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ORIGINAL PAPER

The late medieval and early modern ceramics in the city of Córdoba (Andalusia, Spain). Christian productions under the Islamic tradition

Marta Valls Llorens[1] · **Jaume Buxeda i Garrigós**[1] · **Marisol Madrid i Fernández**[1]

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Abstract
The archaeological knowledge of the material culture in the city of Córdoba (Andalusia, Spain) during the late medieval and early modern periods is very scarce. Urban rescue excavations and archive sources evidence that the so-called Barrio de las Ollerías (potters' quarter) was the main ceramic production area from the early medieval period until the end of the early modern period. Nevertheless, there is a total lack of archaeological and archaeometric studies since research has traditionally focused on Seville city and other production centres closer to the Atlantic Coast. However, archaeological and archaeometric studies concerning Islamic pottery have increased in Córdoba in the last years, although there is a lack of studies on the late medieval and early modern ceramic production. This article aims to contribute to filling this gap through an exhaustive study of the ceramic production of Córdoba in this period. As a first objective, studying the ceramics recovered from the workshops will enable us to define the chemical reference groups (RG). The second step will be the approach to the technology used by the potters for the elaboration of the different products. With these objectives in mind, 120 individuals have been chemically characterised using x-ray fluorescence analysis (XRF) and mineralogically through x-ray diffraction analysis (XRD). The sample includes tin-lead glazed vessels, coarse and cooking ware vessels, and storage and transport jars dated from the fifteenth to the eighteenth centuries.

Keywords Late medieval · Early modern · Pottery · Technology · Provenance · Córdoba

Introduction and objectives

This investigation is part of the ongoing research project of one of us (MVL)[1], which aims at shedding light on the ceramic production in the late medieval and early modern periods in the areas of the ancient Kingdoms of Córdoba and Granada. The Kingdom of Córdoba, like those of Jaén and Seville, was conquered during the first half of the thirteenth century (Córdoba in 1236, Jaén in 1246 and Seville in 1248). On the contrary, the Nasrid kingdom of Granada lasted until the end of the fifteenth century (Granada War 1482-1492). The researchers' attraction for the splendour and glory of the Islamic world has put aside the study of ceramic production and distribution after the Christian conquest. In contrast, Islamic ceramic production has been profusely studied in the last decades, both from an archaeological and archaeometric point of view. Thus, the project's main objectives are to define the products of the Christian Cordoban and Granadian workshops since the fifteenth century and their diffusion through the archaeometric characterisation and the definition of their reference groups (RG). In this paper, we focus on studying the case of workshops and consumption centres of the city of Córdoba after the Christian conquest, from the late medieval to the early modern periods. For this reason, samples from different workshops from Córdoba (fifteenth–seventeenth centuries) (37° 53′ 00″ N, 4° 46′ 00″ W), Priego de Córdoba (sixteenth–seventeenth centuries) (37° 26′ 18″ N, 4° 11′ 53″ W), Granada (sixteenth–eighteenth centuries) (37° 10′ 41″ N, 3° 36′ 03″ W) and Cártama (fifteenth–sixteenth centuries) (36° 42′ 41″ N, 4° 37′ 50″ W), and also from different consumption centres in

[1] '*Caracterització arqueomètrica de les produccions ceràmiques dels Regnes de Còrdova i Granada entorn els s. XV-XVII*'. Translation to English: Archaeometric characterization of the ceramic productions in the Kingdoms of Córdoba and Granada around the fifteenth to seventeenth centuries (ongoing PhD Thesis).

✉ Marta Valls Llorens
mvalls@ub.edu

[1] Cultura Material i Arqueometria UB (ARQUB, GRACPE), Departament d'Història i Arqueologia, Universitat de Barcelona, C/ de Montalegre, 6, 08001 Barcelona, Catalonia, Spain

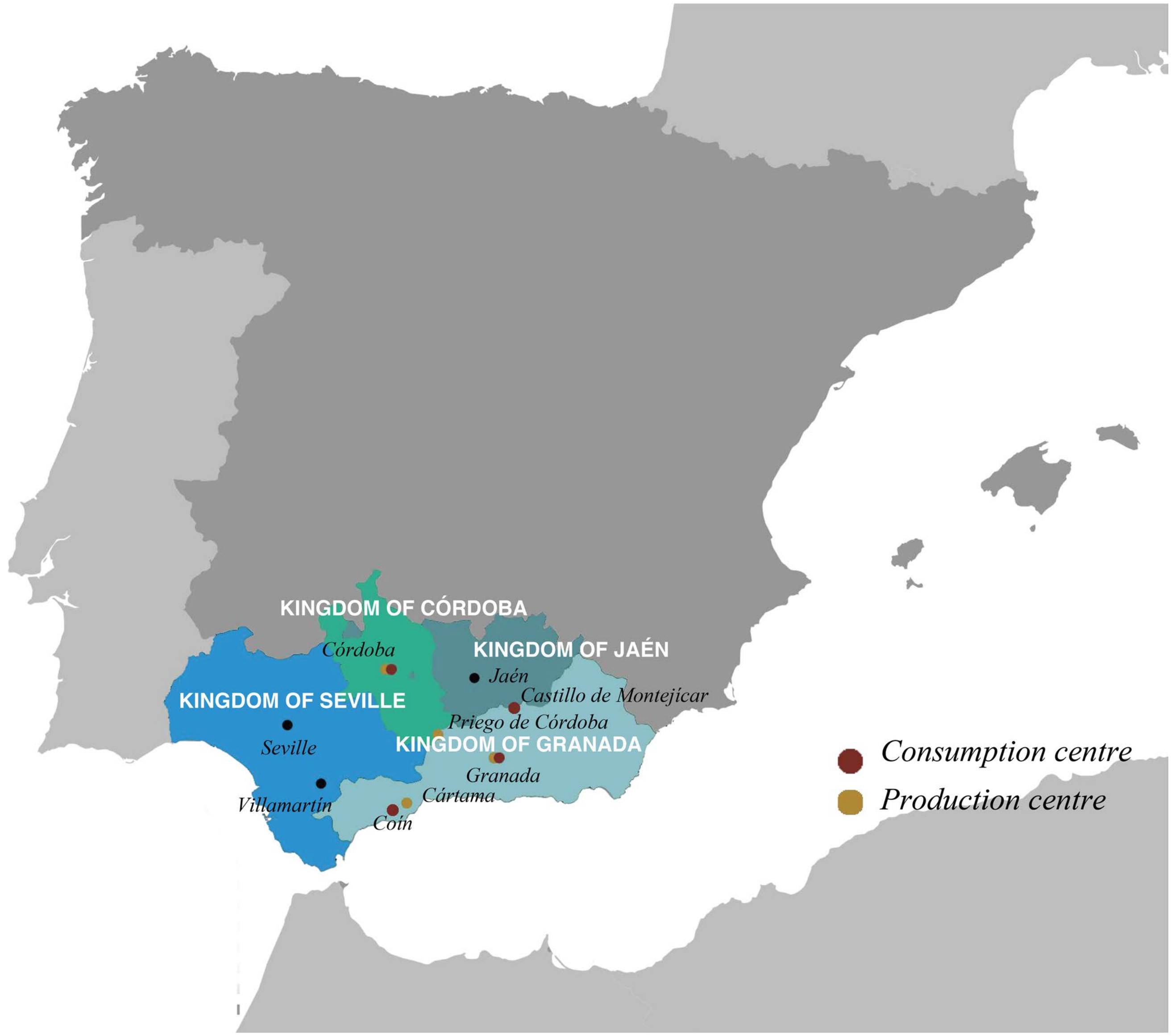

Fig. 1 Location of the sites cited in the present paper

Córdoba (seventeenth–eighteenth centuries), Granada (fifteenth–eighteenth centuries), Coín (fourteenth–sixteenth centuries) (36° 39′ 32″ N, 4° 45′ 25″ W) and Castillo de Montejícar (fifteenth–sixteenth centuries) (37° 34′ 19″ N, 3° 30′ 16″ W) are considered in this project (Fig. 1)[2].

The Kingdom of Córdoba was a territorial jurisdiction of the Crown of Castile after conquering the town in 1236. Córdoba was directly affected by the two important events that marked the start of the early modern period: the Christian conquest of Granada and the colonisation of the Americas (starting in 1492). On the one hand, the conquest of Granada entailed the disappearance of the borders between the Muslim Kingdom of Granada and the Christian Kingdom of Córdoba. On the other hand, the colonisation of the Americas significantly affected the demography of the city of Córdoba, which received people from other regions of the Iberian Peninsula and Europe attracted by the new commercial opportunities. Moreover, people from Córdoba went to the American colonies and contributed to the conquest of new territories and the foundation of cities and villages. Although the primary commercial relationships between the Castilian Crown and the American colonies took place on

[2] The positions for Córdoba, Priego de Córdoba, Cártama, Granada, Coín and Castillo de Montejícar archaeological sites have been considered in relation to the modern towns of Córdoba, Priego de Córdoba, Cártama, Granada, Coín and Montejícar respectively.

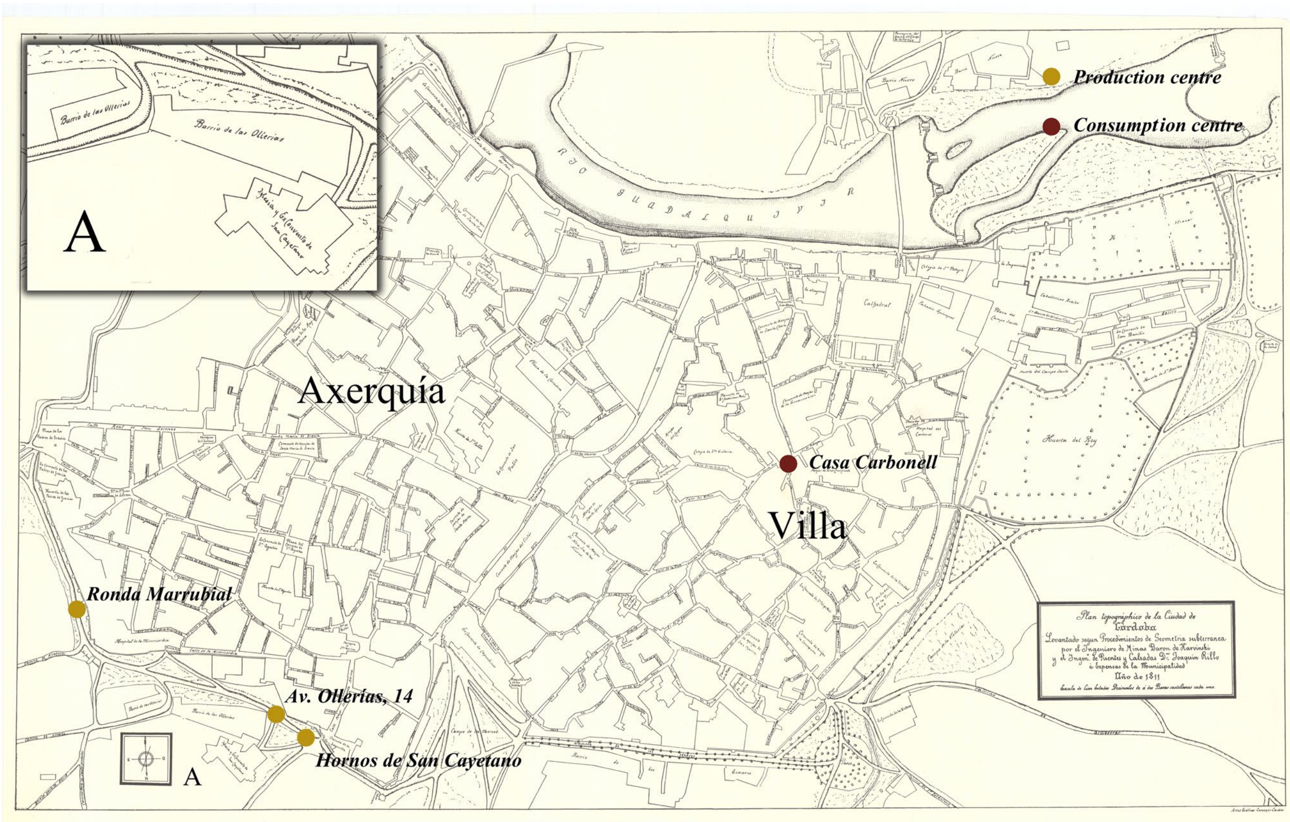

Fig. 2 Map of Córdoba with the location of the sites under study. Based on the map "El Plano de los Franceses" (Baron of Karwinsky and Rillo 1811)

the Atlantic Coast of Andalusia, the city of Córdoba benefited from the creation of new economic structures and networks (Escobar 2008, p. 19). In this sense, the ceramic production in the Kingdom of Córdoba in the early modern period could have been influenced by the so-called 'Carrera de Indias' (the monopoly of the permanent trade route and navigation between the Crown of Castille and the American colonies), consolidating local and regional production centres and, possibly, enabling to export transport jars and other ceramics (Hughes 2014; Kingsley et al. 2014).

Since medieval times, the city of Córdoba has been structured in two main areas, where residential and commercial activities coexisted: *Villa* (called *Medina* in the Islamic period) and *Axerquía* (Escobar 1989, 2008). The *Barrio de las Ollerías* (potter's quarter) was located north outside the *Axerquía* walls. Urban rescue excavations and historical documentation reveal that the *Barrio de las Ollerías* was the main ceramic production area from the early medieval until the end of the early modern periods, thanks to its proximity to important natural clay sources, water and combustible material. The structures and materials linked to these potters' activity include kilns (but only for the Islamic period), dumps, wasters and other objects like kiln rods, saggars and trivets. Ceramics related to these workshops have been studied only for the Islamic period (Aparicio 2016; Molina and Salinas 2010, 2013), and no systematic research concerning the Christian period has been carried out by historians based on written sources or by archaeologists. The only relevant exception is the study of archive sources from the fourteenth to fifteenth centuries that provide information about production techniques and typologies. Cooking pots, casseroles and '*tinajas*' (big jars for liquids, grains or other solid elements) produced in the *Barrio de las Ollerías* are the most common types mentioned in the written records. Concerning cooking ware, historical documentation remarks on the low quality of the products made in Córdoba, which frequently broke down when heating (Córdoba de la Llave 1988–1989, 1990, 1997).

This paper considers tin-lead glazed vessels, coarse ware, cooking ware, storage and transport jars and trivets recovered from three different archaeological sites of the *Barrio de las Ollerías*, plus the consumption context of Casa Carbonell, in the *Villa* area (Fig. 2). The latter is probably related to a convent and offers a well-defined stratigraphic sequence and a significant amount of tin-lead glazed pottery. It is important to highlight that this kind of ceramics is not commonly found in the excavations of modern production

Table 1 Studied individuals by site and ceramic class

	Av Ollerias, 14	Ronda Marrubial	Hornos de San Cayetano	Casa Carbonell	Total
Transport and storage	(**3**) OLL004, 007, 008	(**5**) MRB001, 002, 017, 018, 025	(**1**) CAY030	(**1**) CRB030	**10**
Unglazed coarse ware	(**4**) OLL005, 011, 013, 016	(**12**) MRB003, 007, 009, 010, 011, 013, 019, 020, 022, 024, 027, 028	(**4**) CAY022, 023, 026, 027	(**2**) CRB008, 015	**22**
Cooking ware	–	(**1**) MRB021	–	(**1**) CRB026	**2**
Honey glazed coarse ware	(**11**) OLL006, 010, 012, 014, 020, 025, 026, 027, 028, 029, 030	(**3**) MRB004, 005, 006	(**7**) CAY010, 012, 013, 014, 015, 017, 028	(**10**) CRB007, 009, 010, 011, 012, 014, 025, 027, 028, 029	**31**
Green glazed coarse ware	(**2**) OLL009, 024	(**2**) MRB008, 030	(**4**) CAY011, 016, 025, 029	(**1**) CRB013	**9**
Honey and green glazed coarse ware	–	(**1**) MRB026	(**1**) CAY024	–	**2**
Tin-lead glazed vessels	(**5**) OLL015, 017, 021, 022, 023	(**2**) MRB014, 015	(**12**) CAY001, 002, 003, 004, 005, 006, 007, 008, 009, 019, 020, 021	(**14**) CRB001, 002, 003, 004, 005, 006, 017, 018, 019, 020, 021, 022, 023, 024	**33**
Porcelain	–	–	–	(**1**) CRB016	**1**
Kiln furniture	(**5**) OLL001, 002, 003, 018, 019	(**4**) MRB012, 016, 023, 029	(**1**) CAY018	–	**10**
Total	**30**	**30**	**30**	**30**	**120**

References in bold correspond to the number of individuals for each archaeological site and ceramic type

centres of Córdoba, and the archives do not mention it, raising the problem of whether tin-lead glazed ceramics were locally produced. This study integrates the archaeological data (morphological and decorative characteristics of the pieces) and the archaeometric approach (chemical and mineralogical composition and technical aspects) to define the products of the workshops and their diffusion and identify products of non-local origin. Within this framework, the main objectives of the paper are to (i) identify meaningful ceramic reference groups (RG) (Buxeda and Madrid 2016) of the Cordoban workshops under study, (ii) to provide information on some technical aspects of the local products and (iii) to compare the analytical results with the morphological characteristics of the studied ceramics. Establishing a connection between typologies, decorations, chronologies and the archaeometric results will help improve the classification of ceramics found in consumption centres and the historical interpretations leading to a better understanding of the social and cultural context.

The new data obtained in this study have been compared with the ARQUB database, which includes many analytical results concerning different kinds of late medieval and early modern pottery from production and consumption centres in the Iberian Peninsula and the Atlantic American colonies. These analyses are included in the Tecnolonial project devoted to deepening the knowledge of the interaction, influence and cultural change during the colonisation process in the Americas during the sixteenth–seventeenth centuries through the archaeological and archaeometric study of ceramics. Incorporating more archaeological workshops such as those from Córdoba allows us to improve the knowledge of the complex network of pottery production and distribution over the entire Iberian Peninsula and the American colonies at that time.

The new results have contributed to six new reference groups, besides identifying allochthonous products from a known and unknown origin in the city of Córdoba.

Materials and methods

One hundred and twenty individuals recovered from several archaeological sites in Córdoba have been studied for this project. The criteria for the sampling was to have a representative amount for each archaeological site, including both production and consumption centres. So we considered studying 30 individuals for each of the four archaeological contexts described below. Different types of ceramics, such as tin-lead glazed vessels, coarse ware, cooking ware, storage and transport jars and kiln elements, have been considered (Tables 1 and 2). The sampling has been conditioned by the availability of each ceramic type in the different archaeological sites and the size of the sherds, which should be large enough to perform all the proposed analyses. The ceramics were recovered from three archaeological sites in the *Barrio de las Ollerías* (Fig. 2), where all the kiln structures date back to the Islamic period. However, in addition to ceramics, kiln furniture has also been identified in late medieval and

Table 2 List of individuals studied in the present paper. CG: chemical group (post-analysis). For glazed pottery in = interior and out = exterior (if not stated, it is interior and exterior)

Id	Stratigraphic unit	Archaeological site	Ceramic class	Ceramic type	Glaze	Chronology	CG
OLL001	C-SU 11	Av Ollerías, 14	Kiln furniture	Kiln rod	No	15th century	CGCRV02c
OLL002	C-SU 11	Av Ollerías, 14	Kiln furniture	Kiln rod	No	15th century	CGCRV02
OLL003	C-SU 11	Av Ollerías, 14	Kiln furniture	Kiln rod	No	15th century	CGCRV02c
OLL004	C-SU 11	Av Ollerías, 14	Transport/storage	Vat	No	15th century	CGCRV05
OLL005	C-SU 11	Av Ollerías, 14	Coarse ware	Basin	No	15th century	CGSEV
OLL006	C-SU 11	Av Ollerías, 14	Coarse ware	Bowl	Honey glazed	15th century	CGCRV03
OLL007	C-SU 11	Av Ollerías, 14	Transport/ storage	Large jar	No	15th century	CGCRV05
OLL008	C-SU 11	Av Ollerías, 14	Transport/ storage	Large jar	No	15th century	CGCRV05
OLL009	C-SU 11	Av Ollerías, 14	Coarse ware	Bowl	Green glazed	15th century	loner
OLL010	C-SU 11	Av Ollerías, 14	Coarse ware	Dish	Honey glazed and manganese decoration (in)	15th century	CGCRV03
OLL011	C-SU 11	Av Ollerías, 14	Coarse ware	Salt-cellar	No	15th century	CGSEV
OLL012	C-SU 11	Av Ollerías, 14	Coarse ware	Dish	Honey glazed and manganese decoration (in)	15th century	CGCRV04
OLL013	C-SU 11	Av Ollerías, 14	Coarse ware	Cheese Dish	No	15th century	CGCRV01
OLL014	C-SU 11	Av Ollerías, 14	Coarse ware	Dish	Honey glazed and manganese decoration (in)	15th century	CGCRV04
OLL015	C-SU 11	Av Ollerías, 14	Tin-lead glazed	Bowl	Plain white (*blanca lisa*)	15th century	CGSEV
OLL016	C-SU 11	Av Ollerías, 14	Coarse ware	Basin	No	15th century	CGCRV05
OLL017	C-SU 11	Av Ollerías, 14	Tin-lead glazed	Dish	Santo Domingo blue on white (*azul figurativa*)	15th century	CGSEV
OLL018	C-SU 11	Av Ollerías, 14	Kiln furniture	Trivet	No	15th century	CGCRV05
OLL019	C-SU 11	Av Ollerías, 14	Kiln furniture	Trivet	No	15th century	CGCRV05
OLL020	C-SU 11	Av Ollerías, 14	Coarse ware	Mug	Honey glazed	15th century	CGCRV03
OLL021	C-SU 11	Av Ollerías, 14	Tin-lead glazed	Bowl	Lusterware and blue (*loza dorada y azul*)	15th century	CGSEV
OLL022	C-SU 11	Av Ollerías, 14	Tin-lead glazed	Dish	Santo Domingo blue on white (*azul figurativa*)	15th century	CGSEV
OLL023	C-SU 11	Av Ollerías, 14	Tin-lead glazed	Bowl	Isabela polychrome (*azul y morado*)	15th century	CGCRV05
OLL024	C-SU 11	Av Ollerías, 14	Coarse ware	Pitcher	Green glazed	15th century	CGCRV05
OLL025	C-SU 11	Av Ollerías, 14	Coarse ware	Bowl	Dark/black glazed	15th century	CGCRV03
OLL026	C-SU 11	Av Ollerías, 14	Coarse ware	Bowl	Honey/brown glazed	15th century	CGCRV03
OLL027	C-SU 11	Av Ollerías, 14	Coarse ware	Bowl	Honey/brown (in) and dark/black (out) glazed	15th century	CGCRV03
OLL028	C-SU 11	Av Ollerías, 14	Coarse ware	Bowl	Dark/black glazed	15th century	CGCRV03
OLL029	C-SU 11	Av Ollerías, 14	Coarse ware	Dish	Honey/brown glazed	15th century	CGCRV03
OLL030	C-SU 11	Av Ollerías, 14	Coarse ware	Dish	Honey/brown (in) and dark/black (out) glazed	15th century	CGCRV03
MRB001	1-SU 4	Ronda del Marrubial	Transport/storage	Storage jar	No	16th century	CGSEV

Table 2 (continued)

Id	Stratigraphic unit	Archaeological site	Ceramic class	Ceramic type	Glaze	Chronology	CG
MRB002	1-SU 4	Ronda del Marrubial	Transport/storage	Storage jar	No	16th century	CGSEV
MRB003	1-SU 4	Ronda del Marrubial	Coarse ware	Basin	No	16th century	CGCRV04
MRB004	1-SU 4	Ronda del Marrubial	Coarse ware	Dish	Honey/brown glazed	16th century	CGCRV02c
MRB005	1-SU 4	Ronda del Marrubial	Coarse ware	Pitcher	Honey/brown glazed (in)	16th century	CGCRV02
MRB006	1-SU 4	Ronda del Marrubial	Coarse ware	Bowl	Honey/brown (in) and dark/black (out) glazed	16th century	CGCRV03
MRB007	1-SU 4	Ronda del Marrubial	Coarse ware	Dish	No	16th century	CGCRV04
MRB008	1-SU 4	Ronda del Marrubial	Coarse ware	Dish	Green glazed (in)	16th century	CGCRV04
MRB009	1-SU 4	Ronda del Marrubial	Coarse ware	Basin	No	16th century	CGCRV04
MRB010	1-SU 4	Ronda del Marrubial	Coarse ware	Ind	No	16th century	CGCRV02
MRB011	2-SU 14a	Ronda del Marrubial	Coarse ware	Dish	No	16th century	CGCRV03
MRB012	2-SU 14a	Ronda del Marrubial	Kiln furniture	Saggar	No	16th century	CGCRV03
MRB013	2-SU 14a	Ronda del Marrubial	Coarse ware	Basin	No	16th century	CGCRV02c
MRB014	2-SU 4	Ronda del Marrubial	Tin-lead glazed	Basin	Green and blue basin (*verde y azul*)	16th century	CGSEV
MRB015	2-SU 4	Ronda del Marrubial	Tin-lead glazed	Basin	Green and blue basin (*verde y azul*)	16th century	CGSEV
MRB016	2-SU 5	Ronda del Marrubial	Kiln furniture	Trivet	No	16th century	CGCRV04
MRB017	2-SU 5	Ronda del Marrubial	Transport/storage	Large storage jar	No	16th century	CGCRV03
MRB018	2-SU 5	Ronda del Marrubial	Transport/storage	Large storage jar	No	16th century	CGCRV05
MRB019	2-SU 5	Ronda del Marrubial	Coarse ware	Bowl	No	16th century	CGSEV
MRB020	2-SU 5	Ronda del Marrubial	Coarse ware	Ind	No	16th century	CGCRV01
MRB021	2-SU 5	Ronda del Marrubial	Cooking ware	Cooking pot	Dark/black glazed	16th century	CGCRV01
MRB022	2-SU 5	Ronda del Marrubial	Coarse ware	Pitcher	No	16th century	CGCRV03
MRB023	2-SU 5	Ronda del Marrubial	Kiln furniture	Trivet	No	16th century	CGCRV04
MRB024	2-SU 5	Ronda del Marrubial	Coarse ware	Basin	No	16th century	CGCRV03
MRB025	2-SU 5	Ronda del Marrubial	Transport/storage	Large storage jar	Dark/black glazed (in)	16th century	CGCRV03
MRB026	2-SU 5	Ronda del Marrubial	Coarse ware	Basin	Yellow (in) and green (out) glazed	16th century	CGCRV04
MRB027	2-SU 5	Ronda del Marrubial	Coarse ware	Bowl	No	16th century	CGCRV03

Table 2 (continued)

Id	Stratigraphic unit	Archaeological site	Ceramic class	Ceramic type	Glaze	Chronology	CG
MRB028	2-SU 5	Ronda del Marrubial	Coarse ware	Pitcher	No	16th century	CGCRV01
MRB029	2-SU 5	Ronda del Marrubial	Kiln furniture	Trivet	No	16th century	CGCRV01
MRB030	2-SU 5	Ronda del Marrubial	Coarse ware	Basin	Green glazed (in)	16th century	CGCRV04
CAY001	SU-218	Hornos de San Cayetano	Tin-lead glazed	Bowl	Manganese and white (*blanco y manganeso*)	14th–15th centuries	CGSEV
CAY002	SU-218	Hornos de San Cayetano	Tin-lead glazed	Dish	Santo Domingo blue on white (*azul figurativa*)	15th–16th centuries	CGSEV
CAY003	SU-218	Hornos de San Cayetano	Tin-lead glazed	Bowl or Dish	Sevilla blue on white (*blanco y azul*)	15th–16th centuries	CGSEV
CAY004	SU-218	Hornos de San Cayetano	Tin-lead glazed	Bowl or Dish	Plain white (*blanca lisa*)	15th century	CGNC02
CAY005	SU-218	Hornos de San Cayetano	Tin-lead glazed	Bowl or Dish	Plain white (*blanca lisa*)	15th century	CGSEV
CAY006	SU-218	Hornos de San Cayetano	Tin-lead glazed	Bowl or Dish	Santo Domingo blue on white (*azul figurativa*)	15th–16th centuries	CGSEV
CAY007	SU-218	Hornos de San Cayetano	Tin-lead glazed	Dish	Plain white (*blanca lisa*)	15th century	CGSEV
CAY008	SU-218	Hornos de San Cayetano	Tin-lead glazed	Plate	Plain white (*blanca lisa*)	15th century	CGSEV
CAY009	SU-218	Hornos de San Cayetano	Tin-lead glazed	Bowl	Plain white (*blanca lisa*)	17th–18th centuries	CGCRV05
CAY010	SU-218	Hornos de San Cayetano	Coarse ware	Plate	Honey/brown glazed (in)	14th–15th centuries	CGCRV03
CAY011	SU-218	Hornos de San Cayetano	Coarse ware	Bowl	Green glazed	14th–15th centuries	CGCRV04
CAY012	SU-218	Hornos de San Cayetano	Coarse ware	Bowl	Honey/brown (in) and dark/black (out) glazed	14th–15th centuries	CGCRV03
CAY013	SU-218	Hornos de San Cayetano	Coarse ware	Bowl	Honey/brown (in) and dark/black (out) glazed	14th–15th centuries	CGCRV03
CAY014	SU-247	Hornos de San Cayetano	Coarse ware	Dish	Honey glazed and manganese decoration (in)	14th–15th centuries	CGCRV03
CAY015	SU-247	Hornos de San Cayetano	Coarse ware	Dish	Honey glazed and manganese decoration (in)	14th–15th centuries	CGCRV03
CAY016	SU-282	Hornos de San Cayetano	Coarse ware	Pitcher	Turquoise blue (in) and green (out) glazed	14th–15th centuries	CGCRV05
CAY017	SU-282	Hornos de San Cayetano	Coarse ware	Dish	Honey glazed and manganese decoration (in)	14th–15th centuries	CGCRV03
CAY018	SU-270	Hornos de San Cayetano	Kiln furniture	Trivet	No	14th–15th centuries	CGCRV05
CAY019	SU-270	Hornos de San Cayetano	Tin-lead glazed	Basin	Manganese and white (*blanco y manganeso*)	15th century	CGSEV

Table 2 (continued)

Id	Stratigraphic unit	Archaeological site	Ceramic class	Ceramic type	Glaze	Chronology	CG
CAY020	SU-270	Hornos de San Cayetano	Tin-lead glazed	Plate	Sevilla blue on white (*blanco y azul*)	14th–15th centuries	CGSEV
CAY021	SU-270	Hornos de San Cayetano	Tin-lead glazed	Bowl	Plain white (*blanca lisa*)	15th century	CGSEV
CAY022	SU-270	Hornos de San Cayetano	Coarse ware	Basin	No	15th century	CGCRV05
CAY023	SU-270	Hornos de San Cayetano	Coarse ware	Flowerpot	No	15th century	CGCRV05
CAY024	SU-270	Hornos de San Cayetano	Coarse ware	Ind	Green glazed and manganese decoration (in)	15th century	CGCRV04
CAY025	SU-270	Hornos de San Cayetano	Coarse ware	Pitcher	Green glazed (in)	15th century	CGCRV04
CAY026	SU-270	Hornos de San Cayetano	Coarse ware	Basin	No	15th century	CGCRV05
CAY027	SU-270	Hornos de San Cayetano	Coarse ware	Basin	No	15th century	CGCRV05
CAY028	SU-270	Hornos de San Cayetano	Coarse ware	Plate	Honey glazed and manganese decoration (in)	15th century	CGCRV03
CAY029	SU-270	Hornos de San Cayetano	Coarse ware	Plate	Green glazed (in)	15th century	CGCRV05
CAY030	SU-282	Hornos de San Cayetano	Transport/storage	Botija	Green glazed (in)	15th century	CGCRV05
CRB001	4-SU6	Casa Carbonell	Tin-lead glazed	Dish	Yayal blue (*azul lineal*)	17th–18th centuries	CGSEV
CRB002	4-SU6	Casa Carbonell	Tin-lead glazed	Bowl	Green and white (*verde y blanco*)	17th–18th centuries	CGSEV
CRB003	4-SU6	Casa Carbonell	Tin-lead glazed	Basin	Blue and green basin *(verde y azul*)	17th–18th centuries	CGSEV
CRB004	4-SU2	Casa Carbonell	Tin-lead glazed	Dish	Plain white (*blanca lisa*)	17th–18th centuries	CGGRA
CRB005	4-SU2	Casa Carbonell	Tin-lead glazed	Bowl	Plain white (*blanca lisa*)	17th–18th centuries	CGGRA
CRB006	4-SU2	Casa Carbonell	Tin-lead glazed	Bowl	Plain white (*blanca lisa*)	17th–18th centuries	CGNC02
CRB007	4-SU2	Casa Carbonell	Coarse ware	Bowl	Honey (in) and dark/black (out) glazed	17th–18th centuries	CGCRV04
CRB008	4-SU2	Casa Carbonell	Coarse ware	Dish	No	17th–18th centuries	CGGRA
CRB009	4-SU2	Casa Carbonell	Coarse ware	Bowl	Green glazed	17th–18th centuries	CGNC01
CRB010	4-SU2	Casa Carbonell	Coarse ware	Bowl	Honey/brown glazed	17th–18th centuries	CGNC01
CRB011	4-SU2	Casa Carbonell	Coarse ware	Basin	Honey/brown glazed (in)	17th–18th centuries	CGCRV03
CRB012	4-SU2	Casa Carbonell	Coarse ware	Dish	Honey/brown glazed	17th–18th centuries	CGNC01
CRB013	4-SU2	Casa Carbonell	Coarse ware	Bowl	Green glazed	17th–18th centuries	CGSEV
CRB014	4-SU2	Casa Carbonell	Coarse ware	Dish	Green glazed	17th–18th centuries	CGNC01

Table 2 (continued)

Id	Stratigraphic unit	Archaeological site	Ceramic class	Ceramic type	Glaze	Chronology	CG
CRB015	4-SU2	Casa Carbonell	Coarse ware	Ind	No	17th–18th centuries	loner
CRB016	4-SU1	Casa Carbonell	Porcelain	Ind	White	17th–18th centuries	loner
CRB017	4-SU1	Casa Carbonell	Tin-lead glazed	Bowl	Yayal blue (*azul lineal*)	17th–18th centuries	CGSEV
CRB018	4-SU1	Casa Carbonell	Tin-lead glazed	Dish	Yayal blue (*azul lineal*)	17th–18th centuries	CGSEV
CRB019	4-SU1	Casa Carbonell	Tin-lead glazed	Bowl	Yayal blue (*azul lineal*)	17th–18th centuries	CGSEV
CRB020	4-SU1	Casa Carbonell	Tin-lead glazed	Dish	Yayal blue (*azul lineal*)	17th–18th centuries	CGSEV
CRB021	4-SU1	Casa Carbonell	Tin-lead glazed	Bowl	Fajalauza	17th–18th centuries	CGGRA
CRB022	4-SU1	Casa Carbonell	Tin-lead glazed	Bowl	Fajalauza	17th–18th centuries	CGGRA
CRB023	4-SU1	Casa Carbonell	Tin-lead glazed	Bowl	Plain white (*blanca lisa*)	17th–18th centuries	CGSEV
CRB024	4-SU1	Casa Carbonell	Tin-lead glazed	Bowl	Plain white (*blanca lisa*)	17th–18th centuries	CGNC02
CRB025	4-SU1	Casa Carbonell	Coarse ware	Dish	Honey/brown glazed	17th–18th centuries	CGNC01
CRB026	4-SU1	Casa Carbonell	Cooking ware	Cooking pot	Honey/brown glazed (in)	17th–18th centuries	CGCRV03
CRB027	4-SU1	Casa Carbonell	Coarse ware	Dish	Honey/brown glazed	17th–18th centuries	CGNC01
CRB028	4-SU1	Casa Carbonell	Coarse ware	Dish	Honey/brown glazed	17th–18th centuries	CGNC01
CRB029	4-SU1	Casa Carbonell	Coarse ware	Salt-cellar	Honey/brown glazed	17th–18th centuries	CGCRV01
CRB030	4-SU1	Casa Carbonell	Transport/storage	Water container	No	17th–18th centuries	CGSEV

early modern stratigraphic contexts for the Christian period. The first site is Avenida Ollerías 14 (37° 53′ 30.938″ N, 4° 46′ 29.420″ W)[3]. Marfil excavated the site in 1990 to study the evolution of the *Axerquía* walls between the twelfth and the thirteenth centuries, unearthing a ceramic dump dated to the end of the fifteenth century (Marfil 1997). The second one, Ronda Marrubial (37° 53′ 32.316″ N, 4° 46′ 1.884″ W), was excavated by Vargas in 2009. In this context, several sixteenth-century ceramic materials related to kiln furniture and wasters were identified (Vargas 2010), revealing their connection with a production centre. Finally, the excavation of the third site, Hornos de San Cayetano (37° 53′ 31.157″ N, 4° 46′ 31.447″ W), was carried on by Aparicio in 2012. Several Islamic kilns were identified and studied, but also a fifteenth–sixteenth century ceramic dump was found. On this site, the ceramics span from the fourteenth–fifteenth to the seventeenth–eighteenth centuries (Aparicio 2012). Besides, the consumption context of Casa Carbonell (37° 52′ 55.632″ N, 4° 46′ 47.856″ W), in the *Villa* area, is also considered. This site was excavated by León and collaborators in 1991, and an interesting set of ceramics dated between the seventeenth and the eighteenth centuries could be recovered. It was interpreted as a dump related to a close Carmelite Convent (León et al. 1993).

All the individuals have been chemically characterised through X-ray fluorescence (XRF) and mineralogically through X-ray diffraction (XRD). The chemical characterisation of the 120 individuals was performed using wavelength dispersive X-ray fluorescence (WD-XRF) analysis. Samples of around 15 g were taken from each individual. The superficial layers were mechanically removed, and the samples

[3] The position given for all the archaeological sites sampled except for Ronda Marrubial correspond to the exact geographical location of the archaeological sites. The position given for Ronda Marrubial excavation corresponds to the middle point of Ronda Marrubial street, as the excavation works were performed in several points along this street.

were milled in a tungsten carbide cell mill Spex Mixer mod. 8000. The chemical composition was determined from powder previously dried in an oven for 12 h at 105 °C. To determine the major and minor elements, two 30 mm glass bead replicates were made by mixing 0.3 g of dried sample with 5.7 g of lithium tetraborate ($Li_2B_4O_7$) flux (1/20 dilution) and 5 mg of lithium iodide (LiI) as a release agent. This mixture was homogenised, deposited in a 95%Pt-5%Au crucible, and melted in a fully automatic bead preparation system PANalytical Perl'X-3 at a temperature of 1125 °C. To determine trace elements, pressed powder pellets were made using 6 g of specimen mixed with 2 ml of a binding agent solution of n-butyl methacrylate synthetic resin (Elvacite® 2044) in acetone at 20% by mass. This mixture was manually homogenised in an agate mortar to dryness and placed on a base of boric acid (H_3BO_3) in an aluminium vessel of 40 mm diameter that was subjected to a pressure of 200 kN for a period of 60 s using a Herzog press. The quantification of the concentrations was performed using an Axios^{mAX}-Advanced PANalytical spectrometer with an Rh excitation source calibrated by a suite of 56 international Geological Standards. Interferences were taken into consideration, and matrix effects were corrected using the PANanalytical Pro-Trace software for trace elements. The elements determined were Na_2O, MgO, Al_2O_3, SiO_2, P_2O_5, K_2O, CaO, TiO_2, V, Cr, MnO, Fe_2O_3 (as total Fe), Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Mo, Sn, Ba, Ce, W, Pb and Th. Major and minor elements are expressed as concentrations of oxides in mass fraction percentage (*w* %). Trace elements are expressed as concentrations of elements in µg/g. Loss on ignition (LOI) (expressed as *w* %) was determined by firing 0.3 g of the dried specimen at 950 °C for 3 h. Calcinations were carried out in a Heraeus muffle model M-110, using a heating rate of 3.4 °C/min and free cooling. Even so, some of the major and minor elements were discarded for statistical data treatment because of various problems: Co and W due to the possible contaminations from the tungsten carbide cell of the mill; Mo and Sn by low analytical precision and P_2O_5 and Cu given that several postdepositional processes easily alter them. Moreover, as has been observed in other studies that deal with glazed pottery (Buxeda et al. 2001; Iñáñez et al. 2005, 2007), many individuals present high concentrations of Pb, Sn and Cu due to the diffusion of the glazes in the ceramic matrix during the firing process. These high concentrations of Pb interfere with the signal from other elements and cannot be corrected. Thus, Ga, Rb, Y, Ce and Th are also discarded in the statistical treatment.

Mineralogical characterisation of the 120 individuals was performed by means of powder X-ray diffraction (PXRD). The previously prepared powder specimens were manually side-loaded and pressed with frosted glass in a cylindrical sample holder. Measurements were made using a Bragg-Brentano geometry diffractometer PANalytical X'Pert PRO MPD Alpha-1 (radius = 240 mm) using the Ni-filtered Cu Kα radiation (λ = 1.5418 Å) at a working power of 45 kV and 40 mA, equipped with an X'Celerator detector (active length = 2.122°). Measurements were taken from (5 to 80) °2θ with a 0.026° step size and an acquisition time of 50 s, spinning the sample at 1 Hz. The crystalline phases present in each analysed specimen were evaluated using the PANalytical X Pert HighScore Plus software package that includes the Powder Diffraction File™ (PDF®) of the International Centre for Diffraction Data (ICDD).

Results

Chemical analysis

The results of elemental concentrations of Córdoba samples analysed by XRF (Table 3) correspond with a special case of the projective d+1-dimensional space where the projective points are projected into the simplex $\mathbb{S}^d$. Points are represented by homogeneous coordinates that have a constant sum k ($k \in R_+$),

$$\mathcal{C}(\mathbf{w}) = \mathbf{x} = \left[x_1, \ldots, x_d, x_{d+1}\right] \mid x_i \geq 0 \; (\mathrm{i} = 1, \ldots, d, d+1), x_1 + \cdots + x_d + x_{d+1} = k,$$

(in this current case, $k = 100$). The projective points' vector space is the positive orthant. Both they and their projections in the simplex follow a multiplicative model. Hence, for the statistical data treatment, the raw concentrations have been alr (additive log-ratio) transformed according to

$$x \in \mathbb{S}^d \rightarrow y = \ln\left(\frac{x_d}{x_{d+1}}\right) \in R^d$$

being $\mathbb{S}^d$ the d-dimensional simplex and $\mathbf{x}_d = [x_1, \ldots, x_d]$. They have also been clr (centred log-ratio) transformed following the equation

$$\mathbf{x} \in \mathbb{S}^d \rightarrow z = \ln\left(\frac{\mathbf{x}}{\mathrm{g}(\mathbf{x})}\right) \in H \subset R^{d+1}$$

being $\mathbb{S}^d$ the d-dimensional simplex, g(**x**) the geometric mean of all d+1 components of **x** and $\mathbb{H} \subset \mathbb{R}^{d+1}$ a hyperplane vector subspace of $\mathbb{R}^{d+1}$ (Aitchison 1986; Buxeda 1999; Egozcue and Pawlowsky-Glahn 2011; Martín-Fernández et al. 2015; Buxeda 2018).

The statistical data treatment of the chemical data was performed using R (R Core Team 2021). The first analysis carried out was to calculate the variation matrix that completely determines the covariance structure of compositional data and provides the total variation (tv) of the analysed ceramic assemblage (Fig. 3, left) (Aitchison 1986; Buxeda and Kilikoglou 2003). The total variation for the overall data set equals 1.83, which means a high value indicating

Table 3 Chemical concentrations by WD-XRF. Major and minor elements are expressed as oxides in *w* %; Trace elements in μg/g; LOI (loss on ignition) in *w* %

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	V	Cr	MnO	Fe_2O_3	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Mo	Sn	Ba	Ce	W	Pb	Th	LOI
OLL001	0.60	1.63	14.99	63.27	0.24	3.32	8.75	0.79	107	131	0.11	5.45	62	47	89	85	− 18	137	265	51	254	18	1	119	620	151	444	9716	2	0.53
OLL002	0.54	1.32	15.36	69.58	0.14	3.19	2.66	0.89	95	97	0.11	5.80	50	39	37	74	16	132	129	33	280	21	0	5	576	94	251	585	16	0.83
OLL003	0.50	1.75	15.02	59.34	0.22	3.46	6.70	0.80	107	82	0.13	5.64	22	41	58	93	9	129	196	36	224	20	1	31	733	93	37	2032	13	6.39
OLL004	0.47	2.00	13.77	57.34	0.35	2.73	12.84	0.70	105	96	0.08	5.48	24	37	30	74	14	112	426	25	216	20	1	5	413	70	130	53	17	4.36
OLL005	1.13	2.23	10.35	49.18	0.49	2.25	18.95	0.59	83	69	0.09	4.26	18	30	30	75	11	78	498	20	175	18	1	1	487	62	55	33	12	10.77
OLL006	0.42	1.56	15.04	64.04	0.16	2.32	7.71	0.78	119	115	0.06	6.04	66	49	24	65	− 5	118	229	44	283	19	1	2	392	122	438	5998	8	1.23
OLL007	0.42	2.94	10.93	45.62	0.32	2.24	20.36	0.57	90	80	0.07	4.40	14	34	25	71	12	82	466	20	156	18	1	0	359	54	54	75	13	12.82
OLL008	0.49	3.86	11.47	49.27	0.24	2.02	17.81	0.61	99	85	0.08	4.87	18	42	27	73	12	73	436	21	180	18	1	0	510	62	78	30	14	8.93
OLL009	0.48	2.17	16.12	57.08	0.31	3.40	12.48	0.80	117	93	0.05	6.32	30	38	246	81	0	149	406	40	206	20	1	5	425	117	145	4958	10	0.13
OLL010	0.40	1.45	15.13	67.75	0.16	2.46	6.58	0.83	111	157	0.07	6.22	47	61	34	62	5	118	197	37	306	19	1	1	382	89	304	2902	11	1.16
OLL011	1.08	2.75	10.72	47.38	0.40	2.43	19.25	0.58	90	76	0.07	4.31	20	32	107	76	11	80	462	20	161	18	1	4	366	48	42	136	12	13.52
OLL012	0.43	1.65	14.87	64.02	0.17	2.42	9.08	0.75	101	96	0.07	6.01	50	39	31	60	13	110	259	28	255	19	1	9	420	72	267	733	15	3.00
OLL013	0.41	1.06	16.56	71.31	0.13	2.54	1.50	0.84	108	119	0.07	6.71	57	52	27	57	17	120	81	33	314	21	1	3	446	85	338	140	17	1.07
OLL014	0.46	2.12	14.82	62.00	0.20	2.38	10.66	0.75	107	106	0.08	6.10	49	43	54	74	3	111	276	35	244	18	1	3	416	92	360	3853	10	0.73
OLL015	1.04	3.31	11.46	46.71	0.39	1.09	22.57	0.60	95	97	0.08	4.54	26	41	149	79	− 12	68	564	36	179	17	1	124	296	102	90	6592	4	9.63
OLL016	0.50	2.68	13.48	54.06	0.38	2.59	15.93	0.68	91	110	0.08	5.44	25	45	29	77	13	102	436	24	198	19	1	1	402	63	153	32	15	6.72
OLL017	1.23	3.12	11.28	46.99	0.45	1.21	22.30	0.59	90	91	0.08	4.48	60	42	176	77	− 10	62	538	35	171	16	5	108	296	103	125	6205	6	9.45
OLL018	0.55	2.29	13.49	56.34	0.37	2.63	14.77	0.70	89	105	0.08	5.50	35	43	36	74	12	104	427	27	229	19	1	6	418	79	204	689	15	4.49
OLL019	0.67	2.47	13.92	56.39	0.30	2.71	13.34	0.71	102	108	0.08	5.40	54	45	93	80	1	117	411	34	211	19	1	11	379	88	244	3943	10	3.69
OLL020	0.43	1.56	15.16	62.27	0.33	2.34	8.37	0.76	101	145	0.07	6.25	37	57	35	63	9	110	230	32	271	19	1	3	431	79	294	2014	12	2.20
OLL021	0.96	2.77	10.88	45.45	0.36	0.92	22.27	0.56	114	122	0.07	4.36	35	48	276	80	− 44	70	567	54	184	14	3	36	268	161	102	15435	− 8	9.63
OLL022	1.00	3.00	11.73	47.17	0.83	1.08	19.92	0.60	122	123	0.07	4.67	36	50	217	94	− 44	82	625	57	190	15	4	292	306	174	86	15951	− 5	7.32
OLL023	0.66	2.34	11.32	47.92	0.31	2.02	19.93	0.60	81	89	0.08	4.62	30	35	49	75	3	84	489	27	179	17	1	42	334	64	119	2588	10	9.30
OLL024	0.41	3.95	11.35	47.78	0.26	1.92	17.82	0.59	84	80	0.07	4.64	29	39	213	66	7	73	408	24	187	17	1	7	359	69	118	1310	11	10.69
OLL025	0.41	1.52	14.87	63.56	0.14	2.34	6.72	0.76	120	139	0.07	5.99	144	60	184	68	− 11	117	221	47	283	19	1	4	372	132	1148	7831	6	0.93
OLL026	0.44	1.46	14.89	65.24	0.18	2.38	6.42	0.76	118	119	0.06	6.11	62	51	35	73	− 11	118	196	48	290	18	1	6	385	127	530	7776	6	0.77
OLL027	0.45	1.46	14.50	65.37	0.16	2.33	7.06	0.78	115	116	0.07	5.84	69	45	301	62	− 9	117	216	46	295	19	1	6	386	132	550	7225	7	0.77
OLL028	0.44	1.55	14.31	64.48	0.14	2.21	7.97	0.76	110	127	0.07	5.88	61	49	36	62	1	111	228	39	286	19	1	4	376	97	469	4016	11	1.40
OLL029	0.43	1.44	14.35	65.36	0.26	2.41	6.82	0.79	97	100	0.08	5.81	52	40	27	64	16	113	216	30	291	20	0	2	458	70	410	148	15	1.56
OLL030	0.40	1.41	14.90	64.48	0.20	2.34	6.66	0.74	100	90	0.06	6.16	42	39	35	59	15	112	201	28	268	19	0	4	448	72	322	297	15	2.70
MRB001	0.96	2.40	13.02	54.53	0.18	1.98	15.18	0.70	88	96	0.08	5.30	19	39	21	69	13	91	412	25	220	20	1	3	475	76	77	90	16	5.39
MRB002	0.97	2.30	12.66	54.82	0.25	2.32	14.25	0.70	91	104	0.08	5.04	29	44	27	68	13	101	419	25	218	20	1	1	487	73	84	46	15	6.26
MRB003	0.50	1.74	13.00	63.45	0.20	2.46	8.32	0.79	91	101	0.08	5.27	20	41	28	66	14	104	258	29	280	20	1	0	504	82	109	149	16	3.46
MRB004	0.59	1.89	15.88	62.30	0.19	3.04	5.83	0.87	95	92	0.16	6.09	42	40	32	82	14	120	186	31	213	20	0	1	440	81	186	728	14	2.50
MRB005	0.53	1.34	14.92	68.77	0.14	3.00	1.83	0.75	89	87	0.08	6.86	65	39	38	88	15	133	84	40	283	20	0	6	612	95	229	513	15	1.76
MRB006	0.36	1.32	14.14	67.60	0.16	2.38	4.96	0.90	101	91	0.08	5.83	60	38	37	60	13	115	167	31	340	22	1	2	438	96	294	806	16	1.96
MRB007	0.48	1.44	12.58	64.65	0.24	2.34	8.62	0.83	86	85	0.06	5.00	55	32	27	62	13	103	234	25	293	20	0	4	603	74	154	190	15	3.29
MRB008	0.58	1.88	12.68	61.62	0.17	2.10	11.36	0.75	108	101	0.08	5.10	64	39	519	60	− 1	103	333	36	272	20	1	3	444	111	297	4428	10	2.93
MRB009	0.47	1.73	12.50	64.51	0.23	2.38	9.38	0.80	92	93	0.08	5.04	75	35	32	59	10	107	278	29	302	20	1	1	516	88	356	1234	14	2.53
MRB010	0.55	1.42	16.10	66.40	0.12	3.44	2.50	0.90	106	87	0.13	6.08	77	41	36	91	17	144	124	39	280	22	0	4	703	99	297	45	18	1.60
MRB011	0.39	1.60	14.54	64.09	0.20	2.45	6.62	0.82	106	95	0.08	5.95	28	41	33	62	16	117	221	29	300	21	1	2	499	82	158	121	16	2.97

Table 3 (continued)

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	V	Cr	MnO	Fe_2O_3	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Mo	Sn	Ba	Ce	W	Pb	Th	LOI
MRB012	0.38	1.48	14.59	66.33	0.13	2.17	6.11	0.88	101	121	0.07	6.01	36	46	27	56	16	111	186	30	318	22	1	11	425	89	303	152	16	1.80
MRB013	0.50	1.84	15.75	60.20	0.21	3.32	10.25	0.79	108	105	0.12	5.71	63	40	31	90	18	138	298	32	206	21	1	4	623	95	447	68	17	1.07
MRB014	0.88	3.11	10.80	48.14	0.20	1.36	21.08	0.60	91	86	0.05	4.33	30	25	1525	66	− 4	81	410	32	189	16	0	7	280	90	101	4199	7	7.96
MRB015	0.72	2.88	11.56	46.17	0.21	1.90	20.80	0.62	86	73	0.05	4.63	33	25	116	75	4	74	463	27	165	17	0	71	283	68	65	2333	10	9.70
MRB016	0.45	2.01	12.57	59.00	0.19	2.25	12.59	0.72	88	99	0.08	5.04	53	37	111	66	7	103	344	29	248	19	0	4	456	86	241	2008	11	4.40
MRB017	0.39	1.48	13.95	63.75	0.20	2.26	7.24	0.86	106	86	0.08	5.62	42	36	26	55	15	105	215	27	303	21	1	2	428	73	131	64	16	3.60
MRB018	0.43	2.33	12.14	51.94	0.19	2.17	16.36	0.67	99	90	0.08	4.94	51	38	26	73	13	96	420	25	209	20	1	2	476	69	159	67	14	7.50
MRB019	0.93	2.89	9.86	41.62	0.32	2.08	23.17	0.54	76	76	0.07	3.95	25	31	25	72	10	77	535	20	160	17	1	16	430	56	90	189	13	13.89
MRB020	0.32	0.90	14.70	72.22	0.09	2.23	1.10	0.96	105	92	0.07	6.04	86	38	24	46	17	117	77	33	379	23	1	5	430	91	491	46	17	1.10
MRB021	0.44	1.23	15.57	69.76	0.11	2.41	1.08	0.72	102	103	0.05	7.87	86	41	24	87	13	114	68	36	250	18	0	3	404	81	656	1216	13	0.53
MRB022	0.42	1.40	14.92	66.62	0.19	2.34	5.38	0.78	100	131	0.07	5.99	69	53	27	62	16	114	186	29	278	20	0	4	438	80	324	255	15	1.63
MRB023	0.46	1.82	15.27	58.54	0.25	2.74	11.31	0.84	95	101	0.08	5.86	52	45	46	75	14	120	393	31	248	21	1	5	503	78	248	752	16	2.63
MRB024	0.45	1.53	14.00	66.67	0.14	2.51	6.29	0.88	104	96	0.08	5.56	73	37	25	56	13	114	205	33	324	21	1	2	449	100	474	947	15	1.50
MRB025	0.34	1.28	14.91	67.22	0.13	2.27	4.39	0.82	109	95	0.06	6.13	66	42	24	55	18	117	151	33	342	21	0	2	427	88	405	109	17	1.63
MRB026	0.46	1.85	12.01	63.40	0.15	2.10	11.06	0.72	105	98	0.07	4.88	61	37	226	59	− 2	101	330	35	268	19	1	2	408	91	365	4428	8	2.80
MRB027	0.32	1.26	14.05	67.44	0.13	2.23	5.74	0.91	101	97	0.07	5.75	70	39	24	54	16	113	185	29	326	22	0	2	415	84	362	155	16	2.00
MRB028	0.38	0.92	13.24	74.17	0.11	2.38	1.03	0.90	95	84	0.07	5.31	82	34	22	50	15	111	75	30	357	21	1	3	441	86	528	72	16	0.83
MRB029	0.30	0.88	14.42	73.17	0.08	2.20	0.75	0.96	101	121	0.06	6.00	73	44	27	45	15	109	61	29	371	22	1	3	425	89	521	195	16	0.76
MRB030	0.54	1.94	12.13	59.30	0.18	2.21	12.27	0.69	97	92	0.08	4.89	64	37	284	66	− 3	103	323	35	237	18	1	3	494	93	289	4387	8	4.60
CAY001	1.23	2.65	11.78	47.53	0.31	2.06	20.54	0.61	74	85	0.08	4.76	16	32	26	76	10	68	528	21	162	18	1	4	394	66	54	658	12	8.41
CAY002	0.94	3.44	12.04	51.83	0.52	1.37	17.49	0.68	104	95	0.09	4.95	48	42	82	81	− 12	104	451	40	215	18	1	257	448	108	293	6670	6	5.66
CAY003	1.17	2.56	13.14	50.98	0.33	2.17	17.66	0.68	92	90	0.09	5.22	29	42	234	76	7	111	435	29	188	18	1	16	423	77	81	1751	13	5.92
CAY004	0.55	2.64	12.50	41.97	0.68	2.11	24.17	0.60	88	93	0.09	4.75	17	44	69	93	− 2	93	656	32	148	17	0	48	406	86	35	3760	9	9.76
CAY005	1.98	2.77	11.76	45.24	0.27	0.82	22.46	0.60	75	89	0.07	4.76	20	36	14	73	10	72	577	20	152	18	0	0	325	56	71	95	14	9.52
CAY006	1.25	2.80	12.35	49.29	0.32	1.08	19.27	0.66	107	102	0.08	5.06	26	44	81	73	− 9	62	531	36	185	17	2	100	344	105	80	5877	6	7.63
CAY007	1.16	2.55	14.53	49.94	0.32	1.64	17.12	0.73	115	106	0.07	5.32	20	47	64	89	4	107	512	31	172	19	0	40	435	101	50	3060	11	6.30
CAY008	1.35	2.56	14.36	49.28	0.31	1.43	17.48	0.72	126	107	0.07	5.26	41	52	111	93	− 6	114	506	40	176	18	1	25	382	109	178	6467	7	6.46
CAY009	0.77	2.90	12.39	48.19	0.26	2.21	19.05	0.64	96	105	0.09	5.19	33	46	58	77	4	91	508	29	185	19	1	419	314	84	140	2501	12	8.09
CAY010	0.46	1.48	14.74	65.56	0.14	2.37	6.85	0.86	106	102	0.07	5.95	46	45	34	61	12	115	216	31	318	21	1	13	451	86	222	897	16	1.30
CAY011	0.55	2.16	12.34	58.79	0.19	1.97	13.74	0.72	102	99	0.08	5.07	54	39	166	64	1	91	353	32	247	19	1	1	385	89	311	3166	10	3.93
CAY012	0.46	1.64	14.79	65.53	0.18	2.23	7.38	0.82	115	113	0.09	6.00	54	44	26	67	− 5	111	251	42	305	19	1	1	371	123	469	5568	8	0.77
CAY013	0.40	1.56	14.61	65.36	0.19	2.27	6.31	0.84	100	111	0.09	6.06	45	42	26	59	11	107	223	31	305	20	0	3	440	86	312	955	15	1.70
CAY014	0.46	1.50	14.50	64.84	0.18	2.47	7.34	0.78	106	99	0.08	5.97	46	42	32	60	13	110	221	29	270	20	1	8	422	68	381	582	16	1.93
CAY015	0.47	1.46	14.79	65.64	0.18	2.36	6.58	0.79	98	102	0.07	6.06	47	40	27	58	14	110	192	29	275	20	0	4	418	77	328	298	16	2.33
CAY016	0.52	2.45	12.18	49.84	0.39	2.34	17.98	0.65	79	107	0.08	5.01	20	37	250	71	5	94	454	28	185	18	1	10	356	69	100	2363	11	8.68
CAY017	0.39	1.35	14.69	66.09	0.13	2.31	5.75	0.84	104	94	0.07	6.02	40	38	28	55	13	108	177	31	317	20	1	4	389	87	302	806	15	2.17
CAY018	0.65	2.91	12.89	46.56	0.29	2.37	20.01	0.67	96	113	0.08	5.23	25	46	150	83	− 1	93	535	33	182	18	0	14	295	94	73	4075	9	7.73
CAY019	0.68	3.25	11.93	48.83	0.30	2.08	20.15	0.66	81	86	0.06	4.72	23	29	46	74	6	85	387	28	181	18	0	18	331	77	113	1774	12	7.37
CAY020	0.83	3.54	11.71	48.91	0.27	1.60	20.64	0.66	98	90	0.06	4.66	27	31	69	72	− 7	91	395	36	185	17	1	45	342	108	119	5202	7	6.63
CAY021	0.82	2.72	11.61	51.48	0.19	1.62	18.44	0.66	97	100	0.08	4.62	22	38	64	74	− 3	78	497	32	204	18	1	22	373	100	120	4334	9	7.82

Table 3 (continued)

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	V	Cr	MnO	Fe_2O_3	Co	Ni	Cu	Zn	Ga	Rb	Sr	Y	Zr	Nb	Mo	Sn	Ba	Ce	W	Pb	Th	LOI
CAY022	0.48	2.33	13.54	47.23	0.42	2.59	20.31	0.67	89	95	0.09	5.26	25	41	39	82	12	104	448	22	157	18	0	2	510	63	88	226	14	7.43
CAY023	0.54	2.17	13.45	53.30	0.26	2.49	16.07	0.71	85	102	0.08	5.50	25	41	32	73	13	103	426	25	212	19	1	6	412	69	120	155	14	5.80
CAY024	0.48	1.73	13.80	60.00	0.17	2.28	10.88	0.72	94	100	0.07	5.75	27	40	28	62	14	103	270	26	243	19	1	3	448	68	151	172	15	4.42
CAY025	0.58	2.23	13.66	60.13	0.23	2.47	11.70	0.78	97	99	0.08	5.49	30	39	36	74	13	106	353	27	249	21	1	2	461	83	150	324	16	3.09
CAY026	0.58	2.91	11.18	47.05	0.22	2.05	20.79	0.64	77	93	0.07	4.62	84	36	31	68	11	82	439	20	184	18	0	1	466	59	124	101	14	10.18
CAY027	0.74	2.48	12.53	50.60	0.32	2.46	18.20	0.66	99	102	0.08	5.08	17	38	32	76	12	95	465	22	176	18	1	1	316	63	57	103	14	7.42
CAY028	0.46	1.56	15.76	62.91	0.15	2.52	6.25	0.85	106	97	0.08	6.50	72	43	29	62	15	116	178	34	273	21	1	3	489	86	492	48	17	2.89
CAY029	0.55	2.44	12.21	50.05	0.22	2.29	18.06	0.66	92	106	0.07	4.96	37	38	104	69	9	93	477	25	193	19	1	2	428	75	144	1160	13	8.57
CAY030	0.58	2.74	12.70	52.01	0.26	2.42	16.73	0.68	94	108	0.09	5.17	30	41	338	77	4	101	473	29	193	19	1	9	324	80	151	2171	11	6.56
CRB001	0.80	3.25	11.41	49.44	0.19	1.60	20.50	0.65	96	83	0.06	4.64	19	30	52	69	2	80	418	30	184	18	1	25	335	80	71	2802	11	7.72
CRB002	0.84	3.52	12.36	49.23	0.33	1.38	19.71	0.68	96	93	0.06	5.06	26	31	1253	78	− 9	78	404	39	192	17	0	25	310	111	162	6196	5	6.15
CRB003	0.70	2.95	10.93	45.54	0.30	1.94	21.94	0.60	80	82	0.06	4.34	19	28	152	72	0	87	395	29	168	17	0	31	303	73	69	3049	8	10.02
CRB004	0.60	3.16	15.48	51.41	0.22	2.72	12.09	0.74	103	86	0.08	5.74	26	45	39	94	16	114	239	25	178	19	0	7	517	70	104	307	15	7.61
CRB005	0.51	3.60	17.33	51.19	0.24	3.12	11.54	0.79	111	89	0.10	6.30	34	47	50	101	11	135	227	33	172	20	0	57	547	102	188	2168	14	4.73
CRB006	0.50	2.36	11.32	38.77	0.27	1.90	26.72	0.55	94	90	0.07	4.14	15	41	77	79	− 12	86	608	34	130	15	1	1	352	98	27	6216	4	12.97
CRB007	0.47	2.17	13.26	61.28	0.27	2.21	9.46	0.74	89	95	0.07	5.46	21	37	32	65	9	95	262	27	240	19	0	5	414	77	140	1271	13	3.89
CRB008	0.66	3.47	16.93	55.77	0.43	2.99	8.80	0.82	128	104	0.10	6.26	41	54	74	123	− 9	136	228	48	213	19	1	18	552	141	232	7639	7	2.36
CRB009	0.51	1.70	16.41	66.25	0.16	4.45	1.38	0.85	104	91	0.22	6.15	45	35	57	116	− 1	172	82	48	252	20	0	4	781	134	424	5653	9	− 1.36
CRB010	0.52	1.62	15.54	66.32	0.19	4.21	2.18	0.82	92	84	0.24	5.93	42	33	66	98	13	161	86	36	259	21	0	3	782	106	243	1241	14	2.15
CRB011	0.48	1.54	13.57	66.36	0.18	2.48	6.54	0.90	88	94	0.09	5.47	63	35	23	57	12	105	203	29	320	21	0	3	464	88	548	366	16	1.66
CRB012	0.54	1.68	15.56	64.40	0.18	4.21	2.94	0.84	87	80	0.23	5.88	34	29	55	97	12	149	89	35	231	20	0	3	720	98	188	1428	15	2.59
CRB013	0.66	2.42	11.91	62.73	0.24	2.16	11.32	0.64	96	112	0.06	4.62	38	35	298	62	− 8	106	295	38	226	17	0	3	315	107	206	5530	6	2.32
CRB014	0.53	1.63	15.54	66.39	0.20	4.17	2.34	0.84	91	94	0.24	5.89	55	32	57	92	12	154	80	35	254	20	0	4	745	102	353	1375	14	1.46
CRB015	0.36	3.26	10.43	48.00	0.26	2.29	18.93	0.56	81	88	0.04	3.91	14	29	23	62	11	87	371	20	176	17	0	2	338	56	64	19	13	11.99
CRB016	0.34	0.30	23.76	70.97	0.08	1.31	0.59	0.53	70	80	0.01	0.84	19	25	44	41	31	92	75	16	122	16	0	8	307	60	236	406	14	0.90
CRB017	0.89	3.17	10.70	52.22	0.25	1.29	19.18	0.67	93	91	0.06	4.43	29	27	83	70	− 8	74	362	36	207	16	0	23	328	99	177	5528	5	9.10
CRB018	0.94	3.27	11.13	50.48	0.24	1.37	19.70	0.66	88	90	0.06	4.52	19	26	30	66	− 2	73	377	31	181	17	0	81	368	82	99	3628	9	6.56
CRB019	1.02	3.53	11.54	49.81	0.25	1.22	20.54	0.66	93	91	0.06	4.70	24	29	50	70	− 1	69	397	32	186	17	0	8	303	87	99	3473	8	5.99
CRB020	0.83	3.44	11.43	51.05	0.26	1.33	19.80	0.67	96	98	0.06	4.64	28	27	87	71	− 13	78	399	40	201	16	0	6	610	103	156	6882	5	5.70
CRB021	0.78	3.87	15.86	53.12	0.26	2.32	12.08	0.78	118	109	0.09	5.96	31	48	55	115	− 12	127	216	46	204	17	1	84	431	134	160	7986	5	3.06
CRB022	0.72	3.58	16.11	53.12	0.22	2.59	11.32	0.78	117	109	0.08	5.96	47	48	57	113	− 8	119	221	42	194	18	1	52	442	122	281	7041	6	4.40
CRB023	0.68	3.42	12.32	49.17	0.30	1.77	19.61	0.67	84	93	0.06	5.04	26	29	43	77	1	90	397	31	180	18	0	10	338	84	53	3018	11	6.37
CRB024	0.52	2.29	10.84	37.39	0.26	1.63	27.49	0.52	90	87	0.07	4.04	15	36	62	81	− 11	75	675	32	129	15	1	2	358	85	25	5749	5	14.27
CRB025	0.53	1.73	15.84	65.22	0.18	4.30	2.47	0.84	91	83	0.25	6.02	30	31	61	101	10	154	85	37	231	20	0	4	756	109	166	1831	13	2.07
CRB026	0.44	1.35	13.66	67.61	0.12	2.46	5.15	0.91	100	99	0.08	5.55	29	41	24	53	10	112	183	33	335	21	0	3	458	98	176	1428	14	1.93
CRB027	0.53	1.73	15.90	65.36	0.18	4.33	2.20	0.84	98	89	0.24	6.02	23	37	66	107	10	164	86	40	245	21	0	4	804	112	91	2174	14	2.00
CRB028	0.56	1.65	16.02	66.26	0.16	4.26	1.75	0.86	91	80	0.22	5.88	51	31	52	97	13	157	80	36	260	21	0	2	789	99	282	1224	16	1.73
CRB029	0.57	1.10	15.75	70.41	0.09	2.31	1.40	0.87	107	110	0.10	6.39	81	39	20	57	14	110	70	30	308	20	1	3	420	84	611	670	15	0.50
CRB030	0.99	2.27	13.13	58.73	0.23	2.19	12.20	0.78	92	99	0.08	5.43	28	39	24	68	14	97	369	26	255	20	0	− 2	467	77	165	26	14	3.39

a polygenic group's existence. The compositional evenness graph explores the variability associated with each retained component. When all components introduce equal variability, evenness is maximised, and the information entropy, or Shannon index, attains its maximum value (the logarithm with base two of the number of components) (Buxeda and Madrid, 2016). The more dominated the existing variability by a few or just one component, the more the information entropy drops significantly. The present graph reveals that the elements that introduce more variability are CaO and Sr ($\tau_{.j} < 0.3$), and, to a lesser extent, MnO, MgO and Na_2O ($0.3 < \tau_{.j} < 0.5$). By contrast, Nb and V are the elements that introduce less variability, but their $\tau_{.j}$ values are below 0.9. All these indicators show that even if the chemical variability is mainly linked to a few elements, the compositions vary significantly in all retained components (the information entropy has a value of 3.18 Sh, i.e. 77.73 % of the maximum attainable). In a more detailed exploratory analysis, it is easy to observe that individual CRB016 exhibits a significantly different composition, with very low MgO, CaO, MnO and Fe_2O_3 values and very high ones in Al_2O_3 and SiO_2 (Table 3). As confirmed by its chemistry, this individual corresponds to porcelain and its extreme chemical differences will dominate the whole data treatment; therefore, this individual, a clear outlier, will be excluded in data treatment from now onwards. Once excluded, the compositional evenness graph (Fig. 3, right) reveals that the elements that now introduce more variability are, again, CaO and Sr ($_{\tau.j} < 0.3$) and, to a lesser extent and in a different order than previously, Na_2O, MgO and MnO ($0.3 < _{\tau.j} < 0.5$). Again, Nb and V are the elements that introduce less variability, but their $\tau_{.j}$ values are still below 0.9. The total variation and information entropy drop slightly to 1.73 and 3.13 Sh (i.e. 76.50 % of the maximum attainable), respectively, showing the individual CRB016 in increasing the differences in chemical composition reflected in the position changes of MgO, MnO and Al_2O_3. For the 119 individuals retained for analysis, the influence of CaO and Sr is essential to differentiate the calcareous and low-calcareous ceramics.

To summarise the data treatment, we present the dendrogram (Fig. 4) from the cluster analysis performed on the 119 individuals from Córdoba using the square Euclidean distance and the centroid agglomerative algorithm on the subcomposition Na_2O, MgO, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, V, Cr, MnO, Fe_2O_3, Ni, Zn, Sr, Zr, Nb and Ba, clr transformed. These results show a clear difference between low calcareous (CaO < 5–6%) ceramics placed in the left branch of the dendrogram and calcareous (5–6% < CaO < 25–35%) in the right one. The low calcareous individuals are classified into 3 groups, while the calcareous ones are classified into 10 groups, with 5 individuals remaining ungrouped. Three out of these five ungrouped individuals (pointed with black arrows in Fig. 4) are, in fact, of a Sevillian origin, as will be explained below.

To further investigate those groups, we compare these results with the ARQUB database, which includes a few thousand individuals from the main production centres of the Iberian Peninsula and different sites in the Americas and the Canary Islands. The statistical treatment gives information about the ceramic imports recovered in Córdoba, as well as the places where the Cordoban products were distributed. To summarise, in Fig. 5, we show the dendrogram from the cluster analysis on the previous subcomposition clr transformed, using the square Euclidean distance and the centroid agglomerative algorithm, of the 119 individuals from Córdoba compared to 334 relevant individuals from Priego de Córdoba (unpublished results), Granada (unpublished results), Villamartín (unpublished results) (36° 51′ 33″ N, 5° 38′ 37″ W), and Seville (Iñañez 2007; Buxeda et al. 2015; Fernández de Marcos 2019) (37° 23′ 00″ N, 5° 59′ 00″ W)[4]. The comparison with the database shows no connections out of the area of Andalusia, showing local-regional networks between Córdoba and the territories around. Thus, we find ceramics from the cities of Granada and Seville in different archaeological sites in Córdoba (pointed with black arrows in Fig. 5), mainly in the consumption centre, but also appear in all production ones. These individuals correspond to calcareous pottery and are classified into the groups CGGRA, the one with an origin in Granada, and the CGSEV, whose origin is in Seville (Fig. 4). In this new dendrogram, it is clear that the previous ungrouped individual CRB013 has a Sevillian origin because this individual is classified in a new group of Sevillian ceramics. However, individuals CRB020 and CAY005 (pointed with green arrows in Fig. 5) are still ungrouped. As we will see in the next section, these individuals are affected by postdepositional processes that have altered their chemical concentrations in Na_2O and K_2O. Once these elements are not considered in the data treatment, these individuals are grouped with all Sevillian ceramics. Most of these Sevillian imports are tin-lead glazed sherds exhibiting different types of decoration: plain white (*blanca lisa*), manganese on white (*blanco y manganeso*), green on white (*verde sobre blanco*), Sevilla blue on white (*azul sobre blanco*), Yayal blue on white (*azul lineal*), Santo Domingo blue on white (*azul figurativa*), blue-green basin (*verde y azul*) and lusterware (*loza dorada*)[5]. Furthermore, some examples of seventeenth-century plain white and Fajalauza ceramics from Granada have also been identified.

[4] The position given for Villamartín and Seville archaeological sites corresponds to the modern towns of Villamartín and Seville, respectively.

[5] The terminology used for classifying decorated tin lead glazed ceramics is based on the classification method used by the American academics. The terminology established by the Spanish academics is referenced in parentheses.

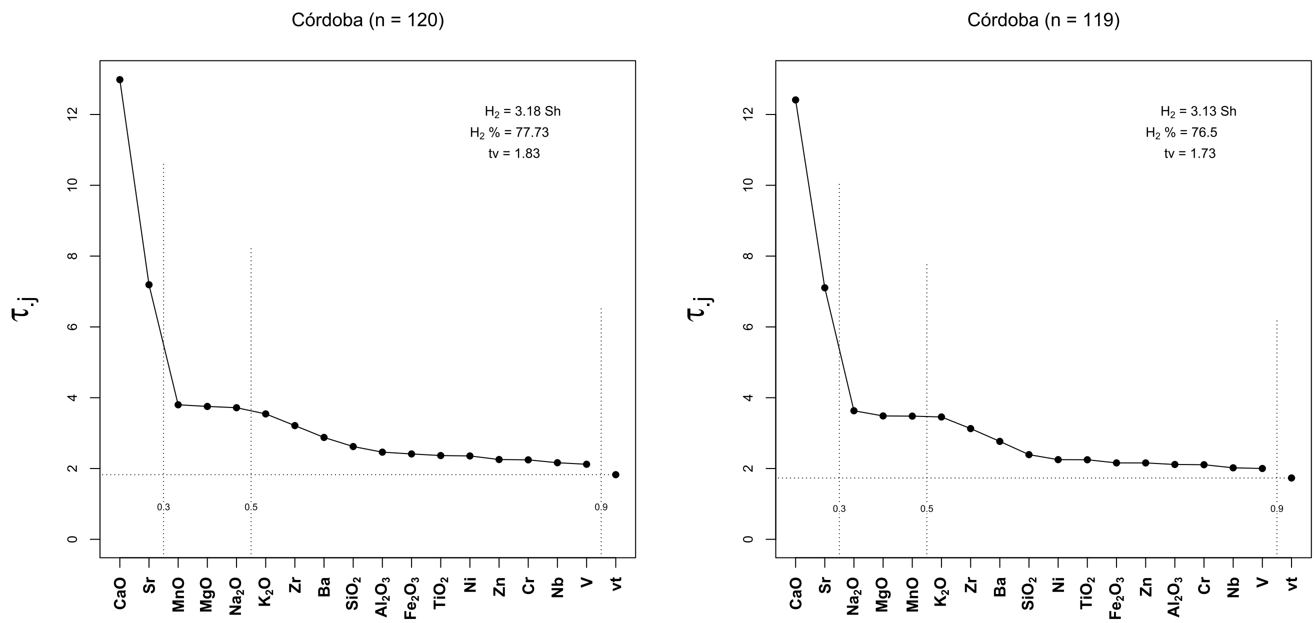

Fig. 3 Left: Compositional evenness graph of the 120 studied individuals. Right: Compositional evenness graph of the 119 retained individuals, excluding CRB016. H_2: information entropy (in shannons, Sh); H_2 %: percentage of the maximum possible attainable; tv: total variation; τ_j: trace of the variance-covariance matrix following the alr transformation using element *j* as the divisor. Vertical dotted lines express different tv/τ_j values

Besides tin-lead glazed vessels, a few Sevillian individuals of transport jars and coarse ware are also present. In addition to these localised reference groups (RG), two paste compositional reference units (PCRU) of unknown origin could be defined (Bishop et al. 1982; Buxeda and Madrid 2016). The first group, labelled CGNC01, includes low calcareous individuals of honey-glazed dishes and bowls that have only been identified at Córdoba (Figs. 4 and 5). In contrast, the CGNC02 group, formed by three calcareous individuals of tin-lead glazed ceramics (Fig. 4), match a group of 5 individuals of unknown origin recovered at Granada (Fig. 5). The comparison with the database also shows that the remaining ungrouped individuals in Fig. 4 (OLL009 and CRB015, pointed with blue arrows in Fig. 5) are still outliers when comparing our results to the database, confirming them as loners. They correspond to fragments of a green-glazed bowl and an unglazed handle, respectively. The remaining 6 groups, labelled CGCRV, represent the product of Córdoba, and only two ceramics from group CGCRV05 have been identified out of this city, one in Villamartín—VLM040—and one in Priego de Córdoba—PRI011—(Fig. 5, pointed with red arrows).

For a better understanding of the chemical differences in the studied set, we performed the singular value decomposition of the double-centred clr transformed data (Aitchison and Greenacre 2002; Greenacre 2010; van de Boogaart and Tolosana-Delgado 2013) on the 119 retained individuals, grouping together all ceramics from a Sevillian origin. The two first principal components' covariance and form biplots (Fig. 6) explain more than 80% of the variance (VE = 86.03%). The first principal component that explains most of the variance (VE = 76.51%) is mainly related to the ceramics' low calcareous or calcareous nature. The components most involved in the group formation are CaO and Sr, together with MgO and Na_2O (Fig. 6), attracted to the right-hand side, while K_2O, MnO, Zr and Ba are attracted to the left-hand one. Moreover, the values of CaO and Sr are strongly correlated. The second principal component (VE = 9.52%) mainly shows Zr's opposition, on the upper side, to MnO, on the lower one. Therefore, the Córdoban groups CGCRV01 and CGCRV02, the CGNC01 group of unknown origin, and the loner CRB016 (not used in this data treatment) correspond to low-calcareous pastes (Table 4) and are placed at the left-hand side of the biplots. All other groups

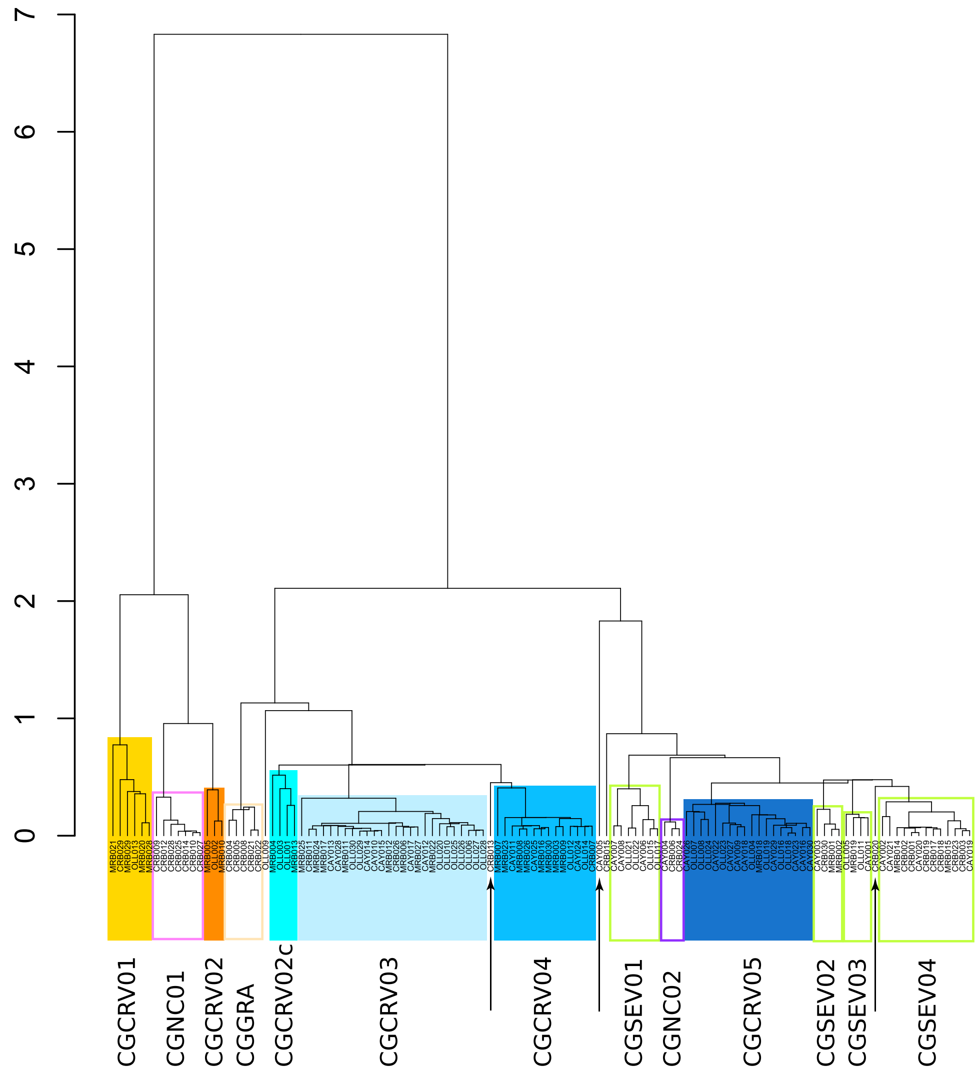

Fig. 4 Dendrogram from the cluster analysis on the subcomposition Na_2O, MgO, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, V, Cr, MnO, Fe_2O_3, Ni, Zn, Sr, Zr, Nb and Ba, clr transformed, of the 119 individuals retained. Black arrows: ungrouped individuals of a Sevillian origin

and loners are considered calcareous. The CaO and Sr concentrations increase from left to right, reaching very high values in group CGNC02. Besides this component of calcareousness of the pastes, we can identify groups CGCRV01 and CGCRV03 at the upper side of the biplots because of their high concentrations of Zr and low ones of MnO. On the contrary, the group CGNC01 is characterised by very high concentrations of MnO, but K_2O and Ba too. It is also important to highlight that groups CGCRV03, CGCRV04 and CGCRV05 show a continuous variation from low CaO and high Zr to high CaO and low Zr. Regarding the Sevillian group (CGSEV), it is easy to see that these ceramics exhibit high concentrations of MgO and Na_2O. The highest MgO values are found in group CGGRA, exhibiting high MnO contents too. Finally, if we do not consider CaO and Sr concentrations in the statistic data treatment, groups CGCRV02 and CGCRV02c mingle. That suggests that the CGCRV02c group could have a similar origin as CGCRV02. Moreover, both groups exhibit high concentrations of MnO.

Mineralogical analysis

Chemical results show that the individuals analysed correspond to ceramics technically considered both low calcareous and calcareous. The individuals are distributed in different areas of the ternary phase diagrams CaO-Al_2O_3-SiO_2 and (CaO+MgO+Fe_2O_3)-Al_2O_3-SiO_2, also called the ceramic triangle, depending on their chemical composition (Fig. 7, left and right). As we can see, low calcareous groups and loner CRB016 are placed in the quartz–anorthite–mullite thermodynamic equilibrium triangle, while the calcareous ones are placed in the quartz–anorthite–wollastonite one. This difference in CaO content implies a marked technical difference between such products. Along these lines, the particular nature of the porcelain (CRB016) is made evident in Fig. 7, right where this individual appears isolated thanks to the extreme low contents of CaO, MgO and Fe_2O_3 in contrast with the very high Al_2O_3, corresponding to another

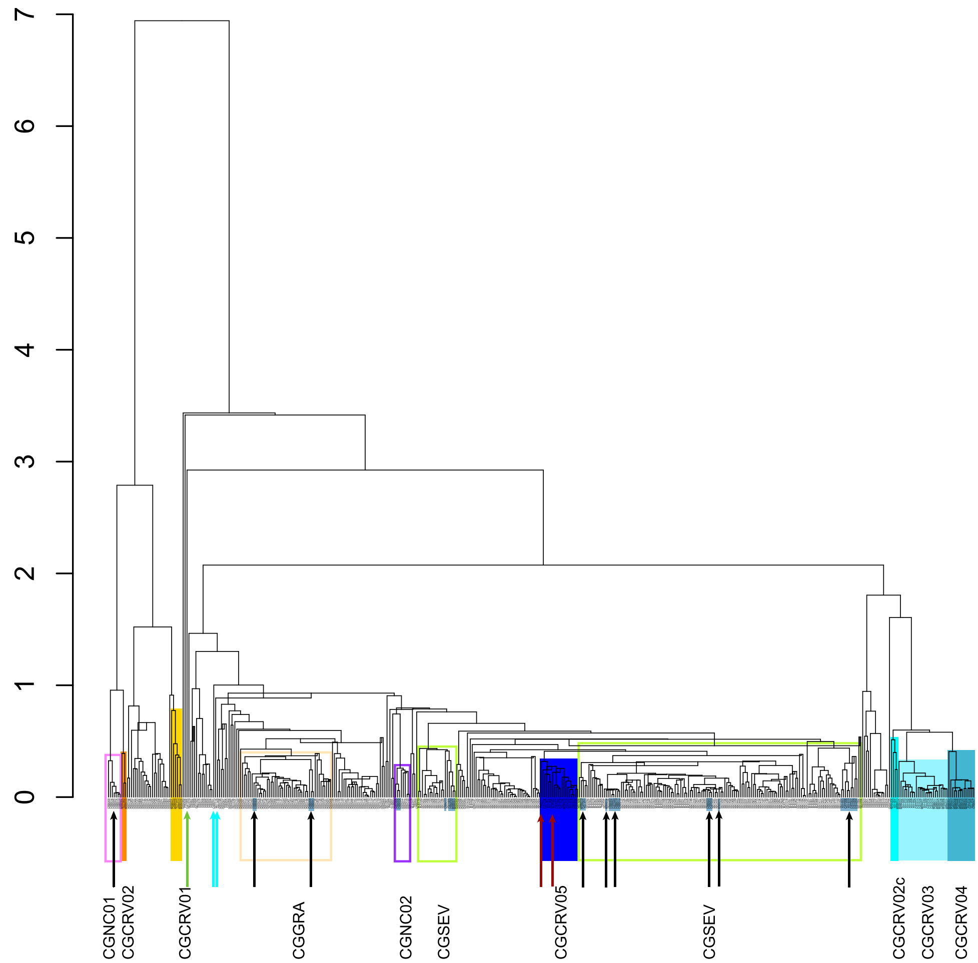

Fig. 5 Dendrogram from the cluster analysis on the Na_2O, MgO, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, V, Cr, MnO, Fe_2O_3, Ni, Zn, Sr, Zr, Nb and Ba subcomposition clr transformed of the 119 individuals analysed in this study, compared with 334 relevant individuals of the ARQUB database. Red arrows: Cordoban products recovered in other archaeological sites. Black arrows: non-local ceramics recovered at Córdoba. Green arrows: Sevillian ceramics recovered at Córdoba but with altered compositions. Blue arrows: loners recovered at Córdoba

very different technical solution. XRD results complete the information on the mineral phases, and they serve as the basis for estimating their equivalent firing temperature (EFT) when explained based on the chemical groups (Roberts 1963; Picon 1973; Tite et al. 1982; Heimann and Maggetti 2014; Gliozzo 2020).

The study of the XRD diffractograms enables identifying different fabrics, i.e. different categories of association of crystalline phases for each chemical group, that enables the establishment of mineralogical scales providing estimations for the EFT of the pottery shedding light on some aspects of the technical process (Buxeda and Madrid 2016: 36). Table 5 summarises the chemical groups and fabrics defined in this study, and Fig. 8 shows a selection of the 6 most relevant diffractograms analysed. In the following lines, we will discuss exclusively the fabrics identified in this study.

The study of the diffractograms of the 6 individuals of the low calcareous group CGCRV01 enables defining three fabrics: F1 (OLL013, MRB020 and 028), F2 (MRB029 and CRB029), and F3 (MRB021). Although all these fabrics exhibit spinel, possibly as a firing phase, the difference in the presence or absence of illite-muscovite (the $d_{(002)}$ peak at 10 Å is always absent) enables estimating different EFT for F1 (< 950/1000 °C) and F2 (> 950/1000 °C). F3 also exhibits the presence of mullite, pointing to an even higher EFT (> 1000 °C).

The low calcareous CGCRV02 group contains 3 individuals classed in two different fabrics. Fabric F1 (MRB005) exhibits the presence of illite-muscovite (including the $d_{(002)}$ peak at 10 Å), but no firing phases are observed. The estimated EFT is below 900/950 °C. In contrast, fabric F2 (OLL002 and MRB010) exhibits the presence of spinel and illite-muscovite (without the $d_{(002)}$ peak at 10 Å). The estimated EFT is in the range of 950–1000 °C. The presence of calcite in all individuals must be due to a secondary phase (Buxeda and Cau 1995; Cau et al. 2002).

The CGCRV02c group behaves as a calcareous group and includes 4 individuals. The EFT estimated for F1 (OLL003) is 800–850 °C because of the absence of firing temperatures, possibly except for hematite. Fabric F2 includes one individual (MRB004) that exhibits clear firing phases (pyroxene, gehlenite and intense peaks of plagioclase) together with illite-muscovite. The estimated EFT is in the range of 900–1000 °C. The third fabric, F3 (OLL001 and MRB013),

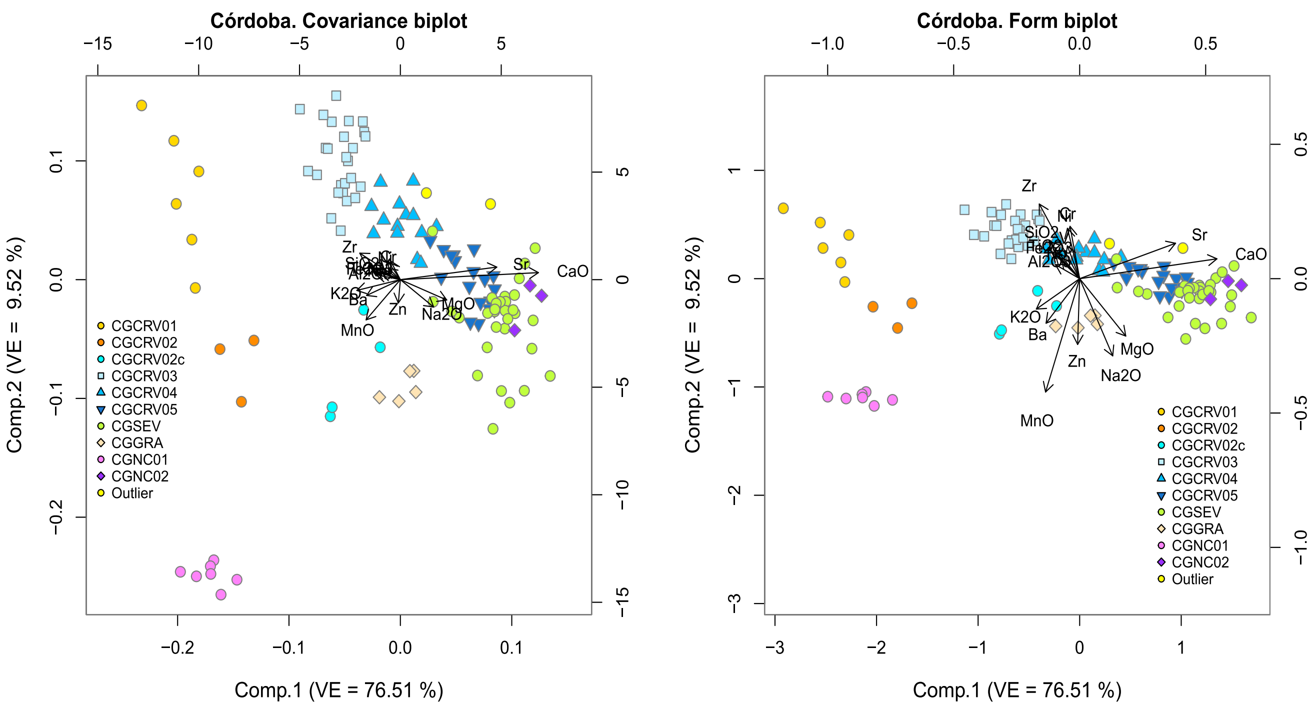

Fig. 6 Covariance (left) and form (right) biplots of the singular value decomposition on the subcomposition Na_2O, MgO, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, V, Cr, MnO, Fe_2O_3, Ni, Zn, Sr, Zr, Nb and Ba, double centred clr transformed. *VE* variance explained

shows the decomposition of illite-muscovite and gehlenite, pointing to an EFT estimated at over 1000–1050 °C. Moreover, both individuals exhibit a yellowish colour (Fig. 9a, MRB013), typical of overfired calcareous ceramics, which also agrees with the decomposition of hematite.

The calcareous group CGCRV03 accounts for 26 individuals scattered in 6 different fabrics. Fabric F1 (MRB0011, 017, CAY015 and 017) exhibits typical firing phases in calcareous ceramics (pyroxene and, especially, gehlenite) and illite-muscovite (including the $d_{(002)}$ peak at 10 Å). The estimated EFT is 850–950 °C. Fabric F2 (OLL006, 020, 029, 030, MRB006, 022, 025, 027, CAY010, 013, 014, 028, CRB011 and 026) is differentiated by the frequent presence of intense peaks of plagioclase and the constant absence of the $d_{(002)}$ peak at 10 Å of illite-muscovite. Thus, the estimated EFT is in the range of 950–1000 °C. The individual MRB012 (F3) exhibits the total decomposition of illite-muscovite. The presence of gehlenite enables estimating the EFT in the range of 1000–1050 °C. The same EFT range is estimated for fabric F4, which only includes individual MRB024. This individual is unique because of its black colour (Fig. 9a, MRB024) due to the presence of magnetite, whose crystallisation points to an intentional reducing atmosphere (Maniatis et al. 1983; Maritan et al. 2005) that corresponds to a different technical solution for this ceramic. Fabric F5 (OLL010, 025, 026, 027 and CAY012) differs because of gehlenite decomposition, a metastable phase in calcareous ceramics (Heimann and Maggetti 2014). The estimated EFT must be slightly over 1050 °C, but these ceramics cannot be considered severe overfired. Finally, individual OLL028 (F6) exhibits the same mineral phases as the previous fabric, and its EFT must be estimated at the same range. Nevertheless, this individual exhibits (Fig. 8a) an intense peak at 9.14 Å (9.67°2θ) that seems to correspond to the $d_{(020)}$ peak (I % = 100) of stilbite-Ca (JCPDS #00-044-1479; (Na, K)$Ca_2Al_5Si_{13}O_{36}\cdot 14H_2O$) a zeolite that could be a secondary phase. Other significant peaks of this mineral, $d_{(13-2)}$ (4.06 Å, 21.86°2θ; I % = 87) and $d_{(15-2)}$ (3.03 Å, 29.42°2θ; I % = 46), are placed in areas that overlap the plagioclase and the possible calcite, rendering complex to assure this identification.

Group CGCRV04, calcareous, includes 14 individuals distributed in four mineralogical fabrics. Fabric F1 (MRB003, CAY024 and 025) exhibits clear firing phases, pyroxene and especially gehlenite, and illite-muscovite (including the $d_{(002)}$ peak at 10 Å). The estimated EFT is in the range of 850–950/1000 °C. In contrast, fabric F2 (OLL012, MRB007, 030 and CRB007) do not show the $d_{(002)}$ peak at 10 Å of illite-muscovite, and the estimated EFT is in the range of 950–1000 °C. Fabric F3 (OLL014, MRB008, 016, 023 and 026) is characterised by illite-muscovite's total decomposition and gehlenite's presence, enabling estimating an EFT in the range of 1000–1050 °C. Finally, fabric F4 (MRB009 and CAY011) shows the total decomposition of gehlenite. Therefore, the estimated EFT is over 1050 °C.

Table 4 Mean ($\bar{X}$) and standard deviation (s) of the defined groups and concentrations of loners (on normalized data). *tv* total variation. Major and minor elements are expressed in *w* %. Trace elements are expressed in µg/g

	CGCRV01 (*n* = 6) (tv = 0.32)		CGCRV02 (*n* = 3) (tv = 0.16)		CGCRV02c (*n* = 4) (tv = 0.26)		CGCRV03 (*n* = 26) (tv = 0.13)		Calculated CGCRV03	CGCRV04 (*n* = 14) (tv = 0.13)		CGCRV05 (*n* = 18) (tv = 0.18)		CGSEV (*n* = 31) (tv = 0.38)		CGGRA (*n* = 5) (tv = 0.13)		CGNC01 (*n* = 7) (tv = 0.09)		CGNC02 (*n* = 3) (tv = 0.05)		CRB015	OLL009	CRB016
	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s			
Na_2O	0.41	0.10	0.55	0.01	0.56	0.05	0.43	0.04	0.47	0.51	0.05	0.60	0.11	1.08	0.29	0.69	0.11	0.55	0.02	0.60	0.02	0.41	0.48	0.34
MgO	1.02	0.14	1.38	0.07	1.83	0.13	1.50	0.10	1.65	1.96	0.24	2.91	0.62	3.19	0.45	3.74	0.24	1.72	0.05	2.79	0.14	3.71	2.19	0.30
Al_2O_3	15.15	1.07	15.70	0.69	15.89	0.54	14.92	0.50	14.61	13.72	0.97	13.53	0.72	12.86	0.97	17.31	0.67	16.25	0.29	13.27	0.62	11.87	16.28	24.07
SiO_2	72.41	2.06	69.29	1.13	63.19	1.48	66.95	1.32	66.56	63.72	2.09	54.85	2.65	54.03	3.24	56.05	1.44	67.48	0.49	45.24	1.47	54.61	57.63	71.89
K_2O	2.36	0.11	3.26	0.24	3.39	0.23	2.41	0.10	2.42	2.39	0.19	2.54	0.21	1.78	0.50	2.91	0.33	4.39	0.09	2.16	0.22	2.61	3.43	1.33
CaO	1.15	0.26	2.36	0.44	8.10	1.91	6.66	0.94	7.14	11.15	1.73	19.12	2.97	20.99	3.47	11.84	1.56	2.24	0.53	30.09	2.78	21.54	12.60	0.60
TiO_2	0.88	0.09	0.86	0.08	0.84	0.05	0.84	0.05	0.82	0.78	0.04	0.71	0.03	0.70	0.04	0.83	0.02	0.86	0.01	0.64	0.03	0.64	0.81	0.54
V	104	4	98	9	107	7	108	8	102	100	7	99	8	102	14	122	8	96	6	104	6	92	118	71
Cr	106	14	92	5	105	19	111	18	106	101	5	107	10	102	13	105	11	88	5	103	1	100	94	81
MnO	0.07	0.02	0.11	0.03	0.13	0.02	0.08	0.01	0.08	0.08	0.01	0.09	0.01	0.08	0.01	0.10	0.01	0.24	0.01	0.09	0.01	0.05	0.05	0.01
Fe_2O_3	6.43	0.85	6.34	0.59	5.90	0.34	6.09	0.23	6.12	5.55	0.38	5.49	0.24	5.15	0.31	6.40	0.18	6.12	0.09	4.95	0.31	4.45	6.38	0.85
Ni	42	6	40	2	43	3	45	7	43	40	3	44	4	39	9	51	3	34	3	46	4	33	38	25
Zn	58	16	86	10	90	6	62	5	66	67	6	81	5	81	9	116	11	104	8	97	7	71	82	42
Sr	73	7	114	25	243	51	208	23	212	316	51	491	43	498	93	240	12	86	4	744	47	422	410	76
Zr	332	50	285	4	231	21	308	23	290	268	21	206	17	204	21	204	16	254	12	156	8	200	208	124
Nb	21	2	21	2	20	1	21	1	21	20	1	20	1	19	1	20	1	21	1	18	1	19	20	16
Ba	431	14	640	73	624	134	435	38	429	479	61	426	73	402	84	527	61	788	28	427	24	385	429	311

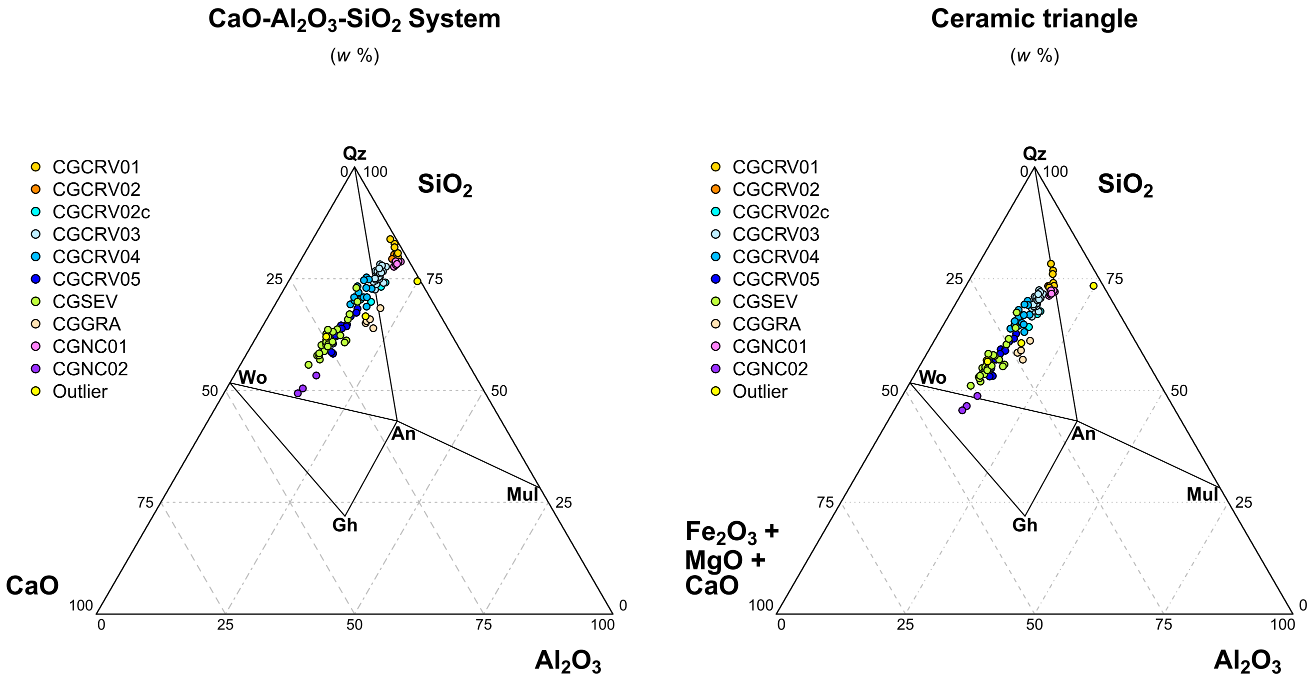

Fig. 7 Ternary phase diagrams of the (left) $CaO-Al_2O_3-SiO_2$ and (right) $(CaO + MgO + Fe_2O_3)-Al_2O_3-SiO_2$ systems with the situation of the individuals analysed. *An* anorthite ($Ca[Al_2Si_2O_8]$), *Gh* gehlenite ($Ca_2Al(SiAl)_2O_7$), *Mul* mullite ($Al_6[Si_2O_{13}]$); Qz: quartz (SiO_2), *Wo* wollastonite ($CaSiO_3$) (abbreviations according to Whitney and Evans 2010)

Finally, group CGCRV05 is the most calcareous local group and includes 18 individuals scattered in 3 fabrics. Fabric F1 (OLL004, 007, 008, CAY027 and 029) exhibits clear firing phases and illite-muscovite, enabling estimating the EFT in the range of 850–950/1000 °C. In contrast, fabric F2 (OLL016, 023 and MRB018) show the absence of the $d_{(002)}$ peak at 10 Å of illite-muscovite. The estimated EFT is in the range of 950–1000 °C. The fabric F3 (OLL018, 019, 024, CAY009, 016, 018, 022, 023 and 026) is, by far, the most represented. While exhibiting gehlenite, the illite-muscovite is decomposed, enabling estimating an EFT in the range of 1000–1050 °C. Finally, individual CAY030 differs from F3 because of vaterite (Fig. 8b), a rare calcium carbonate polymorph that has been previously reported in early modern ceramics (Iñañez 2007; Dias et al. 2012) and that could be present in individuals OLL008 and CAY027 (F1). The presence of vaterite is of a secondary origin from a Ca-rich wet environment (Pradell et al. 2010).

Concerning the Sevillian importations, all individuals are calcareous, and they have been grouped in ten different fabrics. The fabric F1 (OLL005 and 011) does not exhibit any clear firing phase, and the EFT can be estimated below 800/850 °C. The fabric F2 (MRB001, 002, 015 and CRB030) exhibits pyroxene and gehlenite as clear firing phases. Moreover, the absence of the $d_{(002)}$ peak at 10 Å of illite-muscovite enables estimating the EFT at 950–1000 °C. Two individuals of this fabric (MRB001 and CRB030), one individual in fabric F4, and two in fabric F5 could exhibit andradite, a garnet, but its identification is unsure. Individual MRB019 exhibits (Fig. 8c) the same fabric as F2 but with the presence of aragonite, a calcium carbonate polymorph of clear secondary origin, defining fabric F3, whose EFT is also in the range of 950–1000 °C. The fabric F4 (CAY001, 019, 021, CRB003, 018, 019 and 020) differs from fabric F2 because of the total decomposition of illite-muscovite, enabling estimating the EFT in the 950/1000–1050 °C range. The fabric F5 (OLL021, 022, MRB014, CAY002, 003, 005, 007, CRB001, 002, 017 and 023) is the largest fabric for Sevillian ceramics in Córdoba and differs from fabric F4 because of analcime, an authigenic sodic zeolite ($Na(AlSi_2O_6){\cdot}H_2O$). The estimated EFT is in the range of 950/1000–1050 °C, which, for calcareous ceramics, can be considered a non-severe overfiring. At this stage, it is common to observe that these ceramics have undergone a double process of alteration that possibly implies, in a first step, the alteration of the glassy phase already developed. This alteration typically enables the lixiviation of potassium and rubidium that are thus depleted in these ceramics. In a second step, analcime crystallises on the altered glassy phase incorporating allochthonous sodium, enriching its initial concentration (Buxeda 1999; Buxeda et al. 2002; Schwedt et al. 2006). Indeed, some of those individuals (especially CAY005) exhibit the highest concentration of Na_2O and the lowest of K_2O (Table 3), resulting, most

Table 5 Summary of the mineralogical fabrics defined by PXRD analysis for each chemical group

Group (*n*)	Fabric (*n*)	Mineral phases	Individuals	EFT °C
CGCRV01 (6) (LC)	F1 (3)	Qz, Ilt (not 10 Å peak), Afs, Hem, Spl	OLL013 MRB020,028	< 950/1000
	F2 (2)	Qz, Afs, Hem, Spl	MRB029-**k** CRB029	> 950/1000
	F3 (1)	Qz, Afs, Hem, Spl, Mul	MRB021	> 1000
CGCRV02 (3) (LC)	F1 (1)	Qz, Ilt, Afs, Hem, Pl, Cal	MRB005	< 900/950
	F2 (2)	Qz, Ilt (not 10 Å peak), Afs, Hem, Pl, Spl, Cal	OLL002-**k** MRB010	950–1000
CGCRV02c (4) (C)	F1 (1)	Qz, Ilt, Afs, Hem, Pl, Cal	OLL003-**k**	800–850
	F2 (1)	Qz, Ilt, Afs, Hem, Pl, Cal, Px, Gh	MRB004	900–1000
	F3 (2)	Qz, Afs, Pl, Cal, Px	OLL001-**k** MRB013	> 1000–1050
CGCRV03 (26) (C)	F1 (4)	Qz, Ilt, Afs, Hem, Pl, Cal, Px, Gh	MRB011, 17 (Hem?) CAY015, 17	850–950
	F2 (14)	Qz, Ilt (not 10 Å peak), Afs, Hem, Pl, Cal, Px, Gh	OLL006, 020, 029, 030 MRB006, 022, 025, 027 CAY010, 013, 014, 028 CRB011, 026	950–1000
	F3 (1)	Qz, Afs, Hem, Pl, Cal, Px, Gh	MRB012-**k**	1000–1050
	F4 (1)	Qz, Afs, Mag, Pl, Cal, Px, Gh	MRB024	1000–1050
	F5 (5)	Qz, Afs, Hem, Pl, Cal (?), Px	OLL010, 025, 026, 027 CAY012	> 1050
	F6 (1)	Qz, Afs, Hem, Pl, Cal (?), Px, Stb	OLL028	> 1050
CGCRV04 (14) (C)	F1 (3)	Qz, Ilt, Afs, Hem, Pl, Cal, Px, Gh	MRB003 CAY024, 025	850–950/1000
	F2 (4)	Qz, Ilt (not 10 Å peak), Afs, Hem, Pl, Cal, Px, Gh	OLL012 MRB007 (Hem ?), 030 CRB007	950–1000
	F3 (5)	Qz, Afs, Hem, Pl, Cal, Px, Gh	OLL014 MRB008, 016-**k**, 023-**k**, 026 (Hem ?)	1000–1050
	F4 (2)	Qz, Afs, Hem, Pl, Cal, Px	MRB009 CAY011	> 1050
CGCRV05 (18) (C)	F1 (5)	Qz, Ilt, Afs, Hem, Pl, Cal, Px, Gh	OLL004, 007, 008 (Vtr ?) CAY027 (Vtr ?), 029	850–950/1000
	F2 (3)	Qz, Ilt (not 10 Å peak), Afs, Hem, Pl, Cal, Px, Gh	OLL016, 023 MRB018	950–1000
	F3 (9)	Qz, Afs, Hem, Pl, Cal, Px, Gh	OLL018-**k**, 019-**k**, 024 CAY009, 016, 018-**k**, 022, 023, 026	1000–1050
	F4 (1)	Qz, Afs, Hem, Pl, Cal, Px, Gh, Vtr	CAY030	1000–1050
CGSEV (31) (C)	F1 (2)	Qz, Ilt, Afs, Hem, Pl, Cal	OLL005, 011	≤ 800/850
	F2 (4)	Qz, Ilt (not 10 Å peak), Afs, Hem, Pl, Cal, Px, Gh	MRB001 (Adr ?), 002, 015 CRB030 (Adr ?)	950–1000
	F3 (1)	Qz, Ilt (not 10 Å peak), Afs, Hem, Pl, Cal, Px, Gh, Arg	MRB019	950–1000
	F4 (7)	Qz, Afs, Hem, Pl, Cal, Px, Gh	CAY001, 019, 021 CRB003, 018, 019 (Adr ?), 020	950/1000–1050
	F5 (11)	Qz, Afs, Hem, Pl, Cal, Px, Gh, Anl	OLL021, 022 (Adr?) MRB014 CAY002, 003, 005, 007 (Gh ?) CRB001, 002 (Adr ?), 017, 023	950/1000–1050
	F6 (1)	Qz, Afs, Hem, Pl, Cal, Px, Gh, Anl, Vtr	CAY020	950/1000–1050
	F7 (1)	Qz, Afs, Hem, Pl, Cal, Px, Gh (?), Anl, Stb	CAY008	950/1000–1050
	F8 (2)	Qz, Afs, Pl, Cal, Px, Gh, Hyn, Adr	OLL015, 017	950/1000–1050
	F9 (1)	Qz, Afs, Pl, Cal, Px, Gh, Anl, Hyn, Adr	CAY006	950/1000–1050
	F10 (1)	Qz, Afs, Pl, Cal, Px, Anl	CRB013	> 1050

Table 5 (continued)

Group (*n*)	Fabric (*n*)	Mineral phases	Individuals	EFT °C
CGGRA (5) (C)	F1 (4)	Qz, Ilt, Afs, Hem, Pl, Cal, Px, Gh	CRB004, 005, 008, 022	850–950/1000
	F2 (1)	Qz, Ilt, Afs, Hem, Pl, Cal, Px, Gh, Anl	CRB021	850–950/1000
CGNC01 (7) (LC)	F1 (1)	Qz, Ilt, Afs, Pl, Cal, Tlc (?)	CRB012	< 900/950
	F2 (3)	Qz, Ilt, Afs, Pl, Cal (?)	CRB025, 027, 028 (Hem ?)	< 900/950
	F3 (1)	Qz, Afs, Cal (?), Hem, Spl	CRB010	> 950/1000
	F4 (2)	Qz, Afs, Cal (?), Hc	CRB009, 014 (Mgh ?)	> 950/1000
CGNC02 (3) (C)	F1 (3)	Qz, Afs, Hem, Pl, Cal, Px, Gh	CAY004 CRB006, 024	950/1000–1050
Loners (3)	F1 (1) (C)	Qz, Afs, Hem, Pl, Cal, Px, Gh (?)	OLL009	> 950/1000
	F1 (1) (C)	Qz, Ilt, Afs, Hem, Pl, Cal, Px, Gh	CRB015	850–950/1000
	F1 (1) (LC)	Qz, Mul, Crs, Crn	CRB016	1200/1300

n number of individuals, *C* calcareous, *LC* low calcareous, *Adr* andradite, *Afs* alkali feldspar, *Anl* analcime, *Arg* aragonite, *Cal* calcite, *Crn* corundum, *Crs* cristoballite, *Gh* gehlenite, *Hc* hercynite, *Hem* hematite, *Hyn* haüyne, *Ilt* illite (illite-muscovite), *Mag* magnetite, *Mgh* maghemite, *Mul* mullite, *Pl* plagioclase, *Px* pyroxene, *Qz* quartz, *Spl* spinel, *Stb* stilbite, *Tc* talc, *Vtr* vaterite (abbreviations according to Whitney and Evans 2010); ND: not determined. EFT: equivalent firing temperature. **k**: kiln furniture

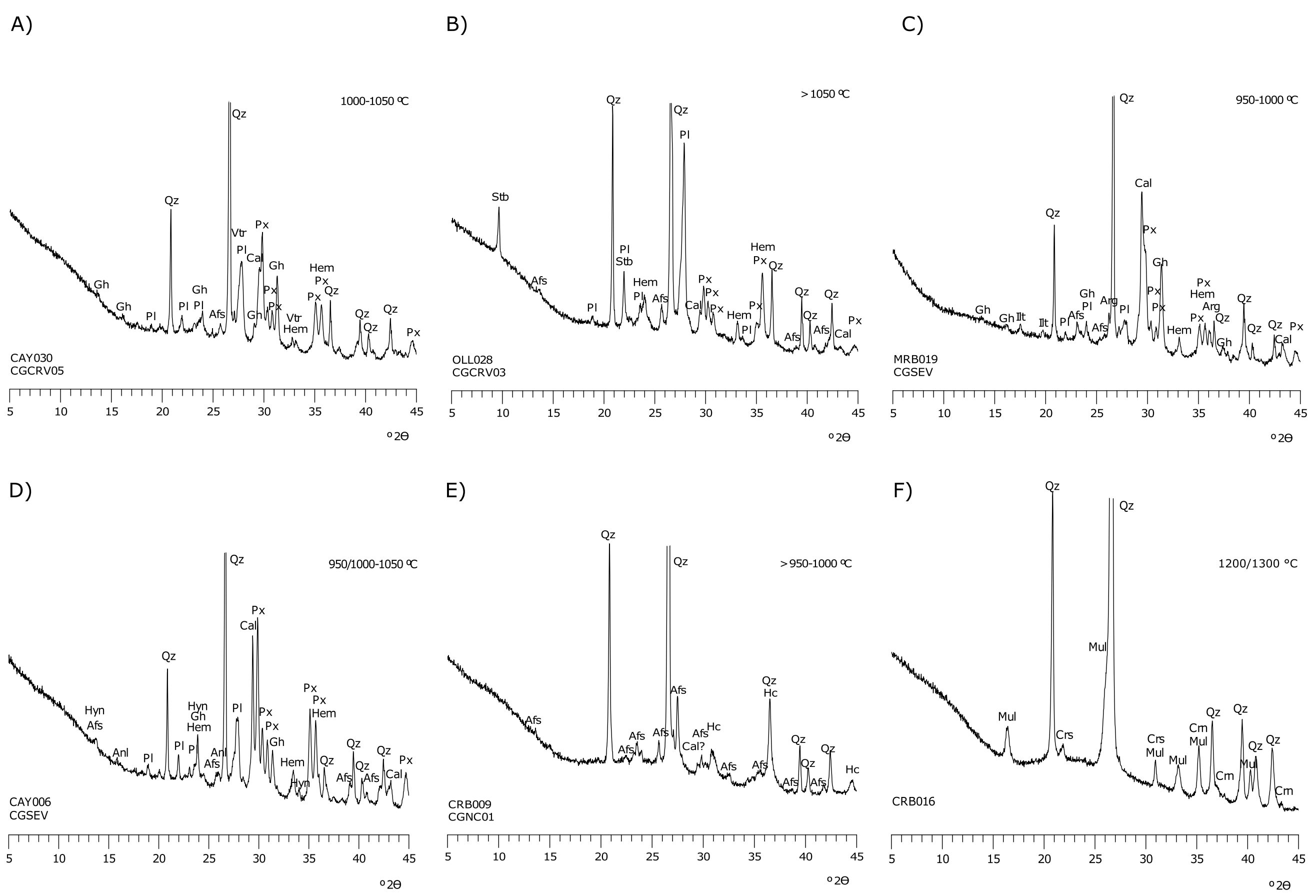

Fig. 8 XRD patterns for the categories of association of crystalline phases as detected by XRD. **a** individual OLL28, group CGCRV03 (C), fabric F6; **b** individual CAY030, group CGCRV05 (C), fabric F4; **c** individual MRB019, group CGSEV (C), fabric F3; **d** individual CAY006, group CGSEV (C), fabric F9; **e** individual CRB009, group CGNC01 (LC), fabric F4; **f** individual CRB016, loner. *Anl* analcime, *Cal* calcite, *Crs* cristoballite, *Gh* gehlenite, *Hem* hematite, *Ilt* illite-muscovite, *Afs* alkali feldspar, *Mul* mullite, *Pl* plagioclase, *Px* pyroxene, *Qz* quartz, *Sp* spinel, *Tc* talc (abbreviations according to Whitney and Evans 2010)

Fig. 9 **a** Photographies of representative ceramics for each one of the Cordoban reference groups. **b** Drawings of representative ceramics for each of the Cordoban reference groups, corresponding to photographs in (**a**). Drawings for individuals MRB010, 021, and OLL007 are not provided as the fragments correspond to an undefined part of the vessel

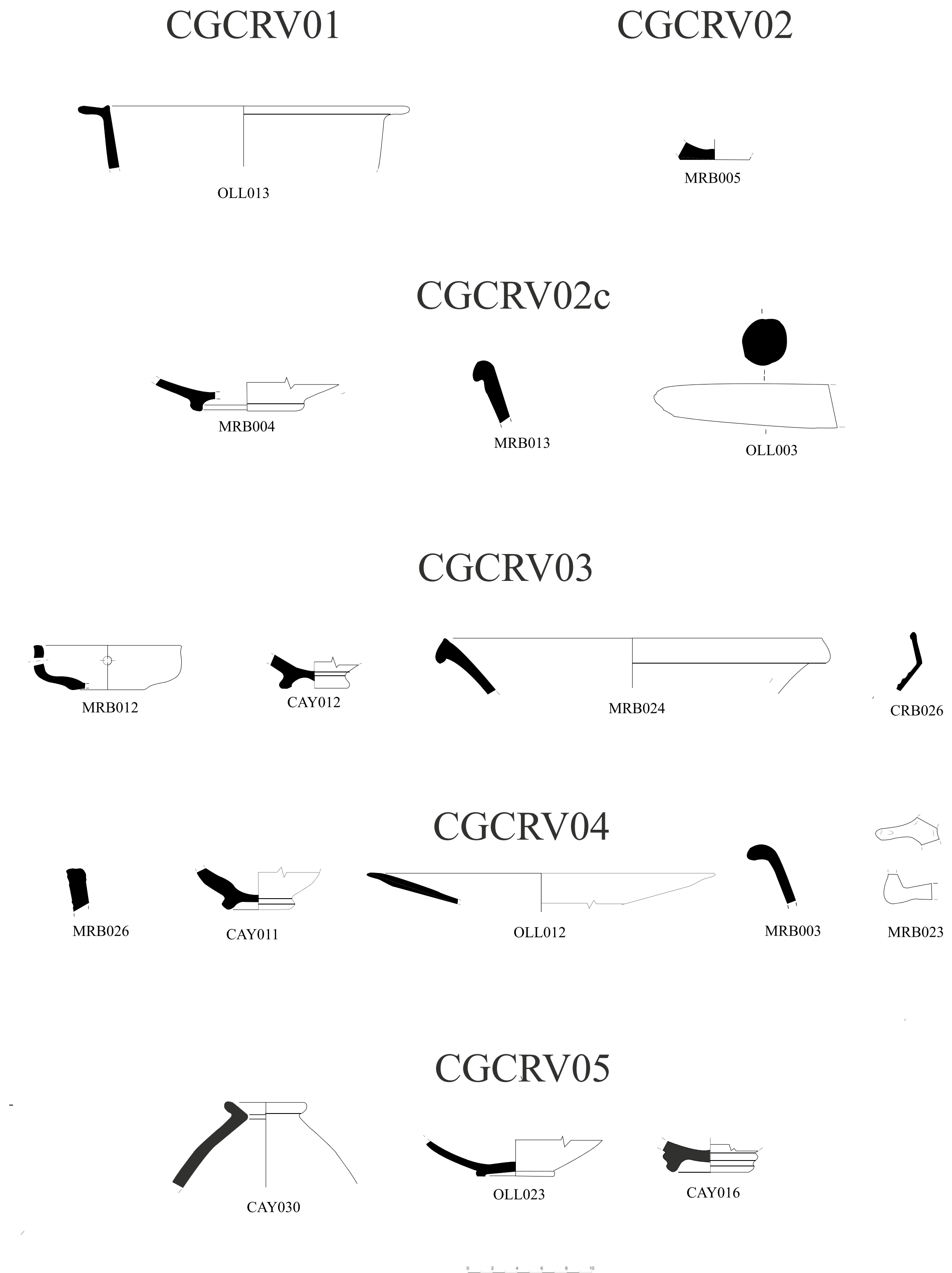

Fig. 9 (continued)

probably, from such alteration processes. The individual CAY020 (fabric F6) exhibits the same mineralogy by XRD plus vaterite, another secondary phase, and the EFT is estimated at 950/1000–1050 °C. A similar situation happens to individual CAY008 (fabric F7) with the mineralogy of fabric F5, but exhibiting stilbite, another secondary phase, and having the same EFT. The fabrics F8 (OLL015 and 017) and F9 (CAY006), in contrast to fabric F5, do not exhibit hematite, but they contain andradite and haüyne (Fig. 8d). The latter phase belongs to the sodalite group and corresponds to an intense peak at 3.72 Å (23.89°2θ) that seems to be its $d_{(211)}$ peak (I % = 100) (JCPDS #01-078-2490; $Na_4Ca_2Al_6Si_6O_{22}S_2(SO_4)Cl_{0.5}$). Individual CAY006 also exhibits low intense peaks of analcime. The EFT estimated for fabrics F8 and F9 is 950/1000–1050 °C. The last Sevillian fabric, F10 (CRB013), is similar to fabric F5 without hematite and gehlenite. The estimated EFT is over 1050 °C.

Regarding the importations from Granada, the calcareous group CGGRA, the 5 individuals are classed in two different fabrics. Fabric F1 (CRB004, 005, 008 and 022) exhibits the presence of clear firing phases, pyroxene and gehlenite, together with illite-muscovite enabling estimating the EFT at the 850–950/1000 °C range. Fabric F2 (CRB021) only differs because of analcime, enabling estimating the EFT in the same range as F1.

If we turn now our attention to the groups of unknown origin, the low calcareous group CGNC01 shows four different fabrics. The fabrics F1 (CRB012) and F2 (CRB025, 027 and 028) do not exhibit any clear firing phase. Since low calcareous ceramics undergo few mineralogical changes, the EFT can only be estimated below 900/950 °C. The difference between both fabrics is the possible presence of talc in individual CRB012, a mineral phase that dehydorxylates between 800 and 895 °C (Liu et al. 2014). The other three individuals correspond to fabrics F3 (CRB010) and F4 (CRB009 and 014), exhibiting clear firing phases besides the decomposition of illite-muscovite. The estimated EFT is above 950/1000 °C. In fabric F3, hematite and spinel can be observed, pointing to an oxidising environment, while in fabric F4, the presence of hercynite (Fig. 8e; Fig. 10a, CRB009) indicates a strong reduction environment at high temperatures.

All individuals in the calcareous group of unknown origin CGNC02 belong to one fabric, F1 (CAY004, CRB006 and 024). The estimated EFT is in the 950/1000–1050 °C range due to the absolute absence of illite-muscovite and the presence of gehlenite.

Finally, focusing on the three loners, we can see that the calcareous individual OLL009 must have an EFT estimated over 950/1000 °C due to the decomposition of illite-muscovite. On the contrary, the calcareous individual CRB015 shows lower EFT (850–950/1000 °C) because of illite-muscovite and clear firing phases, especially pyroxene and gehlenite. The individual CRB016 is an entirely different case (Fig. 8f). This individual is porcelain, implying a completely different technological solution in ceramic products. The presence of mullite, cristoballite and corundum enables estimating an EFT of 1200/1300 °C.

In summary, we can highlight all the ceramic sherds, except individuals MRB024 (calcareous group CGCRV03, fabric F4) and CRB009 and 014 (low calcareous group CGNC01, fabric F4), appear to be fired under mainly oxidising atmospheres.

Considering the local products, low-calcareous groups tend to have lower EFTs than the calcareous ones and those individuals showing higher EFTs (> 950/1000 °C) generally correspond to kiln elements and glazed ceramics. Calcareous groups show a very different range of temperatures, from 800 to 850 °C to above 1050 °C, without a clear difference between glazed and unglazed ceramics. Although corresponding to production centres, only two sherds (OLL001 and MRB013, group CGCRV02c, fabric F3) can be considered overfired. However, as expected, most elements of kiln furniture show high EFTs. Finally, it must be highlighted that the only two examples of tin-lead glazed vessels produced in Córdoba (group CGCRV05: OLL023 (Fig. 9a), fabric F2, and CAY009, fabric F3) have an EFT between 950–1000 and 1000–1050 °C.

If we turn our attention to the imports, Sevillian ceramics are mainly tin-lead glazed individuals with high EFTs between 950/1000–1050 °C. Some differences in the mineral composition can be observed as they come from different reference groups. Nevertheless, the homogeneity in the temperatures proves a good knowledge of the technical process. Lower EFTs correspond to unglazed sherds, even if an example of an overfired ceramic has been identified in CRB013, a green-glazed bowl. Imports from Granada are also very homogeneous (EFT between 850/950–1000 °C in all cases), and the same can be stated for ceramics corresponding to the groups CGNC01 and CGNC02, demonstrating the quality of the imported products.

Discussion

Integrating the results of the archaeometric analysis with the archaeological evidence, we can observe that the defined local reference groups (Fig. 9a and b) have a chronological and functional coherence. From the fourteenth to the sixteenth centuries, four different calcareous reference groups are documented ($\overline{X}_{CaO}$ in chronological order: CGCRV03 –6.66%–, CGCRV05 –19.12%–, CGCRV04 –11.15%–, CGCRV02c –8.10%–), while we only detect the presence of low calcareous products at the sixteenth, or even fifteenth, century ($\overline{X}_{CaO}$ in chronological order: CGCRV01 –1.15%–, CGCRV02 –2.36%–) (Table 4).

The calcareous group CGCRV03 (26 individuals) corresponds to the fourteenth–fifteenth centuries. This group integrates calcareous coarse ware (unglazed and honey glazed), storage and transport jars (unglazed and honey glaze), cooking pots (Fig. 9a and b, CRB026) and kiln

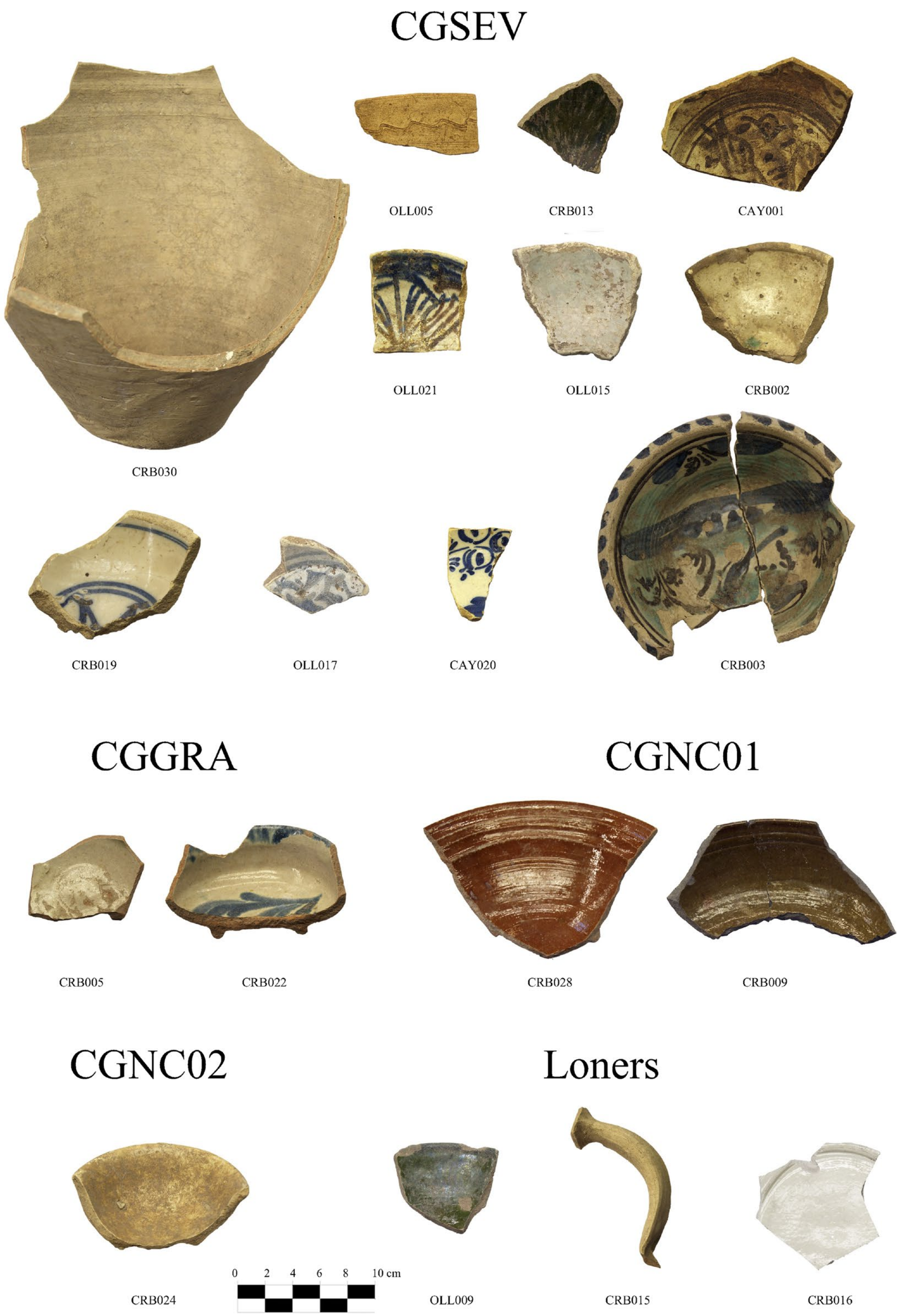

Fig. 10 **a** Photographies of representative imported ceramics recovered in the city of Córdoba. **b** Drawings of representative imported ceramics recovered in the city of Córdoba, corresponding to photographs in (**a**). Drawings for individuals CRB013, and 016 are not provided as the fragments correspond to an undefined part of the vessel

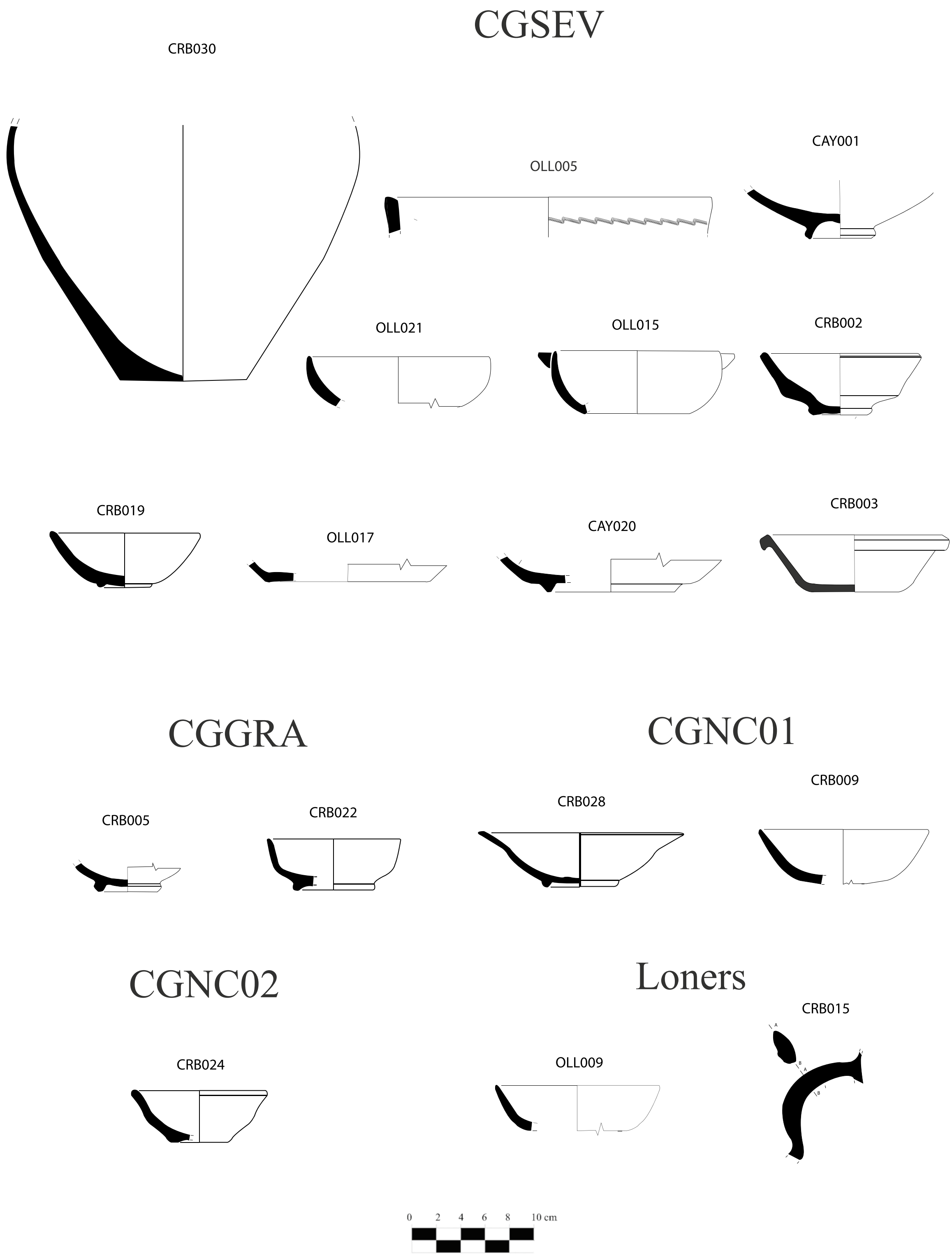

Fig. 10 (continued)

furniture (one saggar, Fig. 9a and b, MRB012). Among this group's products, we must highlight the presence of glazed ware that exhibits honey or honey/brown glaze at the interior and dark/black glaze at the exterior (OLL027, 030, MRB006, CAY012 and 013) (Fig. 9a and b, CAY012). The combination of two different colours for the interior and exterior of the glaze is a characteristic already in the Islamic pottery production of Córdoba (Salinas and Pradell 2018). Even if there are also ceramics of this group exhibiting a uniform dark/brown (OLL25 and 29) glaze or honey/brown (OLL026, 029 and CRB026) glaze in both sites, the individual CRB007 (from group CGCRV04) also shows this combination of two different colours in a consumption centre. This evidence suggests that the existence of ceramics with honey or honey/brown glaze at the interior and dark/black glaze at the exterior is intentional. Another interesting group of ceramics corresponds to plates (CAY028) and dishes (OLL010, CAY014, 015 and 017) with manganese decoration on honey glaze, also present in group CGCRV04 (dishes OLL012, 014) (Fig. 9a and b, OLL012). MRB024, a basin, is one of few ceramics fired under a reducing atmosphere (Fig. 9a and b). Finally, as expected in a production centre, some individuals are discarded waste. Thus, some of the coarse ware vessels are just biscuit pottery not yet glazed, while some of the bowls show holes in the bottom because of the breakage of their thinner parts.

The group CGCRV05 (18 individuals) seems to start in the fifteenth century, even if two individuals (CAY016 and 018) have a broader possible chronology in the fourteenth–fifteenth century. Nevertheless, the chronology given to these two individuals corresponds to a general approximation since the archaeologists did not find evidence suggesting a more tight chronology. Because of that, these two individuals have not been considered to establish an earlier chronology for the group. This group contains unglazed coarse ware, green glazed coarse ware, some storage and transport jars (Fig. 9a and b, CAY030 and OLL007) and some trivets (OLL018, 019 and CAY018). This group also contains the only two examples of tin-lead glazed sherds produced in the city of Córdoba: a bowl glazed in plain white (*blanca lisa*) (CAY009) and another one of Isabella Polychrome (*azul y morado*), decorated in blue and manganese on a white background (Fig. 9a and b, OLL023). Interestingly, there was no evidence of tin-lead glazed ceramic production in Córdoba, and ceramics of this kind recovered in the city were mainly thought to have come from Seville. The high CaO content of this group, the highest in the Cordoban products, could be explained by the attempt to produce tin-lead glazed vessels. Local products have only been identified in this group, and the CaO content seems to drop in the products that follow, once tin-lead glaze manufacture was possibly disregarded. Another interesting case is CAY016 (Fig. 9a and b), which exhibits two different glaze colours, with turquoise blue in the interior and green in the exterior. Finally, CAY023 corresponds to a flowerpot, a ceramic type most probably inspired by Islamic ceramics (Barceló and Rosselló 1996) that was very successful in the Late Middle Ages and the early modern period in cultivating basil and other culinary spices (Serra 2021).

The group CGCRV04 (14 individuals) is active in the fifteenth–sixteenth century, but as in the previous group, one individual (CAY011) also exists with a broader possible chronology in the fourteenth–fifteenth century. The group comprises coarse ware (green glazed and unglazed) (Fig. 9, MRB011 and 003) and trivets (MRB016 and 023) (Fig. 9a and b, MRB023). This group shares with CGCRV03 the existence of honey/brown glaze at the interior and dark/black glaze at the exterior (CRB007), and honey glaze with manganese decorations (OLL012, 014) (Fig. 9a and b, OLL012). Finally, one individual also has a yellow glaze on the interior and green on the exterior (Fig. 9a and b, MRB026), representing this tradition of two different colours in the glaze again.

The last calcareous group, CGCRV02c (4 individuals), is related to the low calcareous CGCRV02 (3 individuals) but contains higher levels of CaO. These two groups seem to be contemporary to the low calcareous group CGCRV01 (6 individuals), whose chronology must be centred to the sixteenth century, even if Avenida Ollerías, 14 site has been roughly dated back to the fifteenth century. This rough chronology affects the three groups, including a few individuals from this site. These three groups comprise kiln furniture (CGCRV02c, the kiln rods OLL001 and 003; CGCRV02, the kiln rod OLL002; CGCRV01, the trivet MRB029) (Fig. 9a and b, OLL003), glazed (Fig. 9a and b, MRB004 and MRB005) and unglazed (Fig. 9a and b, MRB013 and MRB010) coarse ware (including a cheese dish, Fig. 9a and b, OLL013), and one cooking pot (Fig. 9a, MRB021).

Although Córdoba cannot be thought of as a massive production centre, some products manufactured there have been found in other areas in the South of the Iberian Peninsula. During the comparison with our data bank, we identified two ceramics, PRI011 and VLM040, belonging to the CGCRV05 reference group (Fig. 5). The individual PRI011 corresponds to a dish decorated with an interior yellow glaze and an exterior green glaze (similar to Fig. 9a and b, MRB026, group CGCRV04) recovered in a context of the seventeenth century found in the city of Priego de Córdoba, in the border between the kingdoms of Granada and Córdoba. Therefore, we can infer that glazes of two colours were also manufactured in group CGCRV05, even if not detected in Córdoba itself. The individual VLM040 is an unglazed pitcher found in the town of Villamartín, in the area of Cádiz (in Western Andalusia), in a context roughly dated from the fifteenth to the seventeenth centuries. Along these lines, we must highlight that no similarities have been observed with the transport jars of hypothesised Cordoban origin recovered from the Tortugas shipwreck (Hughes 2014).

As expected, most of the importations (Fig. 10a and b) have been found in the consumption centre of Casa Carbonell, although some of them have been profusely recovered in several Cordoban workshops too. Sevillian imports

(CGSEV) have been found in all archaeological sites, both production and consumption centres. Group CGSEV represent 25.83% of the individuals sampled in Córdoba (31 out of 120), going up to 33.33 % in Casa Carbonell (10 out of 30), the only consumption centre. These figures demonstrate a remarkable dependence on this production centre during the late medieval and early modern periods. Although most of the ceramics imported from Seville are tin-lead glazed vessels, some examples of transport jars, storage vessels and coarse ware individuals have been identified. Coarse ware imports contain both unglazed and glazed individuals, including an unglazed basin (Fig. 10a and b, OLL005), a salt-cellar (OLL011) and a bowl (MRB019) (all these from the fifteenth–sixteenth centuries), as well as a green-glazed bowl (Fig. 10a, CRB013) (dated back to the seventeenth–eighteenth centuries). Regarding transport and storage jars, two examples of storage jars (MRB001 and 002) and a water container (Fig. 10a, CRB030) have been identified (sixteenth–eighteenth centuries). Regarding tin-lead glazed ceramic imports, a great variety of forms and decorations have been found in Cordoban archaeological sites dating from the fourteenth to eighteenth centuries, proving the well-established tradition of tin-lead glaze production in Seville and its distribution. The most ancient examples of tin-lead glazed vessels correspond to a bowl (Fig. 10a and b, CAY001) and a basin (CAY019) decorated in manganese on white (fourteenth–fifteenth centuries). Other types are also present: (i) a bowl or dish (CAY003) and a plate presenting Sevilla blue on white decoration (*azul sobre blanco*) (fourteenth–sixteenth centuries) (Fig. 10a and b, CAY020); (ii) a bowl decorated in lusterware and blue (*loza dorada y azul*) (Fig. 10a and b, OLL021) (fifteenth century); (iii) 3 dishes (Fig. 10a and b: OLL017; 022 and CAY002) and a bowl or dish (CAY006) of Santo Domingo blue on white (*azul figurativa*) (fifteenth–sixteenth centuries); (iv) plain whiteglaze (*blanca lisa*), which is the most common abundant, in bowls (Fig. 10a and b: OLL015; CAY021 and CRB023), dishes (CAY005 and 007) and plates (CAY008) (fifteenth–eighteenth centuries); (v) three examples of blue and green basins (MRB014, 015 and Fig. 10a and b, CRB003) (sixteenth–eighteenth centuries); (vi) 3 dishes (CRB001, 018 and 020) and a bowl (CRB017 and Fig. 10a and b, CRB019) presenting Yayal blue decoration (*azul lineal*) (seventeenth–eighteenth centuries); and, finally, (vii) a green and white bowl (*verde sobre blanco*) (Fig. 10a and b, CRB002) (seventeenth–eighteenth centuries). As said before, Sevillian imports form a vast group corresponding to several reference groups. Nevertheless, most ceramics show an estimated EFT between 950/1000–1050 °C (coherent with the technical requirements of this kind of pottery), while estimated EFTs below 1000 °C tend to correspond to other kinds of ceramics like coarse ware or transport and storage vessels.

Imports from Granada (CGGRA) have only been identified in Casa Carbonell consumption centre and are characterised by showing important concentrations of Fe_2O_3 ($\overline{X}$= 6.40%, Table 4) and Al_2O_3 ($\overline{X}$= 17.31%). These concentrations are typical of the chemical composition of Granada, as observed in an ongoing study of the production centres in this city. Technically, this group is homogeneous, containing only two fabrics with an estimated EFT between 850 and 950/1000 °C. As a distinctive feature of the ceramics produced in Granada, it must be noted that illite-muscovite peaks do not disappear, although clear firing phases such as pyroxenes and gehlenite, together with secondary phases such as analcime, can be observed (Table 5). That is explained by the characteristic metamorphic geology of the area of Granada, which is extremely rich in phyllite and schists providing abundant micas to the ceramic paste (Carvajal and Day 2015). Archaeologically, the imports from Granada recovered in Córdoba are mainly tin-lead glazed vessels dating from the seventeenth to the eighteenth centuries. In particular, an unglazed dish (CRB008), a plain white dish (CRB004) and a plain white bowl (Fig. 10a and b, CRB005). Also, two examples of bowls decorated with blue leaf motifs (Garzón 2004: 477, Fig. 468) correspond to the traditional local production of Fajalauza (CRB021 and Fig. 10a and b, CRB022). All these ceramics belong to a unique reference group related to *el Realejo* quarter, one of the main production areas in the city of Granada. According to ongoing studies about ceramic production in Granada, this workshop would be active from the fifteenth to the eighteenth centuries, demonstrating continuity between the Nasrid and the Christian periods in ceramic manufacture. However, we have not identified imports from Granada before the seventeenth century.

Low-calcareous group CGNC01—only found in Casa Carbonell consumption centre—comprises 5 glazed dishes and 2 glazed bowls showing high levels of MnO ($\overline{X}$= 0.24%, Table 4), and its origin is still unknown. It is interesting to note that, even their general homogeneity, some differences in the colour of their pastes and glazes can be appreciated. That phenomenon could be explained because of the differences in their mineralogic composition (Table 5). While most individuals exhibit reddish-brown pastes and honey-brown glazes (Fig. 10a and b, CRB028), individuals CRB009 and 014—from fabric F4—exhibit dark-grey pastes and deep-green glazes (Fig. 10a and b, CRB009). Mineralogically, some of the reddish-brown pastes contain hematite in their composition due to a primarily oxidising firing (CRB010 and, possibly, CRB028). Nevertheless, this mineral phase cannot be found in dark-grey pastes, which may be related to a reducing firing, as reflected by maghemite in CRB014 and hercynite in both individuals, and the diffusion of Fe^{2+} ions into the glaze must cause the colour of the glazes. Thus, primarily oxidising firing produces reddish pastes and honey-brown glazes, while reducing firing produces dark pastes and green glazes (Molera et al. 1997). Nevertheless, these evident colour differences in such a homogeneous set of imported ceramics are difficult to explain from the customer's point of view.

Chemical group CGNC02 has been identified in Casa Carbonell consumption centre and the Hornos de San Cayetano workshop. This group is by far the most calcareous one in this study ($\overline{X}$ = 30.09%, Table 4), and its provenance cannot be identified at the moment. This group comprises three plain white glazed bowls dating from the modern period (Fig. 10a and b, CRB024). All the individuals are technically homogeneous as they correspond to a unique fabric (F1). The estimated EFT for this entire group is considerably high (950/1000–1050 °C), as corresponds to tin-lead glazed ceramics, demonstrating an important knowledge of the manufacturing process for this kind of ceramics.

Finally, three individuals could not be linked to any reference group. These loners are a green-glazed bowl (Fig. 10a and b, OLL009), a coarse ware handle (Fig. 10a and b, CRB015) and a porcelain sherd (Fig. 10a, CRB016).

According to the archives, the first porcelains arrived in Europe from China between the fifteenth and the seventeenth centuries, during the Ming dynasty (1368–1644). These porcelains were, at first, imported for the Portuguese market, and they arrived in the Castilian Crown during the Habsburg period (Dias et al. 2013; Krahe 2014). Concerning their characterisation, instrumental neutron activation analyses (INAA) show important amounts of Na_2O ($\overline{X}$ = 1.25%) and K_2O ($\overline{X}$ = 3.35%)—and low quantities of Fe_2O_3 ($\overline{X}$ = 1.19%)—for Chinese porcelains arriving in Portugal during this period (Dias et al., 2013). High concentrations of Na_2O and K_2O are necessary as fluxes, while low quantities of Fe_2O_3 and TiO_2 are needed to obtain white bodies. Nevertheless, individual CRB016 does not correspond to the characteristics of these porcelains, as Na_2O and K_2O compositions are lower in this sample (0.34% and 1.31%, respectively). The chemical composition of CRB016 would match better with some examples of porcelain produced during the previous Sui-Tang (581–907) and Song-Yuan (960–1368) dynasties. Their compositions have been determined by XRF analyses (Na_2O, $\overline{X}$ = 0.37%, and K_2O, $\overline{X}$ = 1.62%). However, Fe_2O_3 and Al_2O_3 quantities are higher in this kind of porcelain (Fe_2O_3, $\overline{X}$ = 1.29% and Al_2O_3, $\overline{X}$ = 29.47%) (Leung et al. 2000) than in individual CRB016 (Fe_2O_3 = 0.84%, and Al_2O_3 = 23.97%). The same occurs if we compare individual CRB016 with other examples of coarse white porcelains dated from the Sui-Tang period (Lu et al. 2012) and with several proto-porcelains recovered from Pre-Qing archaeological contexts (before 1644) (Wu et al. 2009). Because of its exceptionality, the provenance of CRB016 cannot be identified. Nevertheless, its chronology is determined by the archaeologists in the seventeenth–eighteenth centuries. Technically, the low values of flux elements make us think that individual CRB016 reached very high temperatures, estimating its EFT above 1200/1300 °C.

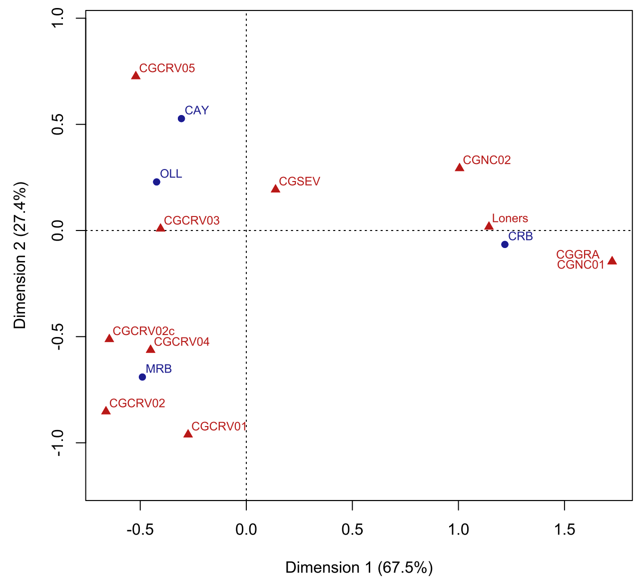

Fig. 11 Biplot of the correspondence analysis between the archaeological sites sampled (in blue) and the reference groups defined (in red). OLL: Avenida Ollerías, 14; CAY: hornos de San Cayetano; MRB: Ronda Marrubial; CRB: Casa Carbonell

The distribution of the sampled archaeological sites according to the defined groups has been studied by employing correspondence analysis. The resulting biplot (Fig. 11) explains 94.9% of the total inertia and shows a clear differentiation between the production sites to the left and the consumption centre of Casa Carbonell to the right. The former attracts the local reference groups, while the latter attracts all the imports and loners, but Sevillian ceramics are placed in a middle position. This differentiation is significative—χ^2 (30, n = 120) = 88.792, $p = 1 \times 10^{-6}$—and reflects that, except for Sevillian products, almost all other importations and loners have been recovered at Casa Carbonell. Moreover, it also appears that Casa Carbonell does not consume a significant number of local products (just 4 out of 30) (Table 2). On the left side, we can also observe a differentiation between groups CGCRV03 and, especially, CGCRV05, attracted by Hornos de San Cayetano and Avenida Ollerías, 14, and all other groups, attracted by Ronda Marrubial. Excluding Casa Carbonell, the loners and all imports except from those coming from Seville, differentiation is also significant—χ^2 (12, n = 88) = 22.37, p = 0.034—showing a trend that links the older groups (fourteenth–fifteenth centuries) to the production sites of Hornos de San Cayetano and Avenida Ollerías, 14, while, the later ones (fifteenth–sixteenth centuries) with Ronda Marrubial.

Conclusions

The present study has enabled us to define the widely known Cordoban ceramic production between the late medieval and early modern periods and study some aspects of the change-continuity phenomenon regarding the previous Islamic times. Moreover, the importations in Córdoba are evidence of the relations between this city and its nearest kingdoms. Finally, it has been proved how some Cordoban products were arriving in other areas of both Kingdoms of Córdoba (Priego de Córdoba) and Seville (Villamartín, Cádiz), but no evidence of Cordoban imports to the Americas has been found.

Local production and imports during the modern period

Although three production centres have been sampled (Avenida Ollerias, 14, Ronda Marrubial and Hornos de San Cayetano), no significant differences have been identified regarding the type of pottery manufactured in each workshop. Nevertheless, some tendencies have been noticed regarding the chronology of the ceramics, being Hornos de San Cayetano and Avenida Ollerías, 14 more active in the fourteenth–fifteenth centuries, and Ronda Marrubial workshop in the fifteenth–sixteenth centuries. Nevertheless, the proximity of the three workshops does not allow to rule out the possibility that all of them were part of a larger complex located in the *Barrio de las Ollerías*.

Concerning the local production in Córdoba, six reference groups have been defined: CGCRV01, CGCRV02, CGCRV02c, CGCRV03, CGCRV04 and CGCRV05. The pottery produced in these workshops shows differences mainly related to CaO and Sr content (Table 4). These differences could be related to the information given by the archives (Córdoba de la Llave 1990: 325-326), which underline the existence of two different types of potters. On the one hand, the *olleros* produced mainly cooking ware by using unmixed clays from different outcrops. According to the 1529 ordinances, these clays were collected from *Valdeleche* and *Rabanales* meadows, but in 1545 the ordinances explain how the activity moved to *Guajardo* domain, of better quality. These clays possibly correspond to the *barro bermejo* (red clay) that, according to the archives, was used for cooking ware. On the other hand, the *tinajeros* produced transport and storage jars. All ceramics not intended for cooking wares were made by mixing red clays and *barro blanco* (white clays), a yellowish clay producing buff colours after firing. Transport and storage jars seem to have been produced by mixing one part of red clay and five parts of white clay, while dishes, jars and other utilitarian wares used two parts of red clay and one part of white clay. Assuming that our group CGCRV01 represents one of these red clays, we have performed a simple calculation assuming that group CGCRV05 corresponds to combining five parts of white clay with one part of red clay. In this way, even if we do not know the initial composition of the white clay, group CGCRV05, clearly dominated by it, is its best close approximation. Using the means of these groups in a two parts proportion of group CGCRV01 and one part of group CGCRV05, we obtain calculated means for this mixture that closely conform to the means of group CGCRV03 (Table 4). All calculated values are close to the observed means of this group within one standard deviation (only MgO deviates + 1.5 standard deviations). Thus, the defined reference groups for Córdoba seem to agree with the archive information on pottery production in this town. The difference in the CaO content could at least refer to the distinction between red (CGCRV01 and CGCRV02) and white clays (CGCRV03, CGCRV04 and CGCRV05) with mixtures at different proportions. Concerning calcareous groups (CGCRV02c, CGCRV03, CGCRV04 and CGCRV05), the differences in the CaO content seem to be related to the kind of pottery produced: honey-glazed coarse ware tends to be related to less calcareous compositions and green-glazed coarse ware to more calcareous compositions. It is important to highlight that large storage and transport jars mostly belong to group CGCRV05, the most calcareous one. Finally, neither historical documentation nor archaeological studies mention tin-lead glazed ceramic production at Córdova. However, we have identified such products in group CGCRV05: OLL023 (Fig. 9a and b) (Isabella polychrome, or *azul y morado*, bowl) and CAY009 (Plain white, or *blanca lisa*, bowl). Due to their exceptionality and low quality may be interpreted as tests, but we cannot discard that tin-lead glazed vessels were really produced.

About the imports found in Córdoba, it must be remarked that Sevillian ceramics were present in the city during all the medieval and modern periods, becoming the principal provider of tin-lead glazed vessels at Cordoba. This situation shows Córdoba's political and economic dependence on Seville since the Christian conquest and the role of Seville as the main production centre of tin-lead glazed ceramics in Europe during the Modern Era. Nevertheless, since the seventeenth century, importations from Granada (mainly plain white and Fajalauza tableware) and the unknown groups CGNC01 and 02 (this could also be present from the fifteenth century) started appearing in Córdoba.

Influence of the Islamic tradition

This study has also given information about the Islamic cultural legacy in the late medieval and early modern Cordoban ceramic production. In this sense, several honey-glazed plates and dishes presenting organic and geometric decorations in manganese have been studied (OLL010, 012–Fig. 9a–and 014; CAY014, 015, 017 and 028). The decorations are usually placed around the border, although sometimes they appear as central motifs. Manganese on honey designs like those has only been studied for Seville as a decoration from the Islamic tradition (Amores and Chisvert 1992, p. 290). In the case of Córdoba, the analyses conclude that manganese on honey ceramics found in the city correspond to local productions related to reference groups CGCRV04 and CGCRV05. The local examples found in Córdoba may also have an Islamic origin, as an inheritance of the first glazed productions identified in the caliphal palace complex of Madīnat al-Zahrā. The manufacture of manganese on honey vessels during the Christian period has been related to the Moorish potters (Córdoba de la Llave 1997, p. 354). In the framework of this PhD Thesis, other examples of manganese on honey dishes and plates have also been sampled in different archaeological sites of the Kingdom of Granada (Granada and Castillo de Montejícar), responding to local productions too. That would mean that it was a decoration that originated in the Early Middle Ages and was still used during the Late Middle Ages and the early modern period, not only in the city of Seville but also in other points of the current region of Andalusia. In addition, many bichrome individuals (showing combinations of honey and dark brown, green and yellow-honey and turquoise-blue and green surfaces in the same individual) have been identified as local productions, too (CGCRV03, 04 and 05 reference groups, Fig. 9a CAY012, MRB026 and CAY016). These bichrome products were also found in other places (PRI011 to Priego de Córdoba). The combination of yellow and green glaze has been identified in Córdoba as a distinctive local production since the very first times of the Islamic occupation, during the Emirate period (eighth–tenth centuries), although the production of glazed ceramics in al-Andalus did not start until the late ninth century at the earliest (Salinas and Pradell 2018). Finally, the Islamic legacy is also present in the ceramic types. Thus, the Christian Cordoban plates show a clear continuity with the previous Islamic *ataifor* (Amores and Chisvert 1992, p. 290), serving bowls used for collective eating without individual dishes. During the Christian period, the *ataifor* is kept, but just as a serving plate, and individual dishes and bowls appear. Another continuity is observed in the presence of flowerpots, a ceramic type that originated in the Islamic period. Finally, some kiln furniture—like kiln rods—has been identified in early modern stratigraphic contexts, showing a relationship with the Islamic world, where these kinds of kilns originated.

Although almost 300 years had elapsed since the Christian conquest of the city, there existed still an evident legacy of the Islamic material culture in Modern Córdoba. Thus, the cultural context of ceramic production in Córdoba considerably differs from other close cities like Seville. In this case, the commercial expansion of the Castilian Crown after the conquest of the Americas turned Seville into the most important ceramic production and distribution centre in Europe, where craftsmen from all over Europe established their workshops. For example, some of the most important ceramists in Seville in this period were the Italian potters Niculoso Pisano and Tomás Pesaro (Buxeda et al. 2015). Consequently, Seville became a reference point in the manufacture of tin-lead glazed vessels, a symbol of the European Renaissance. In this sense, Seville can be considered a dynamic city, open to global trade and influenced by the new ideas and aesthetics emerging in all of Europe. On the contrary, Córdoba, even if integrated into the broader network since the Christian conquest that will be the centre of the Atlantic expansion, could instead have a role as a part of the hinterland and a region more enclosed within itself compared to the Atlantic commercial cities. Córdoba became a regional ceramic production centre that received less immigration and fewer external influences. Thus, traditional production techniques and ceramic forms inherited from the Islamic times remained. To summarise, the cases of Seville and Córdoba illustrate how two close cities conquered at the same time (1236 for Córdoba and 1247 for Seville) developed different social and cultural traits because of their different economic and demographic contexts. Moreover, this example also shows how the ceramic products reflect these realities, as material culture cannot be studied without knowing the social, cultural and historical context of the people who manufactured and used the objects.

Continuity of the research

The future research in this city and the other archaeological sites sampled in this Doctoral Thesis project will help us identify their role as both production and distribution centres. The next step in the research, which is already in progress, is the evaluation of the technical aspects using Optical Microscopy and Scanning Electronic Microscopy. For example, the characterisation of glazes and pigments used for the decorations, to know more about the complex world of the activity of making pottery during this period. This knowledge will be used to learn more about the transition between the Islamic period and Christianisation, identifying the elements that remained and those that were substituted along the time, providing information about the cultural and technological change in a modern society with an important Islamic medieval legacy.

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Data availability All data is available in the main document or referenced publications.

Declarations

Ethics approval and consent Ethics approval is not applicable. The Museo Arqueológico y Etnológico de Córdoba (Spain), and the Delegación Territorial de Cultura y Patrimonio Histórico en Córdoba (Consejería de Fomento, Infraestructuras y Ordenación del Territorio, Cultura y Patrimonio Histórico of the Junta de Andalucía) consents to the use of the ceramics sampled in the museum facilities for destructive analyses and the publication of the results.

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