

REVEALING THE MONASTIC KITCHEN: CHEMICAL ANALYSIS OF THE SOIL INSIDE THE MONASTERY OF CORNELLANA (NORTH-WEST SPAIN)*

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The residues deposited on the floor of the kitchen of the monastery of Cornellana (Asturias, Spain), while it was still in use in the 18th century, have been analysed using different techniques, including the Kjeldahl method, phenol – sulphuric acid assay, FT–IR, SEM–EDX and LOI. This has allowed us to determine the areas of concentration of proteins, carbohydrates, fatty acids, phosphorus and carbonates, and thus approach the interpretation of the layout of the different areas of activity related to the treatment and cooking of foodstuffs in the kitchen. In any case, and regardless of the fact that this is the first time that these techniques have been applied to study a monastic kitchen in the Iberian Peninsula, the aim of this research is to demonstrate their applicability to other case studies of this integrated set of analytical techniques, some of which are not used very often in the analysis of concentrations of residues and analysis of areas of activity on archaeological soils.

KEYWORDS: IBERIAN PENINSULA, 18TH CENTURY, MONASTERY, KITCHEN, CHEMICAL RESIDUES, SOILS, ACTIVITY AREAS

INTRODUCTION

The aim of this work was twofold. First, we sought to test the feasibility of the applicability of an integrated method of study that includes an unusual series of techniques that are not commonly used in the analysis of areas of activity (protein, carbohydrate and fatty-acid content) in addition to more commonly used techniques (phosphates, carbonates and pH). Second, and in particular, we have applied this methodology to the case of the monastery of Cornellana specifically in order to understand the food preparation processes and the functional management of a monastic kitchen in the modern era (18th century) in the north-western Iberian Peninsula. For this reason, different analyses of the chemical residues deposited in the sediment of the kitchen area have been developed with the goal of defining the areas of activity in the kitchen and the layout of the different areas used for preparing food. Consequently, the relative concentrations of the different chemical compounds were analysed and the results were contrasted with the evidence of the kitchen equipment obtained through archaeological excavation.

The substances employed or produced by the kitchen activities are absorbed by the materials upon which they fall, and can be analysed (Barba, 1986, 2007). The residues remain in situ and they are a trustworthy marker for the study of the spatial distribution of the activities and for determining the function of the space analysed (Barba, 2007; Barba & Lazos, 2000; Ortiz & Barba, 1993), as well as for identifying the food consumed (Barba et al. 2014). In order to discern the compounds present in the kitchen floor, different semi-quantitative and quantitative techniques were used to measure the pH and the concentration of proteins, carbohydrates, fatty acids, phosphorus and carbonates ((Barba et al. 1991; Middleton et al. 2010).

This is a research method that has been satisfactorily tested in different archaeological environments and contexts, but which has hardly ever been used in the study of monastic kitchens. In fact, in Europe the only precedent is the analysis of chemical residues in the medieval *cuquina* of San Vincenzo al Volturno (Barba et al. 1991; Middleton et al. 2010), and this is the first time that this methodology has been applied to the study of a monastic kitchen in the Iberian Peninsula.

The monastery of San Salvador de Cornellana (Asturias) was founded in 1024 as a private family monastery, and re-established as a Benedictine monastery in 1122: it was in use until 1835, when the last monks were expelled from the building by the Spanish government. In the 18th century, during a time of economic prosperity, the monastic complex underwent a major architectonic renovation that gave it a monumental baroque finishing touch. In this context, the refurbishing of the kitchen took place and was concluded in 1751. This is the reason why the floor and the infrastructures of the kitchen, which are the subject of this work, have a very clearly defined chronology, between the years 1751 and 1835. In 2016, we were able to carry out an excavation of the area of the kitchen complex, which allowed us to collect samples from the floor in this room (García Álvarez-Busto, 2016). In the other monastery outbuildings, only small surveys had been carried out in previous years, without this type of chemical residue analysis ever having been performed (Adán Álvarez, 2000; García Álvarez-Busto & Adán Álvarez, 2001; see also Fig. 1).

The kitchen of the monastery is a rectangular room that measures 5.92m on the east–west axis by 6.41m on the north–south axis, and covers a total area of 37.94m². The floor is paved with river stone over compacted soil, and among its joints, sediments and residues linked to its use were deposited. Along the north wall, there are two doors: the western one leads to the *cilla* (cellar), and the eastern one to the inner galleries of the cloister. In the northernmost part of the east wall, there is a gap that used to be the serving hatch, allowing food to be passed to the next refectory. In the south-eastern corner, there is a sink that supplies water to the kitchen through a ceramic pipe connected to a nearby spring. Finally, against the southern wall, there are remains of a podium built with stone and limestone mortar, where there used to be one or two fireplaces used for cooking; although on first sight the conserved vestiges did not provide clear proof of this.

MATERIALS AND METHODS

Over the paving of the kitchen, we made a grid and nine samples were taken (A, B, C, D, E, F, G, H and I) every 2m. Although the optimum sampling density is every 1m, which is recommended whenever possible, in this case we decided to sample every 2m, since it was the first time that some of the analysis techniques had been attempted. Thus, the main objective of this study was to demonstrate the validity of this type of integral approach, obtaining some initial results for the case study in question. The samples were taken from the sediment deposited among the stones that form the paving of the kitchen floor. This pavement was built in the middle of the 18th century, and the lower layer of sediment,

from which the samples were taken, was sealed by later levels from the 19th century. The sediment is blackish with a sandy texture, presents a certain consistency due to previously having been trodden on and has an average thickness of 1 cm. Soil samples taken from each square were analysed using a variety of techniques including the Kjeldahl method, phenol – sulphuric acid assay, FT–IR, SEM–EDX and LOI, which are explained below, with the aim of obtaining more in-depth knowledge about the uses of this room during the 18th century.

Protein content

The universality, precision and reproducibility of the Kjeldahl method have made it the internationally recognized technique for estimating the protein content in foods and it is also used to assay soils and waste waters. In this work, we employed the Kjeldahl method in triplicate to determine the protein content of the soil samples. This method is used for the quantitative determination of organic nitrogen; hence the nitrogen content must be multiplied by a conversion factor (N) in order to calculate the protein content. The conversion factor depends on the type of protein present in the sample; however, the range of conversion factors is relatively narrow.

Indeed, the N factor is specifically for food and varies in range from 5.18 (nuts, seeds) to 6.38 (milk). In this work, an N value of 5.97 has been used. This value was chosen taking into account that many different foodstuffs could have been stored and/or handled in the refectory, so this value was calculated as an average of those reported by Merrill and Watt (1973) for different foods (eggs, meat and milk; and flours and processed food containing barley, corn, millet, oats, rice, rye, wheat, beans and nuts).

Determination of total carbohydrates

The phenol – sulphuric acid method (Dubois et al. 1956), modified as follows, was employed to determine the amount of total carbohydrates. First, 1 g of sample was added to 11mL of distilled water and the mixture was sonicated for 15 min (Raypa Ultrasonic Cleaner) in order to extract the soluble carbohydrates from the sample. The suspension was then centrifuged for 10min at 10000 g (Kubota 6500) and the supernatant was recovered. In this method, 0.5mL of 5% phenol and 2.5mL of 96% H₂SO₄ were added to a sample of 1mL of the supernatant to be analysed and the mixture was incubated at room temperature for 1 h. Finally, the absorbance of the samples was recorded at 492nm against a reagent blank employing glucose as standard. Measurements were performed with a UV spectrophotometer (Thermo Scientific Helios Gamma). Samples were analysed in triplicate.

Fatty acids

Fatty acids were extracted from the soil sample using chloroform (Barba, 2007). Briefly, 2 g of soil was weighed and extracted twice using 10mL of chloroform. The filtered extract was rotaevaporated to dryness and then solubilized in 1mL of CHCl₃. This final concentrated extract was analysed by FT–IR spectrometry, using a Varian 670 FT–IR spectrometer with a cell for liquids. Although every fatty acid has its own characteristic FT–IR spectrum, there are certain absorptions that are common among all of them, arising from the common chemical structure. Some of these bands are those at ~2955cm⁻¹, ~2930 cm⁻¹, ~2850cm⁻¹ or ~1730cm⁻¹, corresponding respectively to CH₃– asymmetric stretching, –CH₂– asymmetric stretching, –CH₂– symmetric stretching and C=O stretching (Socrates, 2001). Absorption in the range between 2927 cm⁻¹ and 2970 cm⁻¹ was used as an estimate of the amount of fatty acids; likewise, a calibration curve

of oleic acid in chloroform from 0.2% to 1.0% was prepared. Therefore, the fatty acid content is expressed as an oleic acid content.

Analysis of total amount of phosphorus

Soil phosphorus is naturally low, so it is unique among the elements in that it is a sensitive and persistent indicator of human activity, as human activities related to subsistence tend to concentrate the element around settlements. Thus, phosphorus informs about the presence of past human occupation and offers clues regarding the type and intensity of human activity, including livestock stabling and disposal of household and human waste (Holliday & Gartner, 2007). Energy-dispersive X-ray spectroscopy (EDX) is a chemical microanalysis technique used in conjunction with scanning electron microscopy (SEM). The EDX technique detects X-rays emitted from the sample during bombardment by an electron beam to characterize the elemental composition of the analysed volume. The areas under selected peaks can also be used to provide semi-quantitative elemental composition information. In this work, EDX analyses were performed to determine the phosphorus content of the samples. A JEOL JMS-6610LV scanning electron microscope (SEM), operating at 0.3–30 kV, was employed. Prior to the EDX analysis, samples were dried in an oven at 60 °C overnight and they were sputter-coated with gold to make them electrically conductive. According to Busman, Lamb, Randall, Rehm, and Schmitt (2002), phosphorus is not found by itself in elemental form in nature. On the contrary, in natural systems such as soil, phosphorous exists as phosphate. Consequently, it can be assumed that all the phosphorous measured by EDX comes from phosphates. The decision to perform EDX analyses to determine the soil phosphorus content was due to the fact that this is a very powerful technique that can be employed to characterize a diverse range of materials, including soils (Mavris et al. 2012; Batista et al. 2017).

Quantification of carbonate

The weight loss-on-ignition (LOI) method was employed to determine the amount of carbonate in the soil samples. This method was developed according to Heiri et al. (2001) and is based on sequential heating of the samples in a muffle furnace. Samples were dried at 105 °C overnight and were cooled to room temperature in a desiccator before any measurements were made. The dried samples were homogenized by hand and weighed (2.5–3.0 g). In a first reaction (550 °C, 4 h), organic matter was oxidized to carbon dioxide and ash. In a second reaction (950 °C, 2 h), carbon dioxide was evolved from carbonate, leaving oxide. The weight loss during the reactions was easily measured by weighing the samples before and after heating, and was closely correlated to the organic matter and carbonate content. All analyses were carried out in triplicate, employing an ELF 11/6 muffle furnace (Carbolite).

pH

One gram of soil was suspended in 15mL of distilled water and stirred for 5min. Then, the soil was left to settle and the pH was determined in the supernatant using an Orion pH meter.

Moisture content measurement

The moisture content was determined by a gravimetric method, in triplicate. Two to three grams of each sample were weighed in a stainless-steel capsule and the capsules were placed in an oven (Mettler) at 105 °C ± 2 °C for 5 h. The capsules were then allowed to cool in a desiccator at room temperature for 30 min before finally being weighed. The moisture content data of the soil samples were employed to correct the results obtained

for proteins, total carbohydrates and fatty-acid determinations, with the aim of expressing them on a dry weight basis.

RESULTS AND DISCUSSION

It is widely known that the distribution of chemical residues in a room is neither uniform nor random, but is related to the activities carried out across the floor, with a link existing between these activities and the chemical enrichment pattern (Barba et al. 2014). Based on this premise, we interpret below the results of the analysis performed in each study case. For each chemical marker (proteins, phosphorus, carbohydrates, fatty acids, pH and carbonates), we have made a distribution layout of the kitchen floor so that the concentration with high values is identified as well as the areas with minimum values or without any chemical markers. This layout is made through an interpolation of a raster layer, which gives us continuous data on the surface, calculated based on the values of each of the samples taken. The results of the chemical analysis can be seen in Table 1. Interpolation is a method that predicts the corresponding values for the pixels of a raster surface based on a series of specific values of a layer of sample points. Natural neighbour interpolation finds the subset of input samples closest to a query point, applies weights to them, based on proportional areas, to interpolate a value based on the sample values, and calculates the values for the adjacent pixels, depending on the Thiessen polygons calculated for the entry points and the interpolated points, ensuring that the interpolated values are within the range of the samples used (Sibson, 1981). The ArcGIS program was used to create the different maps of distribution of the residues.

Proteins

The highest values are found in front of the fireplace, which was used for cooking (sample A (1.17)), with an extension along the western strip of the room towards the area of the cilla door (samples D (0.98), G (0.83) and H (0.91)). Another high-concentration point is located towards the eastern strip in the middle (sample F (1.15)). It is remarkable that the lowest values are in the central area of the room (samples E (0.59) and B (0.61)) and near the sink (sample C (0.31)), where—if there was indeed enrichment of proteins—they could have been washed away by water spilt from the sink (Fig. 2). The presence of proteins is linked to the preparation and cooking of vegetable and animal products (meat, blood and eggs). In fact, and as is the case in Cornellana, in the kitchen of the Italian monastery of San Vincenzo al Volturno, the greatest concentration of proteins is located near the hearth and in the two corners of the pantry, where storage areas for meat could be documented—even with slaughtered animals hanging—together with cold meat and dairy produce, all of which are products that are rich in fatty acids and proteins (Carannante et al. 2008).

Phosphates

The presence of phosphates is directly linked to the preparation and consumption of foodstuffs rich in phosphorus. The highest values are in the central area of the room (sample E (1.11)), with an extension towards the area of the western door of the cilla G (1.24) and towards the northeastern corner of the room (sample I (0.93)), where the serving hatch is located, through which the meals were passed into the refectory (Fig. 3). A middle value exists in the area of the fireplaces (sample A (0.52)), which is related to waste generated by the cooking of the food (Pecci, 2013) and ashes from the fireplace (Holliday & Gartner, 2007; Oonk et al. 2009). Other studies carried out in the inner areas present high phosphate values (Pecci et al. 2013), and this is also the case for Cornellana,

where the highest values are in the area between the cellar and the kitchen, through which all the food—stored in the former and prepared in the latter—passed.

On the other hand, the lowest values are located near the sink (sample C (<0.1)), maybe because the organic residues enriched with phosphorus would have washed away by water (Fernández et al. 2002). Phosphorus can be found in soils as inorganic or organic phosphorus (Beltrán-Pineda, 2014). Although inorganic phosphorus in minerals (with calcium, iron or aluminium) lixiviates phosphorus very slowly, organic phosphorus compounds are more soluble. These organic phosphorus compounds come from the microbial degradation of animal and vegetal residues (Achal et al. 2007; Banerjee et al. 2010).

Carbohydrates

The area located opposite the entrance to the cilla (samples G (0.0845) and H (0.0708)) is where the highest values are clearly concentrated (Fig. 4). The presence of carbohydrates is related to foodstuffs of vegetable origin, flour, fruit, root vegetables, seeds and also sugar-rich foodstuffs and dairy produce (Goffer, 2007). All of them, and especially flour, were products that were stored in the cilla, next to the kitchen, so it seems plausible that the highest concentration is identified around the door between the kitchen and the cilla. These results, together with those for the phosphates and proteins, allow us to confirm the initial hypothesis about the use of this adjacent room as a cellar, therefore taking up the canonical place in the Benedictine monasteries, the western wing of the cloister, also known as the 'panda de la cilla'.

Fatty acids

The highest values are located in the south-eastern corner of the room, just beside the sink (samples C (4.7) and B (3.9)), whereas in the rest of the kitchen the values are clearly lower, between 2.1 and 2.7 (Fig. 5). The presence of fatty acids is connected to oil and fat, both of animal and vegetable origin, and to the existence of storage areas or areas for the treatment of foodstuffs rich in these substances, as has been tested in the monastic kitchen of Volturno (Carannante et al. 2008). The concentration of residues in this area seems to indicate that next to the sink there was a place for the treatment of some foodstuffs that were rich in fatty acids (oil, fat, meat, cold meat and dairy produce), and that an abundance of water would probably have been needed in order to treat them. Given its location right between the sink and the fireplace, this is consistent with a high podium that could have functioned as a workplace—between the water and the fire—where foodstuffs could be handled.

Carbonates

The highest values are clearly concentrated in the area located opposite the fireplaces (samples A (7.5) and B (10.9)), and gradually lose intensity as we move away from that area. In fact, the lowest values are recorded in the areas furthest away from the fireplaces (samples G, H and I) (Fig. 6). In Mesoamerica, the enrichment of carbonates accumulated in the kitchens is explained by means of the residue from water with limestone used in the cooking of some foodstuffs (Barba et al. 2014); however, in the Iberian Peninsula, we do not have evidence of this type of cooking during the medieval period or in modern times. In this case, the enrichment of carbonates can be explained in part by the concentration of ashes near the area of the fireplaces (Sullivan & Kealhofer, 2004). However, it primarily seems to occur due to the use of limestone mortar in the construction and maintenance works of the podium where the fireplaces were, as has been

proved in other cases (Pecci et al. 2010). Also, the subsequent destruction of the podium could have caused the dispersion of some calcium carbonate particles in the nearby area.

pH

The highest pH values are recorded in the south-western corner of the room (samples A (9.03) and D (9.31)), just next to the fireplaces, where there is a concentration of ashes (Fig. 7). It is widely known that, chemically, as a result of the combustion activity, there is an increase in pH values, and that values higher than 9 indicate the presence of combustion (Barba et al. 2014). These results have allowed us to corroborate the hypothesis emanating from the archaeological excavation, which identified the fireplace in the southern podium of the room. In any case, the pH values are very high in the rest of the kitchen too (between 8.13 and 8.75), as also occurs in the kitchen of Volturmo, where the pH level is very high all over the room, with values between 8.8 and 9.5; although the highest measurements are near the fireplace and the hearth (Carannante et al. 2008; Pecci & Marazzi, 2006). A second area where we can find a high pH value is right beside the foot of the sink (sample C (9.06)), but in this case, it is due to the fireplace and the ashes rather than the highly alkaline water, since the water supplying the monastery has a pH value of 7.4 (IGME, 2003).

Proposed reconstruction of activities in the kitchen

An analysis of the residues recovered from the kitchen floor of the monastery of Cornellana has allowed us to establish a preliminary layout of the different areas of activity that existed inside it during the processes of managing and cooking foodstuffs (Fig. 8). This map of intensity of use of the kitchen aims to objectify, based on the various variables obtained through the samples analysed, those areas of the room in which there was greater activity. The baseline raster gives us an image of the intensity of concentration of each of the elements analysed. Due to the different nature of each of the samples, it is not possible to analyse them together directly, but it is possible to perform a comparative study of the degree of intensity of each one of them. For this reason, they have been reclassified into 10 sections each, valuing them from 1 to 10, with 1 being the section of lower intensity and 10 the one of greater value for each type of sample. In this way, a new raster of reclassified intensity is obtained, in which each pixel corresponds to a value from 1 to 10, depending on the degree of intensity of concentration of each sample. Each pixel of this resulting raster corresponds to a value that is the sum of the reclassified values of each type of sample for that particular point.

First, a global analysis of the chemical residues thus allows us to identify a greater concentration of them against the walls and a less intense concentration of chemical residues in the centre of the room and in front of the door to the cloister. The reason for this may be explained by the fact that, against the walls, there were the workplaces where foodstuffs were prepared, and therefore the central area of the room was less exposed to the accumulation of residues. Also, the use of a central table can further contribute to explaining the pattern.

In addition, we were able to certify the use of the adjacent room located north of the kitchen as a cellar. This is the usual place for the cilla in the Benedictine monasteries, but up to now, we did not have any other archaeological evidence that could verify its location in the monastery of Cornellana. In this case, on the one hand, in front of the north-western door of the kitchen there is a high concentration of carbohydrates, proteins, phosphates and fatty acids; yet, on the other, there are very low values of carbonates and pH, which are in fact related to the fireplaces. These data show us a movement of products from the cellar, which was a storage area not only for flour, but also for meat, cold meat and dairy

products. Similar behaviour is observed in the pantry of the monastery of Volturmo, a room adjacent to the kitchen used as a storage area and for the initial handling of foodstuffs rich in phosphorus, fatty acids and proteins (Carannante et al. 2008; Pecci & Marazzi, 2006). Moreover, due to written sources, we know what main foodstuffs were stored in the cilla during the last period of use of the kitchen in Cornellana. These include, more specifically, spelt, barley, maize, rice, beans, chickpeas, mutton, lard, salt pork, cheese, oil, almond, salt, sugar, cured fish and wine (García Álvarez-Busto, 2015).

In the south-western corner of the room, however, there is a concentration of the highest pH values, carbonates, proteins and—to a lesser extent—phosphates. These results have allowed us to verify the hypothesis established during the archaeological excavation, which located the fireplaces (most likely two, rather than one) in this area, although their remains were partially washed away, which made an initial identification impossible. Other earlier studies have proved that in the cooking and preparation areas located around the hearth, there are high values of fatty residues, proteins, phosphates, carbonates and pH (Barba et al. 2014). Moreover, in front of these fireplaces, there is a stain extending to the north, which could be related to its use as well as to the cleaning of the fireplaces and the accumulation of ashes, which could have caused the pH to be alkalized. In contrast, the highest values of fatty acids are concentrated in the south-eastern corner of the room, between the sink and the fireplaces, at the foot of the podium, which seems to point to the existence of a workplace on the podium where fat, meat, cold meat or dairy products were handled and that such handling involved water.

Interpretation of the areas of activity may also serve to establish the routes that the monastic community used when moving between the different rooms that configured the south-western corner of the cloister, with two different paths being possible: one along which foodstuffs were indeed ordinarily carried (cellar to cellar door to kitchen to serving hatch to refectory), and another along which they were not (kitchen to cloister door to inner gallery of the cloister). The results of this research offer a first approximation in this sense, but future studies with a higher sampling density, and in which the adjacent rooms are also involved, should be carried out to be able to analyse several rooms as a whole. In any case, the study demonstrates the possibilities offered by these techniques for understanding the uses and the interior pathways within archaeological buildings.

CONCLUSIONS

Chemical analysis of the residues on the kitchen floor has proven to be an outstanding tool not only for revealing the spatial distribution of the different areas of activity documented inside it, but also for identifying or confirming the functionality of some of the structures documented in the excavation (e.g., fire hearths) or the rooms adjacent to the kitchen (e.g., the cellar). In addition, it has allowed us to interpret the processes of preparation of the foodstuffs by the monastic community who inhabited the monastery of Cornellana during the 18th century. In any event, and apart from the results pertaining to the present case, this study acquires greater relevance and versatility by virtue of having used an uncommon comprehensive procedure that combines some usual techniques with others that are not routinely used in the analysis of archaeological soils. The techniques used can be employed rapidly, are effective and relatively inexpensive, and build on the previous existing studies of archaeological areas of activity. In short, the results obtained show the potential of the method used, which is valid for and applicable to the analysis of chemical residues and scientific exploration of areas of human activity at other archaeological sites, regardless of their chronology or geographical location.

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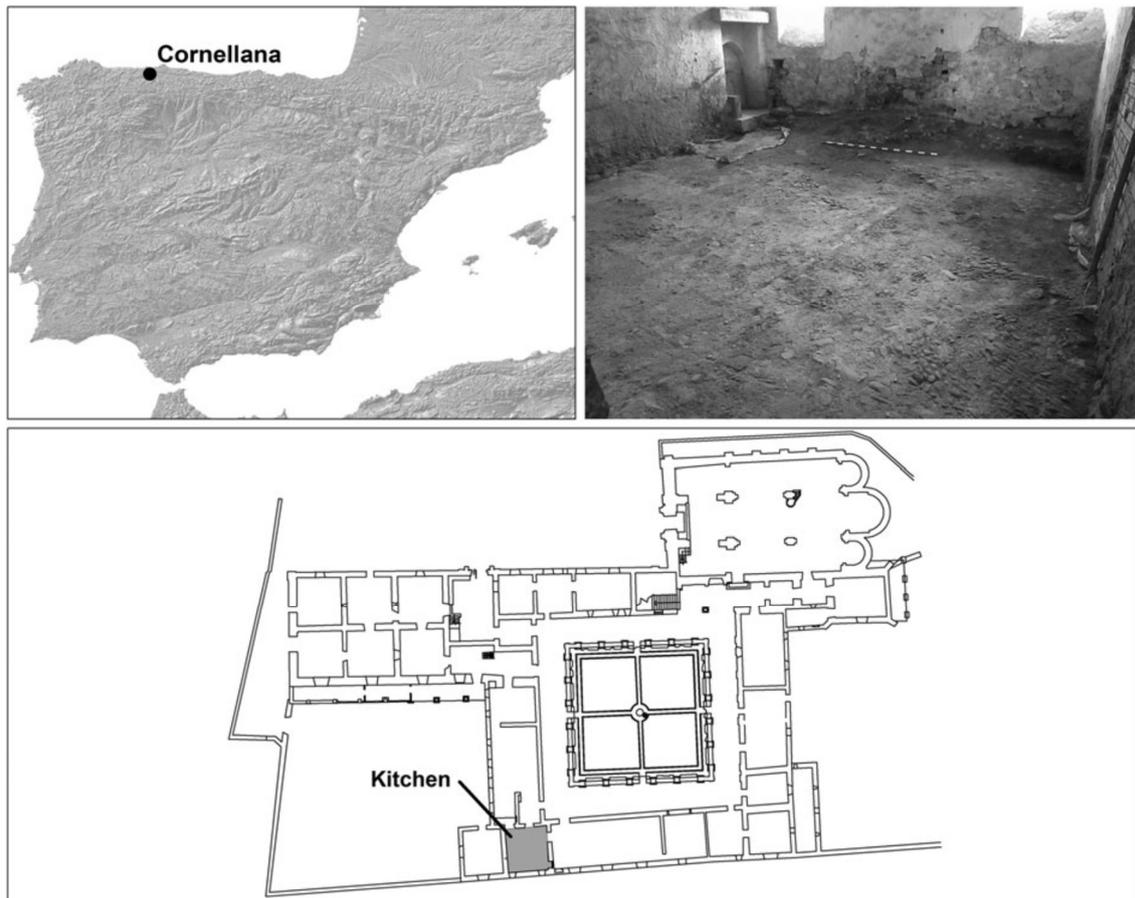


Figure 1 The location of the monastery of San Salvador de Cornellana in the north-west of the Iberian Peninsula (top left). A general view of the kitchen looking north-west (top right) and the location of the kitchen in the general floor plan of the monastic building (bottom).

Table 1 Results of chemical analysis of the residues deposited on the floor of the kitchen of the monastery of Cornellana

	Sample								
	A	B	C	D	E	F	G	H	I
Proteins (% dry weight basis)	1.17	0.61	0.31	0.98	0.59	1.15	0.83	0.91	0.53
Phosphorus (% dry weight basis)	0.52	< 0.1	< 0.1	< 0.1	1.11	0.96	1.24	0.75	0.93
Carbohydrates (mg g ⁻¹ dry weight basis)	0.0453	0.0428	0.0142	0.0412	0.0204	0.0477	0.0845	0.0708	0.0369
Fatty acids (mg g ⁻¹ dry weight basis)	2.7	3.9	4.7	2.2	2.1	2.1	2.4	2.3	2.2
Carbonates (mg g ⁻¹ dry weight basis)	7.5	10.9	4.5	5.4	2.7	7.4	3.2	5.0	2.2
pH	9.03	8.63	9.06	9.31	8.60	8.75	8.13	8.70	8.73

Table 1 Results of chemical analysis of the residues deposited on the floor of the kitchen of the monastery of Cornellana

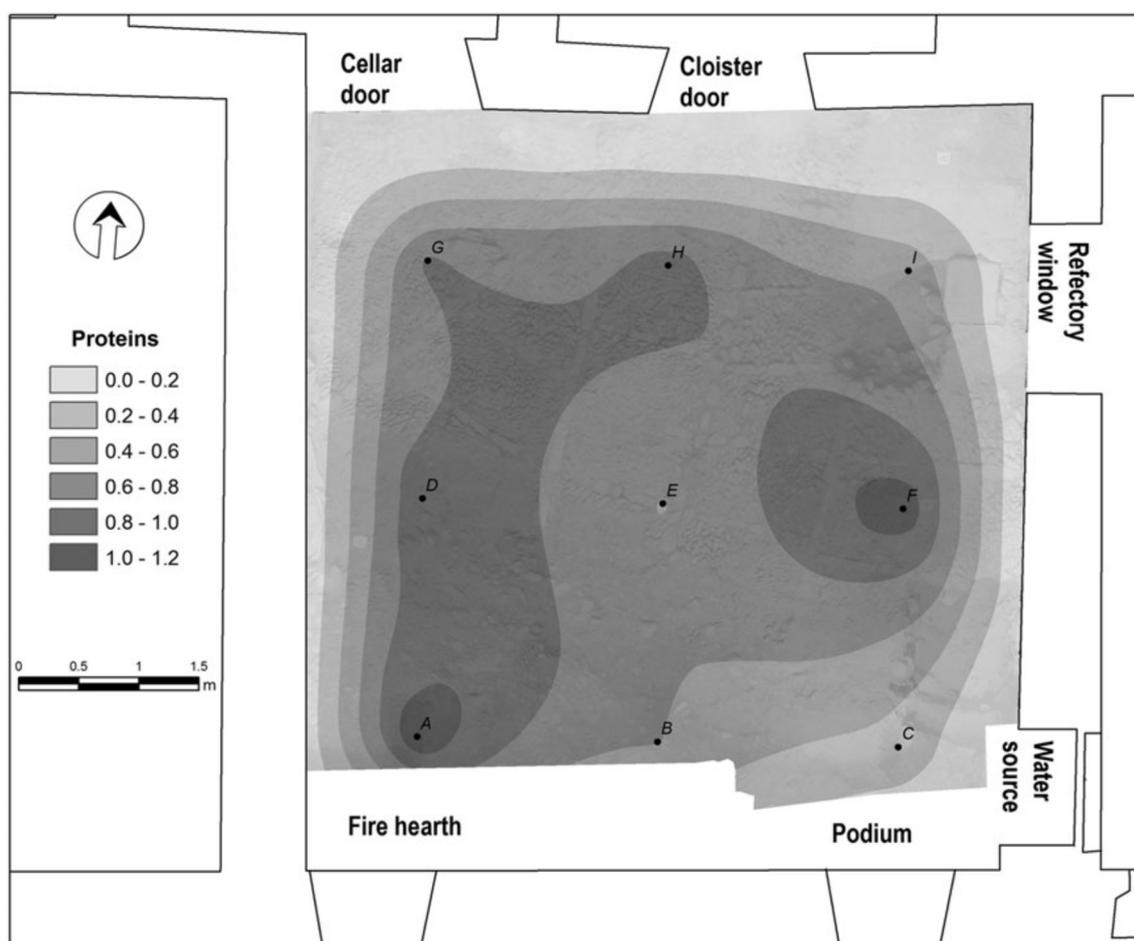


Figure 2 The distribution map for the proteins.

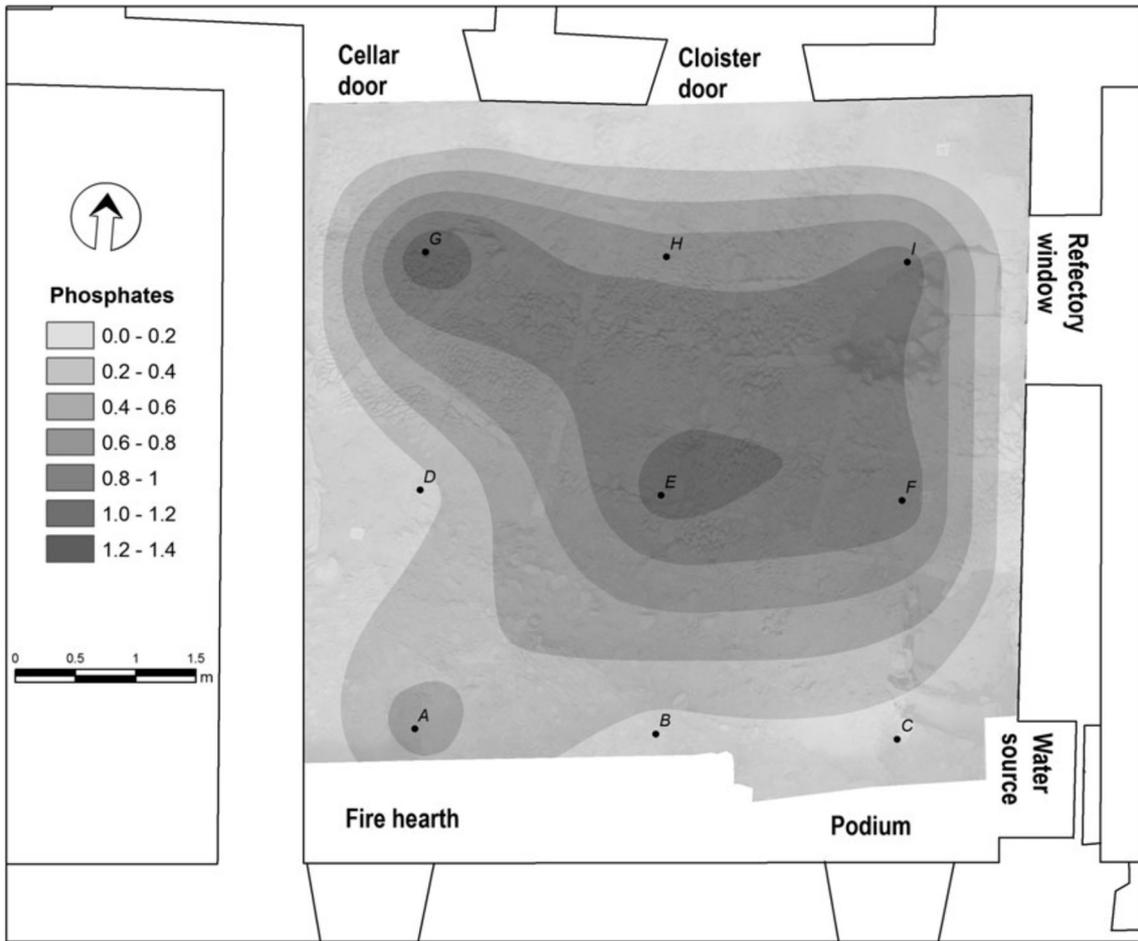


Figure 3 The distribution map for the phosphates.

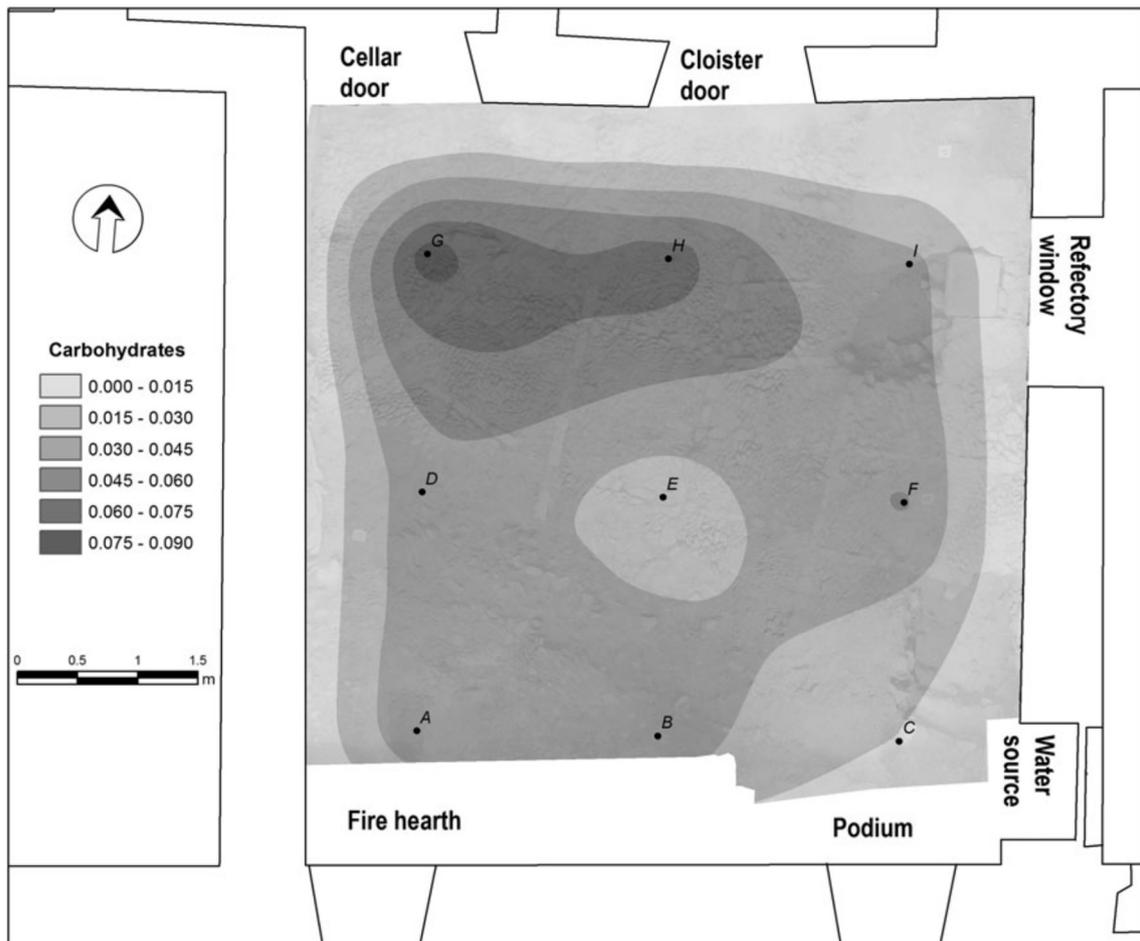


Figure 4 The distribution map for the carbohydrates.

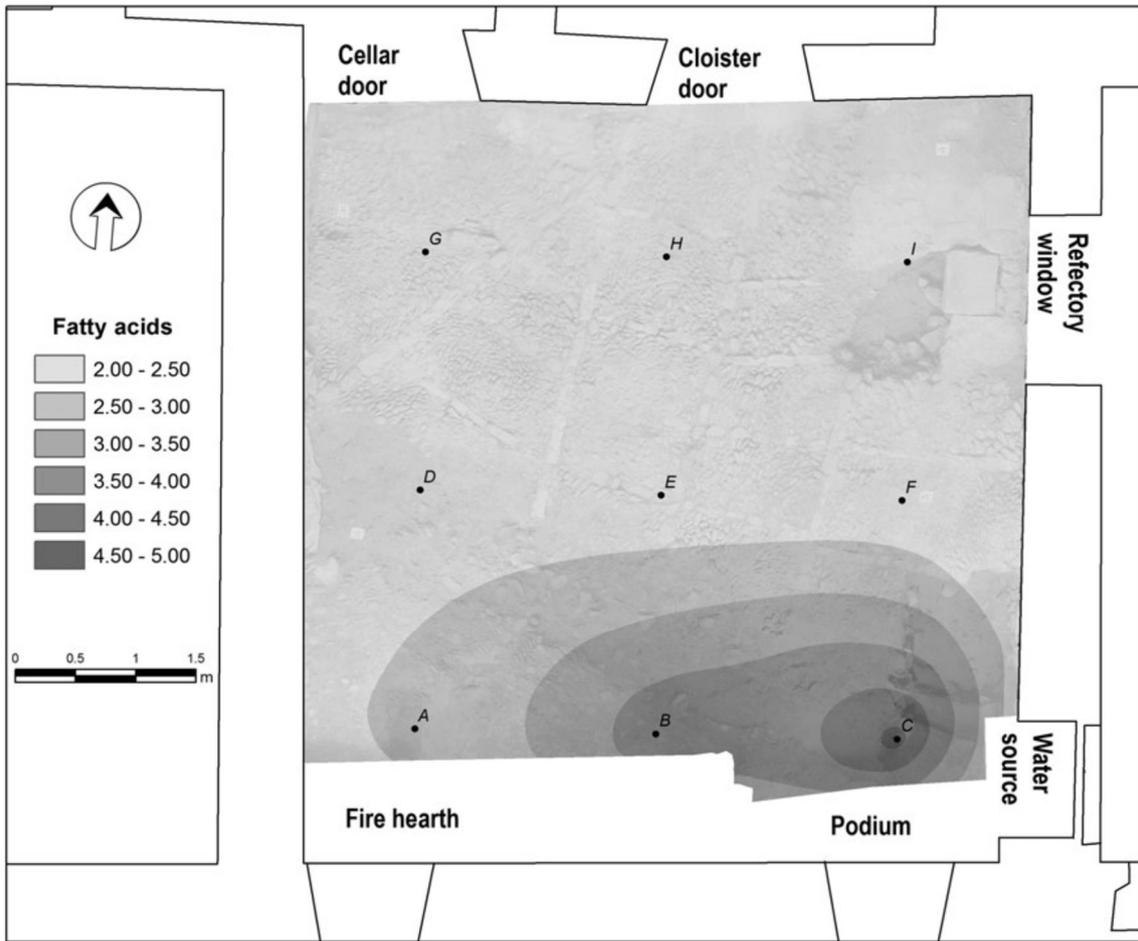


Figure 5 The distribution map for the fatty acids.

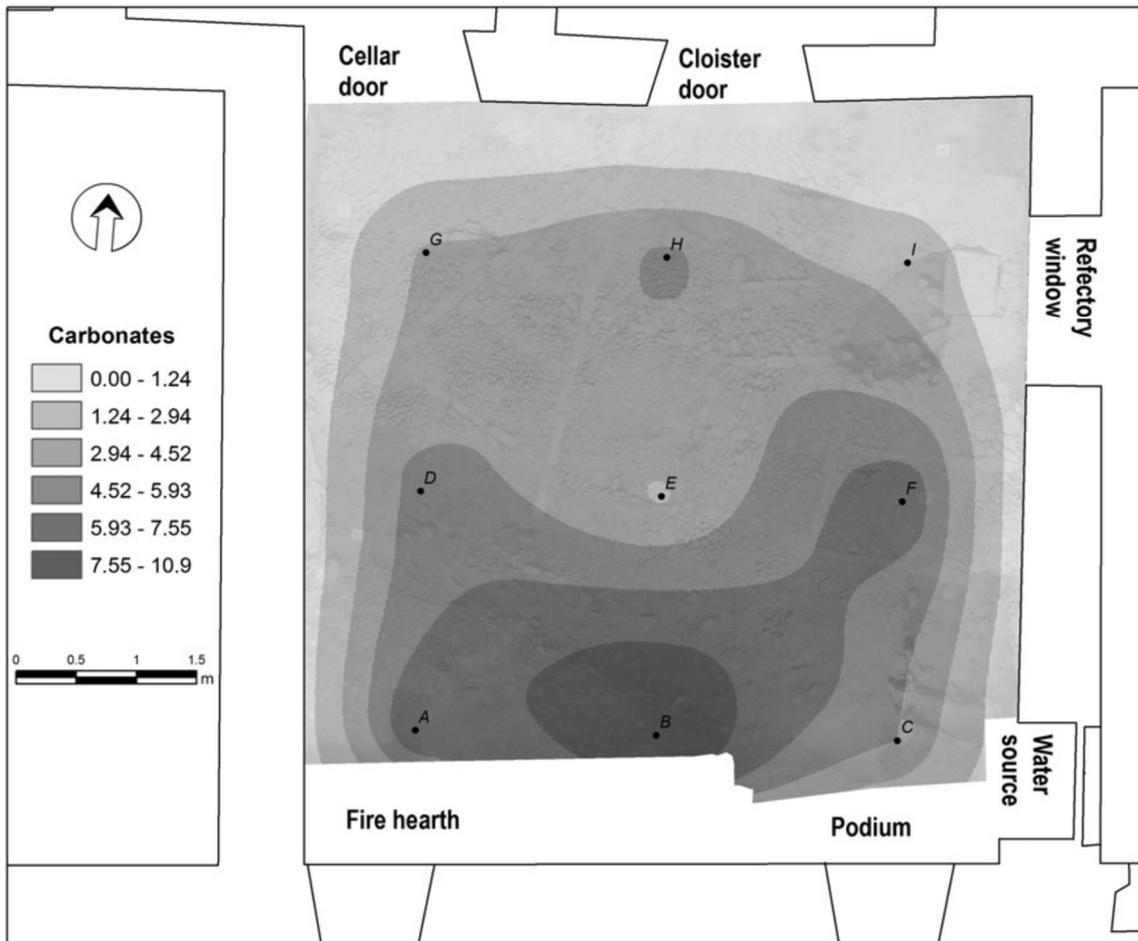


Figure 6 The distribution map for the carbonates.

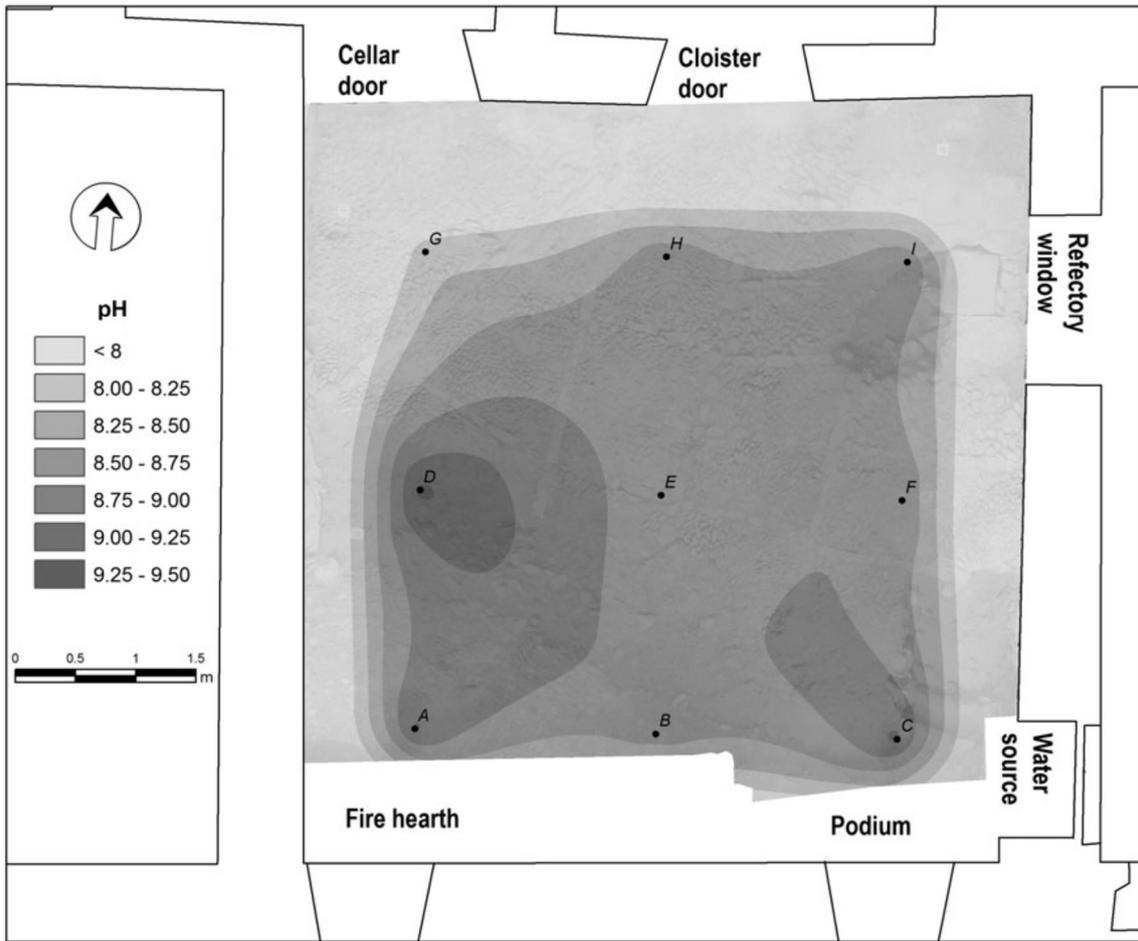


Figure 7 The distribution map for the pH values.

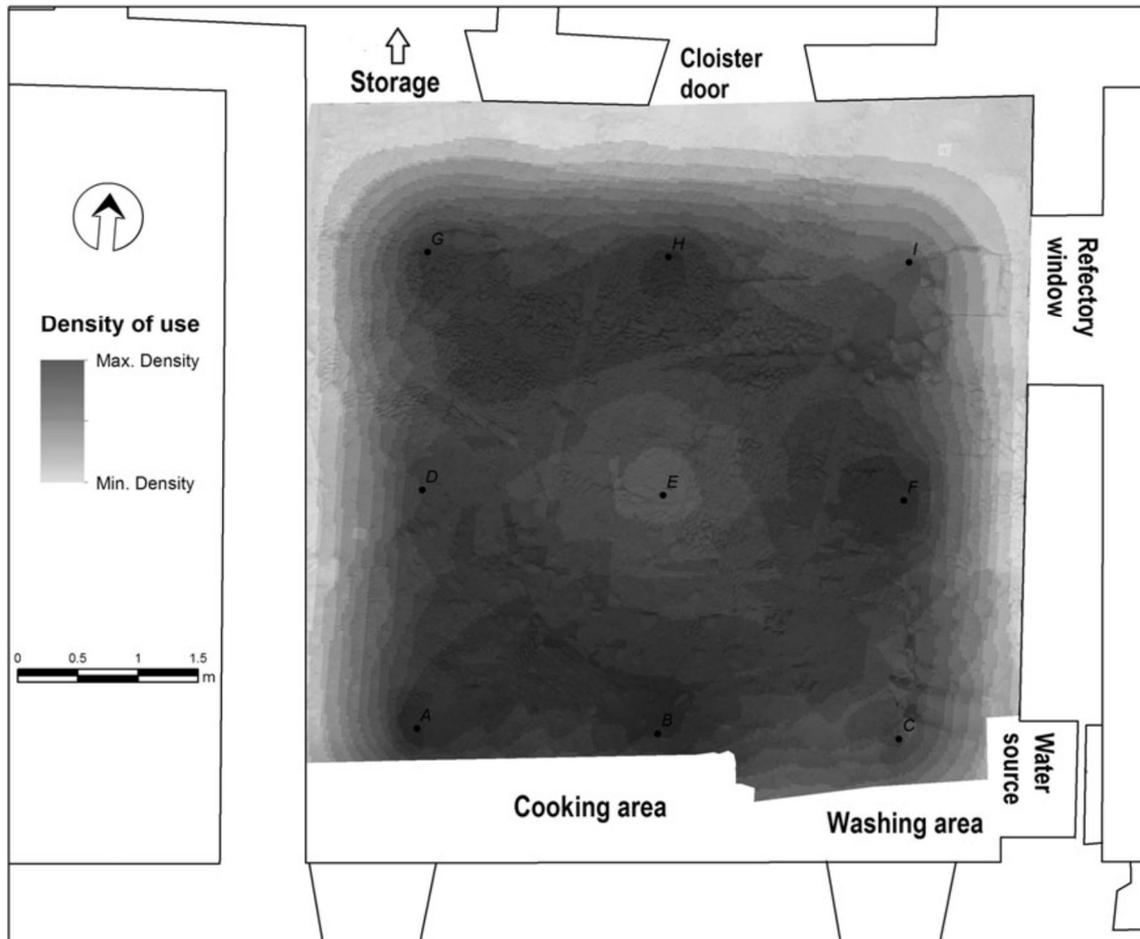


Figure 8 A map showing the density of use of the kitchen and the distribution of the activities undertaken inside it.