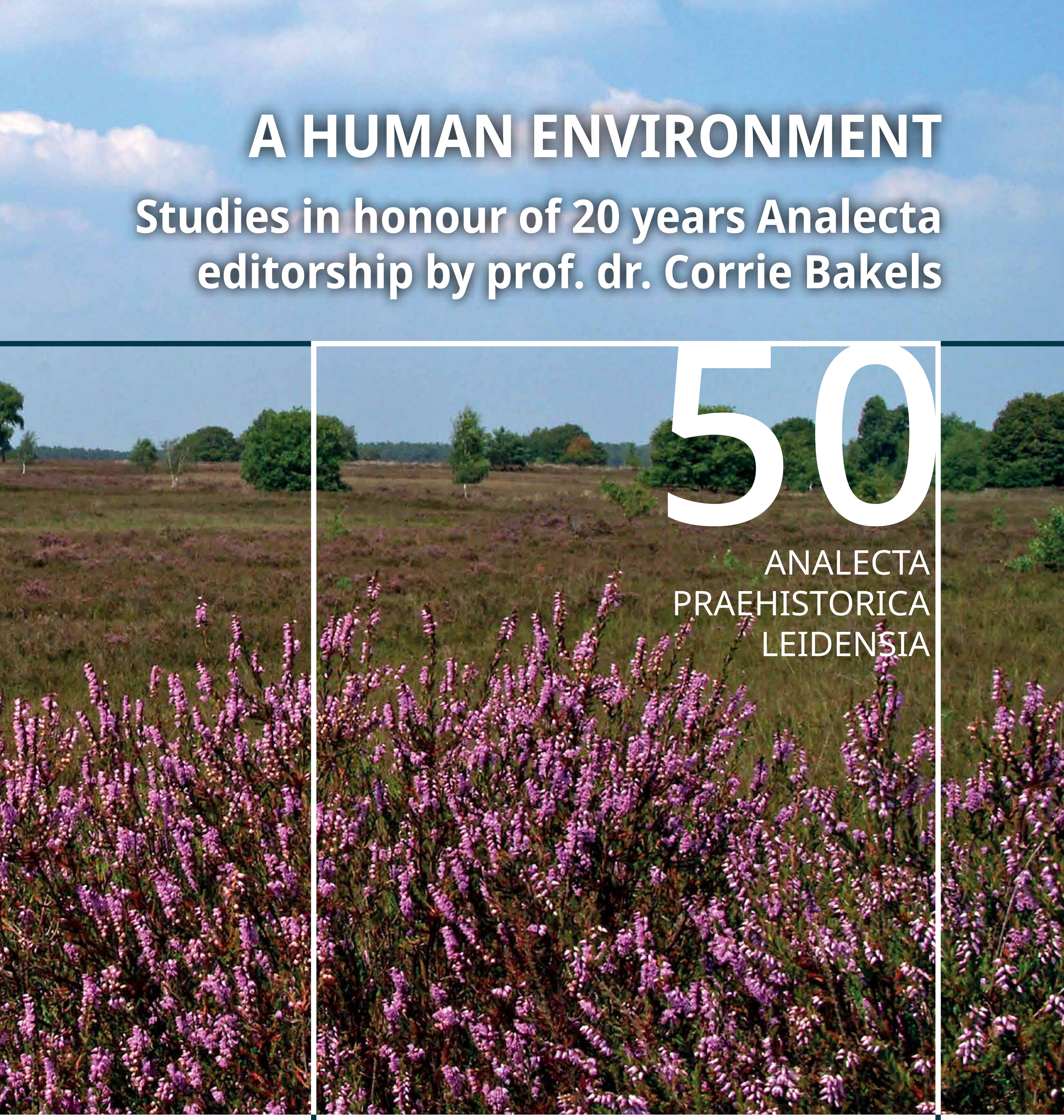
# A HUMAN ENVIRONMENT

## Studies in honour of 20 years Analecta editorship by prof. dr. Corrie Bakels



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ANALECTA
PRAEHISTORICA
LEIDENSIA

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VICTOR KLINKENBERG, ROOS VAN OOSTEN
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# Pre-Hispanic and contemporary raw materials use in earthenware production in the Río Mayales subbasin, Chontales, central Nicaragua

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*Since 2007, the Proyecto Arqueológico Centro de Nicaragua (PACEN), directed by Alexander Geurds, has conducted archaeological research in the Río Mayales subbasin, located on the eastern side of Lake Cocibolca in the Chontales province of central Nicaragua. Through the study of procurement strategies of raw materials in the context of archaeological ceramic and lithic industries, the project focuses on understanding pre-Hispanic and contemporary human-environmental relationships in a valley drained by the Río Mayales. This paper provides the results of the first systematic clay-rich soils survey combined with an ethnographic approach to present-day uses of geological resources. Chemical analysis by means of portable X-ray fluorescence (p-XRF) was applied to characterise geologically-based compositional groups throughout the valley. This resulted in an improvement of the limited geological data resolution previously available and the creation of a reference database of p-XRF values for future research in the area that can potentially link ceramic paste composition with clay outcrops. In addition, the ethnographic study generated valuable data regarding contemporary taxonomic soil knowledge in the area, which is transmitted from generation to generation in the context of declining clay-based production strategies, such as pottery manufacture.*

*Keywords: Pre-Hispanic southern Central America, Pottery technology, Human-environment interaction, Clay raw materials, X-Ray Fluorescence, Ethnoarchaeology*

## 1. Introduction

The Río Mayales subbasin is located approximately 25 km northeast of Lake Cocibolca, the largest freshwater lake in Central America. The valley of Juigalpa is part of the area drained by the Mayales and its tributaries. In the last twelve years, evidence for human presence has been recorded in the valley, including *circa* 1700 man-made mounds distributed in a range of concentrations varying from small sites to large clusters, some numbering in the hundreds of structures (Geurds *et al.* 2009; Geurds and Van Broekhoven 2010; Vlaskamp *et al.* 2014; Arteaga 2017; Donner *et al.* 2018) (figure 1). Recent radiocarbon dates on mounded sites indicate long-term interactions between human groups and the valley, spanning from pre-Hispanic times (cal 400 CE) to the present (Donner and Geurds 2018).

Since 2007, the *Proyecto Arqueológico Centro de Nicaragua* (PACEN), directed by Alexander Geurds, has studied these sites featuring architectural remains. In recent years, efforts have concentrated in Aguas Buenas, the archaeological site with the highest construction investment not only within the area, but throughout Nicaragua. Aguas Buenas is composed of 371 man-made mounds organized in six circular concentric arcs with a central rectangular area (Geurds and Terpstra 2017; Auzina 2018). In order to understand Aguas Buenas' role within its surroundings, PACEN adopted a micro-regional research approach. Since 2014, the project carried out a systematic high-intensity archaeological survey fully covering 52 km$^2$ of the valley, as well as excavations of different mounded (n=16) and un-mounded (n=3) sites (Donner *et al.* 2018), followed by analysis of a diverse set of archaeological materials, such as faunal and botanical remains, and lithic industries. Furthermore, PACEN considered the history and variability of earthenware manufacturing practices in the valley (from 400 CE through the present), through technological, petrographic and compositional analysis (Casale 2017; Donner *et al.* 2019). The main goals of these inquiries were to understand human-environmental relationships, in particular procurement strategies of raw materials (clays, rocks, minerals, water, fuel), in the context of ceramic production, as well as any functional uses of vessels (Ciofalo *et al.* 2020).

Since thorough geological studies are lacking in the research area, this study started with a systematic micro-regional clay survey, which was conducted in an attempt to link the ceramic materials retrieved during archaeological excavations with the available mineral resources in the landscape. The survey integrated an ethnographic approach (Vaughn and Neff 2004; Peacock 1982; Yankowski 2008), so modern uses of clay raw materials in the valley were also examined. The combination of different methods ultimately aimed at

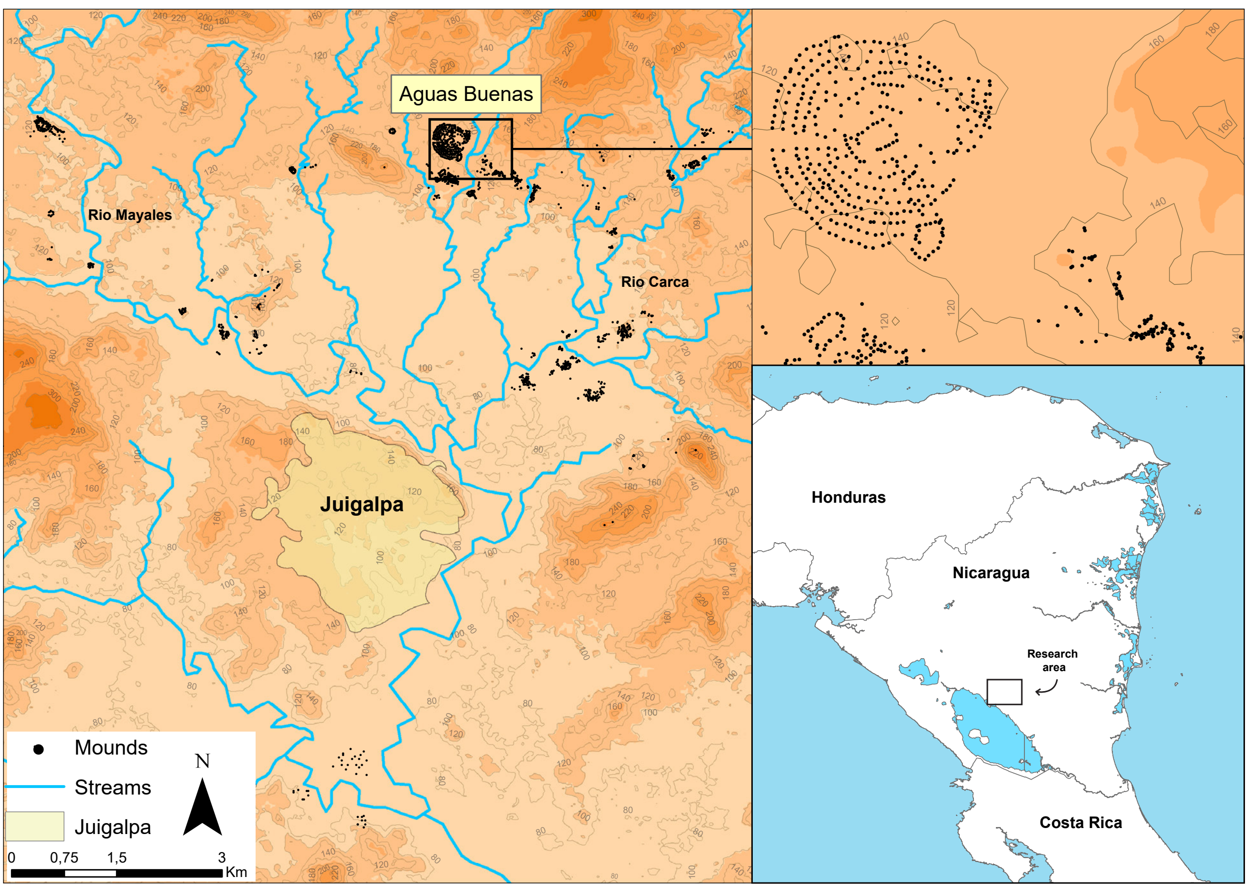


Figure 1: Location of the research area, the valley of Juigalpa, in Central Nicaragua, highlighting mounded sites recorded by PACEN and particularly Aguas Buenas.

providing a historical understanding of the interactions between humans and landscape in the valley of Juigalpa, from pre-Hispanic times through to the present.

### *1.2 Geological context*

The study area is located in the geological province referred to as the Interior Highlands of central Nicaragua (McBirney and Williams 1965), in the present province of Chontales, which is characterised by an Oligocene-Miocene arc. The region is composed of two main geologic units, the Matagalpa and Coyol Groups, both located to the east of the central Nicaraguan Depression. The geology of the area of study mainly comprises porphyritic basalt, basaltic andesite, and andesite to dacitic pumice (Arengi and Hodgson 2000). The topography encompasses elevations, plains, the lakeshore and its islands, as well as the drainage of the Mayales river and its tributaries (Garayar 1972). The geomorphology can be described as a combination of isolated hills together with a plateau and gentle slopes often marked by sharp endpoints.

## 2. Methods

### *2.1 Methodology for tracing clay sources*

The clay survey focused on two areas: north of Juigalpa, between the Mayales and Carca rivers; and south of Juigalpa, in the area surrounding the archaeological site of La Pachona. The area selected, which has an estimated surface of 50 km$^2$, reflects the extension of the pedestrian survey conducted in 2015 and 2016 for identifying and mapping archaeological sites (Donner *et al.* 2018).

The methodology applied in the clay survey consisted of a comprehensive approach that combined ethnographic, systematic, and archaeological sampling to extensively explore the area. First, semi-structured individual and group interviews (Costin 2000) were conducted with active potters and with workers of the various local brick manufactories that are spread across the valley. The goal of the ethnographic approach was to assess the clay-related knowledge and use of the local population as well as to assess ongoing exploitation of clay-rich soils and other pedological materials. These interviews with local craftsmen allowed us to design a preliminary map of the different clay sources that are currently exploited in the area, their general characteristics, local perceptions regarding the materials, as well as their specific location.

The research area was divided in grids of 1 km$^2$ and systematically explored to achieve a low intensity, full coverage pedestrian survey. Grids that included major rivers, streams, creeks, and archaeological architectural remains received a higher attention in order to glean a more comprehensive knowledge of the environment that surrounds each site. The primary objective was to take at least one systematic sample for each grid and then to overlay the dataset with the knowledge of local inhabitants and modern potters. Additionally, it was vital to consider the geology and geomorphology of the area as well as the existing archaeological knowledge (Gorin and Rigat 1993; Hasegawa 1998; Geurds *et al.* 2009; Arteaga 2017; Donner *et al.* 2018) and comparative clay surveys (Vaughn and Neff 2004; Sharratt *et al.* 2009). Therefore, besides the exploration of the main river (Mayales) and largest stream (Carca), a survey of the secondary streams, creeks, slopes and alluvial plains was also conducted. Particular attention was paid to areas featuring presence of archaeological ceramic materials on the surface and man-made mounds. The position of each soil sample was recorded using a handheld GPS, and the geomorphological and archaeological features surrounding the sample area were registered and photographed. Approximately 500 grams of clay were recovered from each outcrop for compositional and experimental analysis.

### *2.2 Chemical and statistical analysis*

The clay-rich samples were analysed by means of portable X-ray Fluorescence (p-XRF), which is a well-established field and laboratory technique for provenance analysis of soil (Shugar and Mass 2012). Prior to running the geochemical analysis, pressed pellets were created by mixing the clay with distilled water and using a plastic tube to make small cylindrical bricks (*circa* 1 cm thick). After that, the clay samples were left to dry for two days and then fired at 350 °C. Then, one side of each pellet was polished with ground paper to flatten and smooth the surface, optimizing the conditions for p-XRF analysis.

A Bruker Tracer III-SD p-XRF device was used to carry out the analysis. For each sample, three measurements in separate areas were taken. The time of analysis was 120 seconds with 40kV and a 14 μA. An Al-Ti-Cu filter was fitted to enhance the instrument's sensitivity in measuring mid-Z trace elements (Rb, Sr, Zr, Y, Nb). The quality of the measurement was monitored through the analysis of five rock and soil certified reference materials (SRG-1 (Green River

Shale), BIR-1 (Icelandic basalt), GSP-2 (Granodiorite Silver Plume), BCR-667 (Estuarine sediments), and CRM NIST-98b (Plastic clay). Semi-quantitative results were gathered using a custom empirical calibration for soil materials.

In order to assess the extent of variability and the potential to differentiate between these clay materials in relation to other areas, five additional raw clay samples were collected on the Zapatera Archipelago, located in Lake Cocibolca. This area is connected to a different geological formation, so compositional differences were expected to be observed in the p-XRF data.

The interpretation of the semi-quantitative data of the soil samples was done through multivariate statistic calculations. Principal component analysis

Figure 2: Clay collection and testing procedure in the field with the help of local experts.

(PCA) was applied for comparisons and to reduce the multivariable dataset to two dimensions for cluster identifications (Baxter 2003).

## 3. Results and Discussion

### *3.1 Results of the pedestrian clay survey*

A systematic exploration integrating ethnographic and geological survey data provided a representative number of samples to cover the area of interest. Preliminary observations spotted several large clay deposits, mostly located in the proximity of rivers and reasonably close to pre-Hispanic settlements (< 500 m).

Various geological differences were noted in the landscape surrounding the Mayales river and the Carca stream. The former has numerous clay deposits along its banks, of which some show evidence of modern exploitation. In contrast, the Carca stream revealed a much smaller number of clay deposits on its banks, while its tributary streams, creeks, and alluvial plains show again an increase in potential mineral resources. The water flow of the Carca is subject to seasonal changes, and during the dry season (November to April) less material is transported. In contrast, the Mayales is a perennial river, which provides better conditions for the formation of deposits along its banks and tributaries. The research focused especially on small streams, which resulted in the most valuable sources of riverine clay outcrops suitable for manufacturing ceramics. When an outcrop was found, water was added to test its plasticity and overall workability (figure 2). In total, 89 samples were collected, of which 39 were adequate for manufacturing items.

Results indicate that clays are widely available in the valley and they feature compositional variability, showing the presence of different geological units with distinctive chemical profiles. Several types of clays were locally identified according to their colour. Local inhabitants differentiate clays by colour to define "*barro*", "*barro amarillo*", and "*barro negro*",[1] while differences in composition and texture are identified as "*barro arenoso*" and "*barro barrial*".[2] Figure 3 shows the location of the clay samples collected, archaeological mounded sites, and the distribution of pre-Hispanic ceramic materials found on the surface (Arteaga 2017; Donner *et al.* 2018). Each archaeological site has one or more clay outcrops located in their proximity (< 500 m), together with fresh water sources; AB has six clay outcrops within a two-kilometre radius.

### *3.2 Compositional analysis of raw clay samples*

The chemical composition of 39 clay samples from the Río Mayales subbasin and five from the Zapatera archipelago was analysed for clustering through multivariate statistics. Table 1 indicates the results of the p-XRF analysis for the soil samples grouped according to the results of the PCA. A selection of elements ($Fe_2O_3$ (wt. %), CaO (wt. %), $TiO_2$ (wt. %), Cr (ppm), Sr (ppm), Zr (ppm) was $\log_{10}$ normalized and statistically analyzed to identify variability among the different clay samples (Baxter 2003). XLSTAT 2018 was used for PCA calculations and analysis.

Four groups were identified by comparing PCA, single elements, and oxide compositions. The soil samples collected on Zapatera clustered significantly away from the rest of the dataset as expected, creating one independent group. Figure 4 plots the first two principal components, accounting for 81% of the total variance in the dataset, and indicates a systematic chemical variation within the clay samples of different rivers and streams within the Juigalpa valley and from the Zapatera archipelago.

Group 1 includes only the samples from Zapatera, which yielded high values of $TiO_2$ (1,9-2,4 wt. %) and $Fe_2O_3$ (15,5-18,6 wt. %) in contrast to the other groups. $Fe_2O_3$ can be connected to clay minerals, which absorb ferric ($Fe^{3+}$) oxides derived from weathering (Degryse and Braekmans 2013). Other sources of iron are Fe-bearing minerals, such as olivine, biotite, amphibole, and orthopyroxene. The presence of these minerals is usually related to volcanic rocks, which are predominant on the island. The limited insular surface extension may not allow a high level of weathering, suggesting a higher quantity of volcanic minerals in the outcrops when compared to the groups in the research area. The high value of iron is a consequence of the mafic origin of the island. Furthermore, the clay samples are depleted in Sr in contrast with other groups from the Río Mayales subbasin. Sr can vary due to water percolation, but the element is rather connected to the presence of plagioclase and carbonates (Nesbitt *et al.* 1980; Wronkiewicz and Condie 1987), so it may reflect environmental differences.

1 In Spanish, *barro* means mud, so *barro amarillo* and *barro negro* stand for yellow and black mud, respectively.

2 *Barro arenoso* means sandy mud and *barro barrial* refers to vertisols (van Dijk 2017).

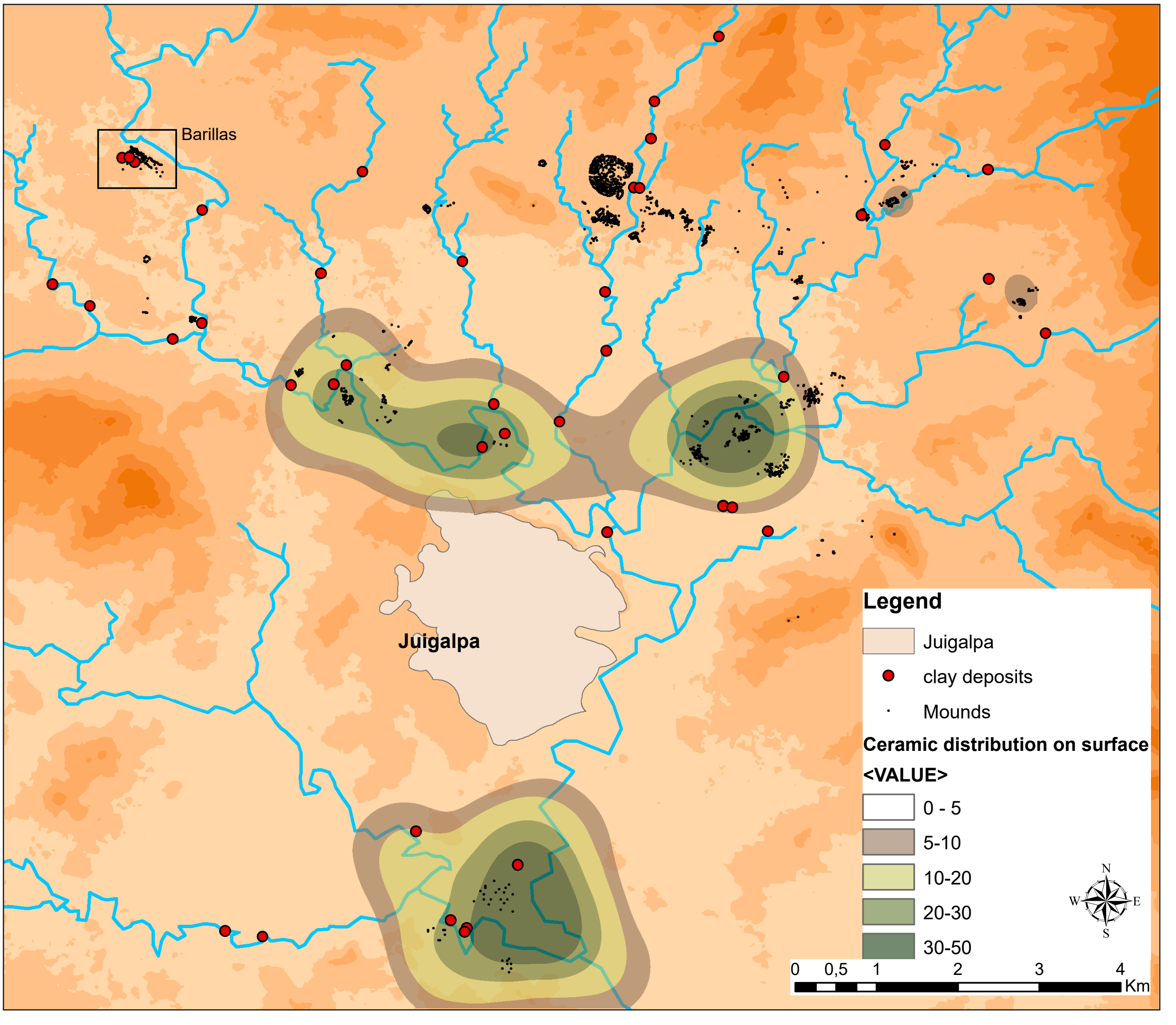


Figure 3: Geographic distribution of clay samples suitable for manufacturing ceramics (red dots) together with mounds (black dots), and densities of surface ceramic remains (based on Donner *et al.* 2018).

| | $Fe_2O_3$ (wt.%) | $Fe_2O_3$ (st. dev) | CaO (wr.%) | CaO (st. dev) | $TiO_2$ (wt.%) | $TiO_2$ (st. dev) | Sr (ppm) | Sr (st. dev) | Zr (ppm) | Zr (st. dev) | Cr (ppm) | Cr (st. dev) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group 1 | 16,9 | 1,2 | 3,1 | 1,1 | 2,2 | 0,2 | 132 | 28,4 | 108 | 6,7 | 286 | 33,7 |
| Group 2 | 11,1 | 1,5 | 2,4 | 0,5 | 1,1 | 0,1 | 302 | 93,6 | 98 | 18,9 | 219 | 105,4 |
| Group 3 | 8,7 | 1,6 | 2,3 | 0,4 | 1,2 | 0,2 | 296 | 53,9 | 124 | 22,7 | 49 | 24,0 |
| Group 4 | 5,9 | 2,4 | 1,8 | 0,36 | 0,8 | 0,3 | 229 | 98,8 | 174 | 30,5 | 0 | 0 |

Table 1: Results of the p-XRF analysis with average and standard deviation (STD) for each group identified through the PCA (Casale 2017).

Group 2 (C3.1, F4.1, F6.1, G6.1, M3.1, M3.2, N3.1, H5.1, N4.2, F6.3, D12.1, H2.2, H2.3, I11.1, H3.1, H3.2, F12.3) is characterised by high values in Sr, CaO, $Fe_2O_3$ and $TiO_2$. Sr and CaO are likely connected to the presence of carbonate materials. $Fe_2O_3$ can be especially related to iron-rich minerals like hematite, orthopyroxene, and hornblende. These minerals are commonly found in intermediate andesitic rocks (Dennett 2016), and can be related to its weathering products. Iron and titanium can be associated to the fractionation of Fe-Ti oxides such as ilmenite, titano-magnetite, sphene or rutile (Degryse and Braekmans 2013). The mountainous formation that is located north of AB is characterised by igneous rocks, which vary from basalt to andesite in association with tuff layers. This geological substrate would explain the composition of the clay samples in this area, and it is likely that this formation is the parent material for most of the clay deposits that are located in its surroundings.

Group 3 (C5.1, D5.1, E5.1, H7.1, I7.1, L7.1, M2.1, 05.1, D5.2, I7.2, L5.2, G11.2, C12.1, B2.4, F12.1) is discerned by a clay composition with a high quantity of $Fe_2O_3$ (~3,9-10,6 wt.%), $TiO_2$ (0,6-1,2 wt. %), and Cr (0-84 ppm), which suggests the presence of more mafic volcanic rich parent rocks. In particular, $Cr^{3+}$ and $Fe^{3+}$ ions behave similarly during the weathering process. High values of chromium can be connected with mafic rocks, and this element can be concentrated mostly in chromite, spinel and clinopyroxene (Degryse and Braekmans 2013). The clay samples in this group are derived from different streams, and variations in water flow during the year may have affected weathering processes and produced a different fractionation of the elements (Wronkiewicz and Condie 1987).

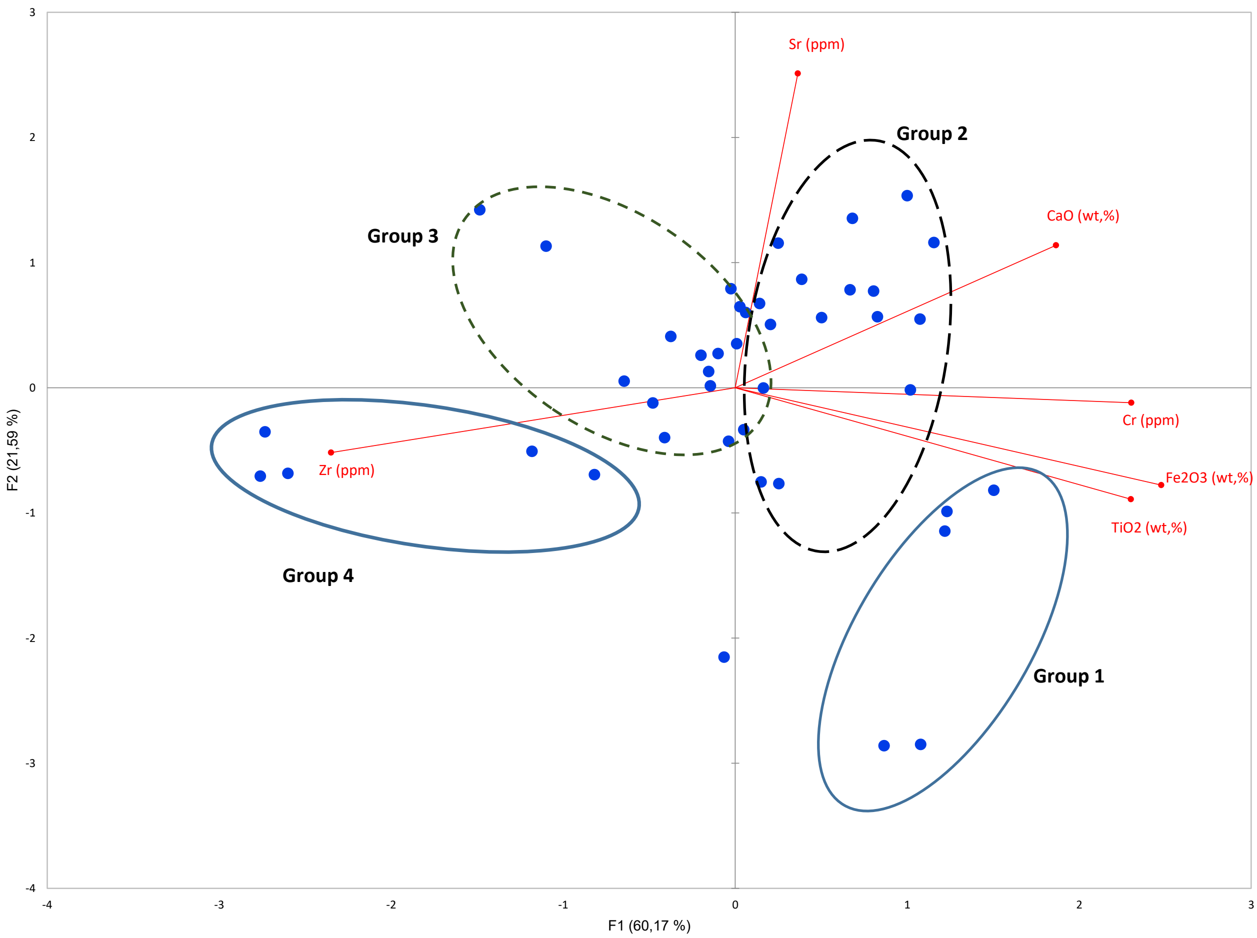


Figure 4: PCA biplot components 1 and 2 of p-XRF compositional data for the clay samples retrieved in the Río Mayales river subbasin and the Zapatera Archipelago.

Group 4 (B2.5, B2.6, B2.7, G11.3, A4.2, I7.3) shows a composition that substantially diverges from the other clusters and thus from the volcanic outcrops. A high value in Zr characterises these clays, which is resistant to weathering and associated with heavy minerals (Nyakairu and Koeberl 2001). The low values for this group in Sr and Ca can be associated with the grade of weathering that the sediments were subjected to before being deposited. Usually, strontium and calcium are lost rapidly and more easily than Zr during chemical weathering, and the amount of loss can be related to the extent of weathering (Wronkiewicz and Condie 1987; Degryse and Braekmans 2013). The alteration of plagioclase crystals might also be of potentially significant influence. Three clay samples (B2.5, B2.6, B2.7) were recovered from an archaeological excavation in the site of Barillas, northwest of AB, at a depth of 1.0 and 1.5 m respectively. The site is located by a large alluvial terrace in immediate proximity to the Mayales river, though the composition notably diverges from the samples collected at the same river.

The behaviour of the different chemical elements during sedimentary processes is complex and is influenced by several natural factors, such as weathering, physical sorting, absorption of ions by clays and other fine-grained particles, coarse grain-effect, diagenesis and metamorphism (Wronkiewicz and Condie 1987; Mahjoor *et al.* 2009; Degryse and Braekmans 2013). However, these chemical results clearly showed the ability to compositionally discriminate two different geological formations, the Zapatera Archipelago and the Río Mayales subbasin, as well as to further divide the Mayales area in three distinct chemical groups. Since these environments are characterised by measurable chemical differences, they demonstrate how the variability in different geological substrates of this region can contribute to create these distinguishable compositional clay groups. Moreover, this partly reflects the diverse geological units described by Garayar (1972). Results of chemical analysis on both clay and ceramics materials from archaeological excavations in the valley show that some clays were selected by pre-Hispanic populations for manufacturing pottery (Casale *et al*. 2020).

### *3.3 Ethnographic survey*

The geochemical analysis of clay beds is an ideal method to connect ceramic objects with various mineral resources. Apart from these chemical characteristics, artisans in past and present may select their material on properties beyond solely the suitability of clay. The data from an ethnographic survey therefore, presented in this section, is based on a series of conversations with local inhabitants of the valley to elucidate these choices and connections. The ethnographic survey started with interviews with both local potters and brick factory workers. Interviews consistently showed that local soils are divided in six major types, according to plasticity, colour and current use for the local economy, such as agriculture, building, and pasture. Table 2 shows the types and local uses attributed to the different clays. The production of bricks and clay-based architecture are the most important activities related to this soil exploitation. Brick manufactories are always located next to water sources and in direct vicinity of the soil deposits used in the production process. There is very little movement of raw materials from different locations, and only *in situ* materials are processed. Factories produced goods with every type of soil and usually the choice of the location is mainly driven by the availability of water and the economic capacity of the owners. For instance, one manufactory produces bricks with only pure sandy material, so their end products are extremely friable specimens of low quality. Another manufactory employed a mix of sandy and clayish materials resulting in a product of higher quality. However, this combination was not linked to a technological choice, but rather to a geological condition. The brick manufactory owner was unaware of the presence of a clay-rich soil layer located between two layers of sandy river accumulation prior to the founding of the factory.

Even though the production of building materials has a wide development in the area, and the use of cement and sheet metal is increasing, houses in these rural areas are sometimes still built using wood and a type of soil called *lanilla*[3]. Figure 6 shows some examples of the current uses of this soil for building walls, kitchens, fireplaces and ovens. *Lanilla* is mixed with water and grasses after which the mixture is added to the wood structure to create the walls. The great advantage of this material is that it is waterproof without the need for firing, creating a strong, insulating wall surface.

A large number of man-made mounds is located on *lanilla* deposits (van Dijk 2017), or in direct proximity to them, and *lanilla* soil is often found during the

3 For more information about modern house construction in *lanilla* and wood, please refer to Arnau Llaudet (in press).

| Local name | Description according to Taylor (1963) and van Dijk (2017) | Modern use | Variations |
|---|---|---|---|
| *Lanilla* | *Young volcanic ash/alluvial soil* | Production of bricks, house walls, pavement, kitchen and oven. Pasture and agriculture. | From beige to light brown |
| *Barro* | *Tropical alluvial soil* | Bricks, tiles, and ceramics. | *amarillo, negro, barro/arenoso* |
| *Barrial* | *Tropical Black soil/Vertisol* | Crops and pasture activities. | *bajo, negro, cafè, barro barrial* |
| *Tierra* | *Tropical brown/alluvial soil* | Crops and pasture activities. | *normal, fina, negra* |
| *Arenoso* | *Alluvial deposits* | Production of bricks. | *barro arenoso* |
| *Arena* | *Alluvial deposits* | Production of bricks. | No variations |

Table 2: Description of local soil names and their uses.

excavation near and within mounds. It seems likely, therefore, that pre-Hispanic populations might have consciously sought out *lanilla* as building materials, similar to the current day strategies.

### *3.4 20th century pottery manufacture*

Regarding the production of earthenware and kitchen goods, the main outcome of the ethnographic survey is that the local production of ceramics has dramatically declined with the advent of cheaper plastic and metal items in the last few decades. The general picture that emerges through interviews is that the majority of the current day population is not familiar with pottery practices or aware of the location of clay sources. Mostly, only people older than 60 years of age are aware of the presence of clay outcrops, while most of them have never produced pots, whereas earlier relatives used to manufacture pottery at the household level.

Even with some exceptions, production in the past was mostly related to the domestic consumption and not for export and/or sale to the local market. The knowledge of clay deposits, the quality and the way of working with raw materials, were all shared between a few individuals or small clusters of families. Such knowledge of a single or dual clay sources was typically used for the entire life span, transmitting the knowledge from generation to generation. All the clay outcrops, except for one, were located within a 500 meter radius from houses, while the longest distance recorded between the production's place and the used clay deposit is around one kilometre. Rarely, different clays are mixed, but most of the time potters use clays without prior processing or preparation, such as sorting, sieving, or tempering. In a single case, one woman, Doña Guadalupe, who lives north of Juigalpa along the Cuapa road, used to produce ceramics for her own consumption. Her clay preparation practices involved mixing two different kinds of clay, a very fine one and a sandier one. One of these two clay outcrops is located one kilometre from her house, representing the longest distance between a potter's household and their raw material source for the research area.

Integral and detailed descriptions of manufacturing practises were documented in two separate communities. The first community, San Isidro, is located very close to AB, where we interviewed Antonia Villegas Ruiz, the last person knowledgeable of how to make ceramic vessels in the area. The second community, Güegüestepe, is a small hamlet where families were fully dedicated to pottery and brick production, located about two km from Juigalpa.[4]

At San Isidro, clay procurement involved an outcrop located 300 meters west of the potter's household, at the shore of a stream. Paste preparation only entailed the addition of water, as well as kneading and percussion gestures to obtain the desired plasticity. Fashioning was done with a clay mass, placed over a convex mould. Percussion is applied on the mold until the desired shape is achieved, and then immediately after a corn cob is hydrated and applied to continue the pre-forming process. Later, pinching and beating are applied to homogenize walls. After drying for a few days, surface treatment is done with a *zapoyol* seed (from the Sapotaceae family). Finally, pots are fired on an open hearth.

4 The medium-length documentary film "Barro Somos", jointly produced by Espora Productions (Mexico) and PACEN is an audiovisual testimony of the experiences of these two case studies (https://vimeo.com/146862913).


Figure 5: From top left to bottom right: different uses of *lanilla* soil to build kilns (figure 5a, courtesy of Espora Productions), houses, kitchen ovens (figure 5c, courtesy of Alejandro Arteaga), and an example of a brick manufactory.

Although pottery production declined, the Güegüestepe community still bases its economy on manufacturing earthenware. In particular, griddles and cooking pots are produced, and then sold on the local market in Juigalpa. Clay procurement practices involve exploiting a clay outcrop located 400 meters south of the village, on the banks of the Mayales river. Paste preparation practices only involved hydration, kneading, and pounding. Fashioning is conducted on a clay mass, a concave mould serves as a rotative support for finishing the griddles, while for jars, a convex mould is employed. Palmar beating is predominant, but pinching and drawing are also applied. A plastic tool is used for scraping, and after drying, surface treatment involves burnishing with a *zapoyol* seed. In contrast to San Isidro, a kiln is used to fire the pots. Apart from that, production in Güegüestepe is commercially oriented rather than satisfying demands at the household level, as is the case in San Isidro.

## 4. Conclusion

Through the combination of both systematic archaeological pedestrian surveying and ethnographic interviewing (Geurds *et al.* 2015, Casale 2017), this research has created an understanding of clay availability across the valley, and how this relates to the use of raw clay materials suitable for ceramic manufacture in the past and present. Previous archaeological studies in the area investigated ceramic through a morphological focus (Gorin 1990), while the results of this study substantially increase information for further research into the longterm ceramic production and selective use of mineral resources from the pre-Hispanic period onwards. This study provides an extensive overview of present day ceramics manufacturing traditions that feeds back across time in the valley of Juigalpa. Today, local potters use and identify only clay outcrops close to their residential or manufacture area. However, the results of the research showed that the quantity of


Figure 6: Modern ceramics production at the Güegüestepe (figure 5a, courtesy of Espora Productions) and San Isidro communities, examples of *ollas* (cooking pots, figure 5b, courtesy of Espora Productions) and *comales* (griddles).

clay suitable for producing ceramics is far greater than what local potters are currently aware of. Petrographic analysis on ceramic materials excavated in other sites located in the valley have shown connections to the clay outcrop exploited in the community of Güegüestepe, demonstrating a continuity in clay procurement practices that goes deep into the present. Figure 3, for instance, shows that each archaeological site has several suitable clay outcrops in a one or two kilometres radius.

In addition, the reported chemical analysis demonstrates that p-XRF in this setting is a reliable technique for studying geological samples in field and laboratory environments, being able to clearly differentiate between clay samples of distinct regions such as the Zapatera Archipelago and the Río Mayales subbasin. The analysis also shows that the valley is not compositionally homogeneous, and substantial geochemical data have allowed for the characterisation of distinct, geologically-based compositional groups throughout the landscape. In these efforts for creating clay chemical profiles as a reference for future studies, three main heterogeneous groups were identified. This resulted in a significant improvement of the limited geochemical data resolution previously available, and it encourages further high-resolution chemical analysis that aims to link clay outcrops with ceramic materials. Future comparisons of ceramics with the raw mineral resources will generate undoubtedly more hypotheses regarding the role of Aguas Buenas as a shared place among different communities in the Río Mayales subbasin.

Lastly, interviews with local potters and manufactory workers revealed significant aspects of the production processes concerning raw materials selection and fabrication sequences. The main conclusion is that artisans are satisfied with a very limited range of clays, regardless of the manufacturing techniques or final use of the objects. Griddles and pots are produced with the same clay, even if they might have two completely different functions, such as cooking or water containers. Differences in firing seem to be connected to the type of production, either related to a manufacture for satisfying domestic demands through the use of open hearths or alternatively kiln firing applied by specialized potters.

The information gained through this study creates a reference baseline for future research in the area, providing a new solid research framework of investigation that can be employed for more detailed and extensive future studies on pre-Hispanic human groups and their use of mineral resources in central Nicaragua.

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