Chapter 12

Chemical Analysis of Residues in Floors and the Reconstruction of Ritual Activities at the Templo Mayor, Mexico

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Lime plaster floors in the "Hall of the Eagle Warriors," Templo Mayor of Mexico-Tenochtitlan, have been studied intensively using chemical techniques after a detailed archaeological excavation. The simultaneous interpretation of chemical, historical and archaeological data has provided new and detailed information concerning the ritual activities performed in this unique structure during Aztec times. Given that the firing process used to produce lime minimizes chemical contamination, then newly plastered floors can be considered to be a clean homogeneous surface on which extraneous chemical compounds are deposited as a result of human activities that left residues in specific areas. This style of research confirms that a significant quantity of potential information is contained in lime plaster floors and illustrates how simple chemical techniques can be applied to the study of ritual activities in the past.

Since its inception in early 1978, the Proyecto Templo Mayor of the INAH has recovered part of one of the most prominent ceremonial complexes of the Mesoamerican world: the Sacred Precinct of Mexico-Tenochtitlan. Some of the most outstanding discoveries include the remains of 15 structures (almost all with various sub-structures), 132 rich offerings with more than 8,000 elements, along with a large number of sizable sculptures, bas-reliefs, mural paintings and ceramic fragments.

Among the most impressive discoveries made during the first season of fieldwork was Building "E" better known as the "Hall of the Eagle Warriors" (*1*). The structure is approximately 52 meters in length by 24 meters in width and corresponds to Phase VI of the Templo Mayor (ca. 1486-1502 A.D.). There are two flights of steps leading into the building at its western end, one facing west and the other south. The stairs are flanked by double inclined moldings in the form of knots. A pair of polychromatic sculptures in the form of eagle heads emerge from the west-facing *alfardas* (Figure 1).

In 1981, after excavating the interior of this building layer, an earlier structure that corresponds to Phase V of the Templo Mayor (ca. 1481-1486 A.D.)

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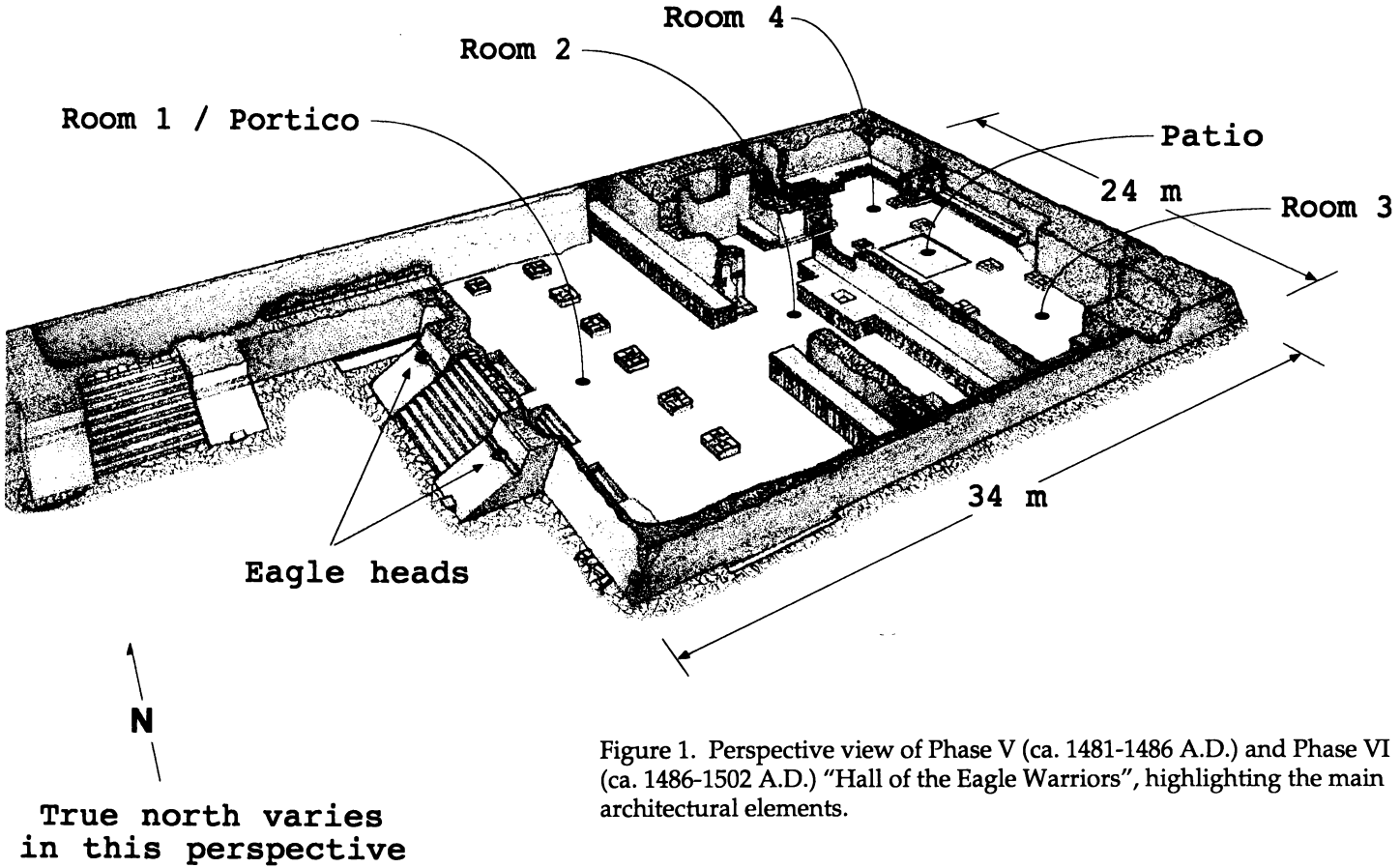

Figure 1. Perspective view of Phase V (ca. 1481-1486 A.D.) and Phase VI (ca. 1486-1502 A.D.) "Hall of the Eagle Warriors", highlighting the main architectural elements.

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was uncovered and found to contain a series of interior rooms that were in an excellent state of conservation. From the exterior plaza level rise two flights of steps which lead to a large portico which was probably covered by a flat roof, of which a series of column bases distributed in the form of an *L* still remains. Two life-size ceramic statues which represent full-bodied Eagle Warriors flanked the entryway to the main room. A doorway protected by a pair of ceramic human skeletons leads to an open-air patio with two additional adjoining rooms at its northern and southern ends. Almost all of the interior walls of the hall conserve the remains of painted murals depicting temples, priests, shields and diminutive warriors. The lower parts of the walls are furnished with long benches which are composed of two vertical sections of bas-relief basalt. The lower and larger section of these polychrome carvings represent various processions of armed warriors which converge on a small altar where the *zacatapayolli* was kept. This was a plaited grass ball and held the *maguey* (*Agave sp.*) thorns that were bloodied during the ritual of self-mortification. The upper section, detailed as a frieze, was decorated with undulating feathered-serpents in bas-relief. Moreover, a total of eight ceramic braziers containing carbonized plant material were found in front of these benches.

It is noteworthy to mention that the physical layout, form, proportions and decorations of the benches of the "Hall of the Eagle Warriors" have many features in common with the Burnt Palace of Tula, as well as the Market, the Temple of the Warriors and the northern and north-eastern colonnades of Chichén Itzá. The strong analogies which can be made between the "Hall of the Eagle Warriors" and other older structures from Toltec and Mayan cultures, along with the ceramic representations of Eagle Warriors, and the continual allusion to acts of ritual self-sacrifice on the benches, have been the subject of many controversies concerning the function and significance of this building (*2 -5*).

To be precise, our current research seeks to obtain archaeological, iconographic, and ethno-historical information which will allow us to determine the functions for which this building was used, its relation to other structures within the ceremonial complex, its religious significance and certain aspects of the military order to which it was dedicated.

The Hall of the Eagle Warriors comprises five main areas which will be denominated rooms 1-4, and the patio. Room 1 is a porticoed space with a series of columns that supported a flat roof. This area leads to Room 2, the first chamber located at the center of the structure, through a doorway guarded by two sculptures of Eagle Warriors. Room 2 contains an altar whose characteristics suggest that it was the most important feature within the enclosure. In front of this altar, two braziers have been found. To the south of this room, there was a stone masonry pit containing large amounts of charcoal and ashes. Towards the north of the room, there is a further doorway, this one being guarded by two fleshless sculptures representing *Mictlantecuhtli* (Death God). This leads to an open space with a sunken patio or *impluvium*, framed by columns. On the eastern side of this patio, there is a bench with two rough braziers. To the north and south of this space, there are two other rooms denominated 4 and 3 respectively. There is an altar in each room, each having two braziers. All the braziers bear an image of *Tlaloc* (Rain God) except for the ones at the patio. The floors of the entire hall are made of lime plaster, a mixture of hydrated lime and ground tezontle (a volcanic scoriaceous rock).

Previous studies and analogies.

Through the study of floors samples we have believe that stuccoed floors are the best substrate for the study of chemical in floors. Stuccoed floors can be considered chemically "clean" just after their construction and gradually they accumulate chemical compounds, mainly in form of solutions spilled on them, which are fixed into the pourous matrix.

It has been demonstrated that "soil from archaeological contexts retains markers of anthropogenic activity" (*6,7*). Research of modern household floors has demonstrated that the distribution of chemical compounds in floors is not uniform nor random. The relationship between human activities and the distribution of chemical elements and compounds has been confirmed. Based on ethnographic analogies and ethno-archaeological experiments, areas of food storage, preparation and consumption, as well as areas of frequent transit have all been located (*8*). Parallel applications of the same methodology to the study of archaeological households have shown that the same patterns observed in ethnographic cases appear can be observed in archaeological floors (*9-10*). The most recent applications of study of activity areas has been in ritual spaces. Until now most of the chemical research into activity areas within archaeological sites had been oriented towards domestic dwellings. Activities performed and materials involved are different in domestic and ritual activities, nevertheless, results from ritual spaces have shown that the distribution chemical compounds is susceptible to archaeological interpretation, as can be seen in the present work. Previous studies associated with ritual activities have analyzed a Aztec altar or *momoztli* in the center of Mexico City (*11*), a Mayan laberinthic structure called Satunsat in Oxkintok, Yucatán (*12*), and a domestic shrine in Oztoyahualco, Teotihuacan (*13*).

Ritual ceremonies are considered here as individual or group acts of symbolic nature which are repeated and stereotyped according to a set of rules. The same ritual ceremony may present prayers, offerings, taboos, games, immolations, self-mortification, magic, or mythical representations (*14*).

The contaminating liquids (blood, sweat, foodstuffs, etc.) which were repeatedly absorbed by the floors during the rituals, allows us to chemically identify the areas where the acts took place and perhaps in the future characterize the perishable materials that were utilized.

We propose that via a detailed investigation integrating diverse fields of study such as archaeology, chemistry, history, historical philology, and iconography it will be possible to identify the kinds of ritual activities which took place within the "Hall of the Eagle Warriors."

In this particular case, there is a large number of ancient documents which testify to the kind of activities and materials involved. Rooms 2,3, and 4 all present elements in common: an altar, the iconographic representation of a *zacatapayolli*, and the *Tlaloc* braziers. All these elements can be recognized on page 79r of the Magliabechiano Codex (*15*), where several individuals are practicing self-mortification in front of a deity, inserting the blooded spines in a *zacatapayolli* and offering *copal (Bursera jorrullensis)* to the braziers.

This approach highlights the potential information contained in lime plaster floors and illustrates how simple chemical tests can be used to study human activities.

Materials and Methods

Materials. High purity chemical reactives were used. All the glassware was rinsed with concentrated nitric acid, deionized water and organic solvent before use. Screw-topped glass vials were used to store the samples to eliminate contamination risk.

Samples. Approximately 500 samples with an average weight of 20 grams were obtained from the stuccoed floors. Based on a 24 x 22 m grid originally laid out during excavation, extraction points were established at the intersection of every grid

line. Samples were extracted using a drill bit 2 cm in diameter and 3-5 cm deep (Figure 2).

Analysis. Once in the laboratory, each sample was subjected to a series of simple tests such as Munsell color comparison, phosphate assay, carbonate assay and pH determination. The results of these analyses showed notable differences of concentrations in certain areas which motivated us to apply a further series of tests to determine the concentration of total carbonates and phosphates as well as organic residues (such as albumin, carbohydrates and fatty acids).

Inorganic tests were performed on all of the samples. Taking into consideration chemical results, archaeological and iconographic data we decided to only apply the organic tests to rooms 2,3,4, and patio since they were the most promising ritual areas. The results from the inorganic tests are the first approach in determining contamination patterns, as a result, we identify the more promising areas in which to apply the rest of the tests.

Three stages can be distinguished in the analysis of floor samples. 1) Application of semi-quantitive tests, allowing the differentiation of the defined zones. 2) Application of quantitative techniques to determine phosphate and carbonate levels giving greater accuracy than at the previous stage. 3) Based on these results, a selection of 228 samples was taken and semi-quantitative analysis were performed to determine organic compounds.

In Table I, the techniques applied at each of these stages are mentioned, semi-cuantitative test are described in detail by Barba, Rodríguez and Córdova (*16*).

Table I. Analytical Techniques

Stage	*Substance or Property Analyzed*	*Method*
1. Semi-quantitative inorganic	Color	Munsell Soil Color Chart
	Phosphates	Ring chromatography
	Carbonates	Effervescence with HCl
2. Quantitative	Phosphates	Method of phospho-vanado-molybdate
	Carbonates	Carbonate evaluation
	pH	
3. Semi-quantitative organic	Fatty acids	Hydrolysis with ammonia
	Albumin	Reaction with alkaline oxides and detection of ammonia
	Carbohydrates	Hydrolysis, dehydration and furfuraldehyde detection

During the first stage, color was determined with 500 mg of the sample which was compared with the Munsell Soil Color Chart (*17*). The pH of each sample was determined by adding 5 mL of distilled water and then measuring with a Beckman 3500 digital pH meter after 2 minutes. Phosphate determination was

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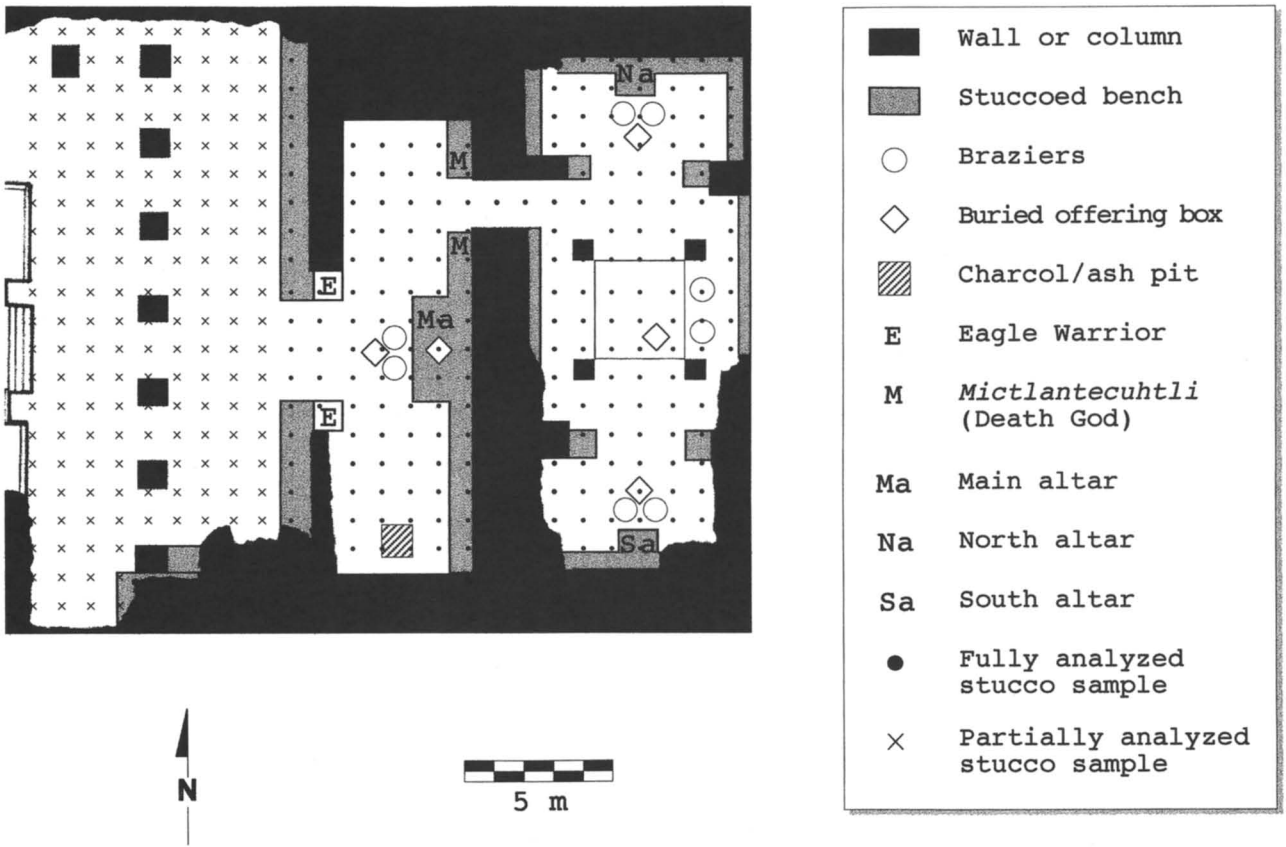

Figure 2. Location of the extraction points and main features within the "Hall of the Eagle Warriors."

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performed by placing 50 mg of the sample in the center of a Whatman No. 42 filter paper. Two drops of 5% w/v ammonium molybdate (dissolved in 5 M HCl) were then added. After 30 seconds, two drops of 0.5% ascorbic acid were added and 90 seconds later saturated sodium citrate solution was added. The intensity of the blue color that developed and the diameter of the ring were compared (graded on a scale one to six) (*18*). Carbonate determination was performed by adding 3 mL of 10% HCl to 50 mg of sample and comparing the difference in effervescence between the samples (graded on a scale one to six) (*19*).

At the second stage, quantitative tests were performed to evaluate the presence of phosphates and carbonates. Phosphates were detected colormetrically through the formation of a phospho-vanado-molybdate complex. 10 mL of 6N HNO_3 were added to 500 mg of the sample. After 15 minutes, 10 mL of 0.5 % ammonium vanadate and 10 mL of 5% ammonium molybdate were added. The volume was then increased to 100 mL. After 15 minutes, colorimetry was performed at 460 nm. Carbonate analysis: 100 mg of the sample were placed in an Erlenmeyer flask and 25 mL of distilled water and 50 mL of 0.1 M HCl were added. The mixture was heated to remove CO_2 and when cool, the solution was back-titrated with standardized NaOH to indirectly determine the quantity of carbonate in the sample (*20*). The correlation between the qualitative and the quantitative values for phosphate and carbonate can be seen in Table II.

Table II. Correlation values.

Semiquantitative scale	*Quantitative scale for Phosphates (mgP/g of sample)*	*Quantitative scale for Carbonates (%)*
0	0	0
1	<0.3	1-34
2	0.3-0.6	35-44
3	0.7-0.9	45-54
4	1.0-1.3	55-64
5	1.4-1.7	65-74
6	1.8-2.1	75-80

Organic compounds were determined using the following tests:

(a) Fatty acids were determined by placing 10 mg of the sample in a test tube and 3 mL of chloroform was added. This was then warmed to form a concentrate. One drop of the concentrate was then placed on a flat glass slide and two drops of 28.7% ammonia were added. After two minutes, two drops of 20% hydrogen peroxide were added. The resulting differences in quantity and stability of foam were compared. (graded on a scale one to three)

(b) Carbohydrate determination was performed by mixing 10 mg of the sample with 10 mg of oxalic acid and placing the mixture in a crucible. Five drops of sulfuric acid (1:3) were added and the mixture was then heated. The resulting furfuraldehyde was determined by observing the reaction with O-dianizidine impregnated on filter paper and exposing it to the resulting vapors. The change in the color of the paper was observed (graded on a scale one to six)

(c) Albumin determination was performed by placing 10 mg of the sample in a test tube and adding 0.1 g of CaO and two drops of water. The mixture was heated for

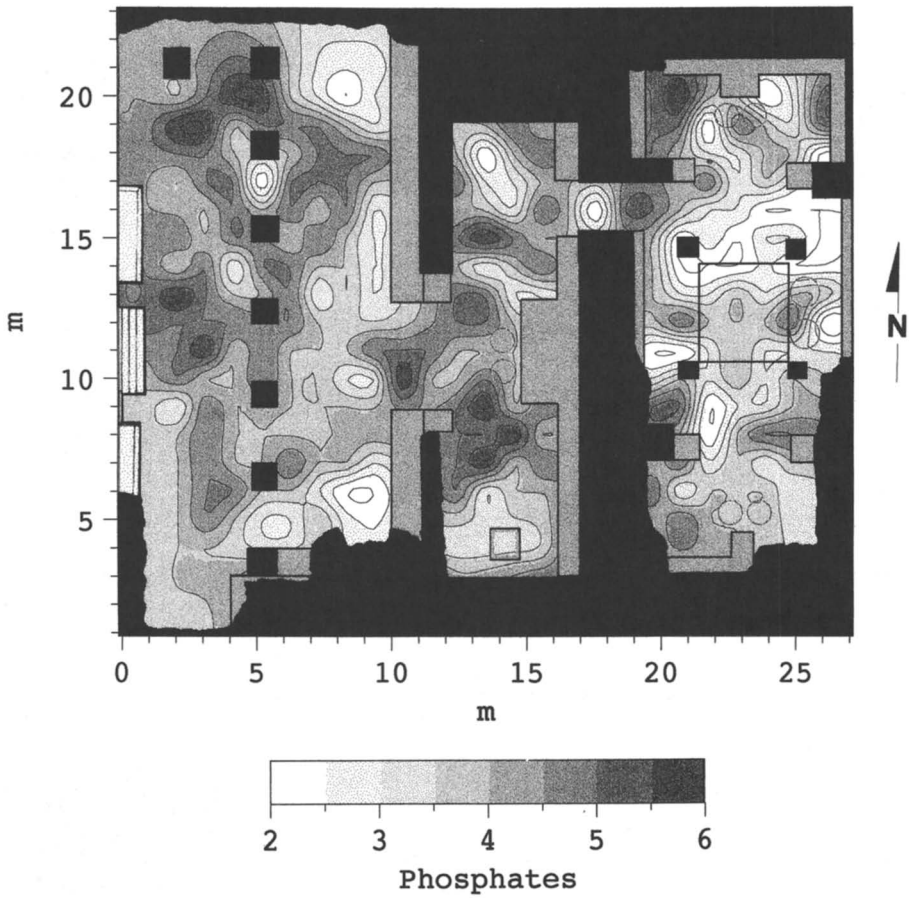

Figure 3. Distribution map of phosphates.

60 seconds and the resulting vapors were exposed to test paper to determine the presence of NH_3 via the change in the color of Whatman full range pH paper .

It should be noted that the lack of iconographic and archaeological elements (altars, braziers, etc.) related with self-mortification rituals in Room 1 was the main reason for excluding the samples of this area from the organic tests.

Visualization. The results from each of the analysis was represented a pseudo-colored raster image to facilitate initial interpretation. Missing data points were interpolated using the Kriging method. Data was then resampled using a bi-cubicly weighted filter and contextualized within the site by overlaying a geo-referenced plan of the excavation. The final representation in gray scales for publication was overlaid with black iso-lines to help distinguish the transitions between values.

Results

Phosphates. Residues of solutions rich in phosphates accumulated and became fixed in the abundant calcium carbonate present in the construction material of the floor, forming calcium phosphates.

In Room 1, two zones can be observed with different phosphate concentrations. The first is an area of high values and is found between the stairs and the columns. The area of low values is found between the columns and the entrance to Room 2. In this, there is a patch of high values close to the doorway which contrasts with the low values around it. In Room 2 high values were observed in two areas, a very extensive one to the south which begins near the main altar and finishes at the charcol and ash pit; the other area is near the altar and extends towards the north. In this room the low values are in the extreme north, however, at the entrance to the patio, another patch of high values can be noted. Rooms 3 and 4 as well as the patio show low values in general except for the zone to the west in Room 4 (Figure 3).

Carbonates. The distribution of carbonates in the floor is directly related to the construction material of the floor. The relative proportions of lime and sand are the principal determinants of the prescence of carbonates, but wear to the surface through constant use modifies the proportion.

In this map, one can again note that the higher values are to be found in the portico (Room 1) and tend to diminish towards the inner rooms though not to the same marked degree as previously. Once again, there is a contrast in Room 2, in front of the main altar, where values show a noticeable decline. Near the braziers, the values diminish slightly and this also occurs in the NW corner of Room 1 (Figure 4).

pH determination. pH values were determined by the levels of hydroxides which are residues of ash. However, in stuccoed floors, the base value for measurements is the equilibrium value of calcium carbonate in water, that is, approximately 8.2. All the differing values will therefore be the result of varying uses of the surface.

Room 1 contains the areas with the highest values of pH in the entire enclosure. Specifically, these are in the NW corner and around the central columns. In Room 2 high values are only to be found near the main altar and at the entrance to the patio. The rest of the room presents low values. In Room 4, the increase is only noticeable in front of the braziers. In the patio, high values are to be found around the *impluvium* and it should be noted that in this case the braziers are not associated

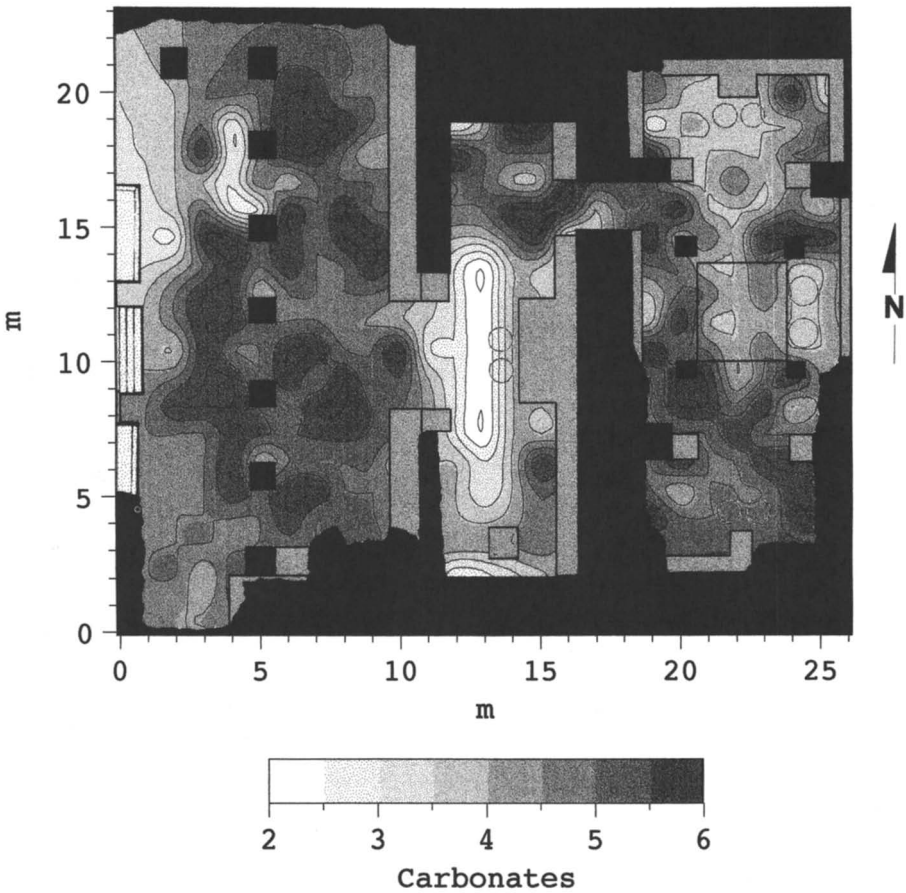

Figure 4. Distribution map of carbonates.

with a high pH level. In Room 3, the highest values are found in the SE corner (Figure 5).

Color comparison. As in the case of carbonates, color is determined by the mixture used to make the floor. Color is homogeneously distributed particularly in the two interior rooms, but in the porticoed area (Room 1) there is a broad zone of a redder color. In a number of samples the color is noticably darker. This may be due to contamination with a small quantity of sub-floor matrix (Figure 6).

Fatty acids. Fatty acids are the residue of substances formed by oils, fats or resins which were spilt on the floor and became impregnated in it. The fact that the distribution of the concentrations is very symmetrical is to be noted.

Room 2 presents high values directly related with the main altar and the braziers. Other zones of high values are the entrances and the area to the north of the charcol and ash pit. In Rooms 3 and 4 and the patio, the highest values are directly associated with the location of the braziers and altars (Figure 7).

Carbohydrates. Carbohydrates are the residues of substances with high starch and sugar levels.

In Room 2, specific areas of high admixture can be noted, particularly to the south of the room directly to the north of the charcol and ash pit. The levels also increase at the two entrances and in front of the braziers of the main altar. In Room 4, there are zones of high values behind the braziers and in three of the corners of the room. In the patio there are two zones of high values directly to the north and south of the *impluvium*, and in Room 3, there is only one occurence in the NW corner (Figure 8).

Albumin. Residues of albumin come from solutions containing proteins that were spilt onto the surface.

In Room 2, there are three main zones: to the south of the room, associated with the charcol and ash pit, and again to the north and center, associated with the entrances. In the patio the residues of albumin were only found in the northeast behind the braziers. In Room 3, two principal zones are observed: in the SE corner and in the entrance to the room (Figure 9).

Discussion

The maps of color and carbonates indicate that there was a change in the proportions used to make the lime plaster mix with which the floor of the Room 1 was constructed, because the color becomes reddened as a result of the *tezontle* present and the increased values of carbonates, indicating a greater proportion of lime in the mix. This might indicate changes in construction methods, going from the use of differently colored *tezontle* to remodelling or the building of extensions.

The results demonstrate that one of the principal areas of activity was in front of the main altar located in Room 2. This is characterized by a reduction in the concentration of carbonates due to wear to the floor, which would have been caused by heating and constant coming and going. This matches the semi-circle of high pH values formed around the altar, the two patches of high concentration of phosphates, as well as the presence of organic residues such as carbohydrates and fatty acids.

The next zones of interest, in terms of their chemical residues, are the areas at the entrances to Room 2 and the patio. These zones present high values of phosphate, pH, albumin, carbohydrates and fatty acids that are similar to the results obtained for the main altar. It is possible that the higher chemical content of this area is due to ritual activities associated with the sculptures guarding these entrances.

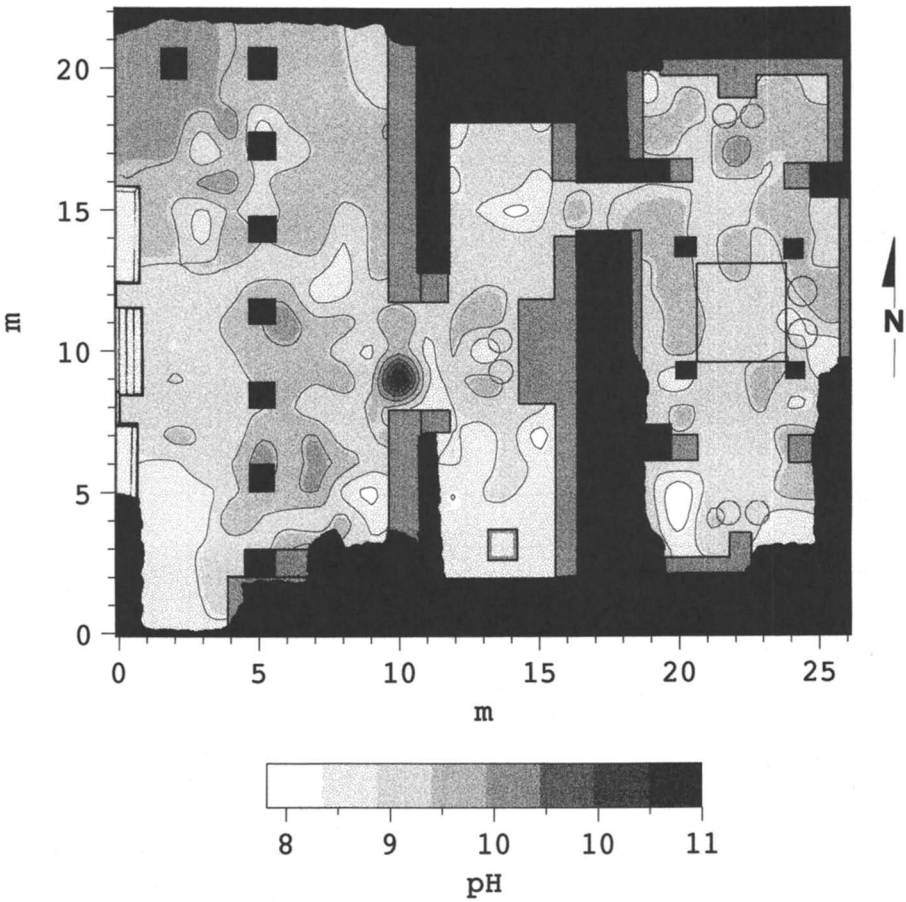

Figure 5. Distribution map of pH.

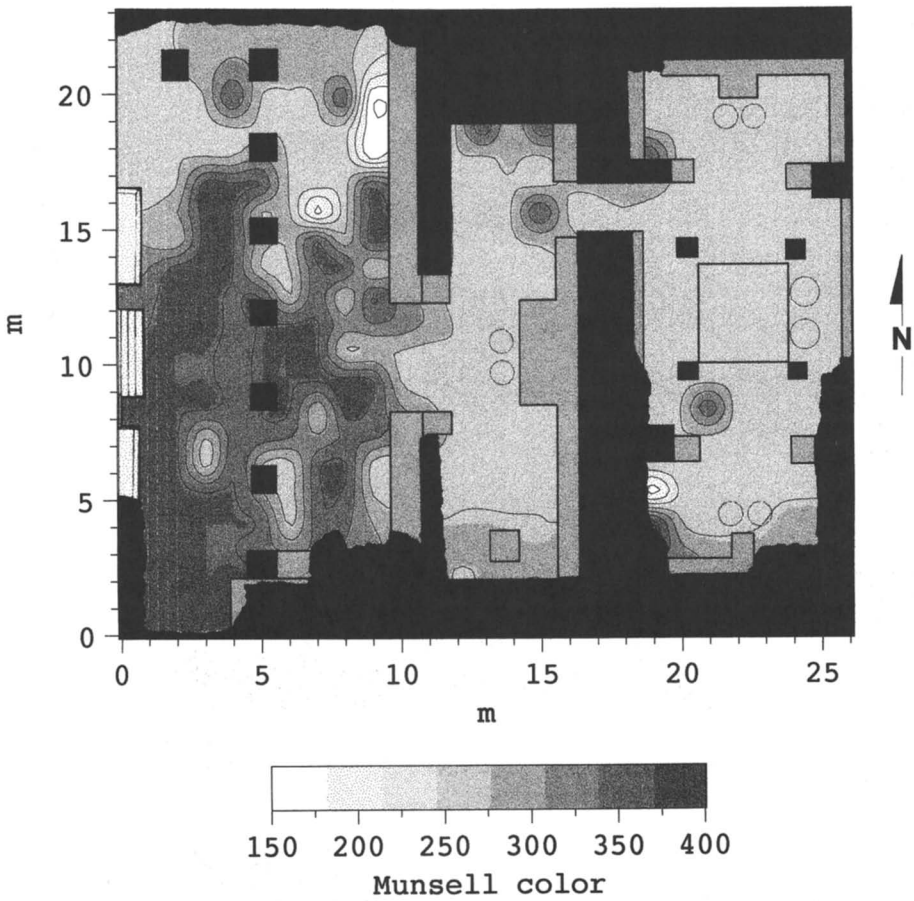

Figure 6. Distribution map of Munsell color.

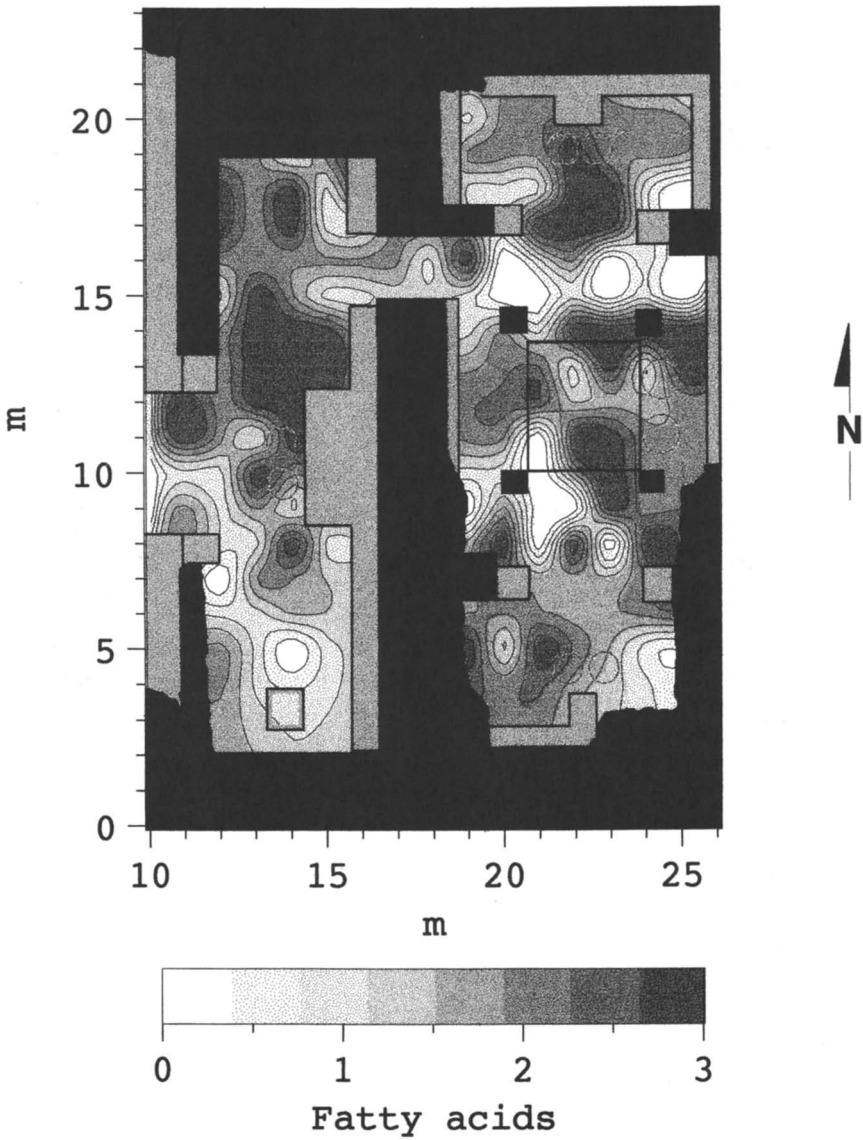

Figure 7. Distribution map of fatty acids.

Figure 8. Distribution map of carbohydrates.

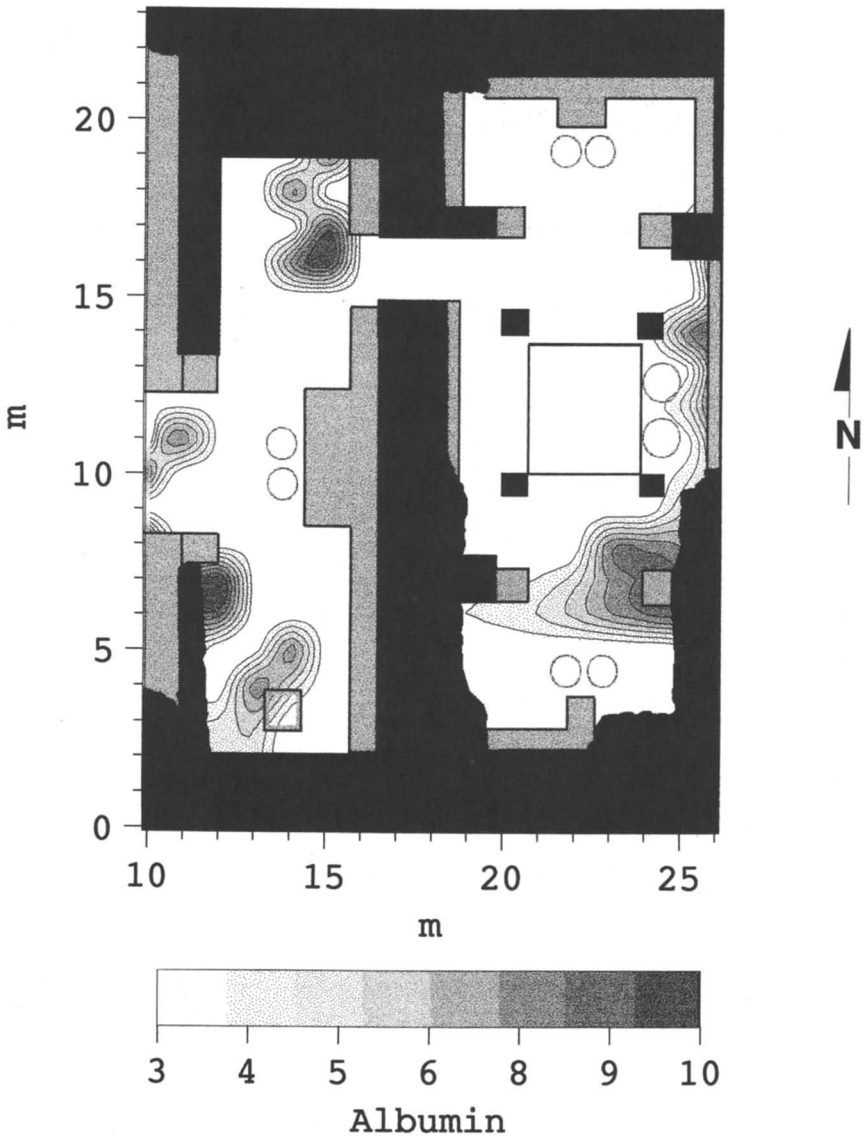

Figure 9. Distribution map of albumin.

The following zone of interest is an area in the angle formed between the two lines of columns in Room 1. In this area again, low carbonate values coincide with high pH and phosphate values which denote higher levels of activity.

The final areas of interest are those located immediately in front of the north and south altars, near the braziers. These results indicate activities clearly associated with rituals. Strangely, the concentrations of chemical compounds behind the braziers in the patio indicate that the activities took place between the benches and the braziers and not on the patio side, as had previously been thought.

In general terms, it is clearly noticeable that the patio with the *impluvium* is the area where the lowest concentrations of compounds were found, and in contrast, the areas in front of the altars are the richest.

The highest levels of chemical indicators were found in the ritual areas around the braziers, the ceramic sculptures and the representations of *zacatapayolli*.

In the Nahuatl literature there are numerous descriptions concerning ritual, sacrifice and ceremonies. León Portilla reports a great diversity of such practices and mentions that in addition to human victims, it was common to offer several species of small animal, fruits, *copal, pulque* (fermented juice of *Agave sp.*), as well as paper and spines sprinkled with blood, just to mention a few (*21*). The rituals were oriented towards deities at altars and braziers. Fluids from these bodies and materials produced the chemical compound enrichment of the floors .

According to Leach (*22*), there are three spatial components in any ritual scene, the first being the sacred area itself. Normally there is some sort of symbolic icon which indicates the materialization of the sacred. The second area is adjacent to the first, and is where most of the ritual takes place. Access to the first and second areas is reserved for the priests and religious servants. Finally, we find the faithful in a third area which is separated in turn from the sacred area by the sector of ritual activity.

Both the first and second areas can be identified in the "Hall of the Eagle Warriors": the first is represented by a series of iconographic elements, such as the *zacatapayolli* (placed on the altars and physically located in the interior or most hidden areas of the hall) and the ceramic sculptures of Eagle Warriors and *Mictlantecutli* (flanking two entrances). The second type of area, where most of the rituals took place, was located in the central and back parts of the hall and can be distinguished by the presence of a series of elements such as braziers and altars.

In conclusion, the Hall of the Eagle Warriors chemically exhibits two of the three key areas for a ritual to take place. The areas of ceremonial activity that stand out are: in front of altars, directly around the braziers, and the entryways where clay figures representing Eagle Warriors and *Mictlantecuhtli* were found. In those places ritual activities spill fluids on the floor whose chemical compounds were fixed and permited their recovery and analysis to reconstruct past human activities performed in this hall.

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