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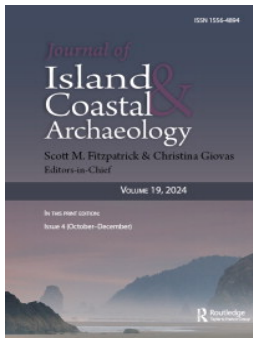
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Sharing ceramic manufacturing processes: A technological and petrographic study on ceramic production and exchange between Hispaniola and Puerto Rico (350–1200 CE)

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ABSTRACT

This study investigates the production and distribution of ceramics across the islands of Hispaniola and Puerto Rico during the Ceramic Age (ca. 800–500 BCE to 1500 CE). The ceramic assemblage from El Frances, Dominican Republic, is analyzed and compared with five other sites from Puerto Rico (Hacienda Grande, Tecla, La Gallera, Dorado-42, Sorcé). Petrographic analysis clarifies the origin of raw materials and the preparation of the clay body. Results show an initial phase (ca. 350–900 CE) of Saladoid ceramics at El Frances that appears to be similar to the Puerto Rican sites in the processing and the origin of some of the raw clay materials. Between ca. 900 and 1200 CE, evidence from El Frances shows technological change, suggesting a process of socio-cultural transformation. This change entailed the production of very coarse and heterogeneous ceramic bodies and the use of locally accessible clays originating from metamorphic parent rocks. The heterogeneous paste preparation is comparable with other contemporaneous sites such as El Flaco and La Luperona, located in the central north, and El Cabo on the east coast of Hispaniola. This study adds insights to manufacturing practices in ceramic production across a long-term period and shows evidence of the occurrence of similar “ways of doing” between distant communities across Puerto Rico and Hispaniola.

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Introduction

Indigenous populations inhabited the Greater Antilles for ca. 5000 years before the European invasion (Keegan and Hofman 2017, 24–6; Rouse and Allaire 1978). The

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study of archaeological materials, including ceramics, has been fundamental to developing a comprehensive understanding of the level of social and cultural interaction that the Caribbean populations developed during this period (Hofman, Bright, and Rodríguez Ramos 2010; Hofman, Rodríguez, and Jiménez 2018). The present study aims to improve our understanding of the spread of ceramic manufacturing knowledge during the Ceramic Age (800/500 BCE–1500 CE) in the Dominican Republic and Puerto Rico through petrographic analysis to clarify the origin of raw materials and the preparation of clay ceramic bodies. In Caribbean archaeology the Ceramic Age is a cultural historical period generally accepted to begin around 800–500 BCE with the migration of Saladoid communities from the Orinoco basin in modern Venezuela (Keegan and Hofman 2017; Rouse 1992). Saladoid migrants were excellent navigators and established themselves extensively in the Lesser Antilles and Puerto Rico, the latter of which is considered the western border of Saladoid expansion (Bérard 2013; Fitzpatrick et al. 2013; Giovas and Fitzpatrick 2014; Keegan 2004; Rouse 1992; Siegel 1992; Wilson 2007). In 2019, however, substantial evidence of Saladoid material culture was discovered at the sites of La Entrada (Casale, Forthcoming) and El Frances (López Belando and Shelley 2020 in the northeastern Dominican Republic). These recent finds raise questions about the spread of Saladoid networks in the Antilles.

The Saladoid occupation of the Caribbean Archipelago is a sub-period of the Ceramic Age. It defines the Early Ceramic Age (ECA) and lasts between ca. 800/500 BCE and 500/700 CE (Bérard 2013; Fitzpatrick et al. 2013; Giovas and Fitzpatrick 2014; Keegan 2004; Rouse 1992; Siegel 1992; Wilson 2007). Saladoid migration, and its accompanying ceramic tradition, brought a substantial change in the social and economic aspects of the Antilles. Saladoid ceramics are high quality and among the most elaborate in the Americas. Ceramics include complex shapes painted with red, black, white-on-red, and polychrome schemes and often decorated with modeled and incised zoomorphic adornos, incisions, and punctuation.

Around 500 CE, a cultural shift occurs in the Caribbean, beginning with the disappearance of Saladoid material culture. This post-Saladoid period, or Late Ceramic Age (LCA), lasts until the European invasion (ca. 1500 CE). The LCA is characterized by rapid population growth, a change in the settlement patterns with a shift from the typical coastal Saladoid sites to more inland inhabitation, and by the construction of ceremonial plazas. New pottery styles and morphological traits appeared and slowly replaced the previous Saladoid pottery (Table 1).

The finds from the site of El Frances (ca. 350–1200 CE) in the northeastern Dominican Republic (Figure 1) are important because they allow us to explore different aspects of ceramic production and technology across the centuries, such as the procurement of raw clay materials and their processing. More importantly they permit diachronic comparisons with other ECA sites that can add new insights about the Saladoid expansion into the Dominican Republic and help to clarify the transition dynamics between the Early and Late Ceramic Age. Technological behaviors, intended as the *chaîne opératoire*, the series of technological operations carried out to manufacture certain artifacts, are rooted within the cultural tradition of social groups. They are socially learned and are the outcomes of knowledge transmission between generations (Cresswell 1983; Dobres 1995, 2000; Dobres and Hoffman 1994; Gosselain 1998, 2000;

Table 1. General description of the ceramic series identified in Puerto Rico and the Dominican Republic.

Location	Styles	Description
Puerto Rico	Hacienda Grande (300 BCE–400 CE) (Early and Middle Saladoid)	Complex shapes decorated vessels with red, black, white-on-red, and polychrome painting. Incisions are generally zoned, crosshatching, and combined with punctuation; there are modeled and incised zoomorphic adornos and strap and loop handles.
Puerto Rico and Dominican Republic	Cuevas styles (400–1000 CE) (Late Saladoid)	Open bowls with inverted bells shape, constricted bowls and oval shapes. Handles and tabular lugs usually rise above the rim symmetrically. Decoration is usually red paint, with stripes decorated in circle, semi-circle, horizontal, vertical, and spiral orientation.
Puerto Rico	La Hueca (800–200 BCE–400 CE)	Predominantly zone-incised, crosshatched pottery without painting. Some figurative modeled motifs are present.
Puerto Rico	Monserrate (600–900 CE)	Predominantly plain vessels with red-slipped and red painted body with often black and negative resist, and smudging decoration. The ceramic body is thicker and coarser body than Saladoid.
	Santa Elena (900–1200 CE)	Vessels gradually increased their thickness, texture of the body. The decorations are simple and limited to vertical and rectilinear incision near the rim and often punctuation and appliqué are added.
Puerto Rico and the Dominican Republic	Ostionoid (600–1200 CE)	Largely undecorated vessels characterized by thin, hard, and smooth surface. A small quantity of decoration consists of red painting and red slip. Vessels yield straight-sided open bowls and boat shape with often loop handles that go over the rim level.
Puerto Rico, the Dominican Republic, and Haiti	Chicoid (800–1500 CE)	Highly burnished pottery that presents a wide range of morphologies, including effigies and white-slipped bottles. The decorations are characterized by large incised lines and dots.
The Dominican Republic and Haiti	Meillacoid (800–1500 CE)	Vessels with thin walls and a hard body irregularly smoothed. Morphologies vary between hemispherical bowls and boat shapes. The decoration motifs are located on the upper part of the vessel and include oblique parallel thin lines together with appliqué, lugs, and adornos with anthropomorphic shape.



Figure 1. The location of El Frances and the five sites from Puerto Rico and Vieques Island.

Lemonnier 1986; Roux 2015, 2019a, 2019b). Ceramic technological studies, following the *chaîne opératoire* approach, produce a sophisticated impression of the entire production process, from the procurement of raw material to the preparation and manufacture of the final artifact, revealing technical choices that reflect socio-cultural patterns among a population (Cresswell 1983; Dobres 2000; Gosselain 1998; Livingstone Smith 2000, 2010, 2016; Roux 2015, 2019a).

Following from this theoretical and methodological framework, this research uses petrography to infer mineralogical and technological knowledge that developed and spread during the Ceramic Age. Petrography has proven to be a well-suited method for clarifying the origin of raw materials and contextualizing ceramic production in Caribbean archaeology. The results of previous petrographic studies showed the extension of important inter- and intra-island exchange networks in the Lesser Antilles (e.g., Donahue, Watters, and Millspaugh 1990; Fitzpatrick et al. 2008; Hofman 1993; Isendoorn, Hofman, and Booden 2008; Lawrence, Fitzpatrick, and Giovas 2021, Lawrence, Marsaglia, and Fitzpatrick 2016; Pavia, Marsaglia, and Fitzpatrick 2013; Stienaers et al. 2020). For example, a detailed petrographic analysis of the ceramic assemblages from Carriacou shows how most of the materials found in the island were likely imported rather than locally produced, a conclusion that was based on the identification of igneous volcanic and quartz tempers associated with Puerto Rico and Barbados, respectively (Pavia, Marsaglia, and Fitzpatrick 2013).

In the Greater Antilles, petrographic studies include those of both pre-Columbian and colonial period ceramic production (Casale et al. 2021, 2022; Milantchí 2018; Ting et al. 2016, 2018; van Dessel 2021). Analysis of LCA material from the site of El Cabo,

on the east coast of the Dominican Republic, revealed the presence of intermediate volcanic rocks that suggests possible importation of raw materials or finishing products from Puerto Rico across the Mona Passage. In another study, Ting et al. (2016) carried out technological studies to clarify changes and similarities among contemporaneous ceramics from the sites of La Luperona and El Flaco (the Dominican Republic) and showed a low level of standardization, with coarse and heterogeneous ceramic bodies and irregular firing conditions. Results are similar to the findings of Casale et al. (2022) for the site of El Cabo and to the study of LCA ceramics in the Leeward Islands conducted by Donahue, Watters, and Millspaugh (1990).

This study adds to current technological knowledge in ceramic manufacturing and provides a comprehensive analysis of the initial steps of the *chaîne opératoire* at El Frances, focusing on raw material sources and preparation of the clay bodies, and modeling/shaping traditions. To explore the technology and origins of pottery manufacturing traditions in this region, we conducted petrographic analysis on 54 ceramic samples from the assemblage of El Frances and the five Saladoid sites from Puerto Rico and Vieques Island. The results represent the first investigation on Saladoid materials in the Dominican Republic and expand our knowledge on LCA communities in the Greater Antilles.

Research background

Between 800/500 BCE and 500 CE, it is generally accepted that the Mona Passage, the water channel that divides Puerto Rico and Hispaniola, was the geographical and cultural border of the Saladoid influence sphere. Only a few examples of Saladoid material culture have been identified in southeastern Hispaniola (Hofman and Ulloa Hung 2008). In contrast, during the LCA (600/700–1500 CE), pottery with varying morphological and decorative traits appeared widely across Hispaniola and the rest of the Greater Antilles, including Cuba and Jamaica, as well as the Bahamas (see Chanlatte Baik 2013, 2005; Curet 2002; Fitzpatrick 2015; Rouse 1992, Ulloa Hung 2014). The site of El Frances is therefore distinctive for containing Saladoid ceramics and evidence for significant occupation west of the Mona Passage during the ECA (Figure 1).

The sites and ceramic assemblages

El Frances

Located on the eastern point of the Samaná peninsula, in the Dominican Republic, El Frances shows potential for clarifying the extent of Saladoid expansion into Hispaniola and the transition between Saladoid and Late Ceramic Age communities. The settlement was established in a small fertile valley ending at a natural gulf that offers protection from the winds. The site was excavated by López Belando and Shelley (2020) and showed evidence for large-scale human occupation dating to cal. 350–200 CE. Direct radiocarbon dating of charcoal samples and preliminary analysis of the material culture divide the human occupation of the site into three main periods. Period 1 (ca. 350–650 CE) is associated with Saladoid ceramic materials. This phase is followed by a more recent occupational layer, Period 2 (ca. 650–900 CE) that shows a considerable overlap

between Late Saladoid (e.g., Cuevas styles) and sherds typical of LCA manufacture (e.g., *Punta Cana* phase or as *Ciguide*¹). Pottery characterized with Chicoid morphological features appears in small quantities. The late phase, Period 3 (ca. 900–1200 CE) is dominated by LCA pottery (Chicoid and *Punta Cana/Ciguide* stylistic traits) with the loss of the Late Saladoid characteristics (Figure 2). Undecorated ceramics characterized by a thick body and typically linked with cooking activities occur across the entire occupation period. The archaeological site corresponds in all its phases to agricultural groups with evidence for intra and inter-island exchange relationships. The extensive description of the archaeological materials, including ceramics, found in El Frances is provided by López Belando and Shelley (2020).

Tecla, Dorado-42, Hacienda Grande, La Gallera, and Sorcé

Five Saladoid sites were selected for comparison based on the presence of ceramic components of comparable age to El Frances. Both the site of Sorcé (370–720 CE), located on the Vieques' island, and the site of La Gallera, on the east coast of Puerto Rico, evidence the presence of a long-term human occupation with three main ceramic components: the Early Saladoid, Huecoid, and Late Saladoid (Chanlatte Baik 1981; Chanlatte Baik and Narganes 1984; Chanlatte Baik, Narganes, and Méndez 2002; Chanlatte Baik et al. 2005). The site of Tecla (170–230 CE) is situated in the municipality of Guayanilla, southwest of Puerto Rico, and contains Mid to Late Saladoid and later Ostionoid ceramic materials (Narganes 1989). Hacienda Grande is situated near the seashore on the northeast coast of Puerto Rico. Here, Early and Late Saladoid materials are followed in time by ceramics of the Ostionoid and Chicoid series (Rouse and Alegría 1990). The site of Dorado-42 is on a karst area in the central north coast of the island and shows the presence of ceramic materials with Late Saladoid and Santa Elena styles (Hernández 2018).

Geological background

The geology of the Greater Antilles is highly variable. Hispaniola and Puerto Rico are located on the northern part of the Caribbean plate. Hispaniola arose from the subduction-collision of the Caribbean intra-oceanic arc and the North American plate, a process that entailed the destruction of a shallow-water carbonate forearc platform and the raise and consequent erosion of mountainous arcs such as the Cordillera Septentrional, the Samaná peninsula, and inliers such as Puerto Plata and Río San Juan (Escuder-Virquete and Castillo-Carrión 2016;



Figure 2. Examples of vessel reconstructions based on the archaeological remains of El Frances. (1) Late Ceramic Age (identified as *Ciguide* style); (2) Late Saladoid (identified as *Cuevas* style); (3) Early Saladoid (after López Belando and Shelley 2020).

Escuder-Viruete et al. 2016). The Samaná peninsula is characterized by a complex mélange of high-P metasedimentary rocks and alternated layers of Late Miocene and Pleistocene limestone formations. Metamorphism processes created different formations that vary from calcitic and dolomitic marbles, blueschist and eclogite facies, and mafic protolith. El Frances is located on the easternmost coast of Samaná, where mixed superficial calcareous coralliferous layers occur between two main outcrops: the Rincon calcitic and dolomitic marble; and the Santa Bárbara schist, characterized by blueschist and greenschist facies (Escuder-Viruete et al. 2011) (Figure 3).

Puerto Rico is divided into three main geological zones: the Cordillera Central, Carbonate, and Coastal lowlands. The island is characterized by the central presence of plutonic and volcanic rocks with alternated volcanic-sedimentary rocks and coastal carbonate areas that form karstic structures. The coasts are dominated by a mix of igneous and sedimentary rocks with extensive alluvial deposits (Wilson, Orris, and Gray 2019).

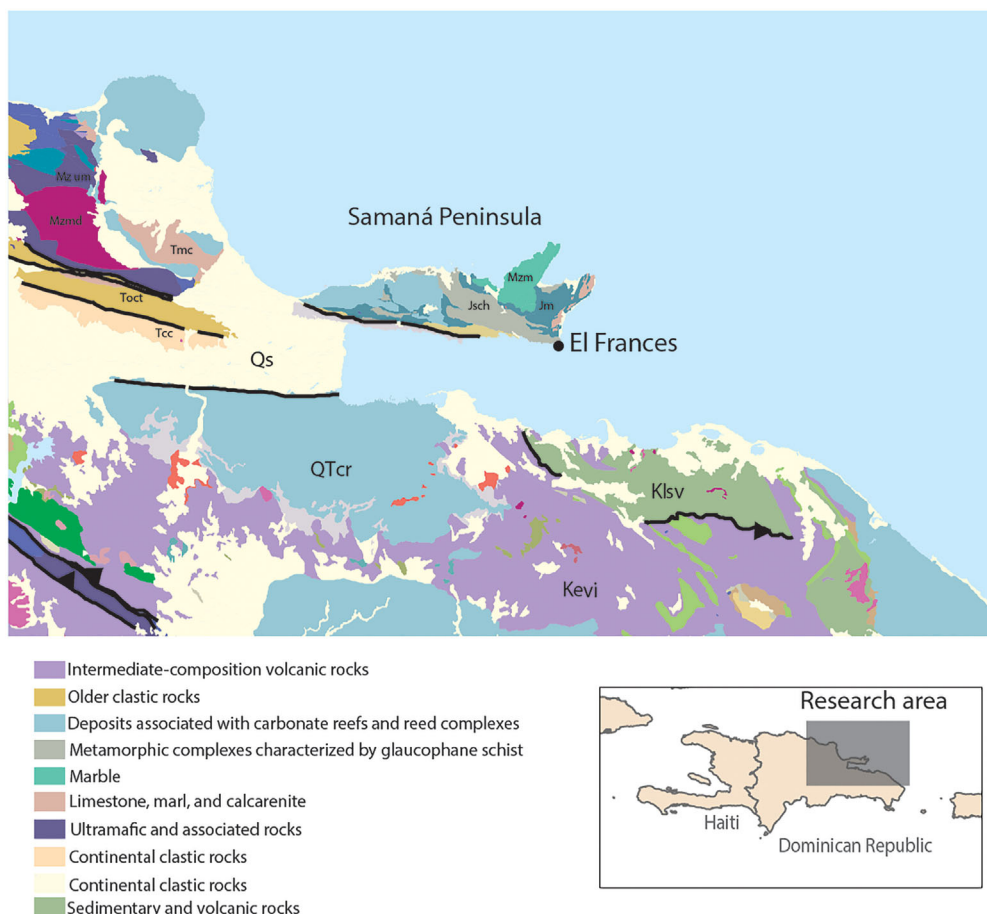


Figure 3. Overview of the Samaná peninsula, surrounding area and geologic map showing the location of El Frances (Geologic map; modified from Wilson, Orris, and Gray 2019).

Materials and methods

Sherds were selected for analysis based on their association with radiocarbon dates gathered from samples at the sites, stylistic aspects, and macro-observations of the clay body (type of inclusions and size, hardness, firing conditions, body color). An initial typological observation was performed to identify preliminary diagnostic features and is used here to organize a review of the ceramic assemblages.

From El Frances, 36 ceramic samples were selected. In addition, for comparative analysis, we chose to analyze two clay outcrops located in the vicinity of El Frances as well as 16 samples from La Gallera, Sorcé, Tecla, Dorado-42, and Hacienda Grande. The samples from Puerto Rico and Vieques include Late Saladoid ceramics and were selected to clarify and contextualize the Saladoid findings of El Frances based on well-known Saladoid sites.

In total, 54 thin sections were prepared. Observations were made with a polarizing microscope (Leica DM750P) equipped with a Leica EC3 camera, which uses transmitted plane-polarized (PPL) or cross-polarized (XP) light. Petrographic analysis followed the methodology of Quinn (2013) and Whitbread (1986), with the goal of being comparable to other published studies from the Greater Antilles (e.g., Casale et al. 2022; Ting et al. 2016, 2018). Analytic results allow us to estimate the origin of the clay sources based on the nature, size, and frequency of the inclusions. Firing temperature and environment were estimated by analysis of the optical activity and color of the matrix, while clay preparation through techniques such as sieving, the addition of temper materials, and modeling of the ceramic body, were observed based on the distribution, sorting and shape of the inclusions, and the nature of the voids (Casale et al. 2022; Quinn 2013).

Results

The petrographic analysis showed the use of various clay sources originating from different geological units. The ceramic assemblage of El Frances evidenced the presence of six different petrographic groups and several sherds that do not match any others, hereby referred to as ungrouped. Metamorphic, volcanic (intermediate and mafic), and sedimentary components were documented. All identified petrographic fabrics displayed internal homogeneity, with some variation in the grain size and typology of the inclusions that formed subgroups (Figure 4). Table 2 summarizes the results for each identified group from El Frances and provides information related to the other analyzed sites (see Supplemental File SI for a detailed description of each group and aplastic inclusions). The complete descriptions of the ungrouped sherds that did not match any groups from El Frances, the Puerto Rican samples, or the clays are included in Supplemental File S1.

Amphibolite/Marble group

The matrix of the Amphibolite/Marble group was poorly sorted and yielded coarse and medium-coarse metamorphic rock inclusions with schist and foliation structures. Metamorphic rock with feldspars and quartzite with intergrowth orange minerals appeared frequently, followed by the common presence of muscovite either as a single

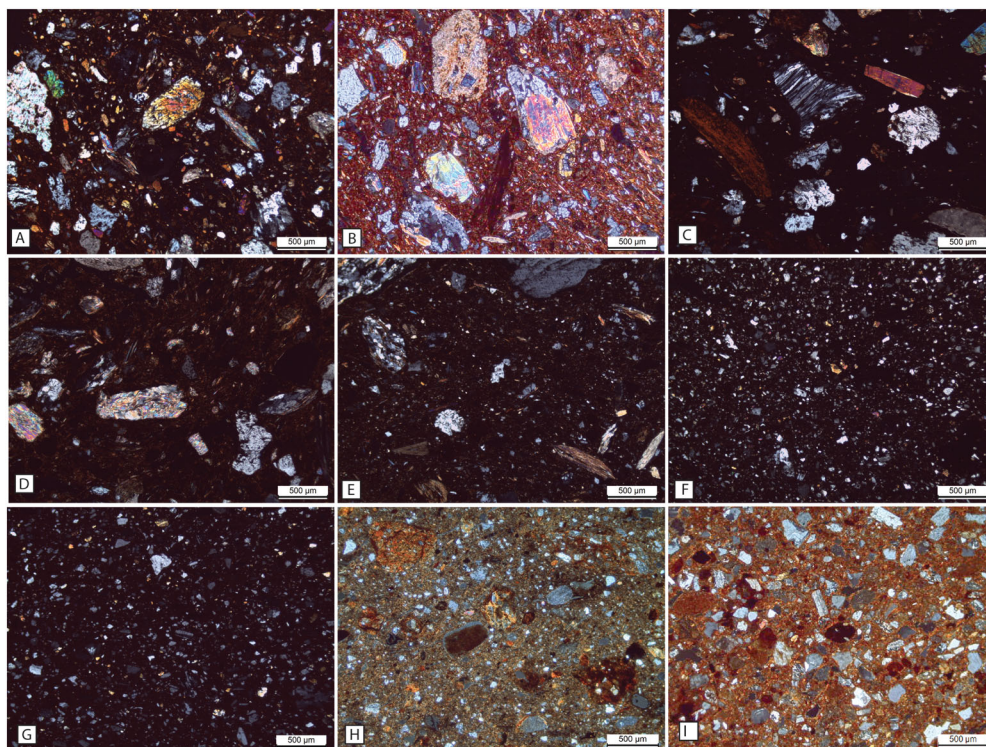


Figure 4. Petrographic groups identified in El Frances. The photos were taken with crossed polarized light. (A) FR6, group 1; (B) FR35 group 1.x; (C) FR13, group 2; (D) FR3, group 2.x; (E) FR12, group 2.y; (F) FR21, group 3; (G) FR29, group 4; (H) FR14, group 5; (I) FR 25, group 6.

crystal or as rock inclusions (Figure 4A, center and low right). The general mineralogical composition and shape of the inclusions (angular to subangular) pointed to primary clay deposits and originated from the weathering of different metamorphic rocks. Subrounded iron-rich inclusions were very rare and fine; size averaged between 100 and 200 µm. Thin, long voids between 200 and 600 µm were present, mostly oriented parallel and sub-parallel to the borders of the vessels. The inclusions were also largely organized semi-parallel to the borders (Figure 5B). The groundmass was dark reddish brown and optically active. Firing occurred in an oxidized condition and with full control of the firing process, as indicated by the homogeneous color of the matrix. Firing temperature was estimated to be below 800 °C.

Subgroup 1.x—coarse metamorphic rocks

The fabric of Subgroup 1.x of the Amphibolite/Marble group was poorly sorted, highly metamorphic, and characterized by very coarse rock inclusions of marble quartzite and amphibolite metamorphic rocks (amphibole was present either as a single mineral or as rock inclusions) (Figure 4B, center). In general, the inclusions were between 500 and 2000 µm, making them coarser than the primary Amphibolite/Marble group, although they were of similar metamorphic composition. Sandstone inclusions were rare and

Table 2. Summary of the results with compositional and technological aspects, supported by chronological division and preliminary ceramic series association. Preliminary stylistic analysis based on Lopez-Belando and Shelley (2020) for El Frances.

Petrographic			External		Parent rocks	Period	Preliminary stylistic traits
group	Site	Techno-group	connection				
1 Amphibolite/Marble 1 Amphibolite/Marble	EL Frances EL Frances	C C		Metamorphic—amphibolite/marble Metamorphic—amphibolite/marble	2 2	Late ceramic age (local styles, Ciguide) Overlapping features: Late Saladoid (Cuevas style)/late ceramic age	
	Coarse Metamorphic rocks 2 Highly Metamorphic 2 Highly Metamorphic 2.x Carbonate rocks	1.x C C C		Metamorphic—amphibolite/marble Highly metamorphic Highly metamorphic Metamorphic marble	2 3 3 3	Overlapping features: Late Saladoid (Cuevas style)/late ceramic age Late ceramic age (local styles, Ciguide) Chicoid, late ceramic Age Overlapping features: Late Saladoid (Cuevas style)/late ceramic age	
2.x Carbonate rocks 2.y Metamorphic and shell inclusions 2.y Metamorphic and shell inclusions 3 Fine Mafic Volcanic 4 Mafic Volcanic		EL Frances EL Frances EL Frances EL Frances EL Frances	C C C A A	Metamorphic marble Metamorphic + shell inclusions Metamorphic + shell inclusions Mafic volcanic Mafic volcanic	3 3 3 2 2	Late ceramic age (local styles, Ciguide) Late ceramic age (local styles, Ciguide) Chicoid, late ceramic age Late Saladoid (Cuevas style) Late Saladoid (Cuevas style)	
	5 Intermediate Volcanic and Chert 6 Intermediate Volcanic Outlier Outlier Outlier Outlier	EL Frances EL Frances EL Frances EL Frances EL Frances	B A B C B	Intermediate volcanic—sedimentary Intermediate volcanic Metamorphic and igneous Metamorphic Sedimentary + shell inclusions Intermediate volcanic and chert	2 2 1 3 2 2	Late Saladoid (Cuevas style) Early Saladoid Late ceramic age (local styles, Ciguide) Late Saladoid (Cuevas style) Overlapping features: Late Saladoid (Cuevas style)/late ceramic age	
Outlier Outlier		EL Frances EL Frances	A A	Quartz rich Igneous (Intermediate and mafic) sedimentary	2 2	Late Saladoid (Cuevas style) Late Saladoid (Cuevas style)	
	Outlier Outlier	EL Frances EL Frances	B C	Metamorphic—amphibolite/marble Metamorphic component	2 2	Late Saladoid (Cuevas style) Overlapping aspects: Late Saladoid (Cuevas style)/late ceramic age	
6 Intermediate Volcanic 6.x		Dorado-42 Dorado-42 La Gallera La Gallera	A A B A	Sedimentary—intermediate volcanic Intermediate volcanic Intermediate volcanic Intermediate volcanic		Late Saladoid Late Saladoid Late Saladoid Late Saladoid	
	Sorcé Sorcé	Hacienda Grande Hacienda Grande	B, A B B	Intermediate volcanic Intermediate volcanic Intermediate volcanic	CE 370–720 CE 370–720 CE 370–720	Late Saladoid Late Saladoid Late Saladoid	
Tecla Tecla			B B	Intermediate volcanic Intermediate volcanic	CE 170–230 CE 170–230	Late Saladoid Late Saladoid	
	Tecla Tecla		B B	Mafic and intermediate volcanic Mafic and intermediate volcanic	CE 170–230 CE 170–230	Late Saladoid Late Saladoid	

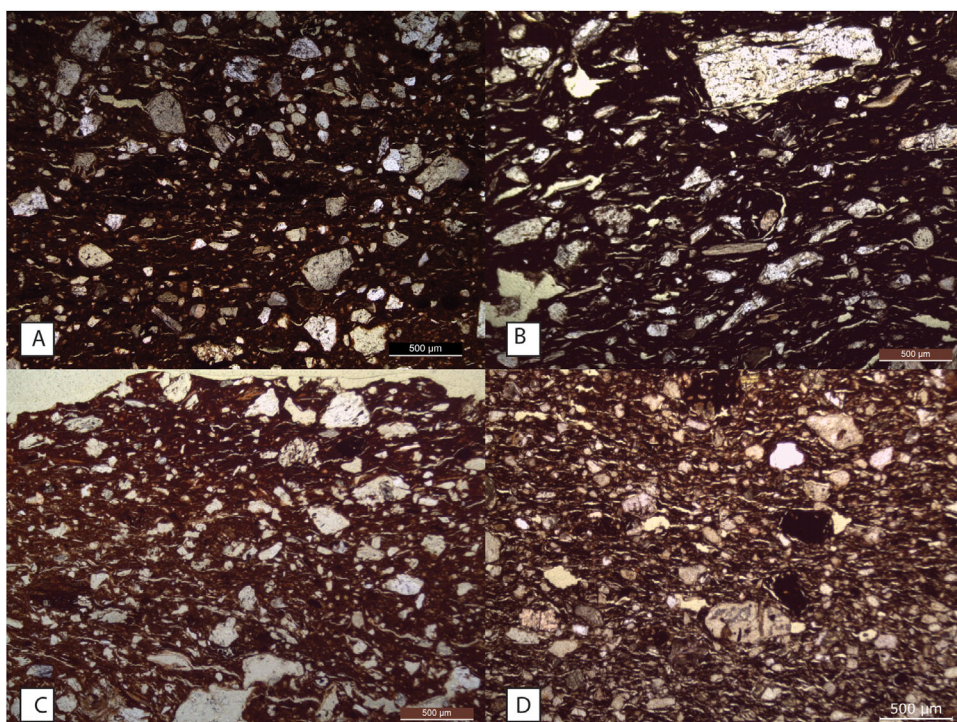


Figure 5. Several examples of voids and inclusions parallel or partially parallel with the border of the sherds. Pictures were taken with plane polarized light: (A) FR1 outlier; (B) FR15 group 1; (C) FR10 outlier; (D) FR29 group 4.

varied in size between 300 and 600 μm . Rock fragments were composed of several minerals, such as brown and green biotite, epidote, and muscovite. Epidotes were also commonly found as coarse single grain.

Highly Metamorphic group

The samples in the Highly Metamorphic group were poorly sorted, with heterogeneous composition. They are characterized by the presence of very coarse rock metamorphic inclusions that vary between quartzite (Figure 4C, center) and more complex schistose rocks that include muscovite, chlorite, and garnet. The rock fragments exhibit angular to subangular shape and highly variable sizes that range from 200 to 1000 μm . Bioclastic inclusions appeared in the matrix, and the presence of pyroxenes indicated clay that was not subjected to heavy weathering and possibly came from a primary deposit not far from the parent rock. The overall character of the matrix suggested that the clay was used without first being prepared through a technique such as sieving or selection for specific inclusion sizes. Voids had a thin and elongate shape varying in size from 100 to 200 μm . The voids and inclusions were positioned parallel and sub-horizontal to the surface of the vessels. The firing temperature was estimated to be below 800 $^{\circ}\text{C}$.

Subgroup 2.x—carbonate rocks

Subgroup 2.x is very similar to group 2; the major difference being the presence of some carbonate inclusions between 500 and 600 μm and the substantial presence of shell remains (Figure 4D, center and center left). Carbonate inclusions may suggest the influence of another metamorphic rock, such as marble, in the clay deposit.

Subgroup 2.y—metamorphic and shell inclusions

Subgroup 2.y is characterized by rock metamorphic inclusions similar to group 2, although the matrix is finer with a minor amount of very coarse inclusions. There were also shell remains, characterized by a colorful aspect and elongated shape (Figure 4E, lower right). The clay seemed to have been partially modified and sieved to be finer; however, it was still heterogenous and not a well sorted fabric.

Fine Mafic Volcanic group

The Fine Mafic Volcanic group is composed of three sherds from El Frances, and one sherd from La Gallera. The fabric was characterized by a well sorted matrix with fine inclusions ($<150\ \mu\text{m}$), made up of quartz single crystals with subangular and subrounded shape. Iron-rich clay pellets characterized by a rounded and irregular shape were present. Plagioclase feldspar (labradorite and anorthite) and olivine, averaging between 50 and 150 μm , were common in the groundmass; rare rock inclusions composed of plagioclase and olivine (200–300 μm) also occurred. The texture showed possible clay mixing with some part of the groundmass with very fine and with almost no coarse inclusions (Figure 4F, center). Voids were generally very small ($<50\ \mu\text{m}$) and partly aligned with the borders of the body; vesicular and more rounded voids are rarer.

Mafic Volcanic group

The fabric of the Mafic Volcanic group was homogeneous, well sorted, and characterized by the occurrence of a few coarse and medium size volcanic lithic fragments (300–1000 μm) that are partially weathered. The groundmass was medium-fine (200 μm), with few medium-coarse sandstone inclusions (400–500 μm). The matrix was characterized by the common presence of colorful olivine and rare pyroxenes (Figure 4G, top left). There were a few rock inclusions (sandstone) and some rare, metamorphosed quartz inclusions. Plagioclase feldspars (bytownite and anorthite) with a euhedral shape were common. Quartz with an irregular angular to subrounded shape was frequently identified. Iron-rich inclusions were rare and were characterized by a subrounded shape and size smaller than 200 μm . The fabric exhibited small, elongated voids that were partly oriented with margins (Figure 5D) and disposed in a circular pattern (i.e., relic coil from the fashioning process). The firing temperature was less than 800 °C, as indicated by the groundmass that is optically active. Although the firing occurred in an oxidizing environment, oxidation was incomplete, as evidenced by the color differences between the core and margins. FR29 indicated a higher firing temperature under

homogeneous oxidizing conditions; however, the sample consists of the same raw clay material.

Intermediate Volcanic and Chert group

The Intermediate Volcanic and Chert group was characterized by a moderately sorted matrix with some rare coarse inclusions. Most of the inclusions were related to an intermediate volcanic and beach/aeolian weathering origin with common chert and sandstone/quartz arenite (Figure 4H, low and top right). Inclusion size varied between 200 and 1500 μm , with a mode of 200–300 μm . Intermediate volcanic rock fragments were few and varied between 500 and 1000 μm ; they were characterized by a subrounded shape, lamellar plagioclase feldspars, and an often-present serpentinite alteration (Figure 4H, top left). A few single plagioclase feldspars (ca. 200 μm) were present, together with very rare yellowish and colorful olivine (<100 μm) and rare augite (100 μm). Quartz was common either as a single mineral or in rock inclusions, and plagioclase feldspars appeared either as a rare single mineral (100–200 μm) or in volcanic rock fragments. There were a few glassy particles of orange brownish color (100–150 μm) (Figure 4H, center). Iron-rich inclusions between 100 and 300 μm in size and subrounded were present but rare. The matrix also had some rounded, argillaceous inclusions (clay pellets). Because inclusions were generally subrounded extensive transport of the clay before deposition was suggested. The presence of a mix of small angular grains and the high presence of organic compounds was associated with the likely superficial origin of the clay. The observed difference in matrix color was due to the presence of fired organic materials. In general, inclusions were poorly aligned with the surface of the body. Grogs or coarse clay streaks were suggested by the presence of some very coarse inclusions.

Intermediate Volcanic group

Sample FR25 from El Frances and DOR4 from Dorado-42 formed the Intermediate Volcanic group. The matrix of both samples was well sorted with an average inclusion size of between 100 and 200 μm . Quartz, chert, and intermediate volcanic rock inclusions smaller than 200 μm were frequent. Plagioclase feldspars were common in the matrix (100–200 μm), while amphibole (150 μm), biotite (200 μm), augite (200 μm), and olivine (100 μm) were very rare. There were a few rounded iron-rich inclusions (ca. <300 μm) and moderate amounts of rounded clay pellets (100–300 μm) (Figure 4I, center left). The groundmass was optically active and indicated a firing temperature below 800 °C. Voids were thin, elongated, and in some areas partly oriented in circular forms following the relic coils.

Discussion

The results indicate that the El Frances ceramic assemblage was manufactured with clay from different sources and that three main techniques were used to prepare the clay mass.

Petrography and provenance of clays

Ceramic fabrics show that their non-clay silt to sand-sized components were derived from three different types of rock units: metamorphic, volcanic, and beach/aeolian sand inclusions. Even though the exact origin of the raw clay materials cannot be established, important hypotheses about this can be formulated based on the geological formation that characterizes the Samaná peninsula and areas of Hispaniola and Puerto Rico. Group 1, group 2, and samples FR1, FR10, and FR33 have clay bodies characterized by metamorphic inclusions. The metamorphic component identified in the clay bodies of groups 1 and 2, such as quartzite, amphibolite, and calcitic marbles, can be associated with the regional metamorphism of the Samaná peninsula and, to a minor extent, with the amphibolite of the San Juan complex northwest of Samaná.

Ceramic samples included in groups 3, 4, 5 and 6 and ungrouped samples (FR22, FR28, FR30, FR31) do not show metamorphic elements. The source of their clay is associated with intermediate and mafic volcanic geology, which is not present in the Samaná Peninsula. Instead, candidate regions which exhibit appropriate igneous (intermediate to mafic composition) geology include central Hispaniola (e.g., Tíreo complex), the province of El Seibo in eastern Hispaniola (Bowin 1966; Toloczyki and Ramirez 1991), and especially several regions of Puerto Rico and the Virgin Islands (Wilson, Orris, and Gray 2019). Volcanic rocks are documented in the eastern part of Hispaniola (Toloczyki and Ramirez 1991; Wilson, Orris, and Gray 2019) and are very common in Puerto Rico, including within the Sabana Grande formation in the southwest, the South Central Maravillas formation, and the Guynabo formation in the northeast. Therefore, whether or not the ceramics were manufactured *in loco*, potters must have traveled to areas away from El Frances to procure those clay materials.

Clay of the two outcrops (FR.B1 and FR.B2) collected $a < 1$ km distance from El Frances does not appear to be the same as that used in El Frances (Supplemental Files SI). Both clay sources have highly weathered inclusions typical of alluvial and marine sedimentation, comprising mostly quartz, some muscovite, a little chert, and a very low metamorphic component. In the past centuries the sea level has fallen (Keegan 1995), and the current context of the site and its surrounding area may have been different at the time of the precolonial inhabitation. FR.B1 and FR.B2 are both coastal deposits and may not have been available or visible in the past. It is probable that the communities that lived at El Frances utilized other clay sources, probably ones that were located inland as indicated by the frequent presence of the coarse metamorphic components in groups 1 and 2.

Clay sources for the five analyzed Puerto Rican and Vieques sites have an intermediate and mafic composition (Supplemental Files SI). This analysis documented three instances where those clay sources were shared by sites: (1) petrographic group 5 (samples FR21, FR23, FR26, and LG3) includes sherds from El Frances and one sherd from La Gallera; (2) petrographic group 6 includes samples DOR4 (Dorado-42) and FR25; and (3) a similar clay source composition for samples 0756 (Hacienda Grande) and H6 (Sorcé). The igneous components vary from intermediated volcanic rocks (dominated by plagioclase and andesine) for the sites of La Gallera, Sorcé, Dorado-42, and Hacienda Grande to a more mafic component (combination of amphibole, pyroxenes, and olivine)

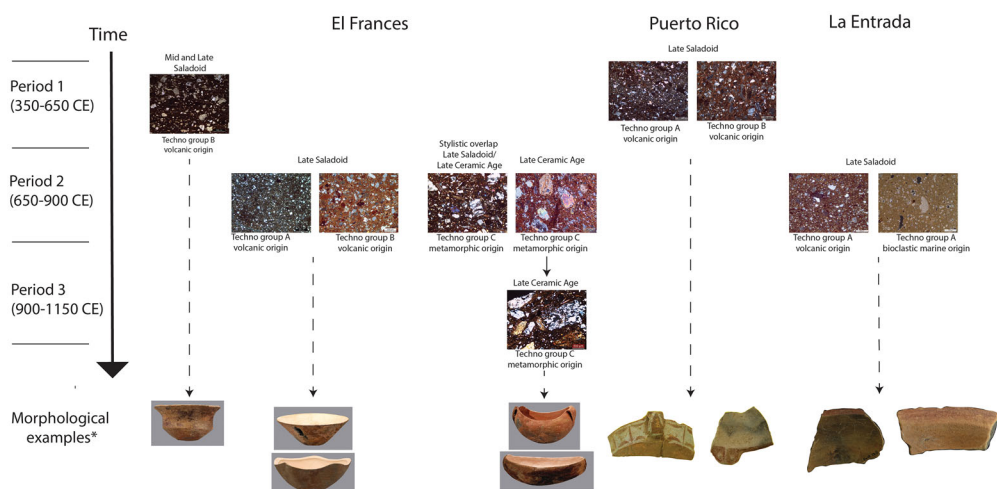


Figure 6. Description of the technological and petrographic data. The three-dimension reconstructions of the ceramic are adapted from López Belando and Shelley (2020), the ceramic fragments shown under Puerto Rico are from the site La Gallera (copyright Ivor Hernández). The ceramic fragments and the vessel reconstructions are not to scale.

for Tecla. At Dorado-42 and Tecla, ceramic bodies also exhibited chert and sandstone inclusions.

Preparation techniques

Based on the ceramic bodies the assemblage can be divided into three main techno-groups (A), (B), and (C) according to the preparation of the clay prior to the fashioning step (Table 2 and Figure 6). Organizing the assemblage in this way facilitates understanding of the synchronic and diachronic transitions that occurred in the El Frances ceramic assemblage and contextualizes the site with respect to other modes of ceramic production. The first two groups (A) and (B), contain all the Puerto Rico and Vieques ceramic samples and the Period 1 and Period 2 (Saladoid) El Frances ceramic samples. Techno-group (A) ceramics are characterized by very fine inclusions ($<150\mu\text{m}$) and a homogeneous body with a well-sorted matrix. Medium-coarse inclusions ($200\text{--}300\mu\text{m}$) are very rare. It is likely that potters either employed particularly fine clay deposits or carefully sieved the clay materials to eliminate coarse grains and achieve a uniform product. Techno-group (B) ceramic bodies contain slightly coarser, moderately sorted grains ($100\text{--}300\mu\text{m}$). Clay sources used to manufacture ceramics vary moderately, with several different petrographic groups identified. For instance, for Tecla and Sorcé, both techniques (A) and (B) were used with the same clay. This interchangeable way of working the clay paste suggests that techno-groups (A) and (B) may be part of the same manufacturing tradition and that the manufacturing process may have been adapted for different vessel uses, such as cooking or serving.

Clay variability declines significantly within techno-group (C), which consists of ungrouped samples FR10 and FR33 and petrographic group 1 and 2 samples from El Frances. Techno-group (C) is characterized by a preference for more heterogeneous and coarser clay materials in the preparation of the clay bodies. Very coarse grains (500--

2000 μm) of variable size are abundant in the ceramic bodies, suggesting potters did not prioritize a uniform body in the finished product, in contrast to techno-groups (A) and (B). Similar clay body characteristics were recorded for contemporaneous Ostionoid and Chicoid ceramic materials from the site of El Cabo, in southeast Hispaniola (Casale et al. 2022) and from La Luperona and El Flaco in central northern Hispaniola (Ting et al. 2016), as well as the site of Tibes in Puerto Rico (Milantchí 2018). The orientation of voids and inclusions in sherds belonging to techno-group (C), and to a minor extent techno-group (B), suggest vessel production by coiling compression by beating or percussion. The preforming phase appears to have deformed the coil structure employed during the roughing-out process, as coils are visible in the ceramic body, although often stretched and elongated instead of circular. Figure 5 shows examples of voids and inclusions parallel and sub-horizontal to the sherd surfaces.

Turning to a chronological aspect, samples that belong to techno-group (C) include: (1) ceramics from Period 2 that show stylistic traits of both Late Saladoid and Late Ceramic Age; and (2) all the Late Ceramic Age pottery of Period 2 and Period 3. The clay in all these samples contain a strong metamorphic component, suggesting it was sourced from local outcrops and used to produce vessels in the Samaná region. Techno-groups (A) and (B), on the other hand, come from clay sources that have an intermediate and mafic volcanic origin, suggesting a non-local origin and the import of raw clay materials or final products to Samaná. For instance, petrographic groups 5 and 6 include samples from El Frances and the sites of Dorado-42 and La Gallera in Puerto Rico. Those samples show a very similar clay matrix, suggesting that the vessels were likely produced using similar or the same clay sources and with an analogous technological tradition. Moreover, recent petrographic analysis performed on ceramics from the site of La Entrada (Casale, Forthcoming), located west of Samaná in the San Juan province, shows that two samples from that site exhibit the same technological (techno-groups (A) and (B)) and raw material origin as samples FR22, FR28, and FR30 from El Frances. La Entrada is contemporaneous with Period 2 at El Frances, with evidence for an early phase (Late Saladoid) reminiscent of the latter site.

Conclusion

This study adds knowledge of the ceramic manufacturing traditions pursued by El Frances' early occupants and their change in use, preparation of the clay sources, and possible connections to other Indigenous communities of Hispaniola and Puerto Rico. The diversity of the assemblage is reflected in the identification of three technological traditions and six petrographic groups. During Period 2 there was the presence of both ceramics manufactured with local and non-locally available clays. The community of El Frances shows strong intra- and inter-island connections such as across the Mona Passage (e.g., identification of similar clay materials as found for the site of Dorado-42 and La Gallera), and evidence for internal exchange with the site of La Entrada on the north coast. This import is supported by the following petrographic and technological evidence:

1. The identification of similar clay materials for ceramics found in El Frances and ceramic found at the sites of Dorado-42, La Gallera, and La Entrada.

2. The presence of Late Saladoid ceramics (petrographic groups 3, 4, 5, 6, and ungrouped samples) that derives from multiple, non-local clay sources.
3. Use of a similar method for preparing the clay mass (techno-groups (A) and (B)) of Late Saladoid vessels at El Frances and at the sites of La Entrada also in the Dominican Republic, Tecla, Hacienda Grande, and La Gallera in Puerto Rico, and Sorcé, Vieques.

These findings conflict with the existing theory of a small and limited Saladoid presence in southeastern Hispaniola (Keegan 2000; Keegan and Hofman 2017). This comparative study indicates that Saladoid communities inhabited northeast Hispaniola. Two explanatory hypotheses that require further analysis are proposed here. The first hypothesis suggests that the similar preparation methods are the result of a common ancestral tradition and, on Hispaniola, represent the post-migration persistence of a way-of-doing. A second possible explanation is that the observed parallels arise from active interaction with Puerto Rico, as suggested by the presence of similar clay materials for El Frances and the sites of Dorado-42 and La Gallera.

During Period 3, vessels appeared that were manufactured with local metamorphic clays and with significantly less attention to the preparation of the clay body (techno-group (C)). This period is characterized by a decrease in the number of clay outcrops used and less exchange of vessels with extra-local areas, as demonstrated by the identification of only two petrogroups. These vessels exhibit a coarse and heterogeneous body similar to the Late Ceramic Age pottery of other contemporaneous sites, such as El Cabo, El Flaco, and La Luperona, suggesting a similar way-of-doing within the Indigenous communities in Hispaniola during the Late Ceramic Age (Casale et al. 2022; Ting et al. 2016).

Overall, this research shows that a technological approach to ceramic analysis can produce important insights that can complement shape and style interpretations. Future analysis should focus on investigating additional technological traits, such as the fashioning steps, with the aim of building a reference compendium of past potters' technological behaviors for the region. This research is an initial pilot study that relies on a small sample size and more research involving the use of compositional analysis (e.g., pXRF and SEM-EDS) and broader sampling from more sites is important for generating a more wholistic understanding of the Saladoid expansion and extension of social networks during the ECA.

Note

1. This term was introduced for the first time by López Belando and Shelley (2020) to define a local ceramic morphology.

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