variances are not homogenous (Levene’s test, $p \leq .01$). The data show patterns similar to those seen on both Blue/Purple and Gray/Tan (including especially high variation in Mg [3.80-338.27 mg kg⁻¹], K [1.05-19.00 mg kg⁻¹], and P [.18-31.43 mg kg⁻¹]), with a few notable exceptions (e.g., Hg and Pb on Lettuce/Squash) probably due to small sample sizes. Pearson’s linear correlation coefficients show strong positive associations between P and many other elements on Elmer 1, including K ($r = .78$), Ba ($r = .87$), Mn ($r = .74$), Ni ($r = .91$), Hg ($r = .73$), Al ($r = .96$), and Pb ($r = .99$). This suggests that P was distributed homogeneously across the patio surface associated with Structure 22 in association with other activities or apart from other activities but in the same spaces as those other activities. A similar observation can be made for Lettuce/Squash, associated with Structure 21B, where $r \geq .70$ between P and K, Ba, Mn, Al, and Pb. This suggests that the patio surfaces near 21A/B and 22 were used for multiple purposes and that activity loci were not necessarily discrete or fixed.

The Kriged interpolations of the chemical elements support the observations regarding the homogeneity of the use of space over time (Figures 9-10). Since the lower (earlier) surfaces are largely devoid of chemical residues, here we focus on the latest Late Classic surfaces. The

northern portion of the patio uncovered by the excavations (represented by Lettuce/Squash Floor) has high concentrations of P and Fe distributed fairly evenly across the surface, while the eastern portion of the patio (represented by Elmer 1 Floor) has lower levels of P and Fe, especially where the space abuts Structure 22. This could suggest that Structures 21A and B may have been involved in more daily residential activities and that Structure 22 may have been reserved for special functions. In contrast to Blue Floor on Structure 19, the distributions of P and Fe in the patio are homogenously distributed across the patio surface. These patterns appear to be similar to those detected for multi-use residential spaces at other Classic Maya settlements (e.g., Wells et al. 2000).

6. Conclusions

Investigating the history and use of Actuncan's palace complex is important for understanding changing strategies of leadership, because these buildings point to the establishment of a residential palace and hereditary leadership at the site. Palaces can be thought of quintessentially as buildings established for the purposes of housing hereditary rulers and their burgeoning family and bureaucracy. As such, their construction marks the expansion of leadership roles beyond those tied to the central temple. Originally constructed during Actuncan's Terminal Preclassic height of power, Structure 19 was only converted into a formal palace complex during the Late Classic period. The small size and limited elaboration of ancillary buildings (including Structures 21A/B and 22) suggest that the palace was inhabited by a secondary elite, not a divine king, ruling Actuncan under the aegis of a more powerful ruler elsewhere, possibly at nearby Xunantunich (Mixer et al. 2013).

Our research on the chemical characterization of sediment samples from multiple sets of plaster surfaces at the palace complex reveals the kinds and locations of various activities. The chemical residues identified in the analysis of floors from Structure 19-1st indicate some level of food storage, preparation (including the combustion of wood/plant material), or consumption in all three rooms. The high P levels in Room 1 are focused along the east side of the room near the doorway. In Room 2, the high P levels are concentrated at the back of the room floor at the base of the bench and along the edges of the room where the floors and walls meet. Room 2 is also distinguished from the other rooms as the only location where Fe does not overlap with P. The high degree of preservation of plaster on the bench and floor of Room 3 allowed for identification of elevated P levels in seemingly circumscribed areas on the bench and on the west side of the doorway. These patterns suggest different functions for the rooms. The clearest pattern may be in Room 2, with a high concentration of P at the base of the bench. This seems more likely to indicate storage as opposed to the patterns in Room 3, which may indicate consumption or other activities.

Overall, these findings contrast with the inferences for other Classic-period palaces in the Maya region, which suggest that the central room in palace room blocks served more political purposes, such as reception areas. At Aguateca, for example, the central room was largely devoid of anthropogenic inputs, while the flanking rooms appear to have been reserved for food preparation or consumption and craft manufacturing (or other diverse activities). Notably, food consumption appears to have been sequestered into one room. At Actuncan, however, there is evidence for the deposition of organics throughout all three rooms, although the way in which food was handled in each room was different. In the central room (Room 3), the large L-shaped bench would have been large enough to accommodate multiple occupants participating in private

gatherings that involved food consumption. In painted scenes on Classic-period vases, lords can be seen seated on palace benches surrounded by bowls of tamales, beverages, and other foods indicative of exclusive feasting (LeCount 2001). Perhaps this kind of formal eating might account for the circumscribed nature of P, as different containers and individuals had designated locations on the bench. In adjacent rooms, food might have been stored (Room 2), prepared, or eaten in the doorway in sight of others (Room 1).

Room 2 (east of the central room) is also distinct from the others in its concentrations of heavy metals, possibly signaling an area for storage of raw materials for ritual paraphernalia or the enactment of ritual performances. Given the location of this room, perched above a large open plaza with a ball court, these performances may have been visible to large groups of people. Inomata and colleagues (2001:300) interpret this configuration as “theatrical space” used in political and ritual performances as documented on Classic Maya pictorial pottery (Reents-Budet 1994, 2001).

The patio floors in front of the ancillary structures (Structures 21A/B, and 22) are all similar in terms of the ranges and locations of activities. The highest (Late Classic) surfaces all contain anthropogenic signatures of a wide variety of activities, similar in organization to the ancillary buildings and terraces in elite residential spaces investigated at Piedras Negras (Wells et al. 2000) and Cancuén (Cook et al. 2006). Lower (earlier) surfaces are largely devoid of anthropogenic signatures, with a few exceptions. This finding could be related to prior construction practices that erased extant residues, the building’s formation processes, or simply our sampling strategy. Yet, if the absence of residues is behaviorally related to the use of the surfaces in antiquity, then these buildings were either kept clean of refuse or else experienced minimal activities in the early part of the palace complex’s history. If this was the case, then

there is evidence that the function of this space likely shifted to a wider range of domestic activities by the Late Classic period. This transition to domestic activities corresponds with the construction and subsequent expansion of the patio groups off the north side of Structure 19, supporting our argument that this construction marked the conversion of Structure 19 from strictly a venue for ritual and polity administration into the focal point of a ruler's palatial residence (Mixer et al. 2013).

Yet the diverse chemical signatures from the palace complex do not support a shift to strictly residential use. Rather, the discrete chemical patterning across each room of Structure 19-1st supports our hypothesis that spaces were reserved for specialized activities, including food consumption, storage and preparation, burning wood/plant material, and ritual performance. Additionally, the lower levels of P directly in front of Structure 22 are similar to patterns found in front of the entrances to temples and shrines at Piedras Negras (Wells et al. 2000). This may indicate that the space was not used for domestic activities, possibly in deference to this eastern building's ritual importance as a shrine.

The broad array of activities at Actuncan's Late Classic palace complex indicates that the construction of agglutinated palaces marks the placement of Maya authority within private residential spaces that contain specific areas for public ritual and administrative activities. This shift in the kinds and locations of palace activities can also be seen in the changing chemical signatures found on Structure 19's floors over time. In contrast to the discrete chemical signatures on the floors of 19-1st, those on Terminal Preclassic floors indicate more widespread food preparation or consumption, evidence that may suggest a shift from inclusive food redistribution by early leaders to exclusive feasting and elaborated ritual by Late Classic rulers.

635 Future analysis of these data should attempt to evaluate our findings with other methods
636 and analytical instruments (e.g., Middleton et al. 2010) as well as address the complexity of the
637 anthropogenic signatures, such as with multiple regression and principal components analysis
638 (e.g., Chang et al. 2001). Additional evidence that might help to explain the chemical patterning,
639 such as that revealed by microartifact data, now can be meaningfully incorporated into these
640 models, for example, through the use of correspondence analysis or multidimensional scaling
641 (e.g., Fulton 2015).

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References

Abrahams, P.W., Entwistle, J.A., Dodgshon, R.A., 2010. The Ben Lawers Historic Landscape Project: the simultaneous multi-element analysis of former settlement and arable soils by X-ray fluorescence spectrometry. *Journal of Archaeological Method and Theory* 17 (3), 231–248.

Abrams, E.M., Parhamovich, J., Butcher, J.A., McCord, B., 2012. Chemical composition of architectural plaster at the classic Maya kingdom of Piedras Negras, Guatemala. *Journal of Archaeological Science* 39 (5), 1648–1654.

Albert, L.E., 1986. Physical and cultural variables affecting phosphate deposition and preservation at archaeological sites. *Bulletin of the Oklahoma Anthropological Society* 35 (1), 13–22.

Anderson, D.S., Bair, D.A., Terry, R.E., 2012. Soil geochemical analyses at the Preclassic site of Xtobo, Yucatan. *Ancient Mesoamerica* 23 (2), 365–377.

Arrhenius, O., 1931. Die bodenanalyse im dienst der archäologie. *Zeitschrift für Pflanzenernährung. Düngung und Bodenkunde* 12, 427–439.

Barba, L., 1990. El análisis químico de pisos de unidades habitacionales para determinar sus áreas de actividad. In: Sugiura, Y., Serra Puche, M.C. (Eds.), *Etnoarqueología Coloquio Bosch*

682 Gimpera 1988. Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de
683 México, Mexico City, Mexico, pp. 177–200.

684

685 Barba L., 2007. Chemical residues in lime-plastered archaeological floors. *Geoarchaeology* 22
686 (4), 439–452.

687

688 Barba, L., Ortiz Butrón, A., 1992. Análisis químico de pisos de ocupación: un caso etnográfico
689 en Tlaxcala, México. *Latin American Antiquity* 3 (1), 63–82.

690

691 Barba, L., Ortiz Butrón, A., Link, K.F., Lopez, L.L., Lazos, L., 1995. Activites humaines
692 reflétées dans les sols d'unités d'habitation contemporaine et préhispanique du Yucatán
693 (Mexique): etudes chimiques ethnoarchéologiques et archéologiques. *Revue d'Archeometrie* 19
694 (1), 79–95.

695

696 Beach, T., Luzzadder-Beach, S., Dunning, N., Cook, D., 2008. Human and natural impacts on
697 fluvial and karst depressions of the Maya lowlands. *Geomorphology* 101 (1-2), 308–331.

698

699 Beach, T., Luzzadder-Beach, S., Dunning, N., Scarborough, V., 2003. Depression soils in the
700 lowland tropics of northwestern Belize: anthropogenic and natural origins. In: Gomez-Pompa,
701 A., Allen, M., Fedick, S., Jiménez-Osornio, J. (Eds.), *Lowland Maya Area: Three Millennia at*
702 *the Human-Wildland Interface*. Haworth Press, Binghamton, New York, pp. 139–174.

703

704 Bethell, P., Máté, I., 1989. The use of soil phosphate analysis in archaeology: a critique. In:
705 Henderson, J. (Ed.), *Scientific Analysis in Archaeology and Its Interpretation*. Institute of
706 Archaeology, University of California, Los Angeles, pp. 1–29.

707

708 Burton, J.H., Simon, A.W., 1993. Acid extraction as a simple and inexpensive method for
709 compositional characterization of ceramics. *American Antiquity* 58 (1), 45–59.

710

711 Canuto, M.A., Charlton, J.P., Bell, E.E., 2010. Let no space go to waste: comparing the uses of
712 space between two Late Classic centers in the El Paraíso Valley, Copán, Honduras. *Journal of*
713 *Archaeological Science* 37 (1), 30–41.

714

715 Chang, C-W, Laird, D.A., Mausbach, M.J., Hurburgh, C.R., 2001. Near-infrared reflectance
716 spectroscopy–principal components regression analyses of soil properties. *Soil Science Society*
717 *of America Journal* 65 (2), 480–490.

718

719 Christie, J.J. (Ed.), 2003. *Maya Palaces and Elite Residences: An Interdisciplinary Approach*.
720 University of Texas Press, Austin.

721

722 Colomban, Ph., Tournié, A., De Montmollin, F.D., Krainhoefer, F.L., 2010. Vegetable ash as
723 raw material in the production of glasses and enamels, for example the contemporary vegetable
724 ashes from Burgundy, France. <http://arXiv:1012.1504v1> (accessed December 10, 2015).

725

726 Cook, D.E., Kovacevich, B., Beach, T., Bishop, R.L., 2006. Deciphering the inorganic chemical
727 record of ancient human activity using ICP-MS: a reconnaissance study of Late Classic soil
728 floors at Cancuén, Guatemala. *Journal of Archaeological Science* 33 (5), 628–640.
729

730 Coronel, E.G., Bair, D.A., Brown, C.T., Terry, R.E., 2014. Utility and limitations of portable X-
731 ray fluorescence and field laboratory conditions on the geochemical analysis of soils and floors
732 at areas of known human activities. *Soil Science* 179 (5), 258–271.
733

734 Coronel, E.G., Hutson S., Magnoni, A., Balzotti, C., Ulmer, A., Terry, R.E., 2015. Geochemical
735 analysis of Late Classic and Post Classic Maya marketplace activities at the Plazas of Cobá,
736 Mexico. *Journal of Field Archaeology* 40 (1), 89–109.
737

738 Cressie, N., 1990. The origins of kriging. *Mathematical Geology* 22 (3), 239–252.
739

740 Dahlin, B.H., Jensen, C.T., Terry, R.E., Wright, D.R., Beach, T., Magnoni, A., 2007. In search of
741 an ancient Maya market. *Latin American Antiquity* 18 (4), 363–384.
742

743 Davis-Salazar, K.L., 2003. A study of Early Classic Maya ritual at Copán, Honduras. Report
744 submitted to the Foundation for the Advancement of Mesoamerican Studies,
745 <http://www.famsi.org/reports/01076/01076DavisSalazar01.pdf>, accessed January 22, 2015.
746

747 Day, M.J., 1993. Resource use in the tropical karstlands of central Belize. *Environmental*
748 *Geology* 21 (3), 122–128.

749

750 Eberl, M., Álvarez, M., Terry, R.E., 2012. Chemical signatures of middens at a Late Classic
751 Maya residential complex, Guatemala. *Geoarchaeology* 27 (5), 426–440.

752

753 Eide, R.C., 1985. Theoretical and practical considerations in the analysis of anthrosols. In: Rapp,
754 G., Gifford, J.A. (Eds.), *Archaeological Geology*. Yale University Press, New Haven,
755 Connecticut, pp. 155–190.

756

757 Entwistle J.A., McCaffrey, K.J.W., Dodgshon R.A., 2007. Geostatistical and multi-elemental
758 analysis of soils to interpret land-use history in the Hebrides, Scotland. *Geoarchaeology* 22 (4),
759 391–415.

760

761 Fernández, F.G., Terry, R.E., Inomata, T., Eberl, M., 2002. An ethnoarchaeological study of
762 chemical residues in the floors and soils of Q'eqchi' Maya houses at Las Pozas, Guatemala.
763 *Geoarchaeology* 17 (6), 487–519.

764

765 Fulton, K.A., 2015. Community Identity and Social Practice during the Terminal Classic Period
766 at Actuncan, Belize (Unpublished PhD dissertation). University of South Florida, Tampa.

767

768 Fulton, K.A., Wells, E.C., Storer, D.A., 2013. Ritual or residential? An integrated approach to
769 geochemical prospection for understanding the use of plaza spaces at Palmarejo, Honduras.

770 *Archaeological and Anthropological Sciences*, DOI: 10.1007/s12520-013-0170-3.

771

772 Furley, P.A., Newey, W.W., 1979. Variations in plant communities with topography over
773 tropical limestone soils. *Journal of Biogeography* 6 (1), 1–15.
774

775 Goffer, Z., 2007. *Archaeological Chemistry*, second edition. Wiley-Interscience, Hoboken, New
776 Jersey.
777

778 Goodman, M.M., 1998. The Effects of Wood Ash Additive on the Structural Properties of Lime
779 Plaster (Unpublished MS thesis). University of Pennsylvania, Philadelphia.
780

781 Hansen, E., 2000. Ancient Maya Burnt-Lime Technology: Cultural Implications of
782 Technological Style (Unpublished PhD dissertation). University of California, Los Angeles.
783

784 Hammond, F.W., 1983. Phosphate analysis of archaeological sediments. In: Reeves-Smyth, T.,
785 Hammond, F.W. (Eds.), *Landscape Archaeology in Ireland*. British Archaeological Reports, No.
786 116, Oxford, pp. 47–80.
787

788 Harrison, P.D., 2003. Palaces of the royal court of Tikal. In: Christie, J.J. (Ed.), *Maya Palaces*
789 *and Elite Residences: An Interdisciplinary Approach*. University of Texas Press, Austin, pp. 98–
790 119.
791

792 Harrison, P.D., Andrews, E.W., 2004. Palaces of Tikal and Copán. In: Evans, S.T., Pillsbury, J.
793 (Eds.), *Palaces of the Ancient New World*. Dumbarton Oaks Research Library and Collection,
794 Washington, DC, pp. 113–147.

795

796 Hauptmann, A., Yalcin, Ü., 2000. Lime plaster, cement and the first puzzolanic reaction.

797 *Paléorient* 26 (2), 61–68.

798

799 Hausenbuiller, R.L., 1972. *Soil Science: Principles and Practices*. William C. Brown Company,

800 Dubuque, Iowa.

801

802 Holliday, V.T., Gartner, W.G., 2007. Methods of soil P analysis in archaeology. *Journal of*

803 *Archaeological Science* 34 (2), 301–333.

804

805 Houston, S., Brittenham, C., Mesick, C., Tokovinine, A., Warinner, C., 2009. *Veiled Brightness:*

806 *A History of Ancient Maya Color*. University of Texas Press, Austin.

807

808 Hutson, S.R., Terry, R.E., 2006. Recovering social and cultural dynamics from plaster floors:

809 chemical analyses at ancient Chunchucmil, Yucatán, Mexico. *Journal of Archaeological*

810 *Science* 33 (3), 391–404.

811

812 Inomata, T., Houston, S., 2001. Opening the royal Maya court. In: Inomata, T., Houston, S.

813 (Eds.), *Royal Courts of the Ancient Maya*. Westview Press, Boulder, Colorado, pp. 3–23.

814

815 Inomata, T., Triadan, D., Ponciano, E., Terry, R.E., Beaubien, H.F., 2001. In the palace of the

816 fallen king: the royal residential complex at Aguateca, Guatemala. *Journal of Field Archaeology*

817 28 (3-4), 287–306.

818

819 Johnson, J., 2014. Accurate measurements of low z elements in sediments and archaeological
820 ceramics using portable X-ray fluorescence (PXRF). *Journal of Archaeological*
821 *Method and Theory* 21 (3), 563–588.

822

823 King, R.B., Baillie, I., Abell, T., Dunsmore, J., Gray, D., Pratt, J., Versy, H., Wright, A., Zisman,
824 S., 1992. *Land Resource Assessment of Northern Belize*. Bulletin No. 43, Natural Resources
825 Institute, Overseas Development Administration, Southampton, United Kingdom.

826

827 Kitanidis, P., 1997. *Introduction to Geostatistics: Applications in Hydrogeology*. Cambridge
828 University Press, Cambridge.

829

830 LeCount, L.J., 2001. Like water for chocolate: feasting and political ritual among the Late
831 Classic Maya at Xunantunich, Belize. *American Anthropologist* 103 (4), 935–953.

832

833 LeCount, L.J., Yaeger, J., 2010. Placing Xunantunich and its hinterland settlements in
834 perspective. In: LeCount, L.J., Yaeger, J. (Eds.), *Classic Maya Provincial Politics: Xunantunich*
835 *and its Hinterlands*. University of Arizona Press, Tucson, pp. 337–369.

836

837 Leslie, V., 1987. The Belize River boat traffic. *Caribbean Quarterly* 33 (3/4), 1–28.

838

839 Lewis, R.J., Foss, J.E., Morris, M.W., Timpson, M.E., Stiles, C.A., 1993. Trace element analysis
840 in pedo-archaeology studies. In: Foss, J.E., Timpson, M.E., Morris, M.W. (Eds.), *Proceedings of*

841 the 1st International Conference on Pedo-Archaeology. Special Publication 93-03, University of
842 Tennessee Agricultural Experiment Station, Knoxville, Tennessee, pp. 81–88.
843

844 Littmann, E.R., 1962. Ancient Mesoamerican mortars, plasters, and stuccos: floor constructions
845 at Uaxactun. *American Antiquity* 28 (1), 100–103.
846

847 Luzzadder-Beach, S., Beach, T., Terry, R.E., Doctor, K.Z., 2011. Elemental prospecting and
848 geoarchaeology in Turkey and Mexico. *Catena* 85 (2), 119–129.
849

850 McCormick, D.R., Wells, E.C., 2014. Pottery, people, and pXRF: toward the development of
851 compositional profiles for southeast Mesoamerican ceramics. In: López Varela, S.L. (Ed.),
852 *Social Dynamics of Ceramic Analysis: New Techniques and Interpretations. Papers in Honour of*
853 *Charles C. Kolb. BAR International Series No. 2683. Archaeopress, Oxford, pp. 22–35.*
854

855 McVey, L., 1998. A Characterization and Analysis of the Plaster Floors from the Acropolis at
856 Copán, Honduras (Unpublished MS thesis). University of Pennsylvania, Philadelphia.
857

858 Middleton, W.D., 2004. Identifying chemical activity residues on prehistoric house floors: a
859 methodology and rationale for multi-elemental characterization of a mild acid extract of
860 anthropogenic sediments. *Archaeometry* 46 (1), 47–65.
861

862 Middleton, W.D., Price, T.D., 1996. Identification of activity areas by multi-elemental
863 characterization of sediments from modern and archaeological house floors using inductively

864 coupled plasma-atomic emission spectroscopy. *Journal of Archaeological Science* 23 (5), 673–
865 687.

866

867 Middleton, W.D., Barba, L., Pecci, A., Burton, J.H., Ortiz, A., Salvini, L., and Rodriguez Suárez,
868 R., 2010. The study of archaeological floors: methodological proposal for the analysis of
869 anthropogenic residues by spot tests, ICP-OES, and GC-MS. *Journal of Archaeological Method*
870 *and Theory* 17 (3), 183–208.

871

872 Miller, T.E., 1996. Geologic and hydrologic controls on karst and cave development in Belize.
873 *Journal of Cave and Karst Studies* 58 (2), 100–120.

874

875 Mixter, D., Jamison, T.R., LeCount, L.J., 2013. Actuncan's noble court: new insights into
876 political strategies of an enduring center in the Upper Belize River Valley. *Research Reports in*
877 *Belizean Archaeology* 10, 91–103.

878

879 Mixter, D.W., Fulton, K.A., Bussiere, L.H., LeCount, L.J., 2014. Living through collapse: an
880 analysis of Maya residential modifications during the Terminal Classic period at Actuncan,
881 Cayo, Belize. *Research Reports in Belizean Archaeology* 11, 55–66.

882

883 Parnell, J.J., Terry, R.E., Nelson, Z., 2002. Soil chemical analysis applied as an interpretive tool
884 for ancient human activities in Piedras Negras, Guatemala. *Journal of Archaeological Science* 29
885 (4), 379–404.

886

887 Pecci, A., Ortiz Butrón, A., Barba, L., Manzanilla, L., 2010. Distribución espacial de las
888 actividades humanas con base en el análisis químico de los pisos de Teopancazco, Teotihuacan.
889 In: Ortiz Diaz, E. (Ed.), VI Coloquio Bosh Gimpera. Universidad Autónoma de México, Mexico
890 City, Mexico, pp. 453–478.

891

892 Reents-Budet, D., Ball, J.W., Bishop, R.L., Fields, V., MacLeod, B., 1994. Painting the Maya
893 Universe: Royal Ceramics of the Classic Period. Duke University Press, Durham.

894

895 Reents-Budet, D., 2001. Classic Maya concepts of the royal court: an analysis of renderings on
896 pictorial ceramics. In: Inomata, T., Houston, S. (Eds.), Royal Courts of the Ancient Maya.
897 Westview Press, Boulder, Colorado, pp. 195–233.

898

899 Russell, B.W., Dahlin, B.H., 2007. Traditional burnt-lime production at Mayapan, Mexico.
900 Journal of Field Archaeology 32 (4), 407–423.

901

902 Shackley, M.S. (Ed.), 2011. X-Ray Fluorescence Spectrometry (XRF) in Geoarchaeology.
903 Springer, New York.

904

905 Terry, R.E., Fernández, F.G., Parnell, J.J., Inomata, T., 2004. The story in the floors: chemical
906 signatures of ancient and modern Maya activities at Aguateca, Guatemala. Journal of
907 Archaeological Science 31 (9), 1237–1250.

908

909 Terry, R.E., Hardin, P.J., Houston, S., Nelson, S.D., Jackson, M.W., Carr, J., Parnell, J.J., 2000.
910 Quantitative phosphorus measurement: a field test procedure for archaeological site analysis at
911 Piedras Negras, Guatemala. *Geoarchaeology* 15 (2), 151–166.
912
913 Vandenabeele, P., Bodé, S., Alonso, A., Moens, L., 2005. Raman spectroscopic analysis of the
914 Maya wall paintings in Ek'Balam, Mexico. *Spectrochimica Acta Part A* (61), 2349–2356.
915
916 Villaseñor Lambert, M.I., 2010. Lowland Maya Lime Plaster Technology: a Diachronic
917 Approach (Unpublished PhD dissertation). University College London, United Kingdom.
918
919 Webster, D., Inomata, T., 2004. Identifying subroyal elite palaces at Copán and Aguateca. In:
920 Evans, S.T., Pillsbury, J. (Eds.), *Palaces of the Ancient New World*. Dumbarton Oaks Research
921 Library and Collection, Washington, DC, pp. 149–180.
922
923 Wells, E.C., 2004. Investigating activity patterns in prehispanic plazas: weak acid-extraction
924 ICP/AES analysis of anthrosols at Classic period El Coyote, northwest Honduras. *Archaeometry*
925 46 (1), 67–84.
926
927 Wells, E.C., 2006. Cultural soils. In: Frossard, E., Blum, W.E.H., Warkentin, B.P. (Eds.),
928 *Function of Soils for Human Societies and the Environment*. Geological Society, London, pp.
929 125–132.
930

931 Wells, E.C., 2010. Sampling design and inferential bias in archaeological soil chemistry. *Journal*
932 *of Archaeological Method and Theory* 17 (3), 209–230.
933

934 Wells, E.C., Mihok, L.D., 2010. Ancient Maya perceptions of soil, land, and earth. In: Landa,
935 E.R., Feller, C. (Eds.), *Soil and Culture*. Springer, New York, pp. 311–327.
936

937 Wells, E.C., Moreno Cortés, J.E., 2010. Chimie du sol et activités humaines anciennes: les
938 exemples archéologiques du Mexique et d'Amérique centrale. *Etude et Gestion des Sols* 17 (1),
939 67–78.
940

941 Wells, E.C., Terry, R.E., 2007. Introduction to the special issue—advances in geoarchaeological
942 approaches to anthrosol chemistry, part II: activity area analysis. *Geoarchaeology* 22 (4), 387–
943 390.
944

945 Wells, E.C., Terry, R.E., Parnell, J.J., Hardin, P.J., Jackson, M.W., Houston, S.D., 2000.
946 Chemical analyses of ancient anthrosols in residential areas at Piedras Negras, Guatemala.
947 *Journal of Archaeological Science* 27 (5), 449–462.
948

949 Wells, E.C., Novotny, C., Hawken, J.R., 2007. Quantitative modeling of soil chemical data from
950 inductively coupled plasma-optical emission spectroscopy reveals evidence for cooking and
951 eating in ancient Mesoamerican plazas. In: Glascock, M.D., Speakman, R.J., Popelka-Filcoff,
952 R.S. (Eds.), *Archaeological Chemistry: Analytical Techniques and Archaeological Interpretation*.
953 American Chemical Society, Washington, DC, pp. 210–230.

954

955 Wells, E.C., Davis-Salazar, K.L., Kuehn, D.D., 2013. Soilscape legacies: historical and emerging
956 consequences of socioecological interactions in Honduras. In: Wingard, J.D., Hayes, S.E. (Eds.),
957 Soils, Climate, and Society: Archaeological Investigations in Ancient America. University Press
958 of Colorado, Boulder, pp. 21–59.

959

960 Figures

961

962 1. The location of Actuncan, Belize and other archaeological sites mentioned in the text.

963

964 2. Plan view map of the palace complex at Actuncan, showing the locations of Structures 19,
965 21A/21B, and 22. (Map by David W. Mixter)

966

967 3. Photo of the excavation of Structure 19, showing Room 1 (bottom), Room 2 (center), and
968 Room 3 (top). (Photo by Lisa J. LeCount)

969

970 4. Plot of functions 1 and 2 from a discriminant function analysis, showing distinctions between
971 Blue, Purple, Gray, and Tan floors from Structure 19 based on different chemical elements. The
972 values associated with each chemical element represent canonical variate correlation
973 coefficients, indicating the substantive nature of each element.

974

975 5. Side-by-side boxplots comparing P and K concentrations (mg kg^{-1}) between Blue and Gray
976 floors in Structure 19.

977

978 6. Side-by-side boxplots comparing Ti, Ni, Cu, and Zn concentrations (mg kg^{-1}) between Blue
979 and Gray floors in Structure 19.

980

981 7. Kriged image map of the interpolated distribution of P across Blue Floor in Structure 19.

982

983 8. Kriged image map of the interpolated distribution of Fe across Blue Floor in Structure 19.

984

985 9. Kriged image map of the interpolated distribution of P across Lettuce/Squash (north) and

986 Elmer 1 (east) floors in the Group 8 patio.

987

988 10. Kriged image map of the interpolated distribution of Fe across Lettuce/Squash (north) and

989 Elmer 1 (east) floors in the Group 8 patio.

990

Table 1. Summary Statistics (mg kg⁻¹) for Extractable Chemical Elements Characterized by ICP-MS.

Structure	Floor	Period*	n	Na	K	Mg	Ca	Sr	Ba	Ti	V	Cr
19-1 st	Blue	LC	64	14.4386 (3.8153)	2.6775 (1.0866)	66.1288 (66.4210)	13530.4888 (2637.7835)	3.1131 (.3577)	1.8894 (.4294)	.0248 (.0212)	.1439 (.0164)	.0140 (.0092)
19-2 nd	Purple	EC/TP	15	14.0060 (2.4891)	5.0531 (1.9521)	41.4676 (8.7568)	10922.2012 (730.3373)	2.6512 (.4767)	2.1550 (.2291)	.0351 (.0225)	.1384 (.0125)	.0133 (.0097)
19-2 nd	Sac	TP	8	15.0064 (1.2004)	4.7459 (.6256)	40.2023 (6.3884)	11341.2477 (606.1744)	2.9089 (.4125)	2.4516 (.2392)	.0109 (.0040)	.1459 (.0080)	.0097 (.0027)
19-3 rd	Gray	TP	8	18.1158 (.9315)	10.5180 (5.3817)	73.4038 (14.5118)	15554.0411 (885.4377)	2.9364 (.5153)	2.3089 (.3895)	.0517 (.0357)	.1412 (.0154)	.0204 (.0110)
19-3 rd	Tan	TP	4	14.7848 (2.5698)	13.4666 (6.3530)	41.3405 (6.1614)	10800.7023 (1182.3848)	3.2479 (.3164)	2.7446 (.2826)	.0339 (.0324)	.1458 (.0059)	.0112 (.0084)
21A	Chive	LC	8	17.3306 (.8475)	3.1661 (.4851)	49.4000 (4.8426)	8297.5194 (483.2010)	2.6652 (.2969)	2.0696 (.1508)	.0406 (.0111)	.1759 (.0120)	.0251 (.0033)
21A	Manioc	LC	8	15.1925 (2.8571)	2.5699 (.6033)	46.6254 (6.6203)	8317.8358 (419.5724)	2.5922 (.3426)	1.9473 (.2611)	.0323 (.0238)	.1841 (.0100)	.0129 (.0071)
21A	Onion	LC	8	15.8079 (2.4472)	5.3535 (2.9564)	52.5530 (21.4967)	8378.8589 (423.4391)	2.7769 (.2514)	2.2096 (.1973)	.0537 (.0303)	.1902 (.0229)	.0242 (.0106)
21B	Lettuce	LC	23	15.3389 (3.8939)	7.2464 (5.2463)	50.4462 (19.6671)	8189.7250 (1737.7252)	3.0991 (.8609)	2.3791 (.8000)	.0512 (.0448)	.1758 (.0390)	.0145 (.0093)
21B	Squash	LC	13	13.4963 (3.5478)	5.9778 (3.9301)	44.5256 (22.5747)	11256.9011 (4618.4101)	2.7833 (.4962)	1.8863 (.3466)	.0341 (.0261)	.1824 (.0400)	.0203 (.0115)
22	Elmer 1	LC	22	14.0294 (2.1227)	3.9722 (1.3539)	84.6313 (72.3820)	15837.1098 (473.8277)	2.0669 (.4046)	2.2161 (1.1034)	.0157 (.0302)	.1147 (.0135)	.0040 (.0053)
22	Elmer 2	LC	17	14.2023 (2.1606)	2.9517 (.7968)	40.4382 (12.5820)	16099.9218 (844.8790)	2.0103 (.4461)	2.1077 (1.5491)	.0076 (.0074)	.1181 (.0114)	.0050 (.0059)
control	offsite	unknown	8	2.9692 (1.0450)	11.5270 (2.2046)	36.8845 (13.5605)	4682.4486 (3521.7464)	1.2360 (1.0545)	4.6490 (1.6164)	.1122 (.0260)	1.7470 (.2320)	.0880 (.0165)
<i>p</i> values (2-tailed) for <i>t</i> -tests comparing archaeological sample means with control sample means				<.001	<.001	.212	<.001	<.001	<.001	<.001	<.001	<.001

Note: values are expressed as: mean (standard deviation)

Period Abbreviations: LC (Late Classic), EC/TP (Early Classic or Terminal Preclassic), TP (Terminal Preclassic)

Table 1. Summary Statistics (mg kg⁻¹) for Extractable Chemical Elements Characterized by ICP-MS continued.

Mn	Fe	Co	Ni	Cu	Zn	Y	Hg	U	Al	Pb	P
3.0485	15.1016	.0364	.6137	.1222	.3975	.0060	.0013	.0007	1.1141	.0020	3.2341
(.5676)	(5.2866)	(.0047)	(.0735)	(.0756)	(.1586)	(.0086)	(.0024)	(.0005)	(1.6557)	(.0040)	(2.9700)
2.3352	18.1702	.0327	.5030	.1793	.3993	.0270	.0007	.0014	2.5281	.0102	3.6690
(.7036)	(3.0527)	(.0038)	(.0281)	(.0949)	(.1014)	(.0236)	(.0005)	(.0016)	(1.8283)	(.0100)	(1.7705)
3.3039	21.9397	.0285	.5613	.1275	.3082	.0016	.0008	.0074	.6794	.0003	.8885
(.6003)	(2.3912)	(.0034)	(.0233)	(.0183)	(.0347)	(.0010)	(.0006)	(.0045)	(.2095)	(.0002)	(.5969)
3.8112	15.6968	.0324	.6046	.2469	.5781	.0428	.0007	.0028	2.7828	.0106	7.5894
(1.9852)	(.9430)	(.0021)	(.0505)	(.1009)	(.2387)	(.0500)	(.0006)	(.0014)	(2.8179)	(.0174)	(6.3850)
3.2199	20.3706	.0324	.5697	.1203	.2457	.0194	.0006	.0027	1.5896	.0050	4.1358
(.7587)	(4.4906)	(.0014)	(.0233)	(.0903)	(.1974)	(.0336)	(.0006)	(.0018)	(2.0941)	(.0093)	(4.3617)
2.9441	24.9232	.0394	.7214	.2319	.6141	.0564	.0002	.0008	11.8722	.0238	5.8433
(.5584)	(1.9558)	(.0036)	(.0661)	(.0265)	(.0501)	(.0120)	(.0002)	(.0001)	(3.6785)	(.0063)	(1.6422)
2.4540	23.2308	.0396	.7956	.1606	.4411	.0125	.0003	.0004	1.7569	.0071	4.8800
(.8182)	(6.4333)	(.0042)	(.1228)	(.0689)	(.1497)	(.0166)	(.0001)	(.0003)	(2.1048)	(.0085)	(3.9637)
2.7866	25.7179	.0421	.8029	.2648	.5619	.0428	.0007	.0012	5.5313	.0150	8.1549
(.4362)	(5.4953)	(.0041)	(.1129)	(.1000)	(.1549)	(.0278)	(.0008)	(.0007)	(3.1390)	(.0088)	(4.8262)
2.9015	25.2324	.0409	.8014	.1417	.4104	.0232	.0003	.0005	4.9136	.0120	7.6102
(.8340)	(7.7573)	(.0093)	(.1905)	(.0722)	(.1975)	(.0289)	(.0002)	(.0004)	(6.1584)	(.0129)	(7.1538)
2.4859	16.2944	.0378	.6945	.1462	.4591	.0226	.0016	.0005	4.2554	.0084	6.1681
(.5107)	(6.7142)	(.0078)	(.1691)	(.0738)	(.1120)	(.0232)	(.0027)	(.0002)	(4.5320)	(.0079)	(5.6757)
2.0017	13.8492	.0245	.4261	.1316	.3010	.0100	.0008	.0008	2.0771	.0099	11.7339
(.7369)	(3.7346)	(.0025)	(.0431)	(.0357)	(.0577)	(.0138)	(.0005)	(.0005)	(2.9597)	(.0111)	(15.2758)
1.5284	15.8035	.0237	.4436	.1564	.3040	.0189	.0006	.0020	.8087	.0123	2.7885
(.4651)	(4.6798)	(.0027)	(.0406)	(.0639)	(.0660)	(.0441)	(.0006)	(.0021)	(1.1997)	(.0115)	(2.1050)
5.0790	14.0333	.0429	.4751	.1588	.6620	.6875	.0000	.0069	44.8840	.1872	.3173
(1.3750)	(9.9323)	(.0252)	(.1057)	(.0613)	(.1082)	(.1580)	(.0000)	(.0030)	(24.4148)	(.0566)	(.3632)
<.001	.036	.018	.002	.764	<.001	<.001	.096	<.001	<.001	<.001	.015

2. ANOVA Statistically Significant Games-Howell Post-hoc Test Results.

Element	Floor ₁	Floor ₂	<i>p</i>
Na	Blue	Purple	<.001
Na	Blue	Gray	<.001
Na	Purple	Gray	<.001
K	Blue	Purple	.002
K	Blue	Gray	.018
Mg	Blue	Purple	.027
Mg	Blue	Tan	.034
Mg	Purple	Gray	.001
Mg	Gray	Tan	.002
Ca	Blue	Purple	<.001
Ca	Blue	Gray	.001
Ca	Blue	Tan	.034
Ca	Gray	Purple	<.001
Ca	Gray	Tan	.004
Sr	Blue	Purple	.012
Ba	Blue	Purple	.010
Ba	Blue	Tan	.017
Mn	Blue	Purple	.009
Fe	Blue	Purple	.025
Fe	Gray	Purple	.044
Co	Blue	Purple	.015
Co	Blue	Gray	.002
Co	Tan	Blue	.011
Ni	Blue	Purple	<.001
Ni	Purple	Tan	.013
Ni	Gray	Purple	.002
Ni	Tan	Blue	.071
Cu	Blue	Gray	.039
Y	Purple	Blue	.019
U	Blue	Gray	.013
Al	Blue	Purple	.023
Pb	Blue	Purple	.027

3. Classification Results for Discriminant Function Analysis.

		Blue	Purple	Gray	Tan	Total
Count	Blue	62	1	0	0	63
	Purple	0	15	0	0	15
	Gray	1	0	7	0	8
	Tan	0	1	0	3	4
%	Blue	98	2	0	0	100
	Purple	0	100	0	0	100
	Gray	13	0	88	0	100
	Tan	0	25	0	75	100

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10