The potters' perspectives: A vibrant chronology of ceramic manufacturing practices in the valley of Juigalpa, Chontales, Nicaragua (cal 300 CE - present)

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6 Laboratory methods and techniques for ceramic analysis

As stated in previous chapters, this project's laboratory work focused on the various itineraries of ceramic manufacturing practices, with the objective of outlining the trajectories of technological steps in the different sites selected for examination. Particularly, analysis concentrated on the physical, mechanical, and thermal properties of pottery, which not only provide information on production techniques, but also on pottery use and the nature of raw materials (Rice 2005). Therefore, ceramic description and analysis are seen as parts of one whole, in which each feature is understood in relationship to the others. Physical properties are complex to understand, since they "(...) are directly affected by materials and by the potter's techniques, [but] also the nature of the material often limits the choice of technique, and both material and technique in turn influence style" (Shepard 1985, 95) Thus, raw materials, manufacturing techniques, and style are all part of social universes of practices that are intertwined and co-relate to each other.[65]

To try to encompass this complexity, the laboratory analysis methodology applied in this study was comprised of five main steps to produce sufficient data in order to evidence the various choices made by communities of potters. In Chapter 8, these technological decisions will be spatiotemporally contextualized.

In general, examination of ceramic sherds was conducted in two stages: "(...) visual and archaeometric (scientific—comprising petrological, compositional and materials-science techniques), reflecting a rising level of complexity (and cost), but decreasing accessibility and a consequent narrowing of the quantity of material that may be processed" (Orton & Hughes 2013, 153). Consequently, traditional characterization methods were merged with archaeometry, challenging and complementing technological studies with mineralogical characterization through thin section petrography. Even though a geochemical approach using portable X-Ray Fluorescence (p-XRF) was also designed for this research, and more than 200 sherds were measured, time constraints prevented the integration of those results into this book. Consequently, they will be published later as a separate article.

As a result, relatively simple procedures were complemented with specialized techniques with the goal of measuring and describing ceramics under precise and reproducible standards (Rice 2005). To fulfill this, various macroscopic and microscopic strategies were applied to the collection, which involved different levels of sampling that will be explained in each section of this chapter.

In order to reconstruct the ancient ceramic manufacturing practices within the research area, the five steps of my method can be summarized as follows:

1. ***Macrofabric classification***: following Rye (1981), Shepard (1985), Sinopoli (1991), Rice (2005), the general procedures and outlines by the Prehistoric Ceramics Research Group (PCRG 2010), Orton and Hughes (2013), and Roux (2016), ceramics were classified according to the macroscopic properties of their paste. During this part of the analysis, the main objective was to achieve a preliminary paste composition characterization, as well as a general overview of firing techniques and vessel shapes.
2. ***Macrotrace analysis***: within the previously sorted macrofabric groups, an adapted version of V. Roux (2016) and S. Manem's (2008) methodology was applied for the identification of macroscopic technological traces. This stage of the analysis mainly focused on the following steps of the *chaîne opératoire*: fashioning, pre-forming, finishing, surface treatment, and decoration.

65 See Chapter 3 for a complete theoretical discussion.

Figure 86: Storage of materials at the project house in Juigalpa (credit: Arnau Llaudet).

3. ***Techno-petrographic groups***: based on the results of the two steps above, the outlines proposed by I. Whitbread (1986), P. Quinn (2013), P. Degryse and D. Braekmans (2017) were applied for mineralogical characterization under the polarizing light microscope. This section of the analysis provided insight on choices related to clay procurement and paste preparation techniques.
4. ***Morphostylistic groups***: based on the combination of all the analyses described above, a small sample was selected for shape and decoration classification, to outline the end products related to the different operational sequences identified in this study (Roux 2016).
5. ***Production sequences:*** through the combination of all the analytical steps outlined above, different ceramic manufacturing sequences were created for each site, from clay procurement practices through firing, decoration techniques and the end products.

Finally, the different methods used to assess the chronological span of this study will be described. A combination of different materials (charcoal, organic sediment, charred residues encrusted on sherds, animal bone, and a burnt seed) were run for Accelerator Mass Spectrometry (AMS) absolute dating. The sampling procedure is described, while pre-treatment for organic sediment dating has already been outlined (Donner & Geurds 2018).

6.1 CLEANING AND STORAGE OF MATERIALS

All the sherds recovered during the stratigraphic excavations were washed with tap water, using a toothbrush on recent fractures and fingers on the external and internal walls to avoid damage of surface finishing and decorations, as well as the creation of fake macrotraces.[66]

After cleaning the materials, they were left for a full day to dry in the shade and placed on top of cardboard unfolded boxes for water absorption. Later, sherds were stored in clean zip-lock bags with their corresponding tags, indicating their excavation contexts. Afterwards, the bags were stored in seven different plastic boxes, organized by site and excavation unit, for easier access (**figure 86**). Also, each box included an inventory of the bags that it contained. The same procedure was applied for the other types of materials found during the excavations: ground stone, chipped stone (obsidian was stored separately), and burnt clay. Animal bones, starch and phytoliths were stored following specific protocols to ensure their optimal preservation (Angeles Flores 2019; Gill *et al.* 2019).

66 For macro and microbotanical remains, as well as future use-wear investigations, various types of artifacts (ceramic, chipped stone, and ground stone) were selected in the field and collected using surgical gloves with a sterilized trowel together with associated sediment. Additionally, sediment from all stratigraphic units was collected for further analysis.

Site Name	Site Code	#Test Pits	2x2m	1x1m	3x1m	2x1m	TOTAL
Aguas Buenas	AB	6	6				3020
Alberto Obando	AO	3	3				875
La Zarcita	ZAR	6	6				458
La Vaina	LVA	4		4			13
Jerry Hernández	JH	5		5			16
Lázaro Villegas	LV	2	2				1972
Sebastián Ríos	SR	1	1				71
La Aventura	LA	3	3				2034
Sebastián Ríos Histórico	SRH	2	2				390

Table 16: Quantification of ceramic materials including the amount and different types of excavation units they were retrieved from.

Materials were stored and macroscopically analyzed at the PACEN Project house in Juigalpa, as well as in the Museo Comunitario Juigalpan. A sample was exported to The Netherlands for archaeometric analyses, which were were conducted at the Laboratory of Artefact Studies, Faculty of Archaeology, Leiden University.

6.2 MACROFABRIC GROUPING

The classification approach took into account the craftsman's perspective, whose first choice—after deciding which end product is desired—is related to the recipe for manufacturing ceramic vessels. This selection can be influenced by ecological (Arnold 1985), cultural (Gosselain 1999; Gosselain & Livingstone Smith 2005), political power and land ownership related issues (Sillar 2000), pottery end products (Arnold 1971; DeBoer & Lathrap 1979), or vessel performance (Rye 1981; Braun 1983; Shepard 1985; Bronitsky & Hamer 1986; Skibo *et al.* 1989; Orton & Hughes 2013). Clay procurement and paste preparation practices may also result from a combination of several of these variables.
In pottery analysis, paste and fabric are used as synonyms to refer to the composition and structure of the fired clay body from which pots are made. Pottery fabric consists of two different elements: the matrix—comprised of clay minerals—and the inclusions. The latter can be seen by the naked eye or a low power microscope, whereas the matrix needs high powered microscopes, such as polarizing light and SEM (Rye 1981; Shepard 1985; Orton & Hughes 2013).
The study of pottery fabrics, which include the description of physical characteristics, appearance, and composition, yields valuable information on raw materials, technological choices in clay preparation practices, firing techniques, use, and post-depositional processes (Orton & Hughes 2013).

6.2.1 SAMPLING FOR MACROFABRIC GROUPING

The first step at the lab consisted of the quantification of the universe of pottery fragments for research, which comprised a total of 30178 sherds. The quantification of the ceramics per site is summarized in **table 16**. The number of fragments was achieved through sherd count in combination with weight measurements, because these two strategies together can provide better comparisons (Orton & Tyers 1990) as well as a more accurate approach to quantification. This collection was retrieved through systematic stratigraphic excavations in nineteen different archaeological sites throughout the research area.[67] This selection includes the site of La Pachona, located approximately six kilometers south of Juigalpa, which was excavated by Roosmarie Vlaskamp and her crew as part of her PhD thesis at the Faculty of Archaeology in Leiden University. La Pachona was initially included in the sample to broaden the spectrum of the available collection by taking into account a Cuisalá River associated site as a comparative parameter with the valley. Even though all materials from the selected unit at La Pachona were quantified and preliminary classified, and all rim sherds were drawn, time constraints made full analysis impossible. Instead, results will be published in a separate paper.

67 See Chapters 4 and 5 for methodology and descriptions of the excavated contexts.

Site Name	Site Code	TOTAL	% of Total
Aguas Buenas	AB	906	30 %
Alberto Obando	AO	262	30 %
La Zarcita	ZAR	137	30 %
La Vaina	LVA	13	100 %
Jerry Hernández	JH	16	100 %
Lázaro Villegas	LV	591	30 %
Sebastián Ríos	SR	71	100 %
La Aventura	LA	610	30 %
Sebastián Ríos Histórico	SRH	117	30 %
Quebrada Profunda	QP	73	100 %
Alcides Montiel	AM	31	30 %
Barillas	UBI	1,017	25 %
Rosa Dolores Oporta	RDO	86	30 %
Wilder Marín	WM	128	30 %
Oporta	OP	370	30 %
Josefa Ocón Robleto	JOR	331	30 %

Table 17: Percentage of sampled sherds after quantification and preliminary analysis. The highlighted sites were the ones then selected for complete examination.

In theory, sherds of >5 cm on their longest side are ideal for technological analysis (Roux 2016). For that reason, the universe studied in this manuscript is problematic, since some sites present a lot of fragmentation (such as Sebastián Ríos Histórico and Alcides Montiel, for example), and others are distinguished by very large pieces, of around 8 cm on their longer axis (for instance, La Pachona and Sabana Grande). Orton and Tyers (1990) divide fragmentation in two different categories: brokenness and completeness. Brokenness is a result of the ceramic properties combined with the sherd's post-depositional history; whereas completeness refers only to post-depositional processes. Therefore, fragmentation variations can be the result of several different factors, such as dissimilar firing temperatures, taphonomic processes, and the biography of vessels, among others. This variability represented a methodological challenge, and discarding smaller fragments during analysis was not considered since this practice can bias the sample. This idea was reinforced after assessing the preliminary results obtained from fragments excavated in Aguas Buenas in 2012 that were smaller than 5 cm. Apart from that, unlike the previous chronology for the area (Gorin 1990), decoration techniques were not granted the highest level in the hierarchy of attributes. The scope of this study focuses on identifying social identities, continuities, and disruptions of the communities of potters through the steps of the manufacturing sequences. Therefore, a stress on

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Ceramic Sampling Form

Context	
Site	
Excavation Unit	
Stratigraphic Unit	
Level	
Bag Number	
Weight	

	Number	< 50 mm	> 50 mm	Sampled
Rim (Open)				
Rim (Closed)				
Rim (NI)				
Rim/Neck (Open)				
Rim/Neck (Closed)				
Rim/Neck (NI)				
Neck/Shoulder (Open)				
Neck/Shoulder (Closed)				
Neck/Shoulder (NI)				
Body (Open)				
Body (Closed)				
Body (NI)				
Base (Open)				
Base (Closed)				
Base (NI)				
Support				
Lug				
Handle				
Total				

Figure 87: Sampling form designed for this study.

decoration techniques—which are among the most unstable factors in pottery industries (Gosselain & Livingstone Smith 2005)—would not be coherent with this theoretical and methodological approach. Consequently, special attention was paid to the more stable methods and techniques, related to the roughing out phase of the manufacturing process (Roux 2011; 2016).

Due to the multiplicity of analytical steps, together with the aim of reducing the number of samples requiring exportation, 30% of the total universe was initially sampled. Sites with a larger quantity of sherds, though, such as Barillas and Sabana Grande, were sampled differently. In the first case, since the excavations retrieved more than 9000 fragments, 20%

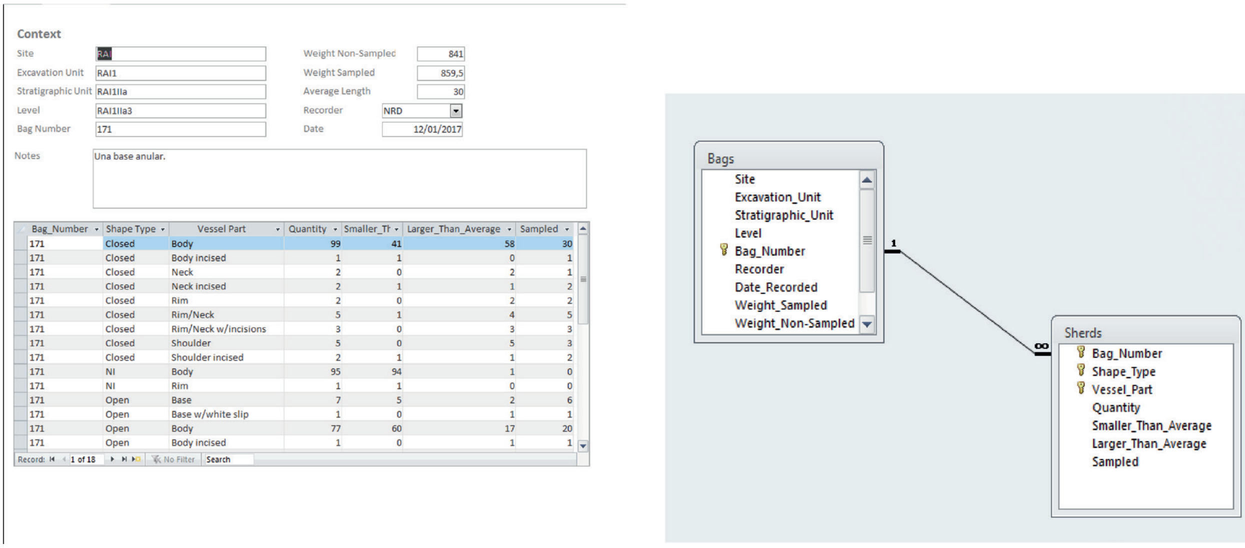

Figure 88: Microsoft Access database for sampling ceramic sherds.

was selected in order to secure a representative sample of the universe. In the second case, Barillas, with more than 4000 fragments, 25% of the assemblage was sampled. Other exceptions to the 30% rule were La Vaina, Jerry Hernández, Sebastián Ríos, and Quebrada Profunda, because their population was below than 100 sherds. As a result, analysis included 100% of their fragments. In contrast, Alcides Montiel was sampled following the 30% rule, since its stratigraphy is problematic, as described in Chapter 5. Quantification of the sample chosen for the study is outlined in **table 17**.

To achieve these percentages, a multi-stage sampling procedure was applied, combining cluster, random, and stratified random sampling strategies (Bernard 2002; Drennan 2009) to ensure the representativeness of all layers of the population within a research universe (Bernard 2002). Therefore, the sampling strategy involved different phases, which included clustering by site, excavation unit, stratigraphic unit, and level. Then, vessel parts were grouped according to the categories established for the database, so a representative sample of rims, rim/necks, neck/bodies, bodies, bases, supports, lugs, and handles were selected. The reason for clustering the different parts of the vessels separately lies in the fact that one of the essential elements in the identification of the *chaîne opératoire* is to recognize the methods and manufacturing techniques applied on the various parts of the pots, ideally involving vessel reconstructions as well. Therefore, the first approach to the macroscopic analysis consisted of a basic division to identify the main phases of the manufacturing process.

To control the sampling, workflow was organized by site, stratigraphic unit, level, and bag. An individual form was filled in for each bag (**figure 87**), first detailing all contextual information and vessel part (body, neck, rim, rim/neck, shoulder, base, etc.) with an annotation regarding decoration (incisions, punctuations, white slips, etc.), as well as a preliminary assessment of shape type (close for restricted, open for unrestricted, and NI for non-identified morphologies). Also, the quantification included the total number for each category and weight, as well as the division between fragments larger and smaller than the average, which was mathematically calculated per site. To do this, the longest axis of all fragments measured and then the average was calculated, which became the standard for each stratigraphic unit within sites. After this calculation, 30% of all vessel parts larger than the fixed measure, open, closed, and NI were sampled for macrofabric characterization.

The sampling form (**figure 87**) used to record this step of the method is an adaptation from the form proposed in the Leiden Code Book for Caribbean Ceramics (Hofman 2005). All the data recorded in the paper forms was then digitized in a Microsoft Access database designed by Leontien Talboom (UCL) (**figure 88**).

6.2.2 HANDLING OF SAMPLES

After the quantification and sampling of the universe of sherds, fragments were labeled using a code comprised of site name, excavation unit (Arabic numbers), stratigraphic unit (Roman numbers), and arbitrary metric level (Arabic numbers). For example, sherds collected on Aguas Buenas, excavation unit 2, stratigraphic unit III, level 4, were labeled AB2. III.4. As a result, each ceramic fragment kept all the necessary stratigraphic information for later chronological interpretations. When these codes were too long to write on the ceramic sherds, an alternative code comprised of site name, excavation unit, and bag number was used on the sherds.

Once labeled, the materials were analyzed by site. Before classification, an examination of the stratigraphy of each site was conducted.[68] If two or more assemblages presented similarities at the sampling stage, they were later analyzed on tables placed next to each other, to facilitate comparisons but ensure continued separation. Also, stratigraphic units and arbitrary metric levels were never mixed; however, when fragments of a single pot were found in several of them, a re-evaluation of the stratigraphy took place immediately.

The basic activities performed with the materials at this stage of the analysis involved handling, making small section cuts, drawing and photographing different vessel parts and techno-markers, examination under the stereomicroscope, measurements, weighing, and descriptions.

After assessing these variables in combination with the stratigraphic analysis of all contexts excavated, seven different sites were sampled for macrofabric characterization: Aguas Buenas, Alberto Obando, Oporta, Josefa Ocón Robleto, Barillas, Rosa Dolores Oporta, and La Aventura. Chapter 7 only focuses on these sites, but some references to the rest of the sites can be found on Chapter 8.

6.2.3 ATTRIBUTES FOR MACROFABRIC CHARACTERIZATION

Attributes are observable physical properties, meaning that they are part of the basic analytical units in pottery technology, because they are related to specific techniques. In ceramic assemblages, there are common attributes which are shared, but also discriminatory attributes, which aid in setting up the boundaries between groups. In the macrofabric stage of this study, descriptions incorporated nine basic attributes: inclusions, voids, cross-section core-margin relationships, color, hardness, fracture, feel, thickness, and radius.

- *Inclusions*: clays usually contain other minerals in addition to the clay minerals themselves, as well as organic materials. These particles are known as inclusions, which can be related to parent rocks, erosion and transport, deposit conditions, and other factors (Rye 1981; Shepard 1985; Orton & Hughes 2013).
- *Voids*: the gaps between or inside solid particles (Rice 2005) are referred to as pores or voids. They may be the result of technical gestures (such as kneading), organic inclusions or tempers (for example, plants), or naturally occuring. They can be key to understanding certain aspects of the *chaîne opératoire* and the nature of the raw materials employed in pottery manufacture.
- *Cross-Section Core-Margin Relationships:* when making fresh section cuts on sherds fired lower than 1000 °C, sometimes variability can be observed in the core's tone when comparing it to the margins of the section and/or the surface (Rye 1981; Shepard 1985; Orton & Hughes 2013). This differentiation is related to the carbonaceous content of the clay, in combination with the firing atmosphere, temperature, and duration. The typical "sandwich" core, for example, is related to short duration and/or low temperature firing, which causes the surface carbon to burn and exit as carbon dioxide, while the one present deeper in the clay does not burn completely and therefore shows a dark coloration (Shepard 1985).
- *Color*: this attribute is first related to clay composition (especially iron compounds and carbonaceous matter), firing atmosphere, temperature, and duration, as well as post-depositional processes (Shepard 1985). Then, color is also changed or "disguised" in the following chapters of the vessel's life history after it has been fired due to the absorption of stains during use, wear, deposition of carbon in cooking, or substances from the soil after discard (Rye 1981; Shepard 1985).
- *Hardness*: the pot's resistance to penetration, abrasion, and scratching provides valuable information on serviceability. However, hardness is problematic because lots of

68 See Chapter 5.

Contextual Data	
Macro-Group Code	
Site	
Excavation Unit	
Stratigraphic Unit	
Level	
Bag #	
Weight	

Color		
Cross section	Core	
	Int. Margin	
	Ext. Margin	
Internal Surface		
External Surface		
Slip		
Paint		

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Ceramic
Macro-Fabric
Group

Form
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Inclusions	
Identity	
Frequency	<5% - 5% - 10% - 15% - 20% - 25% - 30% - 35% - 40% - 45%
Size	Pebbles / Granule / Very Coarse / Coarse / Medium / Fine / Very Fine / Silt
Sorting	Very well sorted / Well sorted / Moderately sorted / Poorly sorted
Roundness	High / Low Sphericity
Shape	V. Angular / Angular / S-Angular / S-Rounded / Rounded / W. Rounded / Irregular / Flat
Orientation	Parallel to wall / Sub-Parallel to Wall / Horizontal / Oblique / Concentric / Chaotic
Color	

Voids	
Visible	YES - NO
Shape	Plate-like / Oval-Sphere / Rhombs / Irregular
Orientation	Parallel to wall / Sub-Parallel to Wall / Horizontal / Oblique / Concentric / Chaotic

Other Characteristics	
Hardness	Soft / Hard / Very Hard
Fracture	Subconchoidal / Smooth / Fine / Irregular / Hackly / Laminated
Feel	Harsh / Rough / Smooth / Soapy / Powdery

Core-Margin Relationships	
A	1 - 3 - 5 - 7 - 9
B	2 - 4 -6 - 8 - 10

Figure 89: Macrofabric group paper form.

processes affect it, such as firing duration, porosity, inclusion grain-size and distribution, and post-depositional mechanisms (Orton & Hughes 2013). However, it was included as an attribute in the analysis because it remains a standardized procedure in ceramic analysis and is helpful in well preserved collections.

- *Fracture*: the particular way in which potsherds break is related to firing temperature, the amount and size range of inclusions, and even fashioning techniques (Orton & Hughes 2013; Roux 2016).
- *Feel*: the combination of hardness, inclusions, and surface treatment gives a particular "feel" to the sherds, which is a very good empirical tool for fast identification. Even though it is a very subjective attribute, it has proven to be useful in previous classification experiences (Donner & Hernández Arana 2018).
- *Thickness*: the variation in the widths among vessel parts and between vessels is related to the size of the inclusions, firing techniques, drying processes, end product uses, etc.
- *Radius*: the radii of different parts of pots (rim, neck, mouth, body, base) are relevant in the reconstruction of ancient cooking, eating, drinking, and storage practices.
- *Percentage estimate of the total of the vessel*: using the same chart applied for calculating the radius, the percentage of the vessel represented by the sherd was also calculated.

6.2.4 ANALYTICAL STEPS

The sampled fragments were classified into different clusters based on various characteristics of their fabric, establishing ranges of variation within groups to avoid over-splitting but also taking into account differences to avoid lumping. Once these preliminary groups were created visually, the analysis was refined with a thorough fabric description. To begin with, inclusions were characterized, since they are the largest features present in pottery fabric. To describe them, different categories were taken into account, as shown in the macrofabric group form within the section dedicated to inclusions (**figure 89**).

Name	Grade Limits (Diam. in mm.)
Pebble	64-4
Granule	4-2
Very coarse	2-1
Coarse	1 - 0.5
Medium	0.5 – 0.25
Fine	0.25 – 0.125
Very fine	0.125 – 0.0625
Silt	0.0625 – 0.0039

Table 18: Classification of different textures (modified from Shepard 1985, 118).

Whenever possible, a key to identify inclusions was applied (Peacock 1977). When that was not possible, generic descriptive values were used, such as red dots, elongated black plates, grey angular, etc. The preliminary identification of inclusions, which are the most visible features of the fabric, was important to characterize each macrofabric group easily. For frequency, or the proportion of inclusions present in the fabric, a visual chart (Matthew *et al.* 1991) was applied. Taking into account the inclusion size in mm (0.5, 0.5 to 2.0, and 0.5 to 3.0), frequency was recorded using percentage values (<5%, 5%, 10%, 20%, 30%, and >30%). For classifying texture, grain size was measured and characterized using the geometric ratios proposed by Shepard (**table 18**), which were based on the Wentworth scale.

For sorting, understood as an assessment of homogeneity or heterogeneity of the relationship between inclusions as well as inclusions and clay matrix, a diagram was used (PCRG 2010, 50) (**figure 90**).

To characterize roundness and shape, visual charts were applied (PCRG 2010, 52). Sphericity was classified as either high or low (**figure 91**), and then shape was sorted into one of the six different classes for each type of inclusion.

Regarding orientation, which can aid in the identification of fashioning and pre-forming techniques, suggestions by V. Roux (2016) and S. Manem (2008) were followed. Accordingly, the orientation of the inclusions was classified according to their relationship with the vessel wall (**figure 92**).

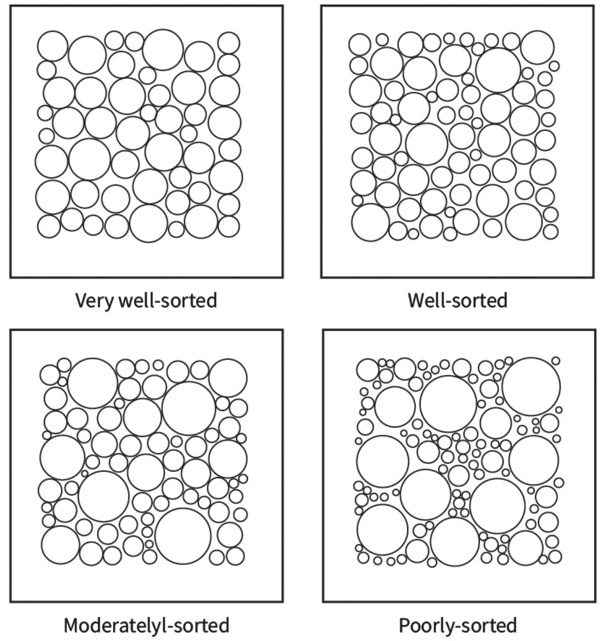

Figure 90: Visual diagram to classify sorting (redrawn from PCRG 2010, 50).

The different colors of the inclusions were recorded using the Munsell soil color system. Apart from that, the cross-section margin relationships established by Orton and Hughes (2013) chart and code (based on Rye 1981, 116) were applied, which provide valuable information on firing temperature, duration, and atmosphere (**figure 93**). New categories for establishing these relationships were established in this research and then added to the chart. Additionally, the Munsell soil color chart was used to record the color of the different parts of the cross-section (core, internal margin, external margin), as well as the internal and the external surface, slip, and paint when present.

For describing voids, the first step consisted of identifying their presence or absence, then their shape (plate-like, oval-sphere, rhomb, irregular), and finally their orientation, using the same criteria applied for inclusions. Also, hardness was measured according to the Mohs scale. Fracture was described according to six different variants: subconchoidal (when the fracture resembles those found in flint or obsidian), smooth (when no ripples are visible), fine (when the cutting device cuts through the inclusions), irregular (fractured around inclusions), hackly (similar to the hackles on a dog's back; it is

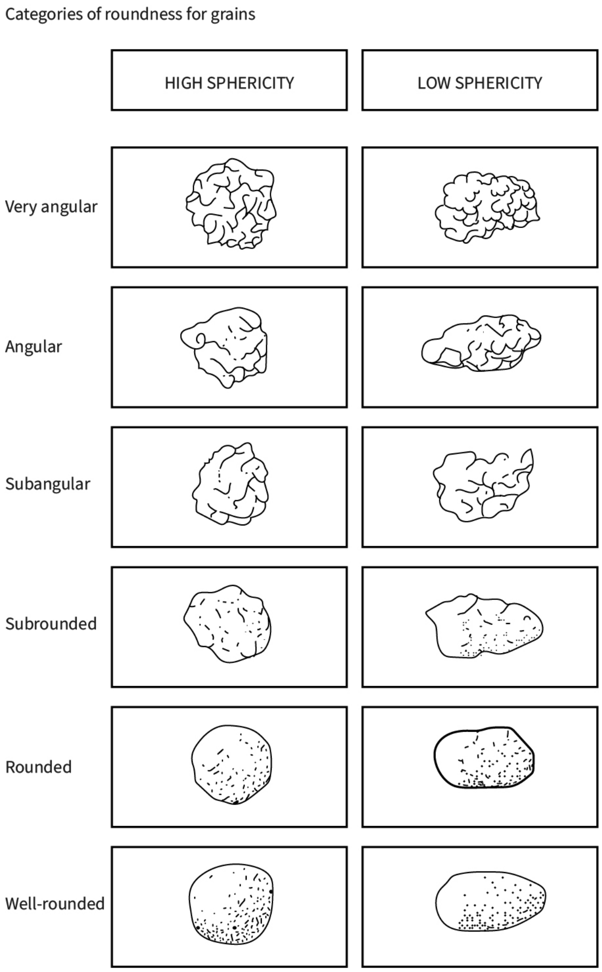

Figure 91: Visual chart for characterizing roundness and shape, (redrawn from PCRG 2010, 52).

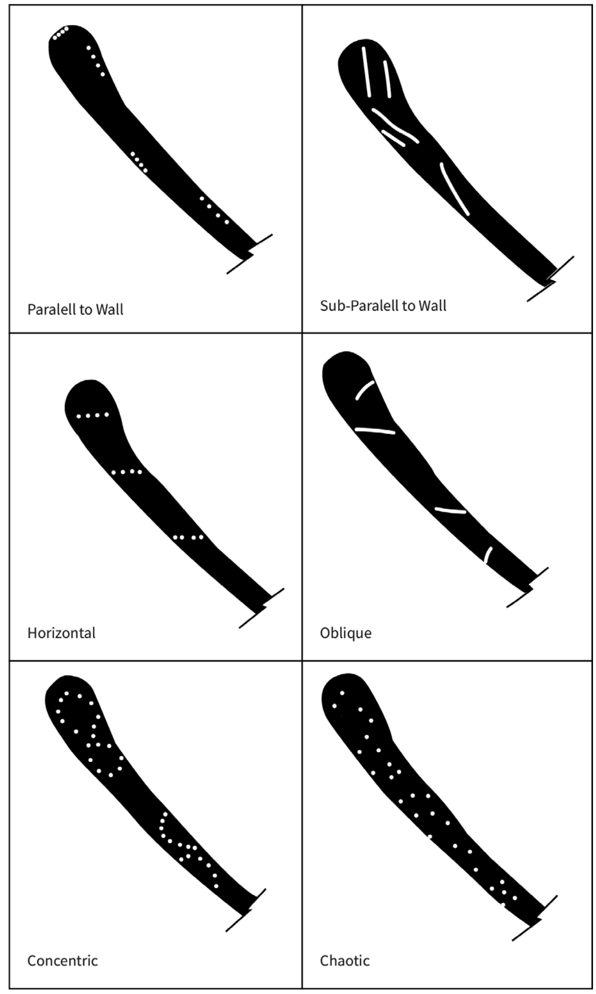

Figure 92: Visual chart to classify the different types of orientations for inclusions and voids.

jagged, sharp, and uneven), and laminated (when layers are visible). Finally, the "feel" classification was included, which was described by rubbing the thumb on the sherd's surface.

Following V. Roux's (pers. comm. 2017) suggestions, each macrofabric group was subdivided according to the presence or absence of coating, as well as its position. A simple numerical codification system was used for this, which was attached to the name of each macrofabric group. In this system, the number 1 stood for coating on the external surface of the sherd, number 2 for the internal wall, number 3 for cases in which both surfaces were coated, and number 4 for samples with no coating at all. As a result, macrofabric groups were referred to as, for example, AB2.E2, which means that this group corresponds to Aguas Buenas excavation unit 2, macrofabric group E, sherds coated only on the internal surface. Each macrofabric subgroup was weighed for later assessment of choices regarding coating practices.

Once macrofabric groups were characterized and described, all rims were drawn using a standardized guideline (Bagot 1999) and were photographed—together with the decorated samples—using a professional LUMIX camera and a tripod, artificial and daylight.

The creation of macrogroups was a fundamental tool to approach the assemblage for the first time. It yielded invaluable information on the range of clays used for pottery manufacture in the area of

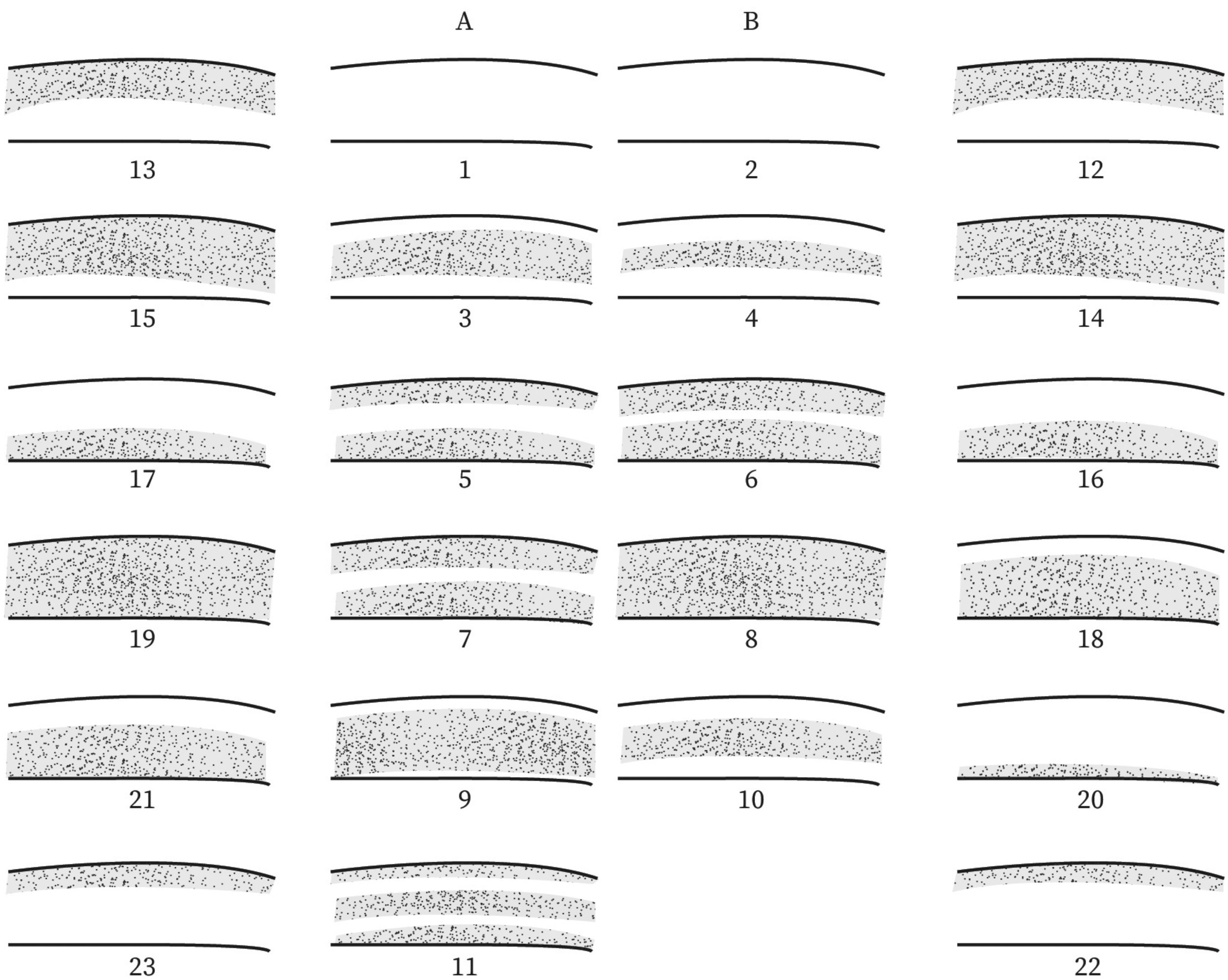

Figure 93: Cross-section margin relationships (adapted from Rye 1981, 116).

study, as well as some insights on manufacturing techniques, morphostylistic features of the pottery, its possible uses, and firing technologies. Apart from that, it provided a general panorama of the similarities and differences among the excavated contexts. As a result, macrofabric characterization aided in the preliminary identification of possible paste recipes, which were later confirmed or discarded by thin section petrography, and also related to different fashioning choices, which were examined through a technological analysis.

6.3 TECHNOLOGICAL ANALYSIS OF MACROSCOPIC TRACES

As discussed in Chapter 3, the study of manufacturing processes is of extreme importance when research questions and goals are related to situated ancient craft practices. That is, to be able to actually construct narratives of the different itineraries of pottery manufacturing practices, it is necessary to deepen understandings of those community-shared knowledges, learning processes, and bodily gestures. As archaeologists, one of the most valuable tools to achieve this goal is the examination of the actual pots and sherds. Complementing and challenging this with archaeometric analytical techniques provides an overall insight into the different processes. In particular, this stage of the analysis was pivotal for further sampling, as well as characterization of the sample variability at the inter and intra site level and of the synchronic practices within and between the different ancient communities examined. Consequently, the identification of diagnostic traits for techniques, methods, procedures, tools, and different gestures or bodily practices through archaeological ceramics is the most powerful means of studying social identity through ceramic manufacturing technology.

The main objective of this stage of the research was to identify the principal technological groups available in the collection. Consequently, the methodology used in this study for characterizing macroscopic technological analysis of pottery is the one that was proposed by V. Roux (2011; 2016). The method was developed after decades of both ethnographic and laboratory research and built upon a mountain of previous ethnographic, experimental, and analytical research. To ensure the correct application of the methodology, personalized training from S. Manem at the Institute of Archaeology, University College London (October 2016) and V. Roux at the Maison d'Archéologie & Ethnologie in Paris (February 2017) was received. For the definition of the basic categories of analysis, a combination of Roux's model with classical work such as Rye (1981), Shepard (1985), Sinopoli (1991), Rice (2005), Orton and Hughes (2013) was applied. The concepts employed during analysis were described in Chapter 3, so the next subsection will explain the laboratory work process.

6.3.1 SAMPLING FOR TECHNOLOGICAL GROUPING

Macroscopic analysis of technological traces has considerable logistic advantages and disadvantages. On the one hand, it is a low cost and low-tech method; thus, it is very easy to mount a mobile lab that can be used anywhere, especially with simple devices such as a Dino-lite portable microscope. On the other hand, reconstructing the full operational sequence is highly time-consuming,[69] and the total universe (even after the 30% initial sampling) consisted of more than 6500 sherds. Thus, to avoid a superficial examination of the manufacturing processes, an additional sampling strategy was applied at this stage of the analysis to achieve a number of sherds which could be subjected to complete analysis according to the time allotted for this study. Without sampling, this analysis would have been limited and would have not allowed for the reconstruction of operational sequences, but only the assessment of the first few techniques, such as fashioning and pre-forming.

Operational Sequence Step	Percentage	No. of Sherds
Fashioning	100% of total	3710
Pre-forming	30% of total	1113
Finishing	15% of total	556
Surface treatments	15% of total	556
Decoration	100% of total	298

Table 19: Outline of the different analytical approaches applied to diverse sampling groups.

Therefore, sampling at this stage proved to be essential to the objectives of this research and was applied combining two different strategies from probabilistic methods: stratified random sampling and cluster random sampling (Bernard 2002; Drennan 2009). Within the macrofabric groups previously outlined, fashioning technique was examined in 100% of the universe (see **table 19**), then 30% for pre-forming, and 15% for finishing and surface treatments. All decorative techniques were described and quantified. Monochromes (including slipped fragments) were not quantified as decorated, but their occurrence was measured and compared to non-coated samples.

6.3.2 IDENTIFYING TECHNICAL GESTURES: ANALYTICAL STEPS

Within the macrofabric groups previously outlined, technological groups were created based on the examination of macroscopic traces of technical gestures. Fragments from the same pot were identified and grouped together, following a sherd count criterion (Orton & Tyers 1990).

The general analytical procedure and terminology was based on S. Manem's checklist for analyzing ceramic technology.[70] Also, a manual for identifying

69 For example, a preliminary study of fashioning techniques on 884 sherds took just two weeks to complete, while a thorough examination of 30 samples was conducted over two months. A thorough technological assessment of a collection that size would take at least four months working full time.

70 Manem's form was designed for the European Research Council Project EUROFARM: Transmission of innovations: comparing and modelling the spread of farming practices in Europe. His methodology was first developed for his PhD dissertation, *Les fondements technologies de la culture des Duffaits (Age du Bronze Moyen)* (Manem 2008), which was co-supervised by V. Roux (2016) and then edited for his current project.

technological traces especially for fashioning and pre-forming in handmade pottery was followed (García Rosselló & Calvo Trias 2013), in conjunction with standard guidelines (Rye 1981; Shepard 1985; Rice 2005). According to S. Manem (pers. comm. 2016) it is important to follow a strict procedure in the analytical process, where observations are recorded first according to the form and interpretations are made at the end of the process. Therefore, the database consisted of two main parts, the recording of the observations first and the interpretative section at the end. These two databases were combined when integrating both archeometric and macrotrace analysis.

Within each macrofabric group, first the different parts of vessels were analyzed to try to identify regularities and variations in base, body, neck, and rim fashioning, pre-forming, finishing, surface treatment, and decoration. Therefore, the procedure outlined in the following paragraphs was conducted first on the various vessel parts and then projected onto hypothetical complete vessels to reconstruct full operational sequences.[71]

First, I describe the topography in relationship to the cross-section (regularity, thickness) and the internal and external surfaces (depressions, fissures, cracks, fractures, digital impressions), as well as protuberances (bumps, thickening, crests, compression folds). Also, I look at the modes of fracture, their orientation (random or preferential), and profile (straight, U shaped, oblique). These features provide evidence for different fashioning techniques; for example, they allow me to interpret the presence of assembled elements or the construction of the vessel from a clay mass. Also, even in the case of homogenous fashioning techniques, I can identify differences in coil sizes, for instance, or techniques for placing them (vertically, from inside to outside, from outside to inside, alternatively, etc.)

Additionally, I looked at internal and external surfaces, focusing on color, brightness, granularity (highlighted, covered, floating, inserted, microextracted), microtopography, striation patterns, and microrelief. These attributes are excellent for identifying fashioning and especially pre-forming techniques on either wet or leather hard clay.

Then, I recorded the structure of the cross-sections, taking into account their nature (continuity), morphology, porosity distribution, level of pore compression, pore morphology, and orientation of inclusions. This step of the analytical procedure aids in the identification of mainly fashioning and pre-forming techniques.

For interpreting the fashioning and roughing out, four parameters were taken into account: elemental volume (homogeneity), forces (pressure or percussion, type, localization, and orientation), types of pressure, and hydric state of the paste. When possible, a preliminary separation between the two main fashioning techniques, which either involve assembled elements or a clay mass, was conducted. Within these variables, pressure (pinching, drawing, crushing) and percussion (beating) gestures were identified. In case of coiling or slabbing techniques, the particular mounting (spiral, double spiral, rings, segments, stretched coil/s) and joining (straight, oblique, U) procedures, as well as specific sizes of assembled elements, were thoroughly described.

Regarding tools, their context of utilization (wet or leather hard clay), orientation (gesture), type (active or passive), forces, function, material, and morphology was interpreted when possible. Finally, pre-forming techniques were classified into two main categories; wet clay and leather hard clay techniques, which were in turn classified relative to the different types of force, pressure and percussion.

Also, the procedures for assembling elements (base, body, neck) were described. First, the different articulation modes were observed between each assembled element, such as supports and base, base and lower body, lower body and upper body, upper body and neck, and base-body-neck. Then, the modalities for reinforcing the junctions between elements at different sections were examined, for example between supports and base (internal and external), between base and body (internal, external, and embedding), lower body and upper body, and so on. Additionally, fashioning of appendages (supports, lugs, handles, etc.) was analyzed first by classifying the technique (rolling, drawing, modelling, coiling) followed by the type of insertion (wet clay or leather hard clay).

Regarding finishing, both the internal and external surfaces of fragments were observed, first establishing the hygrometric state of the clay and then the different techniques that were applied. For wet clay, smoothing was separated in two different ways: the technique that

71 During excavations, only two complete vessels were recovered (one from the site of Barillas and another one from RDO).

adds external water to the process and the technique that only works with the humidity of the clay. For leather hard clay, smoothing and brushing were differentiated mostly focusing on the different striation patterns. Also, pressure was recorded according to continuous versus discontinuous application and if any traces of finishing tools were identified.

For surface treatment, internal and external surfaces were analyzed separately, starting by separating the different surface treatment techniques. Then, friction techniques, such as burnishing (with or without rehydration), polishing, and lustrage, were described. Then, coating techniques were characterized according to the materials employed: clay (*barbotine*, plastering, slip), organic materials, graphite, silica, smoking.

Decoration styles may vary according to their location (base, body, body/neck interjection, neck, or rim) within a vessel, which was described first. Then, the different techniques were recorded, such as paint (surface) and impression (wet, leather hard or dry clay), which can be punctual, tilted, rotated, stamped, or beaten, performed with a tool or with the fingers. Incisions were characterized according to their hygrometric status, different techniques (punctual, rotating, scraped, and engraved), gestures (continuous, discontinuous), and tools. Excision was also classified according to the hygrometric degree of the clay, gesture, and tools. These three techniques—impression, incision, and excision—were classified within the category of decorative techniques that imply a removal of clay from the surface, either internal or external. In contrast, relief techniques were split into two main types. First, those that entail the application of elements, which are divided according to the hygrometric status of the clay and the form of the element, which can be either a rope, pellet, or button. Second, the elements that are modelled and then added to the vessel.

Finally, interpretations related to firing technology were included. First, the two different types of atmospheres, either oxidation or reduction, were taken into account. Then, specific techniques applied were classified in relationship to their contact—or lack thereof—with fueling agents.

6.4 ARCHAEOMETRIC ANALYSIS

Archaeometric analysis of ceramics employs methods from the physical sciences to identify the specific fingerprints of raw materials modified by past human behavior (Glascock 2016). Particularly, it groups like objects according to the types of raw materials employed in manufacturing processes, allowing us to make interpretations concerning raw material sourcing, ceramic provenance, production sites, trade, exchange, distribution, and migration, as well as providing some insights into production techniques (Quinn 2013; Glascock 2016). Consequently, "(...) scientific measurements (...) are not only powerful tools for the characterization of matter, but are also the mean of understanding and quantifying a variety of phenomena that are important for modern everyday life and past human achievements" (Artioli 2010, 16).

This type of analysis can be split into two main categories. On the one hand, mineralogical approaches study the properties of minerals in ceramics. X-ray diffraction (XRD) and the application of the polarizing light microscope to observe thin sections are examples of these techniques. On the other hand, geochemical approaches focus on characterizing the signature elements to the level of parts per billion. Neutron activation analysis (INAA), X-ray Fluorescence (XRF), and inductively coupled plasma mass spectrometry (ICP-MS) are some of these techniques (Quinn 2013).

Both approaches are complementary, and their combination can provide powerful insights into production, consumption, and distribution practices (Tite 1999). That's why "Optimally, characterizing a ceramic involves both mineral and chemical methods" (Peacock 1970, 381), so the results obtained by both types of techniques should be compared and contrasted and not seen as mutually exclusive or redundant.[72] For example, chemical characterization provides unique information concerning the trace constituents of the material, and only mineralogical techniques can elucidate the structure of the fabric (Rice 2005).

There are several aspects that need to be taken into account to select the appropriate compositional analytical techniques. First, archaeological research questions regarding pottery manufacture practices need to be translated into scientific hypotheses that can be tested in physicochemical categories (Rice 2005; Orton & Hughes 2013). Second, it is

72 For a good example of how the research community can view these approaches as "rivals", see the debate on "Olmec" ceramic provenance (Donner 2015).

necessary to formulate specific research questions about different steps of the operational sequence, which will directly influence the part of the ceramic fragment to be manipulated. For example, if the goal is to study clay procurement and clay recipes, then analysis should focus on paste and inclusions rather than slips or paints. Following the same example, special attention is paid to the body of the sherd and not its surface, as well as on bulk compositional rather than point analysis (Rice 2005). Also, it is relevant to check previous studies in the area or region in order to situate the project in a regional or more synthetic perspective and contribute useful reference materials. Apart from that, the study must be deemed primarily qualitative or quantitative. The first type focuses on the external appearance of materials, and it deals with presence and absence of properties (such as minerals, or elements); whereas the latter measures their amount (Rice 2005; Artioli 2010) .

In this study, thin section petrography was applied to a sample which was selected based on the results of all previous analytical techniques (macrofabric and macrotrace analysis). Moderate time, low cost, and relatively low destruction rates favored this technique, as well as the ability to re-utilize the samples.

6.4.1 SAMPLING FOR ARCHAEOMETRIC ANALYSIS

One of the most complicated decisions to make in pottery analysis relates to the number of samples required to establish compositional groups. Even though it has been suggested that a group is minimally constituted by ten examples, some circumstances do not allow such resolution. However, the relationship between number of analyzed samples and degree of confidence in data interpretation is directly proportional (Orton & Hughes 2013). As a result, the technological groups defined within the different macrofabric clusters were sampled proportionally for compositional analysis; this will allow for the reconstruction of the different steps involved in production sequences. A mineralogical characterization will also define tendencies in local potting practices and their development through time at the community level, as well as the connections among different communities. Therefore, when time or budgetary restrictions affected the sampling process, priority was given to dominant and secondary classes, consisting of more than 60% and 20% of the universe respectively (Roux 2016). When case groups were distributed equally (for example, all range between 15-18% of the universe), all of them were analyzed proportionally. The analysis started with the most regular groups so that outliers can then be correlated (when possible) to them.

The total sample analyzed (167 fragments) was selected for compositional analysis through a probabilistic strategy that combined random stratified sampling with random cluster sampling (Bernard 2002; Drennan 2009). A two-stage sampling plan was followed, which first concentrated on the techno-petrographic groups and then on subgroups (Orton 2000). As a result, samples from the majoritarian macrofabric groups were selected; rim sherds were given priority due to the fact that they link manufacturing steps with specific end products, but bases and body sherds were also included in order to elucidate variations in the production sequences depending on the different parts of the vessel.

6.4.2 MINERALOGICAL CHARACTERIZATION

Since low-fired, relatively coarse ceramics share characteristics with rocks and sediments (Rice 2005; Reedy 2008; Peterson 2009; Orton & Hughes 2013; Quinn 2013), a set of techniques originally applied in petrology and earth sciences was borrowed for the study of pottery. Mineralogical characterization aids in the identification of minerals, their abundance, and associations in the clay body and both internal and external surfaces. Also, it helps examine particle orientations; void sizes, shapes, and locations; surface treatments; and firing alterations, as well as post-depositional factors (Rice 2005).

Petrological techniques applicable to ceramics can be divided in three. First, thin section petrography; second, textural analysis (which can be done in combination with the former); and lastly heavy mineral analysis (Orton & Hughes 2013). This study concentrated on the first technique, which provides a good preliminary overview of the materials' variability, as well as indicates further research questions to be answered through future chemical analysis.

Thin section petrography

Thin section petrography mainly consists of the analysis of 30 µm thick ceramic fragments under the polarizing microscope,[73] a device that shows how

73 Samples of 20-25 µm (ultra thin sections) are sometimes used for analyzing building materials or fine high temperature ceramics (Quinn 2013).

a transparent substance affects light that passes through it (Rice 2005). In particular, thin section petrography examines the optical properties of minerals through plane polarized light (PPL) and cross-polars (XP), which allow for the identification of crystalline phases, their relationship, texture, morphology, and size (Artioli 2010). Therefore, it is an excellent preliminary technique to achieve an overall geological perspective of the assemblages examined. Such a perspective can be complemented later with further textural analysis, as well as with geochemical approaches (Artioli 2010). However, this technique has a value that sets it apart from other archaeometric techniques—such as geochemical approaches—because it not only aids in answering questions about provenance, but also addresses technological choices (Quinn 2013). For that reason, in this study, thin section analysis is referred as a techno-petrographic classification (Roux 2016).

The technique was applied for the first time on archaeological ceramics during the last half of the nineteenth-century by a few pioneers (Quinn 2013) but was not performed systematically in archaeological research until 1942, when Anna O. Shepard published her study on Rio Grande glaze paint ware (Shepard 1942) and Wayne Felts published his research on Troy ceramics (Felts 1942). In later decades, after these two fundamental works and the rise of processual archaeology as a new theoretical and methodological perspective, thin section ceramic petrography was recognized as a valid scientific approach (Quinn 2013).

In this book, thin section petrography was applied after the classification of the different macrofabric groups and the general identification of the different steps of the operational sequence within those groups. Petrographic analysis was divided in two main components. Firstly, it focused on the petrographic facies, providing the geological context (Roux 2016); second, it concentrated on the classification of techno-petrographic groups within these petrographic facies. As a result, the relationships between geological context—petrographic facies—and technological choices—techno-petrographic groups—was observed. In this respect, petrography works as a tool for supporting or discarding certain hypotheses based on macrofabric and macrotrace grouping. Also, it can aid in reformulating these questions or generating new ones.

Handling of samples

Samples chosen for mineralogical characterization were hydrated with water and then cut with a diamond-tipped saw in a vertical orientation, following the original position of the artifact, so more information on fashioning and pre-forming techniques can be gathered (Quinn 2013).[74] The result was a ceramic chip of at least 3 cm long and weighing 5 grams that was sent to the Miekina Geotechnical laboratory located in Krakow, Poland. There, samples were impregnated with an epoxy resin mix, grounded, and attached to a glass microscope slide, where the majority of the ceramic chip was cut out.[75] Later, the thin section was polished to 30 µm and labeled with a contextual code. Sections were stored in a plastic box specially designed for this purpose, to ensure their durability and potential re-use in further research.

Equipment employed in thin section analysis consisted of two different polarizing light microscopes (LEICA, models DM2700P and DM750P), as well as specialized software for digital image analysis (provided by LEICA). Additionally, reference manuals were used for the identification of minerals in thin section (MacKenzie & Adams 2017). Also, for comparative reasons, other thin section collections were consulted at the Laboratory for Artefact Studies at the Faculty of Archaeology, Leiden University, which were made available by Dr. Dennis Braekmans. Moreover, Dr. P. Quinn from the Institute of Archaeology, University College, London, granted access to thin section slides from other regions of the world with comparable geological fingerprints.

Mineralogical descriptions

For the mineralogical descriptions, this study adopted the descriptive systems developed by D. Peacock (1977), I. Whitbread (1986), and P. Quinn (2013), in combination with Braekmans and Degryse's suggestions (Degryse & Braekmans 2017). The first step in the analysis consisted of visual classification and description, which lead to an initial grouping. This was achieved by a rapid check of the thin sections at low magnifications (x25 and x40) in both XP and PPL and sorting in fabric clusters, and then

74 Some samples were cut horizontally or tangentially in order to observe the pre-forming techniques from different perspectives.

75 The remainder of the chip was kept for future geochemical characterization.

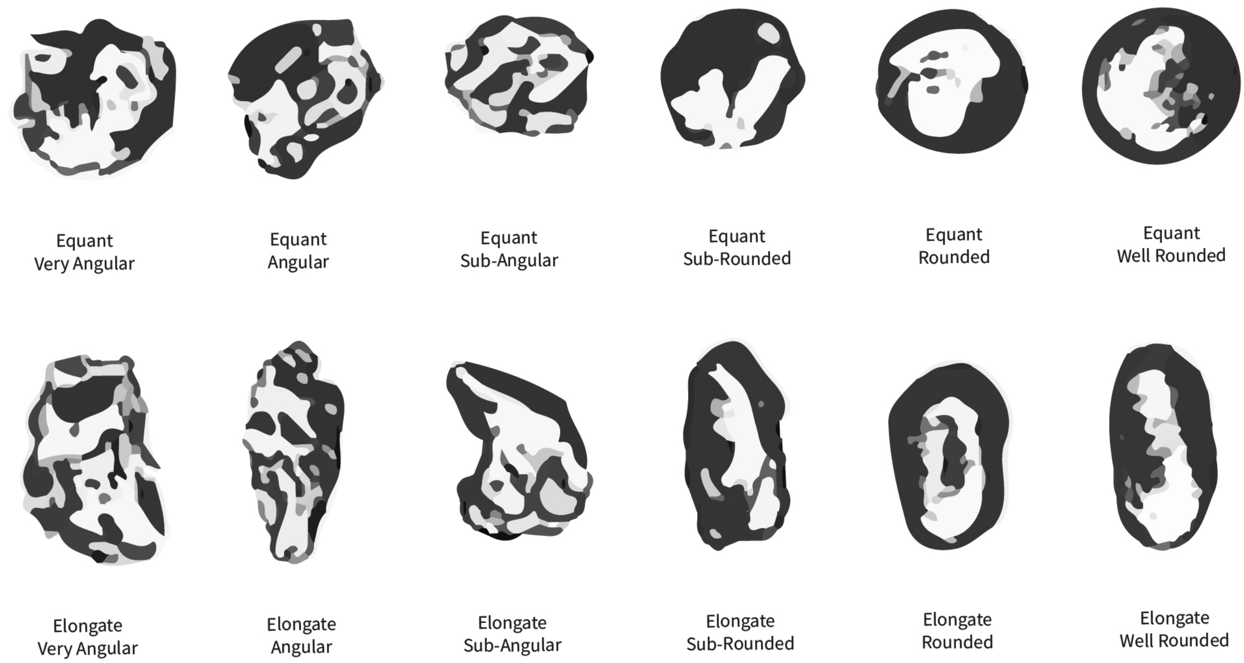

Figure 94: Chart for classifying inclusion shapes (redrawn from Quinn 2013, 84).

by increasing the magnification and separating groups and classes, or subcategories (Quinn 2013). The three main elements observed and described in thin sections are the clay matrix, which is the "(...) the dominant, seemingly amorphous brown material" (Quinn 2013, 39); voids, which are pores; and inclusions, which represent the coarse fraction of the fabric (Peterson 2009). The distribution, orientation, identification, shape, texture, and other features of these three main elements aided in the creation of fabric families, groups, and subgroups. Before going into detail in the three main sections of the analysis, it was important to measure the relative abundance of each in relationship to each other, which was calculated by subtracting the estimated proportions of each in relationship to the others from 100% (Quinn 2013).

Inclusions

First, the percentage of inclusions was estimated according to visual charts and characterized as predominant (>70%), dominant (50-70%), frequent (30-50%), common (15-30%, few (5-15%), very few (2-5%), rare (0.5-2%), and very rare (<0.5%) (Kemp 1985). Then, size was measured, and shapes were recorded (equant or elongated, see **figure 94**). Later, the angularity of these shapes was established through the application of a comparative chart that classifies them as very angular, angular, subangular, subrounded, rounded, and well rounded (Pettijohn 1975). Afterwards, packing was determined as close-spaced when inclusions were in contact; single-spaced when a mean diameter was applicable; double-spaced; or open-spaced. Also, orientation was classified as weak, moderate, strong, very strong (relative to the degree of its parallelism in relationship to the vessel walls), subparallel, or concentric (relic coils). Sorting degrees were especially important to understand the presence or absence of temper and were described as well, moderately, poorly, or very poorly sorted (**see figure 90**). According to this classification, grain size distribution was characterized as unimodal, weakly bimodal, moderately bimodal, strongly bimodal, or trimodal (Whitbread 1986; Quinn 2013).

Voids

Porosity of the clay matrix was recorded using estimation charts and is important for assessing technological choices. Sizes of voids were classified as micro (<0.05 mm), meso (0.05 mm-0.5 mm), macro (0.5-2 mm), and mega (>2 mm). Void

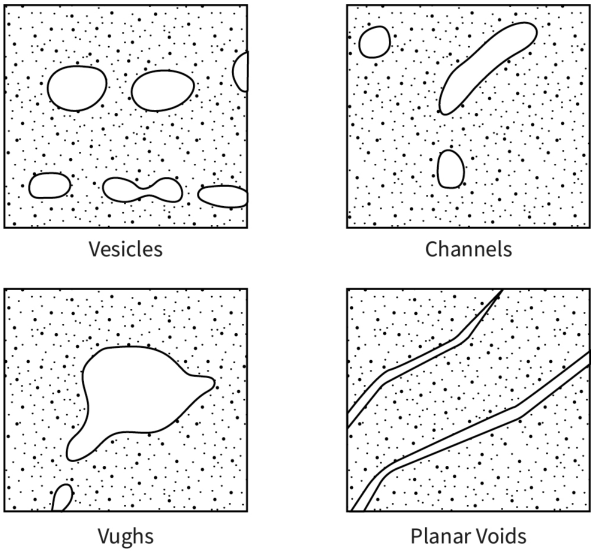

Figure 95: Visual diagram to identify and differentiate vesicles, channels, vughs, and planar voids (redrawn from Quinn 2013, 98).

shapes were recorded using soil micromorphology terminology, so vesicles were characterized as equant, spherical, planar and channel (sometimes grouped as elongated), or vughs (**figure 95**). The degree of alignment of elongated voids was recorded as random or preferred. Additionally, the orientation relative to the vessel wall was observed because it also yields information on fashioning and pre-forming techniques. Voids might be the result of fashioning (center or junctions of coils, for example), firing technology (destruction of organic matter, bloating), and/or post-depositional processes (dissolution of carbonate inclusions or calcite deposits, for instance) (Whitbread 1986; Quinn 2013), so these interpretations were recorded when possible.

Clay matrix

Since the clay matrix itself comprises clay minerals and extremely small inclusions (<0.01 mm), the petrographic information that can be obtained from its examination is limited. However, interpreting raw materials, technological choices and fabric characterization has a lot of potential (Quinn 2013).

The procedure for describing the clay matrix began by assessing the presence/absence and abundance of calcite and iron. Then, color was recorded to examine the clay mineral composition as well as firing technology. Descriptions related to the

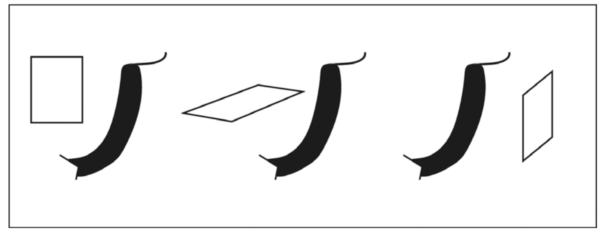

Figure 96: Orientation of the sample in relationship to the vessel shape (redrawn from Whitbread 1996).

clay matrix heterogeneity or homogeneity (slight, moderate, high) were relevant for later interpretations related to clay recipes (clay mixing, tempering, raw materials, etc.) Since the matrix's optical activity yields information on firing technology, specifically indicating vitrification processes, it was recorded as slight, moderate, or high in different sections of the slide. Finally, the orientation of the clay domains was recorded for later interpretations of fashioning and pre-forming techniques (Whitbread 1986; Quinn 2013).

Technological choices studied through thin section petrography

In order to make any interpretations about ceramic manufacture through thin section petrography, it was first important to establish the orientation of the sample in relationship to the vessel or sherd. This orientation was classified as vertical, horizontal, tangential, or unknown (see **figure 96**) (Whitbread 1986; Quinn 2013).

Then, the inclusions were described in greater detail, taking into account five main characteristics (**figure 97**). First, the boundaries between the inclusion and the fabric matrix, which were classified as sharp, clear, diffuse, or sharp-to-merging. Second, roundness, which could be angular to well rounded (such as argillaceous rock fragments, ARF), angular to subrounded (for example, grogs), or rounded to well rounded (such as pellets). Third, shape was defined as prolate and conchoidal, prolate and equant, or equant and distorted. As a fourth step, optical density was classified as high, neutral, or low, depending on the visual contrast between the fabric and the inclusions. Finally, features were identified as either concordant or discordant (Whitbread 1986; Quinn 2013). These deeper characterizations aided the identification of temper and clay mixing(s), as well as fashioning and pre-forming techniques.

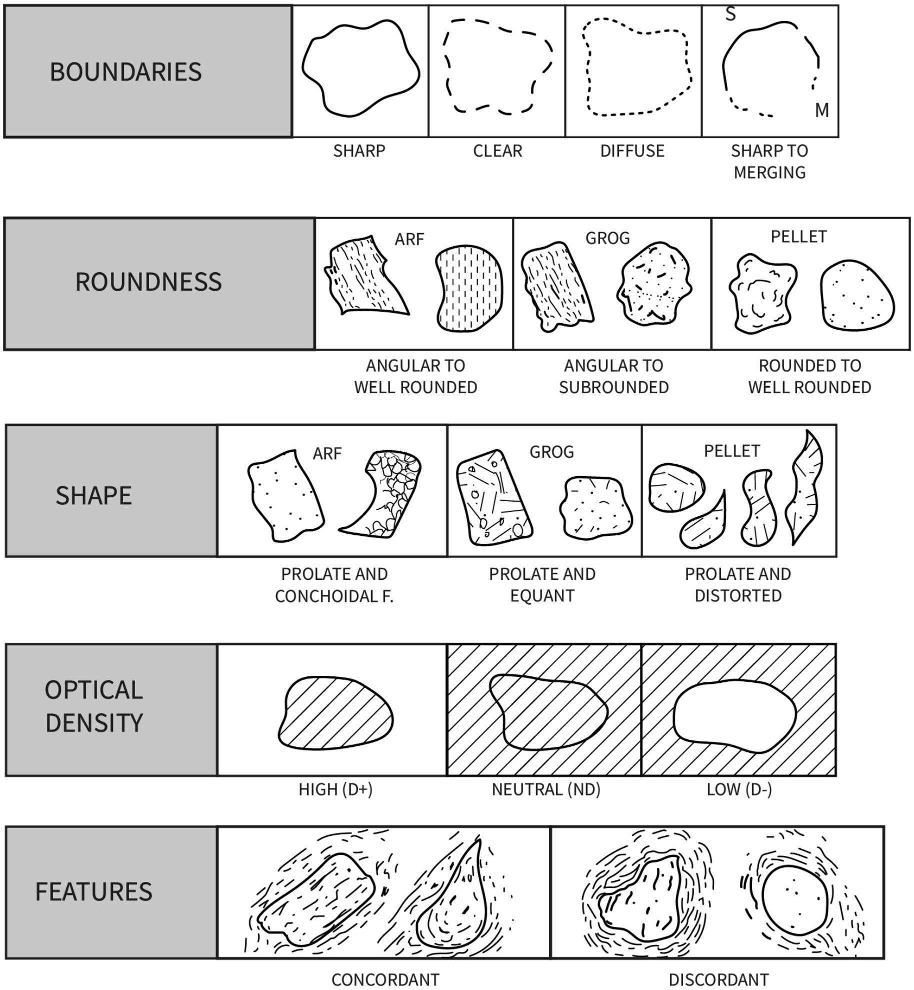

Figure 97: Visual charts for classifying boundaries, roundness, shape, optical density, and features of inclusions (redrawn from Whitbread 1986, 80, table 1).

	Vertical	Horizontal	Tangential
Wheel-thrown	Poor to strong	Strong, parallel to wall	Strong
Clay mass	Strong at wall Poor at center	Strong in center Strong at wall	Poor in center
Slab	Strong (possible angle to horizontal)	Poor	Poor
Coil	Poor or strong	Strong, parallel to wall	Strong, horizontally aligned

Table 20: Different types of orientations for inclusions helpful to infer forming techniques.

In fact, one way to better distinguish these techniques was through the detailed description of the preferred orientation of inclusions, voids, and clay minerals. The different types of orientations (vertical, horizontal, tangential, see **table 20**) differed in degree according to their forming techniques (Whitbread 1986; Quinn 2013).

It was also important to outline the granularity, or position of the grains, which is described by Roux (2016) for macroscopic analysis of technological traces but has not been explored for thin section characterization. When surfaces were well preserved, the grains were characterized as highlighted (uncovered or covered with a fine layer of clay), "floating" grains, inserted, or negative. The application of these observations in thin section petrography has proven to be a suitable complement for macroscopic analysis, allowing observations in thin section that are not possible with a stereomicroscope on the surface of the sherds.

Also, surface treatment and decoration techniques were described when visible, as well as the presence or absence of post-depositional processes, such as layers of micritic calcite on the surface or deposits on voids.

Finally, for identifying firing techniques, two variables were recorded. First, the optical activity/inactivity of the clay matrix (Whitbread 1986), which is related to firing temperature. Second, the colors observed on the surface and within the core were described to reconstruct firing conditions following the characterizations proposed by Rice (2005, 345), which take into account surface and core colors and relate them to probable firing atmospheres.

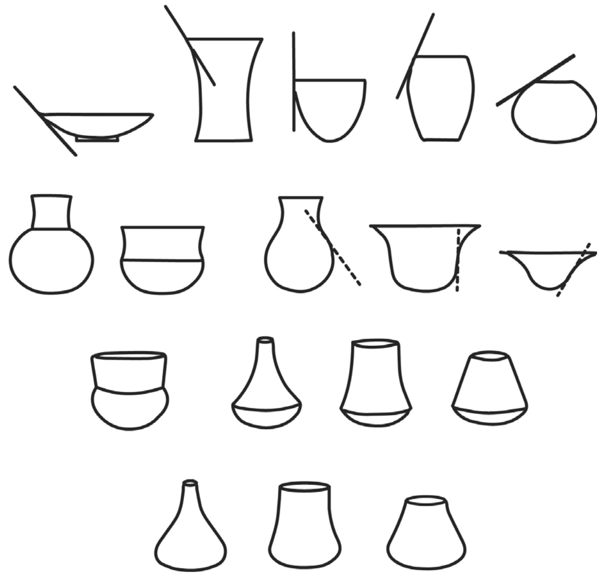

Figure 98: Visual chart to establish restricted and unrestricted vessel shapes (redrawn from Shepard 1985, 229).

6.5 MORPHO-STYLISTIC GROUPS

Traditional pottery classifications usually organize their groupings according to morphological types and decorative attributes (Norweb 1961; Baudez 1967; Healy 1980; Gorin 1990). However, this study followed a technological approach (Roux 2016) and left morphostylistic classification until the end of the analysis. Studying macrofabrics, then technological gestures, and later characterizing the composition of ceramics through thin section petrography allows for the identification of the different steps of the *chaînes opératoires*, as well as their variability. Only then it is valuable to include the end products, the particular intentions of the potter. In turn, this examination helps to "*(...) évaluer si la variabilité des chaînes opératoires est liée aux catégories fonctionnelles présentes au sein de l'assemblage ou à la présence de plusieurs groupes sociaux*" (Roux 2016, 267).

Also, morphostylistic analysis is of extreme importance in order to create correlations between the multiple analytical groupings outlined in this study and the current available data on pottery throughout Nicaragua and the entire Isthmo-Colombian area. Without this step of the analysis, the study would not only lack the connection with the actual end product which was conceptualized before undertaking the manufacturing sequences, but also a comparative baseline with previous research in the area (Magnus 1976; Gorin 1990) as well as other regions in Nicaragua, Honduras, and Costa Rica. Additionally, as outlined in Chapter 3, a ceramic study that intends to reconstruct practices would be seriously flawed if it did not include anything about one of the main sections of a pot's biography, its "life" as a vessel within the community. Exacerbated stress on attributes, macrotraces, mineralogical or chemical characterization only results in very partial views of pottery.[76]

6.5.1 SAMPLING FOR MORPHO-STYLISTIC GROUPS

All rim sherds, bases, and appendages, both decorated and undecorated, were drawn, photographed and measured, and a database was created especially for recording them. The variables taken into account included type of vessel (unrestricted, restricted, or unidentified), shape (see below), wall angle, base angle, diameter, percentage of the vessel, rim profile, rim angle, and lip morphology.

6.5.2 ANALYTICAL STEPS

Shape classification

Pottery manuals (Shepard 1985; Orton *et al.* 1993; Rice 2005; Orton & Hughes 2013) were followed for

76 See Chapter 3 for a complete discussion.

Code	Shape
C	bowl
CR	straight walled bowl
CRD	outflaring straight walled bowl
CC	curved bowl
CCC	convergent curved bowl
CCD	divergent curved bowl
CRC	convergent straight walled bowl
O	olla, jar, or cooking pot
P	plate
CML	griddle
ML	*molcajete*
T	neckless jar

Table 21: Codes used for vessel shape characterization.

the classification of shapes within each macrofabric group. Complete profiles were taken into account and classified according to geometric shapes rather than functional categories (**figure 98**), to avoid conflating description and interpretation (Daneels 1988; 1996; 2002; Roux 2016).

When possible, specific shape identification was conducted following the coding system developed by Donner and Hernández Arana (2018), which is mainly based on Daneels (1988; 1996; 2002). **Table 21** summarizes the generalized shapes and their respective codes used in this research.

Classification of decoration

The localization, general structure and "grammar" of the decorations (Roux 2016) was described following classical procedures for analyzing archaeological pottery decoration (Shepard 1985; Rice 2005; Orton & Hughes 2013). Decorated sherds were photographed and quantified depending on the techniques applied: incisions, punctuation, appliqué (annotation in case of zoomorphic or anthropomorphic ones), paint, double slips, corrugated surfaces, or impressions. Colors and part of vessel that was decorated were recorded as well, taking into account their contextual and macrofabric classifications.

6.6 INTEGRATION OF APPROACHES

The final stage of this analytical strategy consisted in the creation of a database integrating all the relevant aspects related to the different steps of the production process. This database included macrofabric code, stratigraphic information, vessel part, shape (when identification was possible), diameter (for rim sherds and bases), wall thickness, macrofabric assessment, petrographic group, texture, coil measurement (in cm), size of the lip coil in relationship to body coils, position of the lip coil, the identification of coils as equidistant or not, position of the coils, pre-forming hypothesis, grain position in relationship to the surface, striations, hygronomic state for finishing, surface treatment, firing temperature, context (off-mound or on-mound), and comments. These variables were combined to propose the reconstruction of the main production sequences for each assemblage analyzed, from clay procurement and paste preparation practices through firing and decorative techniques.

6.7 DATING TECHNIQUES

As the main objective of this study consists of establishing the spatiotemporal relationships between the different pottery manufacturing traditions, different materials were tested for absolute dating. Relative dating was performed mainly through the integration of stratigraphic data with the ceramic analysis, together with a comparative examination of the different technological steps between assemblages determined as synchronic or diachronic through absolute dating techniques.

6.7.1 ABSOLUTE DATING

In this study, absolute dating techniques consisted of accelerator mass spectrometry radiocarbon dating (C14-AMS) of different kinds of materials, such as charcoal, organic sediment, zooarchaeological remains, charred encrustations deposited in the internal surfaces of sherds, and a charred seed. Except for organic sediment dating, sampling strategies were based on the randomness of evidence, meaning that collections were only possible when adequate samples were retrieved during the excavations. In contrast, sampling for bulk sediment dating was based on detailed stratigraphic analysis, meaning that it allowed for the selection of specific features and stratigraphic units based on their depositional history and co-occurrence of other materials. As a result, the combination of diverse methodologies and different laboratory facilities granted reliability in the process of building a solid chronology.

Sampling strategy
Samples for C14-AMS dating were collected in every stratigraphic unit that presented them, with no exceptions. For their preservation and to avoid contamination, samples were wrapped in aluminum foil and then stored in Ziploc bags with their correspondent tags. Once at the lab, they were placed in plastic boxes for preservation. Zooarchaeological and botanical samples were selected by specialists after analytical procedures, as in the case of the charred encrustations on pottery sherds.
Samples for bulk organic sediment dating were collected in two different moments. In the case of features, samples were retrieved during excavation. Also, at the end of the excavations, specific stratigraphic units were selected for sampling in accordance with their stratigraphic position and characteristics.
Collections were done following the guidelines established for luminescence sampling (Nelson *et al.* 2015), with a few suggestions made by J. Pagán Jiménez (pers. comm. 2016). Equipment utilized consisted of a *machete*, rubber mallet, 7.62 cm wide 15cm long PVC tubes, PVC lids for vacuum seal, aluminum foil tape, distilled water for cleaning the tools and containers, and Ziploc bags. First, the *machete* was cleaned with distilled water and then used to clear the surface from which the sample was to be taken from. Then, the strongest lid was placed on one of the PVC tubes, which penetrated the surface by percussion with the rubber mallet (**figure 99**). When at least half of the tube was full, the second lid was placed. The tube was then wrapped in aluminum foil tape, labeled with its stratigraphic context (site, excavation unit, stratigraphic unit, level, and sample number), and finally stored in a Ziploc bag. During the rest of the fieldwork day, samples were placed in the shade, and once at the lab, they were securely stored in a fridge until they were exported.

Organic sediment dating
Bulk organic sediment dating was conducted by Beta Analytics lab, located in Miami, FL, USA. Once at the lab, sediment pretreatment involved soaking in warm water for a period of time before sieving through a 180 μm sieve to remove roots and macrofossils. The material that passed through the sieve, which is considered as the bulk sediment, was then kept for analysis. Later, dilute hydrochloric acid was applied for the removal of carbonate. Then, the filtrate was rinsed with deionized water and dried in

Figure 99: Sampling for organic sediment dating at Barillas, excavation unit 1 (EUBI1).

an oven. If macrofossils (plant, charcoal, shell, etc.) were found in the sample, they were collected in the sieve. Finally, AMS dating was applied to the bulk sediment remaining from this process. Additionally, the laboratory provided the C13 isotope amount for each sample, which yielded information on paleoenvironment.

AMS carbon dating
AMS carbon dating of charcoal samples took place at Beta Analytics lab, and zooarchaeological samples, charred residues on sherds, and charcoal were measured at the Keck-Carbon Cycle AMS facility at University of California, Irvine (USA). Finally, the charred seed sample was analyzed at Poznań Radiocarbon Laboratory (Poland). Carbon-14, a weak radioactive isotope of Carbon, was first measured, and then radiocarbon age results were calibrated to calendar years with OxCal v4.3.2.2 (Bronk Ramsey 2017) using the IntCal13 curve (Reimer *et al.* 2013) and CalPal online employing the CalPal_2007_HULU curve, Bomb13NH2 Curve (Bomb13NH2.14c), and post-bomb atmospheric NH2 curve (Hua *et al.* 2013).

6.7.2 RELATIVE DATING
Stratigraphic analysis, in combination with absolute dating, provides an overview of the life cycle of each site studied in this manuscript. As outlined in Chapter 3, ceramic chronologies can be based on two different principles. On the one hand, they can involve the calculation of relative frequencies of different ceramic groups by stratigraphic units,

excavation units, sites, or sets of sites. On the other hand, non-metric multidimensional scaling can be applied through the analysis of group co-occurrence (Sinopoli 1991). These approaches, as well as seriation and cross-dating (Rice 2005), are usually undertaken. In contrast, this research, based on the premises outlined in Chapter 3, only used comparisons of co-occurrence (of technical choices) to aid in the chrono-narrative, and these variables were not circumscribed to time boxes because the trajectories of their itineraries cannot be reduced to a Cartesian chart.