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REVIEW

The ceramic productions of Puente de Santa Bárbara: a Bell Beaker metallurgical centre in the Almanzora Basin (Huércal-Overa, Almería, SE Spain)

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Abstract

Puente de Santa Bárbara (Huércal-Overa, Almería) is a fortified settlement (1.5 ha) dating from the Middle and Late Copper Age. It is near Cerro Minado, a copper mine known for its high arsenic content according to chemical results obtained by XRF analyses. Excavations at Puente de Santa Bárbara unearthed a great amount of evidence of metallurgical activity suggesting the site's specialisation in the production of metal tools and small ingots that were transported to other more important settlements of the Lower Almanzora Basin such as Almizaraque. Twenty ceramic samples of varying typology, including four crucibles, served to characterise the Santa Bárbara production. The main group, according to mineralogical and petrographic analyses, were produced locally. They respond to the demands of the local population which included, as evidenced by the crucibles, metallurgical production. The finds of certain red-slipped vessels, in turn, were probably produced elsewhere, notably at Almizaraque.

Keywords SE Iberia · Copper Age · Bell Beakers · Ceramic technology · Petrographic analyses · Colourimetric analyses · Image analyses · Technological choices

Introduction

Ceramics are the first artificial or synthetic object produced by humans, fashioned by simply exposing clay to fire, an action that modifies the physical and chemical properties of clay. This fact allows ceramic studies to apply the same analytical methods and techniques as those serving in geological research. Nevertheless, there is a fundamental difference as ceramics served specific demands: pottery for food processing and storage and crucibles for metal production. Due to their common use and resistance to erosion, these artefacts are recurrent (albeit often altered or fractured) among the archaeological record since the Neolithic (Berducou 1990).

Moreover, independent of their state, ceramics allow archaeologists to establish typologies and characterise cultures as they are fundamental in identifying technological and cultural changes. In other words, these finds can yield relevant data as to the provenance of their clays, firing temperatures, and production techniques as well as offer information as to social and commercial relations between groups and communities.

A variety of data can be gleaned through different analyses, especially when archaeological artefacts, as is the case of

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those of the current study, are collected in contextualised and stratified contexts. This study therefore characterises the ceramic production of a small fortified mining settlement located in the Almanzora Basin in the Andalusian Municipality of Huércal-Overa (Almería) dating to the Middle and Late Chalcolithic. The study adopts as polyhedral approach resorting to macroscopic, microscopic and mineralogical analyses to obtain as much data as possible as to the manufacture techniques at a settlement revealing evidence of metallurgical specialisation. Despite its great fragmentation, the ceramic materials offer the possibility to identify a number of regional ceramic production strategies, a subject that remains to date poorly explored for Chalcolithic period (Galván Martínez 1995; Galván Martínez and Galván García 1993; Del Pino et al. 2019). This type of research is equally scarce in other areas of southeastern Iberia such as the Lower Vinalopó (González Prats et al. 1992-94), the Plain of Granada (Dorado et al. 2017; Vico 2016; Vico et al. 2018) and the Guadix-Baza-Huéscar Plateau (Pinillos de la Granja 2019). This study therefore intends to fill this research gap by defining the strategies and operational sequence of ceramic fabrication at Santa Bárbara.

The settlement of Puente de Santa Barbara and the context of its ceramic production

The fortified settlement of Santa Bárbara occupies a plateau overlooking the Almazora River (Fig. 1). Its northwestern orientation follows the same pattern as that of other settlements identified in the region for this period. Its topographical setting allows a visual control of the thoroughfares between the Vera River Valley and the Upper Almanzora Valley lowlands. The first archaeological surveys here were carried out in the early 1990s in the framework of the Research Project *Los inicios de la metalurgia en la cuenca del río Almanzora* (Camalich et al. 1993, 1998). The early work, financed by the General Directorate of Cultural Heritage of the Junta of Andalucía and co-directed by Mª D. Cámalich Massieu and D. Martín Socas, identified the site and, given the its significance, bolstered the necessity of undertaking archaeological work. The construction of the Puerto Lumbreras-Almería motorway, a direct threat to the site, ultimately led to two rescue operations in 1991 financed by the enterprise charged with the construction.

The archaeological intervention at Santa Bárbara brought to light a fortified settlement extending over a surface of 1.5 ha dated to the Middle and Late Chalcolithic (3000/2900-2200/2150 cal BC) (Mederos Martín 1995:84; Molina et al. 2004:155–156). Evidence of metal working was identified around one of its major defensive structures, a semicircular bastion (González Quintero et al. 2018:77 fig. 4, 81, fig. 11). Analyses of four samples (29.8, 27.7, 10.1, 9.94% As) as well as a metal drop (6.66% As) indicate a copper with high arsenic content suggesting it was mined at Cerro Minado situated about 3 km to the NE on the opposite bank of the Almanzora River. The chemical analyses of the materials and debris of Santa Bárbara and Cerro Minado mine (Table 1) were carried out by portable X-ray fluorescence by means of Innov-X Alpha in metal measurement mode. The acquisition times of the spectra were set at 40 s, and the equipment was previously calibrated for metal analyses. The quantitative values are corrected with the fundamental parameter method by software with virtual standards. The anode is Ag so the detection limit for silver -Ag- and antimony -Sb- is 0.20%, while that of the remaining elements is 0.02%.

The chronological framework of this mine is based on a series of stone pickaxes and hammers from a level dated by ^{14}C to 3905±21 BP (Delgado Raack et al. 2014:30) equating with 2466-2301 cal BC at 2σ (recalibrated with Calib 8.1, Reimer et al. 2020) which corresponds to an early phase (circa 2500 BC) of the Late Chalcolithic. The population at Puente de Santa Bárbara during the Bronze Age must shift about 600–700 m to the Cerro de San Miguel to take advantage of this hill's better natural defensive features.

The pottery from Santa Bárbara can be classified typologically into the following seven groups (Fig. 2): small cups (type I), bowls (type II), deep bowls (type III), Bell Beaker cups (type IV), plates (type V), plates with an inward lip (type VI) and storage vessels (type VII) (Dorado et al. 2020). All can be linked to different productions identified at other settlements in the surroundings. It is nevertheless arduous to correlate these finds specifically with other settlements from the Middle and Late Chalcolithic due to the scarcity of morphometric studies for this period. Analogous research has only been carried out at two Late Chalcolithic sites in the south of the Iberian Peninsula (Vico 2016) notably at two sites in the Province of Granada: Cerro de la Virgen (Orce) (Molina et al. 2017; Pinillos de la Granja 2019) and Los Castillejos (Montefrío). At Los Castillejos (Vico 2016), a site with few Bell Beaker finds (Arribas and Molina 1977, Arribas and Molina 1979; Vico et al. 2018), there are no small cups (type I). Maritime and impressed ware at Los Castillejos are nonetheless in phase IV which lines up with the Millares II sequence. Moreover, its phase V comprises Ciempozuelos type Bell Beaker characteristic of the Late Chalcolithic. The scarcity of these types has led the authors to advance that they may be imports from elsewhere in the Granada Plain (Vico et al. 2018: 48) such as nearby El Manzanil (Fresneda Padilla 1980: pl. XVIII, Fresneda Padilla 1983: 137; Carrilero 1991) or Cerro de la Encina (Dorado et al. 2017) where finds of this type are more common. Cups (type II) and plates (type V), on the other hand, reveal parallels with types II, III, and VIII respectively of the Castillejos assemblage. Noteworthy is the practical absence of any type of storage vessel, a

Fig. 1 Location of the Copper Age settlement of Puente de Santa Bárbara (Huércal-Overa, Almeria, Spain) and other sites cited in the text

potential sign of the site's specialisation in metal working (González Quintero et al. 2018).

Although the study of the decorated Bell Beaker finds of Cerro de la Virgen, the second site in Granada serving as for comparison, is only preliminary, certain parallels between the assemblages of the two sites have nonetheless been identified. They are associated, possibly due to the geographical proximity of the sites, with level II (Schüle 1980, 1986; Molina et al.

Table 1 Chemical results obtained through XRF on materials from Santa Bárbara (SB) and debris from the Cerro Minado mine (CM) expressed in % (from González Quintero et al. 2018:83) (Supplementary material: mineralogical results by means XRD)

Analysis number	Type	Site	Number of inventory	XRF results												
				Fe	Ni	Cu	Zn	As	Ag	Sb	Pb	Bi	Ti	Mn	Co	Others
PA25245	Crucible	SB	SB-91-25/155	4.94	0.06	0.45	0.03	0.07	n/d	n/d	0.01	n/d	0.39	0.03	0.14	93.86
PA25246	Crucible	SB	SB-91-1-248	6.86	n/d	0.54	n/d	0.03	n/d	n/d	n/d	n/d	0.78	0.06	n/d	91.7
PA25247	Crucible	SB	SB-91-1/399	4.99	n/d	7.76	0.12	0.64	n/d	n/d	0.01	0.01	0.24	n/d	n/d	86.21
PA25248	Metal drop	SB	SB-sn-1	3.79	0.07	89.1	0.3	6.66	n/d	n/d	0.07	n/d	n/d	n/d	n/d	n/d
PA25249	Mineral Cu	SB	Sb-sn-2	3.26	1.16	92.0	2.07	0.89	n/d	n/d	n/d	n/d	n/d	n/d	0.66	n/d
PA25250	Mineral Cu	CM	SB-sn-3	17.2	n/d	51.6	0.67	29.8	n/d	0.34	0.07	0.28	n/d	n/d	n/d	n/d
PA25250B	Mineral Cu	CM	SB-sn-3	23.8	n/d	46.8	0.49	27.7	n/d	0.76	0.2	0.22	n/d	n/d	n/d	n/d
PA25251	Mineral Cu	CM	SB-sn-4	6.32	0.42	82.3	0.55	9.94	n/d	n/d	0.06	0.18	n/d	n/d	0.2	n/d
PA25252	Mineral Cu blue	CM	SB-sn-5	1.36	0.45	85.5	1.49	10.1	n/d	n/d	n/d	n/d	n/d	n/d	0.3	n/d
PA25253	Mineral Cu green	CM	SB-sn-6	0.98	0.17	30.0	0.51	0.14	n/d	n/d	n/d	n/d	n/d	n/d	n/d	68.09
PA25254	Mineral Cu blue	CM	SB-sn-7	1.48	0.08	9.03	n/d	0.12	n/d	n/d	n/d	n/d	n/d	n/d	n/d	89.25

2004) dated between 2500 and 2150 BC (Molina et al. 2017), a range that correlates the assemblage of Santa Bárbara with the Late Chalcolithic. Furthermore, the main thrust of the research on the Bell Beaker phase of Cerro de la Virgen is founded on the coexistence between examples of the first Maritime style and the local Bell Beaker style (Schüle's Phase II) among which is type IV from Santa Bárbara, a cup with no decor at the base and a low shoulder. Vessels with these geometric incised decors are known at almost all the large settlements of the Late Copper Age in the SE of the Iberian Peninsula including Los Millares (Arribas and Molina 1987), Terrera Ventura (Gusi and Olaria 1991: fig. 106-2) and Ciavieja (Carrilero and Suárez 1989–90: 127 fig. 11a). They are likewise in Granada at Cerro de la Encina (Dorado et al. 2017: 280 fig. 2-2) and El Manzanil (Fresneda Padilla 1980: pl. XVIII, Fresneda Padilla 1983: 137; Carrilero 1991). Other examples from Santa Bárbara also bear decors. The great degree of fragmentation and deterioration indicate nonetheless that they are not from primary contexts as they are usually unearthed in domestic or funerary contexts, and only in certain burials as at Los Millares (Arribas and Molina 1987; Molina and Cámara 2005; Afonso et al. 2011).

Geological framework

Puente de Santa Bárbara is in the Oriental Baetic Mountains in the Huércal-Overa Basin. It is framed to the north by the Sierra of Las Estancias, to the south by the Sierra de Almagro and to the east by Los Filabres. The area can be divided from south to north into four tectonic complexes: Nevado-Filábride, Ballabona-Cucharón, Alpujarride and Maláguide (Egeler and Simon 1962).

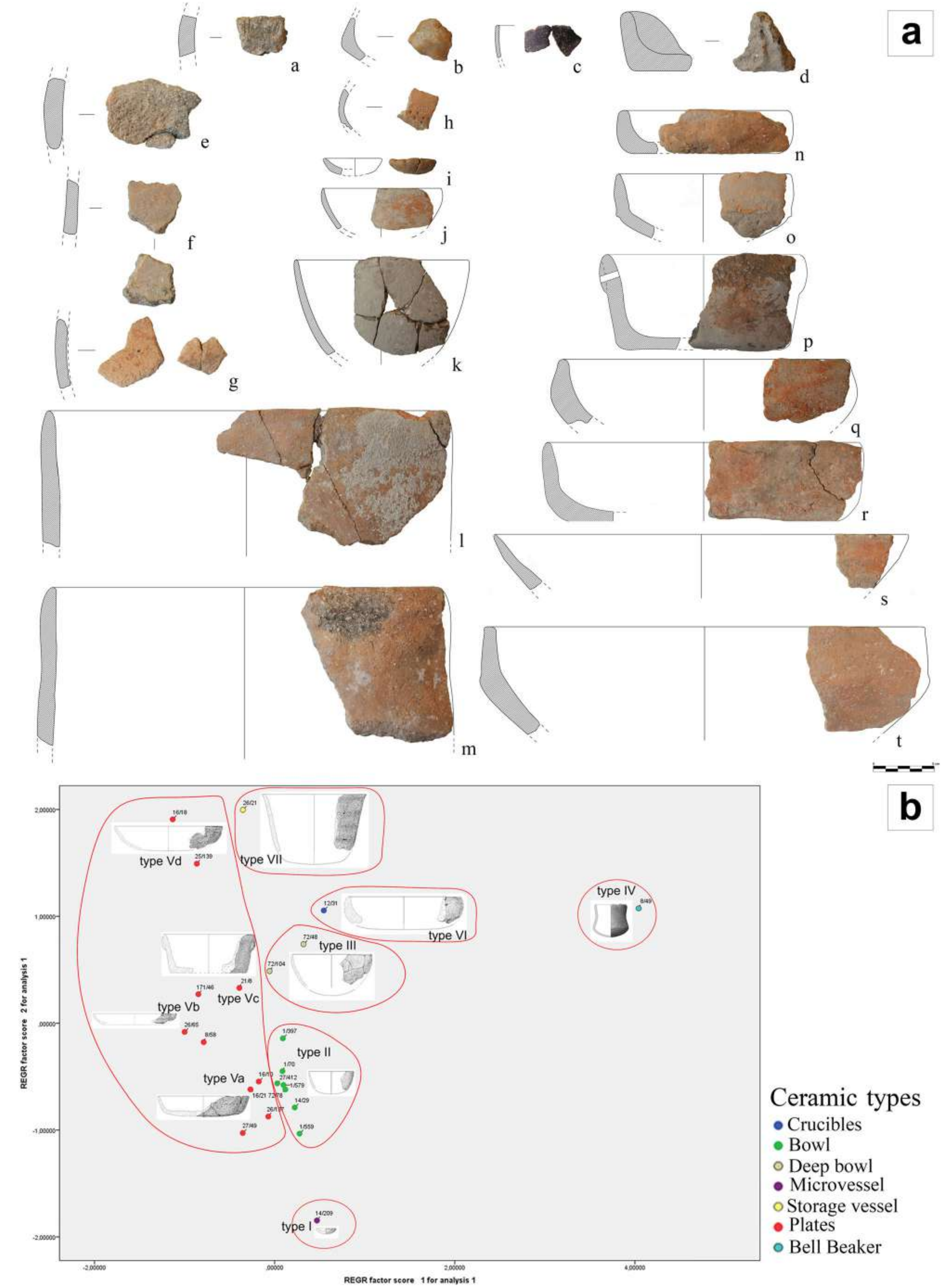
From the geological, the study area standpoint forms part of an EW and NE-SW tectonic indent that determines the sedimentation, drainage and metamorphic elements (Fig. 3) and presents two large lithological groups (García-Meléndez et al. 1997). The main units of mica-schists, quartzites, fillites, limestones and dolomites are interspersed with gypsum, slate, sandstones and greywackes in the Sierra of Almagro and marbles in the Cerro de Limaria. These outcrops are mainly linked to the Alpujárride tectonic complex and in part to the Maláguide and Nevado-Filábride complexes (Sierra de Almagro and Limaria). They are grouped into different formations and tectonic units and on the whole greatly deformed and fractured along differing orientations.

The second set of materials is that of the sedimentary infill of the Huércal-Overa Basin corresponding to Miocene alpine tectonic deformations. Its lithology consists of conglomerates, breccias and marls inter-layered with gypsum, sandstone, reef limestones and travertine, gravel, lime and clay.

Materials and methods

To obtain an optimal characterisation of the ceramic productions of the site, this study opted to implement a series of different techniques intended to identify the *chaîne opératoire* applied by the ancient potters (Rye 1981; Calvo et al. 2004; Livingstone Smith 2007; De la Fuente 2017). The

Fig. 2 The Puente de Santa Bárbara ceramic artefacts: **a** The assemblage under study: microvessels (b and i), plates (n, o, p, q and t), bowls (c and j), crucibles (a, e and f), double crucible (d), storage vessels (l and m), deep bowl with red slip (k) and other decorated sherds (g, h and s). **b** Morphometric schema of the different types (from Dorado et al. 2020) ▶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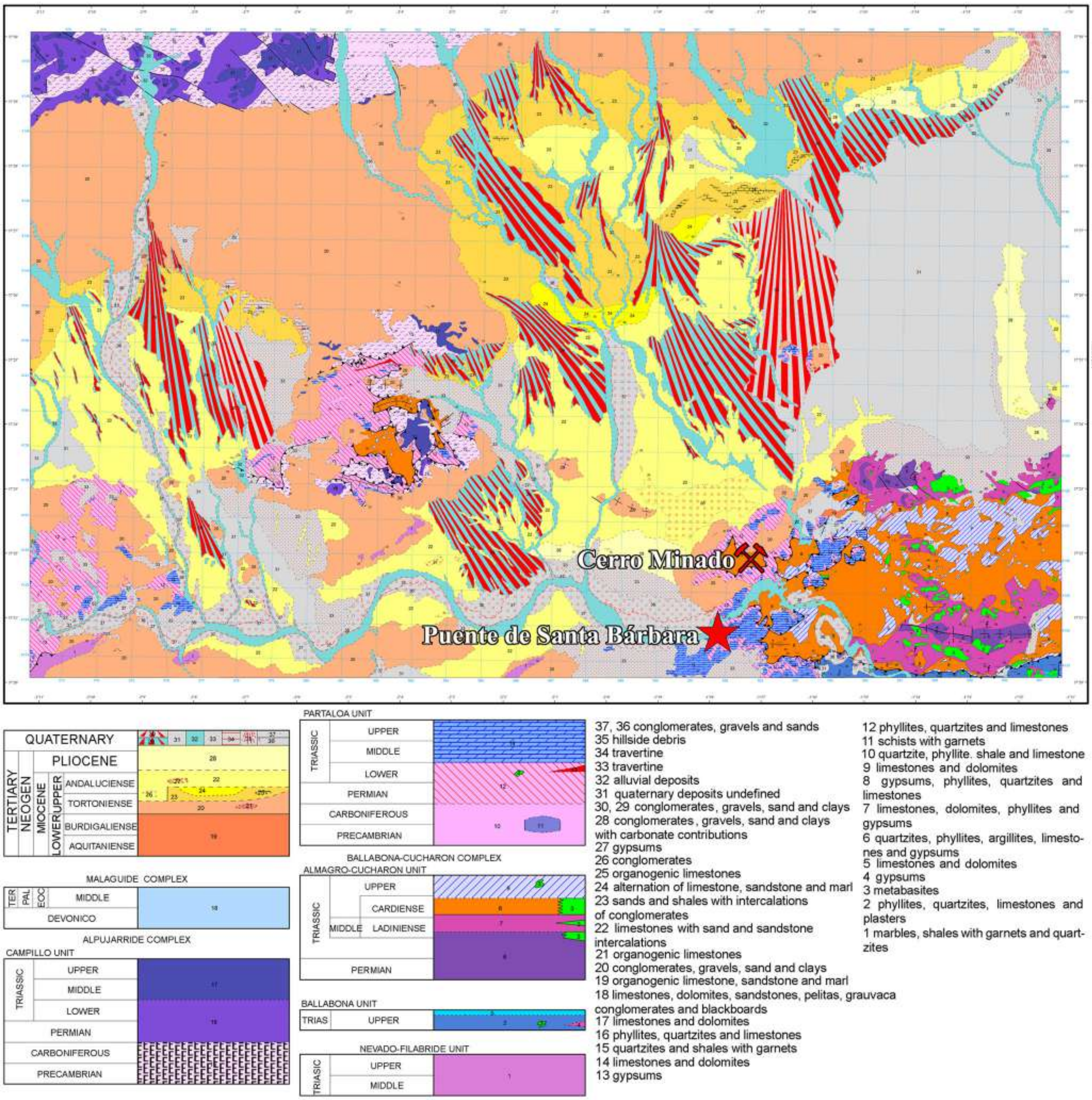


Fig. 3 Location of Puente de Santa Barbara in relation to the surrounding regional geology and lithologies (cartography base from the Instituto Geológico y Minero de España)

assemblage retained for analysis consisted of 20 samples (Table 2) representative of all the typological variants identified during the archaeological intervention (González Quintero et al. 1993; Dorado et al. 2020). It comprises four crucibles (SB-91-25/155, SB-91-1/248 and SB-91-1/399), one of which is double (SB-91-7-1/42), three bowls of varying size (SB-91-1/579, SB-91-1/617 and SB-91-1/397), two small cups (SB-91-14/209 and SB-91-10/16), two storage vessels (SB-91-26/148 and SB-91-1/557-564-596) and a series of plates and platters of varying size (SB-91-25/139, SB-91-26/137, SB-91-17-1/46, SB-91-21/8, SB-91-12/31 and SB-91-27/49). It also consisted of two red-slipped vessels (SB-91-17/5, SB-91-17-1/88 and SB-91-1/397 too) and a small fragment of an impressed and incised symbolic vessel (SB-91-21/23).

So as to attain a complete overview of the production strategies, the study began with a micro-trace analysis intended to define fabrication techniques (Roux 1994; Forte 2013–14, 2020; Forte et al. 2020). This included an analysis of the topography of a vessel's surface and its clay matrix to pinpoint

Table 2 Listing in the samples analysed in the present study, indications of their form and selection criteria (with no shape), firing atmosphere and the types of analyses: *M*, binocular microscopy; *Col*, colourimetry; *XRD*, X-ray diffraction; *ThS*, thin section; *SEM*, scanning electron microscopy

Register identification	Form and selection criteria	Firing atmosphere	Type of analysis	
SB-91-10/16	Microvessel	M	M, Col, XRD, SEM	Fig. 2a.b
SB-91-12/31	Plate	O	M, Col, XRD, ThS	Fig. 2a.q
SB-91-1/248	Crucible	R	M, Col, XRD, ThS, SEM	Fig. 2a.e
SB-91-1/397	Deep bowl. Red slip	R	M, Col, XRD	Fig. 2a.k
SB-91-1/399	Crucible	M	M, Col, XRD	Fig. 2a.f
SB-91-14/209	Microvessel	M	M, Col, XRD	Fig. 2a.i
SB-91-25/155	Crucible	R	M, Col, XRD	Fig. 2a.a
SB-91-1/557-564-596	Storage vessels	O	M, Col, XRD, ThS, SEM	Fig. 2a.l
SB-91-1/579	Bowl	M	M, Col, XRD, SEM	Fig. 2a.j
SB-91/617	Bowl	R	M, Col, XRD, SEM	Fig. 2a.c
SB-91-17-1/46	Plate	O	M, Col, XRD	Fig. 2a.r
SB-91-17-1/88	No form. Red slip	O	M, Col, XRD, ThS, SEM	Fig. 2a.s
SB-91-17/5	No form. Red slip	O	M, Col, XRD	Fig. 2a.g
SB-91-21/23	No form. Decorated	O	M, Col, XRD, ThS	Fig. 2a.h
SB-91-21/8	Plate	O	M, Col, XRD	Fig. 2a.p
SB-91-25/139	Plate	O	M, Col, XRD, ThS	Fig. 2a.t
SB-91-26/148	Storage vessels	O	M, Col, XRD	Fig. 2a.m
SB-91-26/137	Plate	O	M, Col, XRD	Fig. 2a.o
SB-91-27/49	Plate	O	M, Col, XRD	Fig. 2a.n
SB-91-7-1/42	Double crucible	O	M, Col, XRD	Fig. 2a.d

potential faults when building the body. This was followed by detailed observations of the fractures and other features such as colour, brightness, grain size, temper and microtopography to identify the modelling techniques (moulding, simple hollowing out, coiling, etc.). Observations of stress lines and their dimensions also served to define surface treatments. Identification of surface slip, its loss during deposition or its quality was undertaken using the ImageJ software with the DStretch® plug-in. Although this method traditionally serves for rock art or painting research (Fernández Ruiz 2009; Herrera Maldonado 2009; Evans and Mourad 2018), it can also be applied to ceramics (Dorado Alejos 2018).

The study of the matrixes by means of textural analyses was carried out taking into account clay colour variations and various factors of the temper including identification, density, morphology as well as homogeneity of distribution (Capel and Delgado 1978; Velde and Druc 1999; Gámiz et al. 2013). The colourimetric analysis was meant to determine hue variations between the different productions so as to identify the firing strategies. The objective is to organise the samples in groups and add new data to the limited set of information yielded by the textural analyses (De la Fuente and Vera 2013: 265, note 3). The analyses were carried out on powdered ceramic samples by means of X-ray diffraction. So as to guarantee homogenous results, the fabric serving for the powder was extracted from the core (not the surface). The analyses were then carried out with a colourimeter PCE-CSM 2 with a silicon photodiode sensor, a capture geometry of 8/d and a LED source with blue light excitation. The colour range is CIE L*a*b*C*h with an error of ≤0.80 ΔE*ab. The values were then processed by means of a principal component analysis (Aitchison 1983, 1984).

The mineralogical characterisation of the 20 vessels (and the two red-slipped ware) was carried out by X-ray diffraction using a Bruker D8 Advance with a high-stability copper anode X-ray source, a source detector and a fast detector (Lynxeye) applying Bragg-Brentano geometry and Cu Kα radiation. The analyses were configured at θ–2θ, $\Delta\theta$=0.04° with a 1 s interval, 2θ = 5–70° at room temperature conditions (25 °C) using the traditional powder method (Moore and Reynolds 1989). The sample was pulverised in a mortar until obtention of optimum granulometry (60µ) and a working power of 40kV and 40 mA. The resulting diffractograms were then examined with the XPower software (Martín-Ramos 2006) and the data base PDF2 of the International Centre for Diffraction Data. The standard was quartz (Chisholm 2005) (PDF2 database, 85-0796: Quartz) quantified with the Reference Intensity Ratios (RIR) method (Chung 1974; Hubbard and Snyder 1988; Davis et al. 1990).

The mineralogical analyses were complemented by six thin sections observed with plane polarised light and crossed nicols and described following the modified system advanced by Whitbread (1995, 2016). This groups the samples according to their main features: inclusions, matrix and porosity (expressed as c:f:v) with 10μm serving as the limit between large and fine grain (Whitbread 1995: 371). On the other hand, the distribution of the grain size and the orientation of the components were estimated visually following the guidelines of Bullock et al. (1985), applying the same technique of identification of the frequency category according to Matthew et al. (1997). The six thin sections were selected in order to delve deeper into the findings of the previous techniques. This allowed features such as the origin of the calcium carbonate (primary or secondary) or the organisation of the minerals/ rocks in the matrix to be examined according to textural, colourimetric and technological groupings.

The microstructural characterisation was carried out on six samples with fresh fractures to observe the level of sinterisation and vitrification of the matrix, information that can relate to the estimated firing temperature obtained by X-ray diffraction (XRD). These analyses were carried out with a Carl Zeiss High Resolution SEM with Gemini (Fesem) emission field and a Schottky electron field emission source.

Results

Macrotraces and textural analyses

Despite the high degree of vessel fragmentation which restricts a thorough study of the modelling techniques, in particular that of a red-slipped cup (SB-91-17/5) and an impressed and incised cup (SB-91-21/23), the analysis identified four different pottery building techniques: simple hollowing out (pinching), moulding, moulding plus coiling and stretching from the base combined with coiling. The simple hollowing out technique corresponds to two bowls (SB-91-1/579 and SB-91-1/617), two small cups (SB-91-14/209 and SB-91-10/16) and a deep bowl (SB-91-1/397) (Fig. 4a). Its identification is based on the experimental work of Roux (2019) and Forte et al. (2020). The simple modelling technique generates small notches on the surface as a consequence of the pressure of the tips of the fingers. Furthermore, the fractures of vessels fashioned by this technique are always vertical, and their rim is irregular. Moulding, the second technique, is identified by means of macrotraces on a red-slipped cup (SB-91-17-1/88), a double crucible and two other crucibles (SB-91-7-1/42, SB-91-1/248 and SB-91-25/155) (Fig. 4b–d). Indicators of the technique are the series of imprints on the lower sections of the body and the barbs of clay where the vessel was in contact with the mould. Another characteristic is the irregularity of the wall thickness due to successive layers of clay serving to raise the body. Finally, a single storage vessel (SB-91-26/148) applied coiling, a technique that allows fashioning high vertical-walled vessels by the superimposition of tubular coils (Fig. 4e). This is identified due to the lack of treatment or finishing, leaving an irregular, even wavy, surface. The technique is also indicated by presence of horizontal fractures corresponding to the weak points between the coils.

A combination of techniques (moulding and coiling) is identified among a few plates of different typology (SB-91-26/137, SB-91-17-1/46, SB-91-27/49 and SB-91-25/139), a crucible (SB-91-12/31) (due to the thickness of its walls) and a storage vessel (SB-91-1/557-564-596) (Fig. 4f). In each of these cases, it is possible to identify the moulding technique by the lower section and by a raising of the walls by coiling. In only one case was the vessel built by modelling a lump of clay into a base which was then completed by coiling (SB-91-21/8) leading to a morphology differing from the others (Fig. 4g).

Surface treatments presumably are adopted to the function of the vessels. Burnishing resulting in anti-adherent properties, for example, is reserved for the inner and outer surfaces of small cups and bowls (Cuomo di Caprio 1985). Surface smoothing to the external surface of certain bowls, the most common technique among the assemblage, was reserved for plates, pots and crucibles. One of the more significant treatments was application of a slip represented by a thin layer of very fine clay with the objective of giving the vessel a particular aesthetic value as well as sealing its pores (Echallier 1984) (Fig. 5a–f). Only one case bears a decor consisting of impressions (made with the point of an awl) topped by a horizontal incised line (Fig. 5g). Lastly, traces of spatula are identified in the inner surface of pots. Another aspect worth highlighting is the alteration of certain surfaces stemming from their use in metal working as is in the case of crucibles bearing traces of slag (Fig. 5h) and metal drops (Fig. 5i).

Despite the variability of the modelling techniques, forms and surface treatments, the ceramic from Santa Bárbara is quite homogeneous as to its matrix and raw materials despite certain internal differences that lead to its being divided into two groups. The first consists of bowls and small cups, slipped and decorated ware (Fig. 6a–f). These reveal mica-schist, quartz and mica temper in proportions that oscillate between 2 and 10% of the total matrix (SB-91-1/397, SB-91-17-1/88, SB-91-17/5, SB-91-21/23 and SB-91-1/617) that are inferior to 1 mm, sub-rounded and rounded, well-ordered and oriented parallel to the wall. Organic temper is also at times present in small proportions (SB-91-14/209 and SB-91-10/16). This is indicative of a poor refinement of the raw material due to resorting to techniques such as decantation or levigation, techniques more common to more recent chronological phases (Coll Conesa 2000). The presence of small pellets or clay lumps is likewise indicative of a lower degree of kneading.

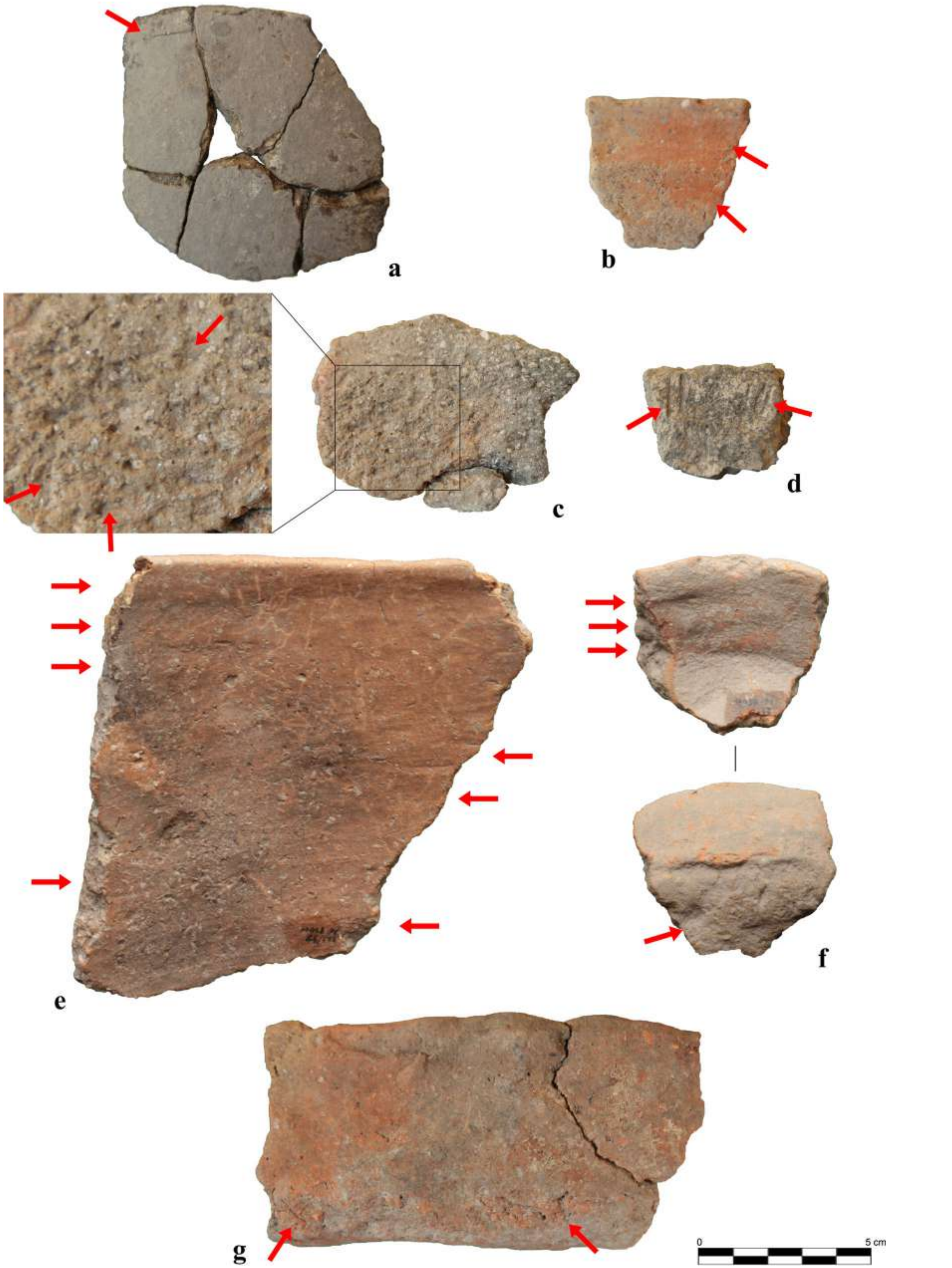


Fig. 4 Macrotraces identified according to the different modelling strategies: **a** hollowing (SB-91-3/397); **b**, **c**, **d** moulding (SB-91-17-1/88, SB-91-1/248 and SB-91-25/155); **e** coiling (SB-91-26/148); g combination of moulding and coiling (SB-91-26/137 and SB-91-17-1/46) (red arrows pinpoint the macrotraces evidencing the techniques)

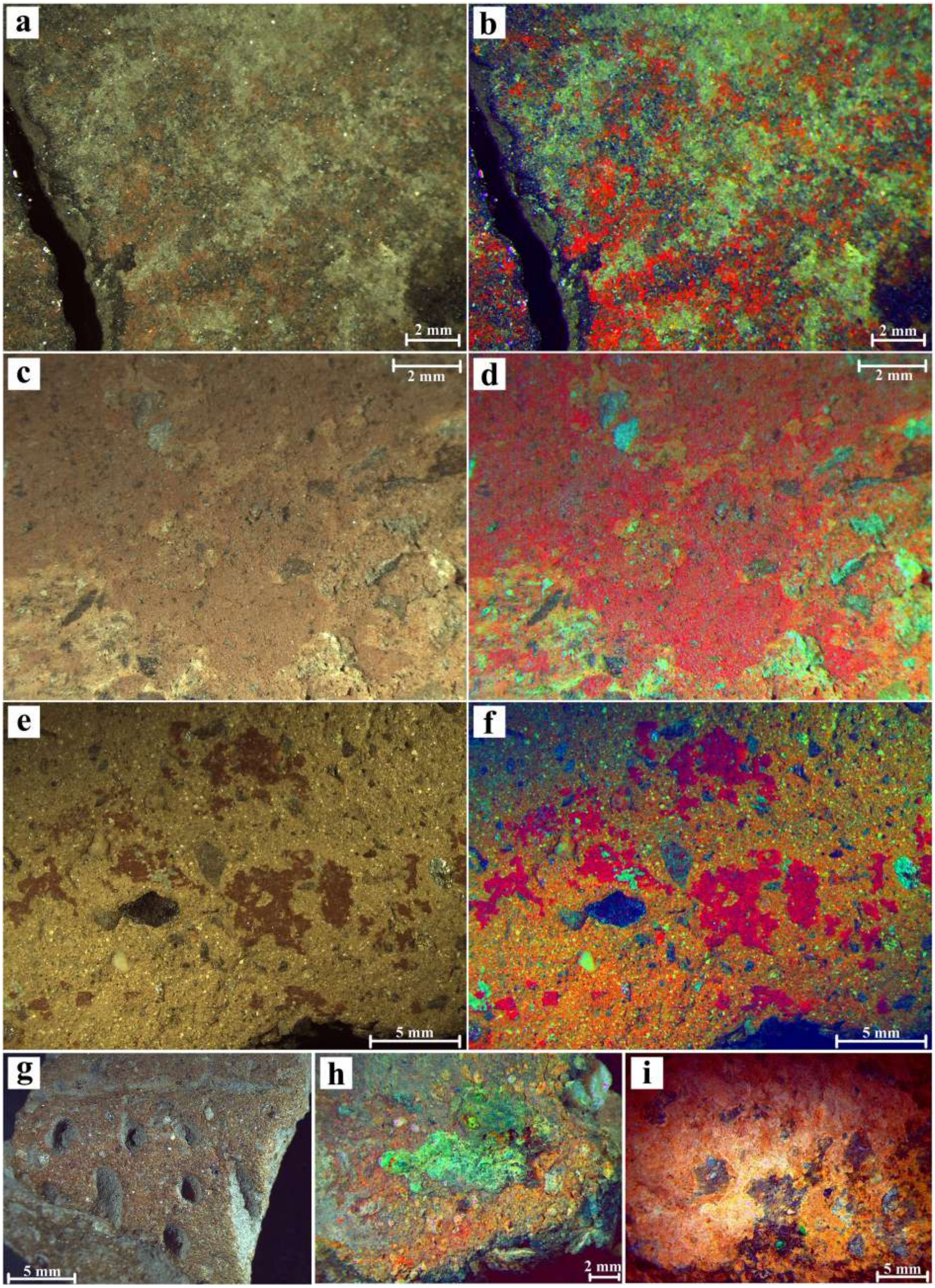


Fig. 5 Image analyses of three vessels (left, photograph without filters; right, rgb filter application) (**a**–**f**) and microphotograph of decors (**g**) and crucibles (**h**–**i**)

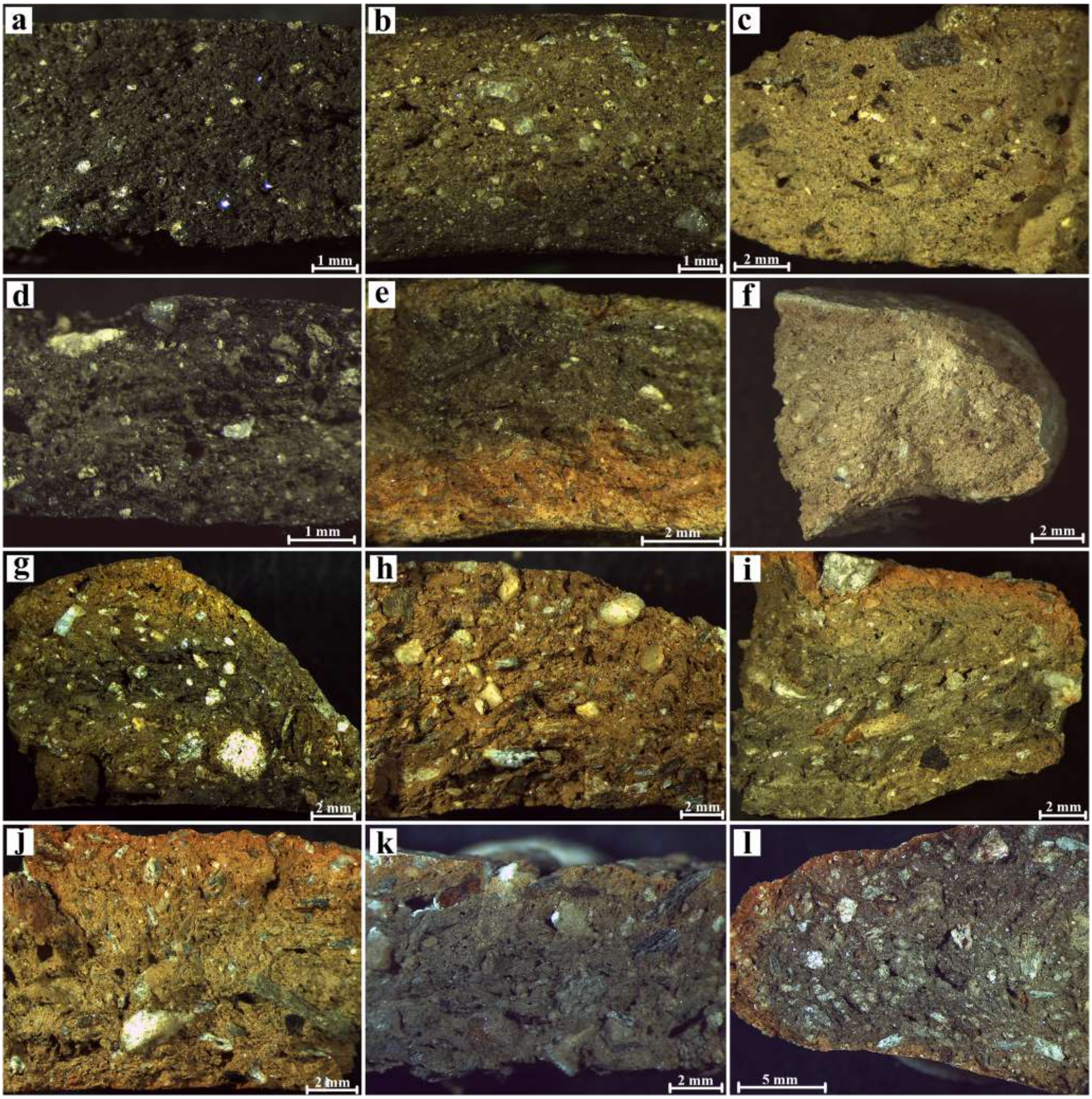


Fig. 6 Microphotographs corresponding to the two textural groups established through macroscopic analysis: **a**–**f** group 1: SB-91-14/29, SB-91-1/397, SB-91-17/5, SB-91-1/617, SB-91-14/209, SB-91-10/16; and **g**–**l** group 2: SB-91-26/148, SB-91-1/557-564-596, SB-91-26/137, SB-91-17-1/46, SB-91-21/8 and SB-91-25/139

The second group consists of larger vessels such as pots, storage vessels and crucibles (Fig. 6g–l) with temper similar to that of the previous. The difference is its higher density and larger size. It consists of subangular mica-schist, quartz and mica (SB-91-26/148, SB-91-1/557-564-596, SB-91-26/137, SB-91-17-1/46, SB-91-12/31, SB-91-21/8, SB-91-27/49, SB-91-25/139 and SB-91-7-1/42) ranging between 1 and 2 mm and representing between 15 and 30% of the body.

Colourimetric analyses

Each of the two ceramic groups comprise examples fired in different conditions yielding hues that range from orange-beige in the case of oxidising atmospheres to grey and black in the case of reduction. However, the tonality does not respond exclusively to firing strategies and can reflect factors such as chemical and mineralogical composition

(Klaarenbeek 1961; Kreimeyer 1987; Mirti 1998; Cultrone et al. 2011). Therefore, the colourimetric were therefore divided into five groups (Fig. 7a) that explain the internal variations of the Santa Bárbara assemblage (Fig. 7b). The first, the largest, presents higher A* c* and h* values and is mainly made up of plates and bowls, a single crucible and two pots (Table 3). The second, characterised by slightly lower A* c* and h* and slightly higher L* and b* values, comprises three plates, a small cup and a bowl. The third with higher A* c* and h* and lower b* values includes a bowl, a plate and a pot. Finally, groups IV and V, each made up of a single crucible, do not fall in line with the variations of the previous groups.

Mineralogical characterisation

The minerals of the samples were characterised by XRD. As stated above, it was not possible to identify substantial variations among the samples with the exception of certain crystalline phases (Table 4) such as paragonite mica which is present in small proportions (Martín-Ramos 1976). This phase is identified among other Argaric ceramic assemblages of the southeast of Iberia during the Early and Middle Bronze Ages (Albero and Aranda 2014), in the Late Bronze and Early Iron Ages (Dorado Alejos 2012, 2013; Sanna 2015) and in Roman times (Marín and Dorado 2014; Dorado and Marín Díaz 2018). The assemblage of Santa Bárbara is thus characterised by low values of chlorite identified in three samples with values that oscillate between 5.7 and 7%. As noted above, paragonite micas ($NaAl_2(Si_3Al)O_{10}(OH)_2$) are also recorded in ten of the samples with values ranging from 4.7 and 12.3%. Muscovite micas ($KAl_2(AlSi_3O_{10})(OH)_2$), in turn, are identified in almost all the samples with a mean of 16.07% (σ 5%). Its absence is recorded in only one of the crucibles (SB-91-25/155).

The variations identified among the phyllosilicates are recorded in other crystalline phases. This is the case of quartz (SiO_2) with mean values of 62% featuring nevertheless a high standard deviation of 11%. Among feldspars, potassium feldspar ($KAlSi_3O_8$) reveals relatively low mean values (4% or σ 1%) and is absent in the thick wall of a plate (SB-91-12-31). The plagioclase group ($(Na,Ca)(Si,Al)_3O_8$) is also common throughout most of the samples with values that vary between 3.8% for a small cup (SB-91-10-16) and 18.9% in one of the crucibles (SB-91-1-248). Therefore, it presents a slightly higher value than the potassium feldspars with means of around 7% (σ4%). This phase is once again absent only in the plate with the thick walls (SB-91-12/31). Finally, calcium carbonate and dolomite are secondary crystalline phases with the exception of the sample assigned to Fabric 2 whose origin is linked to bioclastic rocks.

Two XRD analyses were carried out on samples SB-91-17-1/88 and SB-91-17/5 with the intention of characterising the slip of different types of cups (Table 2). The first revealed low values of muscovite (7.9%) and quartz (21.8%), highlighting the absence of plagioclases (Fig. 8, top). It contains, on the contrary, higher proportions of potassium feldspar (9.6%), calcite (8.7%), dolomite (11.3%) and gypsum (14.1%). Noteworthy is the presence of haematite (Fe_2O_3) at 12.2% and maghemite ($Fe^{3+}{}_2O_3$) at 14.4% that would not have been identified if the total sample was pulverised. The second surface analysed also reveals differences when compared to the total pulverised sample (Fig. 8, bottom). There is, for example, no presence of muscovite, paragonite or plagioclases. The values of quartz (31.6%) and potassium feldspar (12.7%) are lower, while calcium carbonate appears in greater proportions (12.1%). Other phases such as dolomite (11.6%), haematite (14.3%) and maghemite (17.7%) are also present.

In sum, it is possible due to the identification of different crystalline phases to identify the firing strategies put to use to produce these ceramics. They are subdivided into three groups (Fig. 9). A first comprising most of the samples of the site corresponds to pieces fired below 700 °C (SB-91-10/16, SB-91-1/397, SB-91-14/209, SB-91-1/557-564-596, SB-91-1/617, SB-91-17/5, SB-91-21/23, SB-91-25/139 and SB-91-27/49). This group also includes the samples containing paragonite as this mineral begins to collapse at this temperature (Comodi and Zanazzi 2000). This explains the presence of chlorites in three cases where it would have disappeared at around 750 °C. The same destruction at around 700/800 °C takes place among the pieces with calcium carbonate and dolomite in the raw materials (Peters and Iberg 1978). This second group is less numerous and comprises the ceramics that are within the heat celling indicated by the presence of muscovite (SB-91-12/31, SB-91-1/248, SB-91-1/399, SB-91-1/579, SB-91-17-1/46, SB-91-17-1/88, SB-91-21/8, SB-91-26/148, SB-91-26/137 and SB-91-7-1/42) which disappears at 800 °C and above (Buxeda and Tsantini 2009). The same argument also serves to define the last group formed by a single crucible (SB-91-25/155). It is nonetheless necessary to highlight the lack of other high temperature phases represented by diopside ($CaMgSi_2O_7$), wollastonite ($CaSiO_3$) or gehlenite ($Ca_2Al_2SiO_7$) which appear between around 800/850 °C (Capel 1986: 116). It is therefore not possible to discard that muscovite in this case could have been absent among the raw materials serving to produce the crucible.

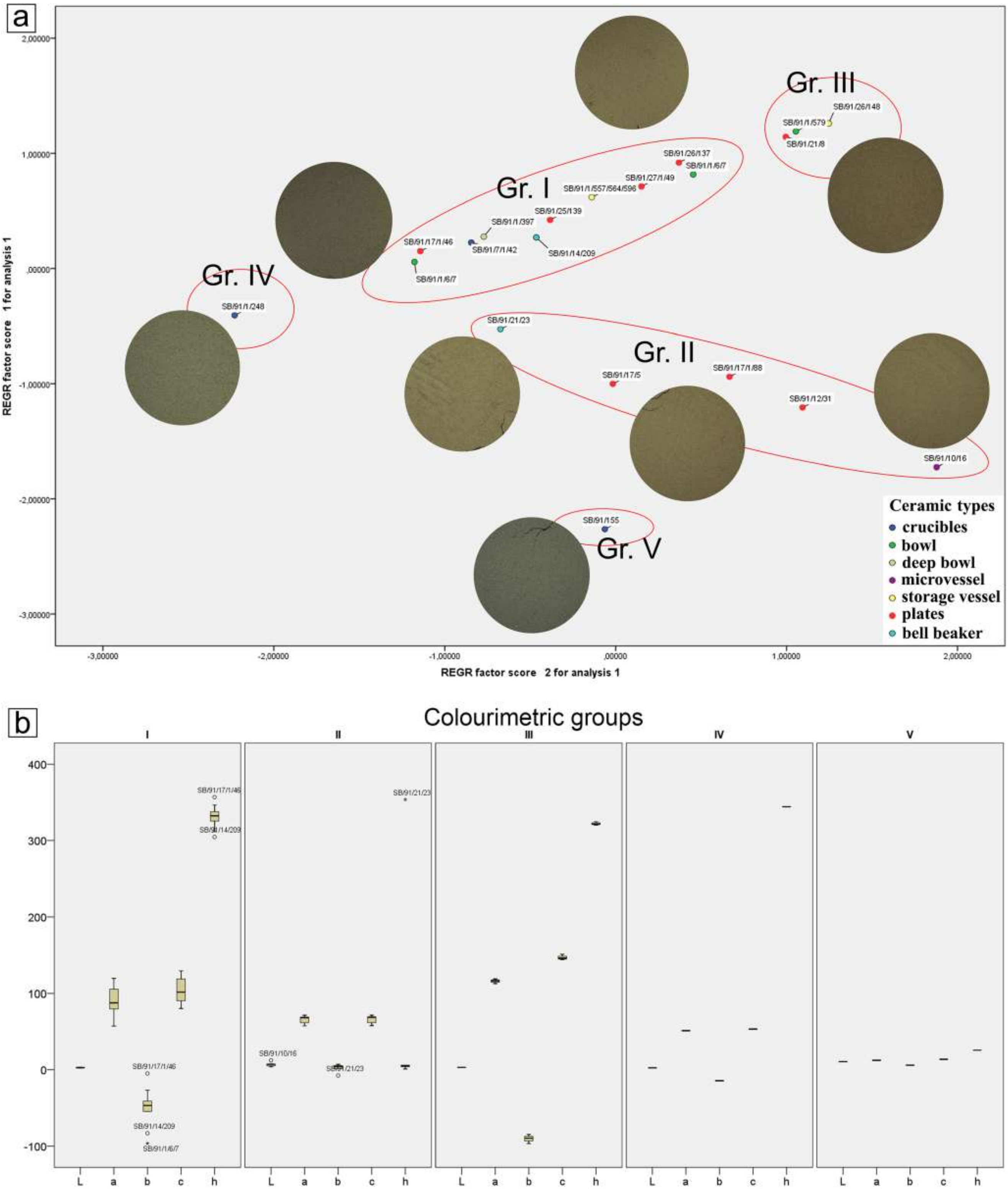


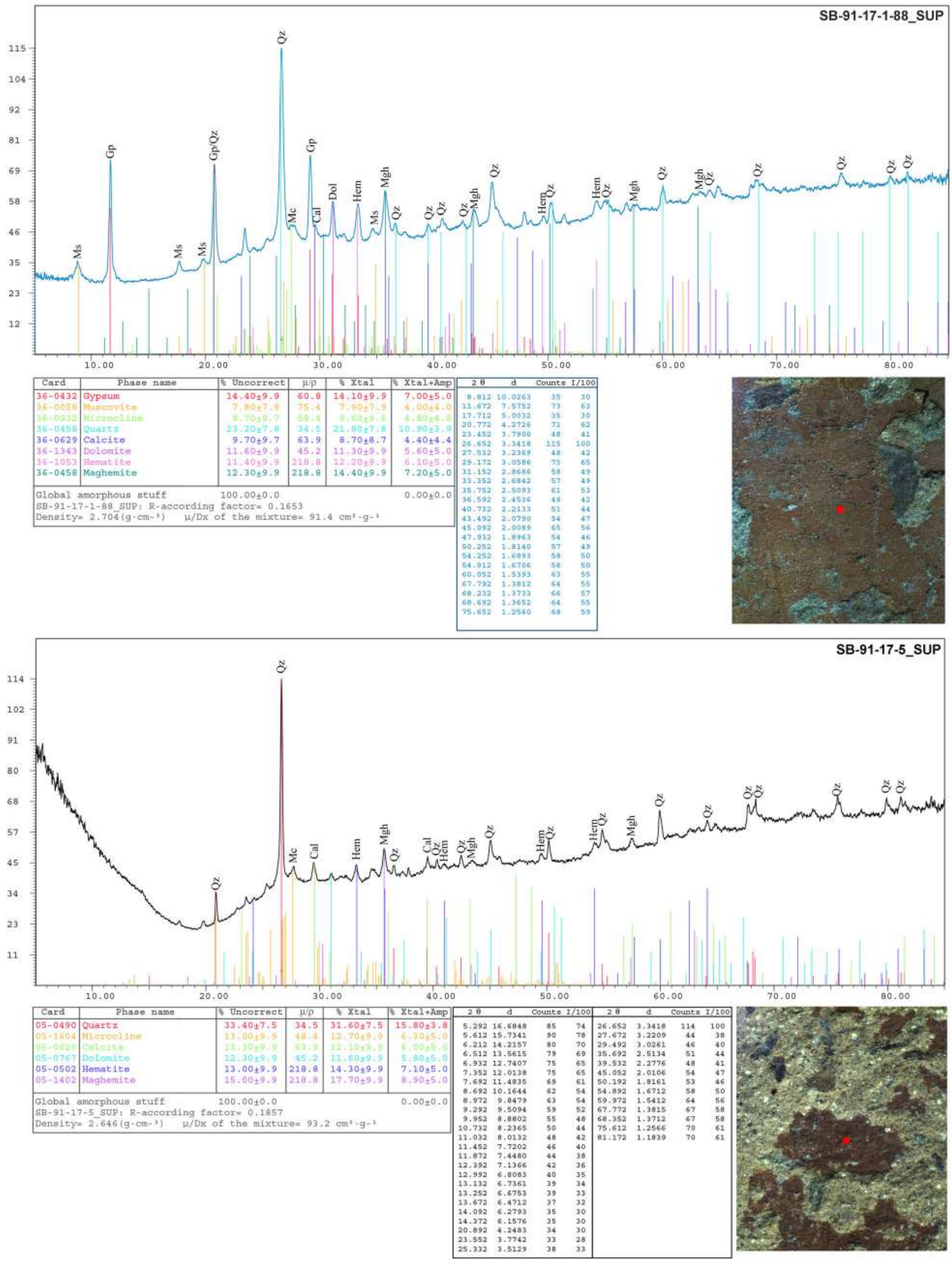
Fig. 7 Charts illustrating the results of the colourimetric analyses: **a** CIELab Ch results according to the defined types based on principal component analysis; **b** variations of the spectra CIELab Ch for each group

Table 3 Results of the colourimetric analysis carried out on the ceramic assemblage of Santa Bárbara (Huercal-Overa, Almería)

Colourmetric groups		Colour parameters				
		L	*a*	*b*	*c*	*h*
I	Mean	2.8000	88.9200	− 49.2570	104.9070	331.2670
	Number	10	10	10	10	10
	Standard deviation	.32558	19.42182	25.78733	17.18664	15.16819
II	Mean	7.1780	65.5740	2.0720	65.8120	73.9860
	Number	5	5	5	5	5
	Standard deviation	3.22888	5.79366	5.82488	5.78828	156.37682
III	Mean	3.0167	115.8600	− 90.2267	146.9200	322.1100
	Number	3	3	3	3	3
	Standard deviation	.09504	3.10569	6.02528	3.75029	2.20218
IV	Mean	2.4200	51.2000	− 14.4200	53.2000	344.2700
	Number	1	1	1	1	1
	Standard deviation	-	-	-	-	-
V	Mean	10.5800	12.3400	5.9000	13.6800	25.5700
	Number	1	1	1	1	1
	Standard deviation	-	-	-	-	-

Table 4 Listing of the minerals obtained from a semiquantification applying the RIR method of the crystalline phases of ceramic samples from Puente de Santa Bárbara and an estimation of their firing atmosphere (*mix* mixed, *o* oxidising and *r* reducing) (mineral abbreviations from Whitney and Evans 2010)

ID	Firing atmosphere	Chl	Ms	Pg	Gp	Qz	Kfs	Pl	Cal	Dol	Hem	Mgh	Estimated firing temperature
SB-91-10/16	Mix	0	13.8	5.6	0	63.3	4.4	3.8	9	0	0	0	<700
SB-91-12/31	O	0	13.9	0	0	79.7	0	0	6.4	0	0	0	<800
SB-91-1/248	R	0	14.8	0	0	59.2	7	18.9	0	0	0	0	<800
SB-91-1/397	R	0	19.6	5.9	0	54.4	7.3	8.7	4.1	0	0	0	<700
SB-91-1/399	Mix	0	16	7.1	0	58.9	5.9	8.2	3.9	0	0	0	<700
SB-91-14/209	Mix	5.7	18.8	5.9	0	53.9	4.9	10.7	0	0	0	0	<700
SB-91-25/155	R	0	0	0	0	69.6	5	14.5	5.3	5.5	0	0	>800
SB-91-1/557-564-596	O	6.8	19.3	4.7	0	59.1	3.6	6.5	0	0	0	0	<700
SB-91-1/579	Mix	0	16.5	0	0	68.9	5.4	4.7	4.6	0	0	0	<800
SB-91-1/617	R	0	15.5	4.7	0	67.6	4.8	7.4	0	0	0	0	<700
SB-91-17-1/46	O	0	17.4	0	0	69.2	4.7	4.1	4.5	0	0	0	<800
SB-91-17-1/88	O	0	14.1	0	0	64.7	5.1	4.8	7	4.2	0	0	<800
SB-91-17/5	O	0	26.9	12.3	0	37.4	3.5	16.1	3.7	0	0	0	<700
SB-91-21/23	O	0	27	12.3	0	37.5	3.5	16.1	3.6	0	0	0	<700
SB-91-21/8	O	0	10.3	0	0	78.4	3.7	3.9	3.7	0	0	0	<800
SB-91-25/139	O	0	17.8	6.6	0	60.5	5	5.4	4.6	0	0	0	<700
SB-91-26/148	O	0	18.8	0	0	71.9	4.5	4.8	0	0	0	0	<800
SB-91-26/137	O	0	11.9	0	0	72.5	5.8	5.8	4	0	0	0	<800
SB-91-27/49	O	7	16.1	5.4	0	61.5	5.1	4.9	0	0	0	0	<700
SB-91-7-1/42	O	0	13	0	0	69.9	5.6	6.3	5.3	0	0	0	<800
SB-91-17-1/88_SUP	O	0	7.9	0	14.1	21.8	9.6	0	8.7	11.3	12.2	14.4	-
SB-91-17/5_SUP	O	0	0	0	0	31.6	12.7	0	12.1	11.6	14.3	17.7	-



Card	Phase name	% Uncorrect	µ/ρ	% Xtal	% Xtal+Amp
36-0432	Gypsum	14.40±9.9	60.8	14.10±9.9	7.00±5.0
36-0058	Muscovite	7.80±7.8	75.4	7.90±7.9	4.00±4.0
36-0932	Microcline	9.70±9.7	58.4	9.60±9.6	4.80±4.8
36-0456	Quartz	23.20±7.8	34.5	21.80±7.8	10.90±3.9
36-0629	Calcite	9.70±9.7	63.9	8.70±8.7	4.40±4.4
36-1343	Dolomite	11.60±9.9	45.2	11.30±9.9	5.60±5.0
36-1053	Hematite	11.40±9.9	218.8	12.20±9.9	6.10±5.0
36-0458	Maghemite	12.30±9.9	218.8	14.40±9.9	7.20±5.0
Global amorphous stuff		100.00±0.0			0.00±0.0

SB-91-17-1-88_SUP: R-according factor= 0.1653
Density= 2.704 (g·cm-³) µ/Dx of the mixture= 91.4 cm²·g-¹

2 θ	d	Counts	I/100
8.812	10.0263	35	30
11.672	7.5752	73	63
17.712	5.0032	35	30
20.772	4.2726	71	62
23.452	3.7900	48	41
26.652	3.3418	115	100
27.532	3.2369	48	42
29.172	3.0586	75	65
31.152	2.8686	58	49
33.352	2.6842	57	49
35.752	2.5093	61	53
36.592	2.4536	49	42
40.732	2.2133	51	44
43.492	2.0790	54	47
45.092	2.0089	65	56
47.932	1.8963	54	46
50.252	1.8140	57	49
54.252	1.6893	58	50
54.912	1.6706	58	50
60.052	1.5393	63	55
67.792	1.3812	64	55
68.232	1.3733	66	57
68.692	1.3652	64	55
75.652	1.2560	68	59

Card	Phase name	% Uncorrect	µ/ρ	% Xtal	% Xtal+Amp
05-0490	Quartz	33.40±7.5	34.5	31.60±7.5	15.80±3.8
05-1604	Microcline	13.00±9.9	48.4	12.70±9.9	6.30±5.0
05-0629	Calcite	13.30±9.9	63.9	12.10±9.9	6.00±5.0
05-0767	Dolomite	12.30±9.9	45.2	11.60±9.9	5.80±5.0
05-0502	Hematite	13.00±9.9	218.8	14.30±9.9	7.10±5.0
05-1402	Maghemite	15.00±9.9	218.8	17.70±9.9	8.90±5.0
Global amorphous stuff		100.00±0.0			0.00±0.0

SB-91-17-5_SUP: R-according factor= 0.1857
Density= 2.646 (g·cm-³) µ/Dx of the mixture= 93.2 cm²·g-¹

2 θ	d	Counts	I/100	2 θ	d	Counts	I/100
5.292	16.6848	85	74	26.652	3.3418	114	100
5.612	15.7341	90	78	27.672	3.2209	44	38
6.212	14.2157	80	70	29.492	3.0261	46	40
6.512	13.5615	79	69	35.692	2.5134	51	44
6.932	12.7407	75	65	39.532	2.2776	48	41
7.352	12.0138	75	65	45.052	2.0106	54	47
7.692	11.4835	69	61	50.192	1.8161	53	46
8.692	10.1644	62	54	54.892	1.6712	58	50
8.972	9.8479	63	54	59.972	1.5412	64	56
9.292	9.5094	59	52	67.772	1.3815	67	58
9.952	8.8802	55	48	68.352	1.3712	67	58
10.732	8.2365	50	44	75.612	1.2566	70	61
11.032	8.0132	48	42	81.172	1.1839	70	61
11.452	7.7202	46	40				
11.872	7.4480	44	38				
12.392	7.1366	42	36				
12.992	6.8083	40	35				
13.132	6.7361	39	34				
13.252	6.6753	39	33				
13.672	6.4712	37	32				
14.092	6.2793	35	30				
14.372	6.1576	35	30				
20.892	4.2483	34	30				
23.552	3.7742	33	28				
25.332	3.5129	38	33				

Fig. 8 Diffractograms obtained from the mineralogical analyses of the slip on the surface of two pottery sherds

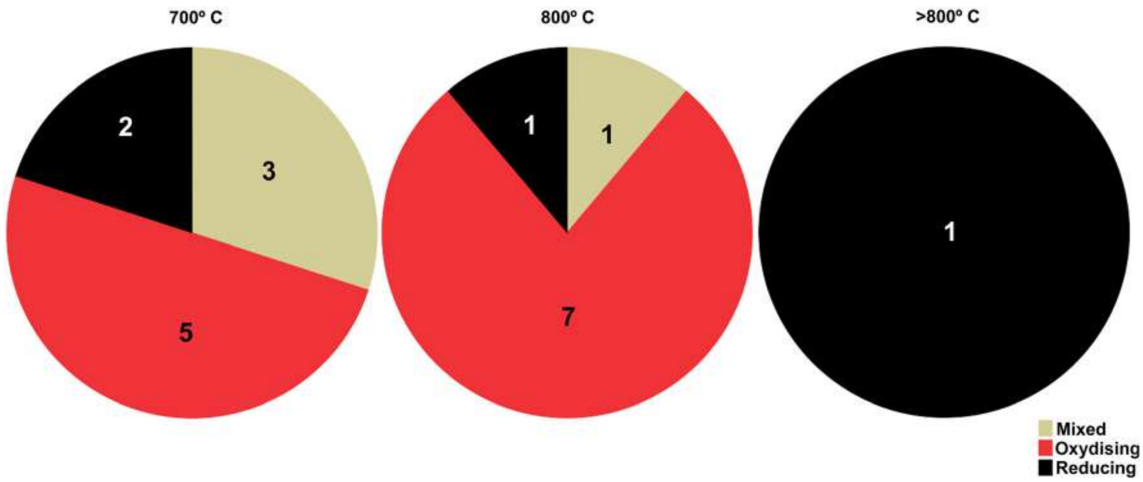


Fig. 9 Sector diagrams illustrating estimated firing temperatures related with the atmospheres according to the different ceramic samples

Petrographic analyses

As indicated above, the lack of a large corpus of ceramics at Santa Bárbara led to selecting the most significant elements for petrographic analyses. These were carried out on the thin sections of six samples leading to a classification of three types of fabrics (Table 5):

Fabric 1: Fe-rich clay matrix containing metamorphic rock fragments (Fig. 10)

This group made up of samples SB-91-1/557-564-596 (storage pot), SB-91-12/31 (plate), SB-91-21/23 (decorated cup) and SB-91-25/139 (plate) is characterised by phyllites, schist and quartzites (c:f:v 10μ = 20:75:5 to 30:55:15). The fabric presents many thick anti-plastics in the form of metamorphic rocks (phyllites) and a lesser quantity of mica-schists and quartzites that can present graphite and iron oxides (Fig. 10a–c). The inclusions of elongated morphology adhere to a bimodal distribution. Other inclusions are quartz, white mica and opaque minerals. Noteworthy is sample SB-91-25/139 marked by larger metamorphic rocks. Samples SB-91-21/23 (Fig. 10d) and SB-91-25/139 (Fig. 10f) likewise bear small pellets of clay suggesting a poor processing of the clay before modelling. Finally, other noteworthy technological aspects are the temper's orientation, most often oblique and horizontal.

Fabric 2: Fe-rich clay matrix containing metamorphic rock fragments and a few foraminifera (Fig. 11)

This fabric group comprises a single slipped-ware sample (SB-91-17-1/88). This slip, on both inner and outer surfaces,

Table 5 Microscopic features of the petrographic fabrics of the ceramic samples from Puente de Santa Bárbara

Samples	Porosity	Matrix	Inclusions	
Fabric 1—Fe-rich clay matrix with metamorphic rock fragments (20:75:5 to 30:55:15)				
SB-91-1/557-564-596 SB-91-12/31 SB-91-21/23 SB'91-25/139	Common: *meso*- and micro-vesicles	Fe-rich clay, red-orange colour optical activity	Sand-sized, elongated sub-rounded to subangular, oblique and horizontal	Dominant: metamorphic rocks (phyllites) Common: mica-schists and quartzites that can contain graphite and iron oxides Rare: Quartz, white mica and opaque minerals
Fabric 2—Fe-rich clay matrix with metamorphic rock fragments and low presence of foraminifera (15:80:5)				
SB-91-17-1/88	Common: *meso*- and micro-vesicles. Rare: macropores	Fe-rich clay, red-orange colour optical activity	Sand to coarse-sized, equant-elongated from very-angular to sub-rounded and oblique to horizontal	Dominant: metamorphic rocks (phyllites) Common: mica-schists and quartzites that can contain graphite and iron oxides, as well as calcium carbonate, in some cases with a bioclastic origin (foraminifera). Rare: opaque minerals.
Fabric 3—anisotropic matrix with quartzite fragments (45:35:20)				
SB-91-21/248	Common: macropores; rare: *meso*- and micro-vesicles	Vitrified matrix, dark brown colour optical activity	Sand-sized, sub-rounded to sub-angular, obliquely oriented	Dominant: quartzites Common: quartz

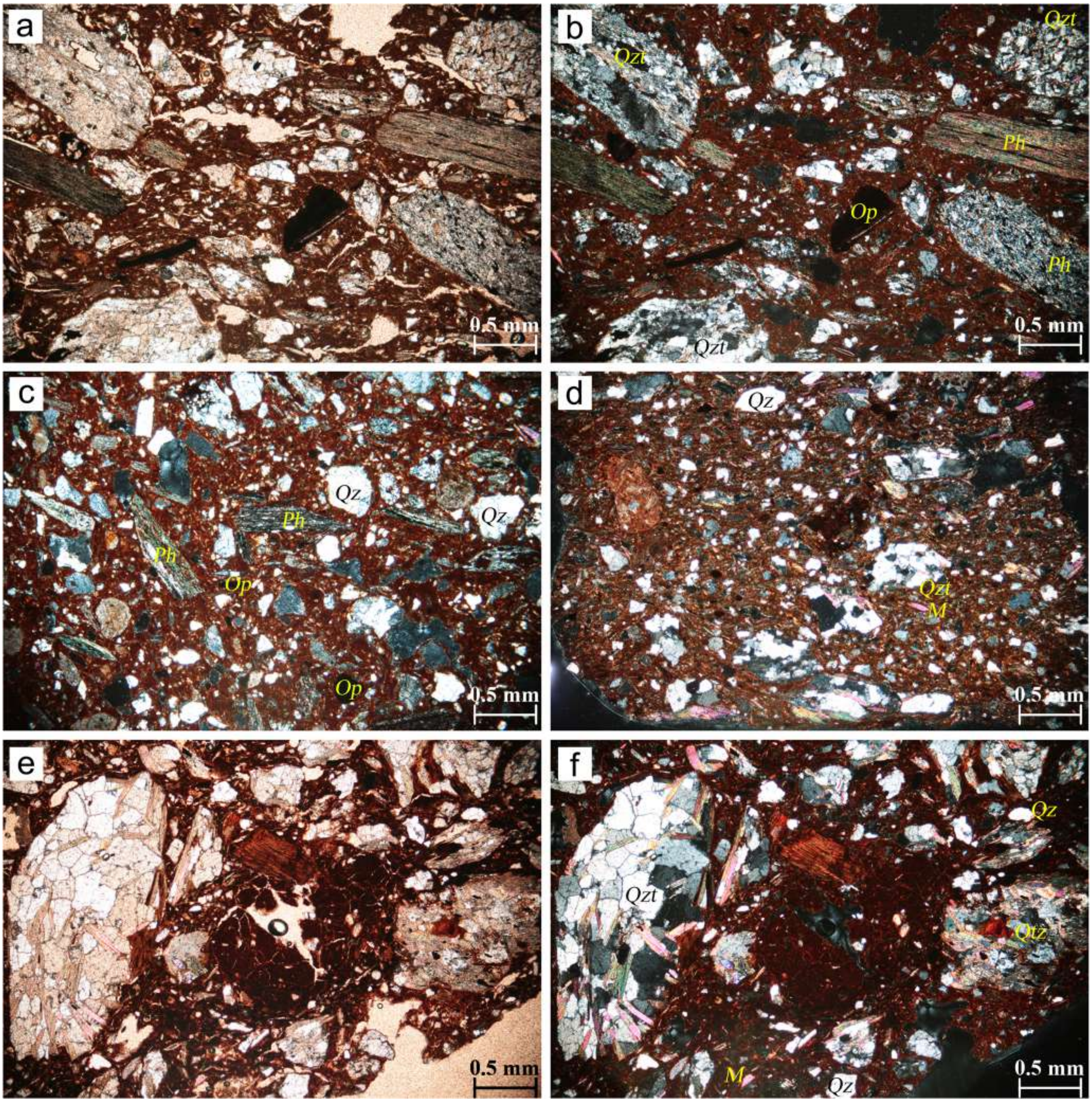


Fig. 10 Microphotographs depicting *Fabric 1*. SB-91/557-564-596, a storage vessel observed through LPP (**a**) and LPX (**b**) (×5); SB-91-12/31, a plate, LPX (**c**) (×5); SB-91-21/23, on a sherd bearing a symbolic decor, LPX (**d**) (×5); and SB-91-25/139, classified as a plate, LPP and LPX (**e**, **f**) (×5)

is characterised by phyllites, schists, quartzites (Fig. 10a, b) and small fossils (Fig. 11c) (c:f:v 10μ = 15:80:5). It contains thinner temper in the form of phyllites, mica-schists and quartzites that they can contain graphite and iron oxides as well as calcium carbonates (in certain cases identified as foraminifera of bioclastic origin). The fabric contains a mixture of Ca-rich clays with FeO inclusions and opaque minerals (Fig. 11d). As in the previous case, the inclusions are elongated and distributed in a bimodal mode, except for the carbonates which are rounded. It also contains quartz, white mica and opaque minerals which tend to be larger and in the form of carbonate inclusions. Worth highlighting is the temper which tends to follow an oblique and horizontal orientation due to the modelling technique.

Fabric 3: anisotropic matrix containing foraminifera and quartzite fragments (Fig. 12)

This fabric corresponds to a crucible (SB-91-21/248). Contrary to the previous cases, it is characterised by the almost

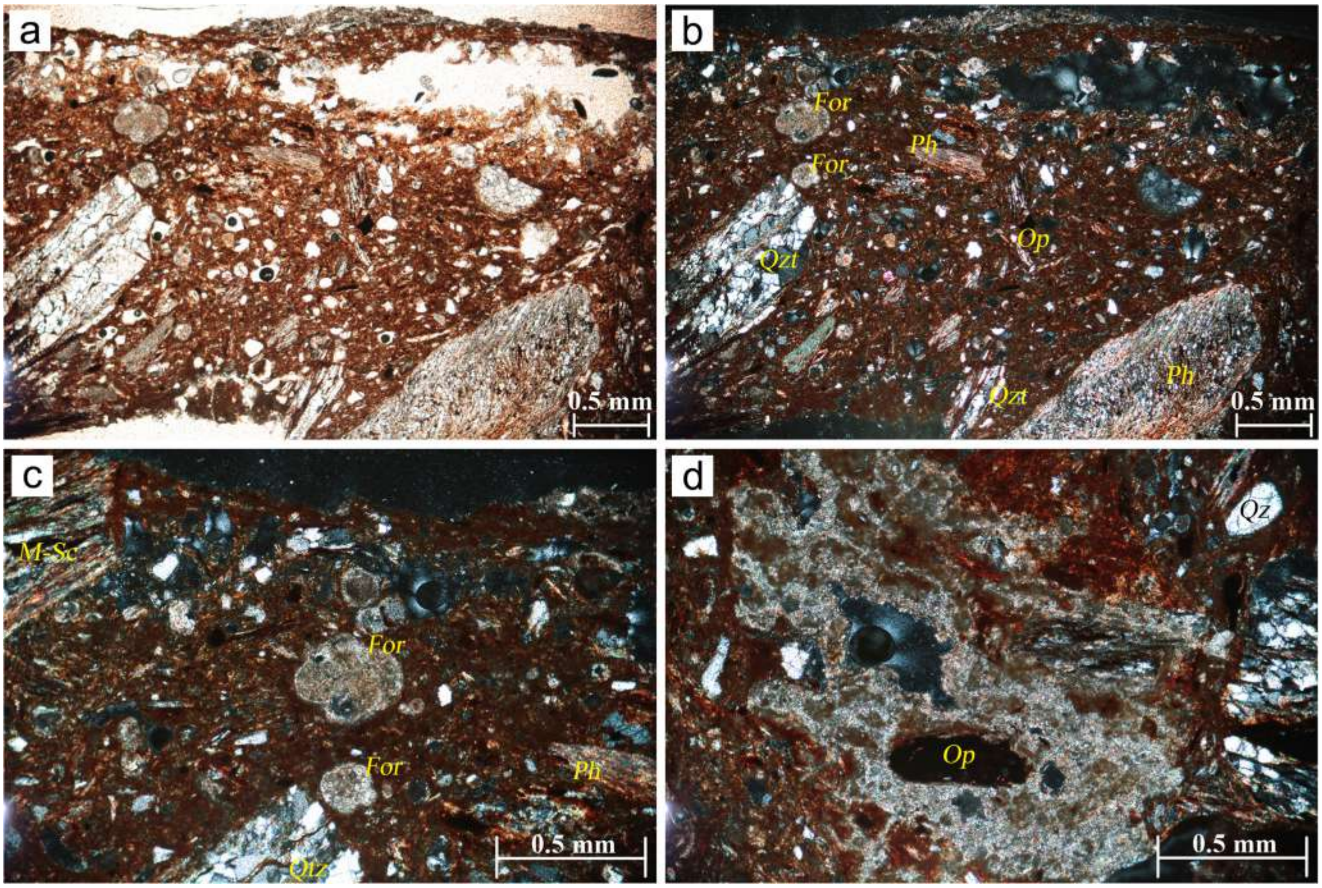


Fig. 11 Microphotographs of sample SB-91-17-1/88, a red-slipped cup of *Fabric 2* type. The anisotropy of the thick fraction is observed through tones varying from brown to orange, LPP (**a**), and dark brown, LPX (**b**) (×5), as well as through microfragments of metamorphic rocks seen in the semi-vitrified mass, the latter also hosting foraminifera remains (**c**) (×10) and a mix of Ca-rich clays with FeO and opaque inclusions (**d**) (×10) (LPX)

exclusive presence of quartzites (Fig. 12a, b) (c:f:v 10μ = 45:35:20) and a greater amount of larger temper. This is in line with its function in metal working. Its exposure to high temperatures allowed observing certain gradual variations from the internal to the external surface. In fact, it is its interior surface that was exposed to higher temperatures. The thin section of the sample reveals surface vitrification and an abundance of anti-plastics and remnants of small metallic prills (Fig. 12c, d). The degree of vitrification lowers when reaching the outer surface where temperatures were much lower. As in the previous cases, the temper varies between sub-rounded and sub-angular and is distributed in a bimodal manner and oriented obliquely.

Microstructural analyses

The differences identified among the firing strategies of the different ceramics are likewise expressed at a microstructural level. The scanning electron microscope (SEM) is a fundamental tool serving to detect variations in the clay and information regarding the firing temperature in the kiln (Tite and Maniatis 1975; Tite et al. 1982; Freestone 1982; Freestone and Middleton 1987). This technique indicates that the clay of the samples fired below 700 °C is hardly vitrified as is the case of a small cup (Fig. 13a, b), a storage vessel (Fig. 13c, d) and one of the bowls (Fig. 13e, f). The microstructural findings thus coincide with those of the XRD analyses. It is nonetheless necessary to note that ceramic matrixes can present a texture with clay orientations deriving from the pressure exercised by the hand of the potter during modelling. The greater or lesser quantity of small stretched and elongated pores also suggests different levels of potter dexterity.

The second group made up of pieces fired at temperatures around 800 °C reveal a more or less extensive vitrification of the clay matrix yielding a viscous structure with round pores visible in a fresh fracture. The vitrification is especially visible on one of the crucibles (Fig. 14a,b). As noted above, their exposure to great temperatures led to a thermic alteration of certain areas of the clay which was more extensive within the matrix. The vitrification of certain cups led to fractures and crackling extending more or less regularly throughout the surface (Fig. 14c, d). In general terms, these reveal less porosity, and the pores are more regularly spaced within the matrix (Fig. 14e, f).

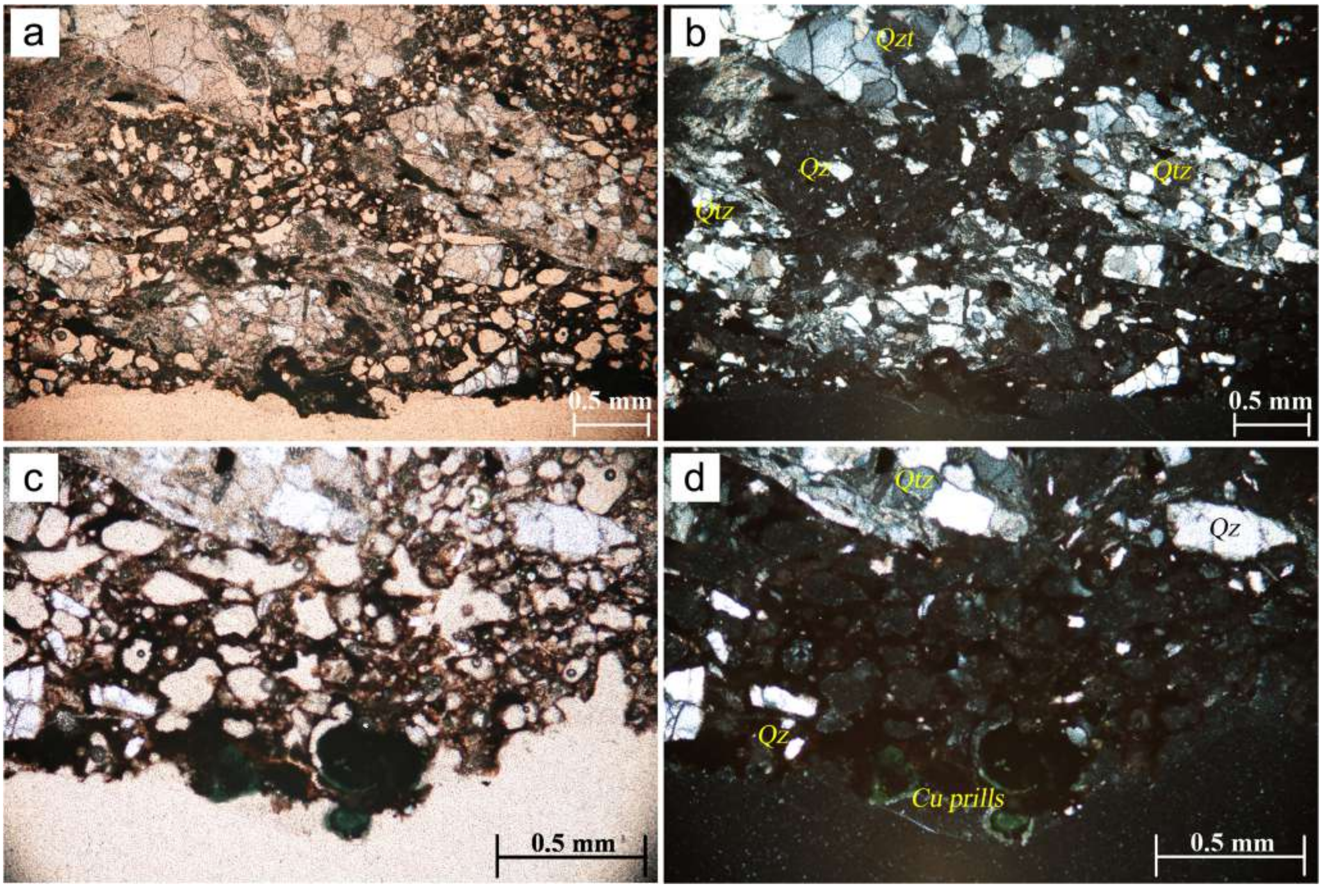


Fig. 12 Microphotographs corresponding to *Fabric 3* corresponding exclusively to sample SB-91-1/248 identified as a crucible. The image depicts the isotropy of the thin fraction as well as the thermal alteration caused by exposure to high temperatures, LPP (**a**) and LPX (**b**) (×5), due to its role in metal working. This also explains the presence of small Cu-based oxidised metallic prills adhering to the internal surface, LPP (**c**) and LPX (**d**) (×10)

Defining the ceramic production strategies

All the different phases and strategies of the *chaîne opératoire* adopted by a potter are equally important. They consist of a series of concatenated actions serving to produce a container bearing certain characteristics (Lemonnier 1992, 1993; Roux 2019). In this sense, the choice of raw materials and their preparation and firing bestow the final product with specific properties and qualities which will either differentiate or match them with others. These strategies require nonetheless a balance between the knowhow of individuals acquired within a cultural frame (communities of practice) acting as a social agent and a production dynamic which will lead to the creation of new objects that escape cultural determinism through innovation (Knappett 1999). On the other hand, there are elements that escape these innovations and the intention of the potter. These include the choice of raw materials restricted to the geological context of the settlement. Hence, the potters of Puente de Santa Bárbara resorted to materials from the vicinity consisting mostly of mica-schists, quartzites and limestones (promontories) identified by the textural analyses. These components are identified in all the samples subjected to macroscopic and petrographic analyses. The inclusions, in turn, suggest their presence in deposits likewise containing the FeO which are characteristic of certain fluvisols of Almería (Gallardo 2015) such as the nearby northern floodplains of the Almanzora River. Only the red slipped-ware vessel (SB-91-17-1/88) can be traced to other areas. This is based on the identification of foraminifera during the petrographic analyses and could be linked to the medium and short distance circulation of metals (González Quintero et al. 2018)

With the exception of the crucible, no other case reveals the intentional grinding and addition of temper. This, on the one hand, suggests its presence within the original raw materials. It is a question that remains unclear as a local sampling of the sediments is still not widespread enough to define their characteristics. The variations identified macroscopically can nonetheless correspond to a degree of preparation of the clay leading to the elimination of the inclusions. This aspect which leaves no visible trace in the archaeological record must be studied from an ethnoarchaeological perspective as it is a practice typical of a many traditions (Druc

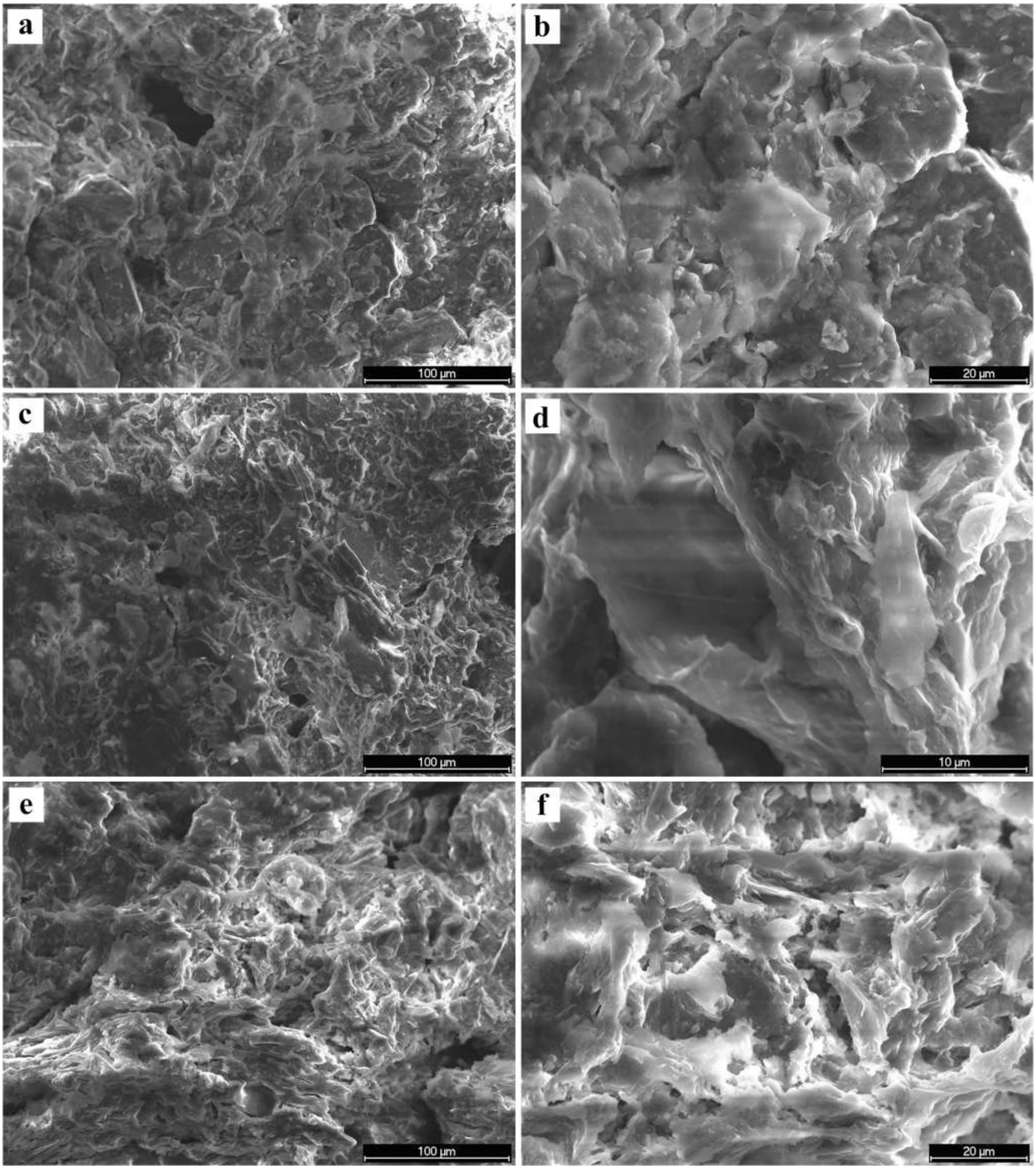


Fig. 13 Microphotographs of the matrixes of ceramics fired under 700 °C: **a**, **b** small cup (SB-91-10/16); **c**, **d** storage vessel (SB-91-1/557-564-596); and **e**, **f** bowl (SB-91-1/617)

1996; Arnold 2000; González Ruibal 2005; Gosselein 2008; García Roselló 2008).

The analyses of the modelling of the vessels, despite the high degree of fragmentation of assemblage, indicate that the potter resorted to pre-established strategies depending on the desired form. A simple hollowing out is the technique applied to small cups and certain bowls of varying size. Other forms, in turn, resorted to moulding. This is the case of a red-slipped cup and the three crucibles of different type (one applied a mixed technique including coiling). This is surprising due to

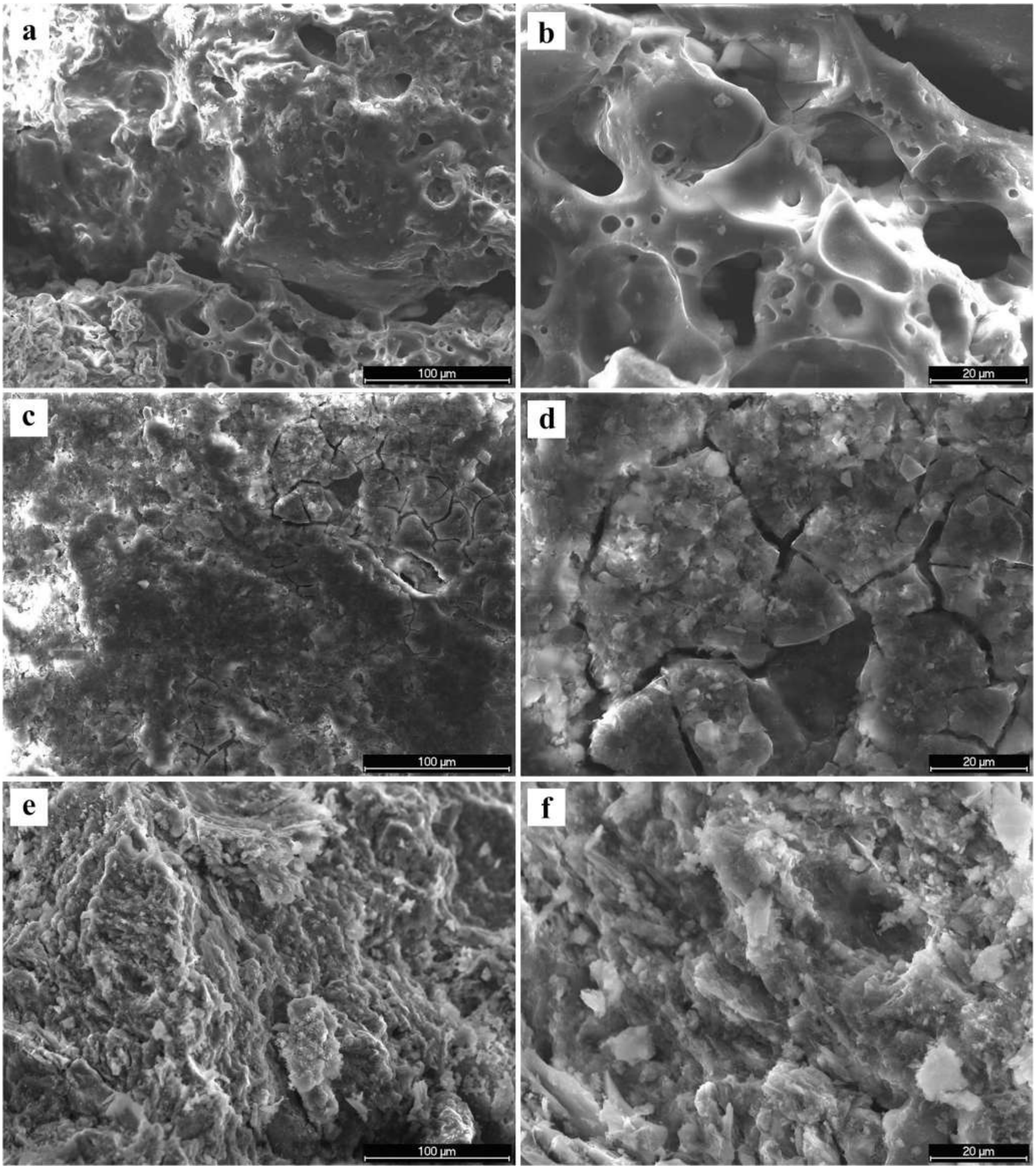


Fig. 14 Microphotographs of the matrixes of ceramics fired around 800 °C: **a**, **b** crucible (SB-91-1/248); **c**, **d** bowl (SB-91-1/579); and **e**, **f** red-slip platter (SB-91-17-1/88)

the fact that until now only ceramics destined for consumption, production and storage are recorded, and none is linked to metal working. This leads to the idea that both ceramic and metal working could have been carried out by the same individuals as they possessed technical knowledge in both fields. Individuals at Puente de Santa Bárbara in fact could have produced both conventional pottery and as well as artefacts destined to grinding, reducing and producing small ingots or metal tools. An identical dynamic is recorded at two Vinča Culture sites (Belovode and Pločnik) in Serbia dating to the

Late Neolithic/Early Chalcolithic (Amicone et al. 2020), as well as at the Chalcolithic settlement of Las Pilas (Spain) (Murillo-Barroso et al. 2017: 1550, fig.7), suggesting the co-existence of different craftsmen during the early stages of metallurgical production. More recent archaeological contexts do not offer such clear evidence of this association maybe due to the fact that it only occurred during the outset of metal working. However, the findings of ceramic research carried out at large settlements such as Los Millares reveal evidence of differentiated production areas as well as an advanced degree of specialisation (Molina and Cámara 2005). Other modelling techniques have been identified including the technique of coiling among a number of plates and a combination of simple hollowing and coiling in the case of a plate. These techniques point to the variability of strategies and a savoir faire that may or may not be linked to different potters.

This variability diminished when analysing surface treatments due to the exclusive use of burnishing for small cups and bowls that is not surprising if we take into consideration this technique's anti-adherent properties (Cuomo di Caprio 1985; Diallo et al. 1995; Lepère 2014). The technique was applied with the intention of attaining a specific function for these small containers probably destined to personal solid and liquid consumption. This technique is fairly generalised among bowls, plates, platters and cups based on the records from the Chalcolithic settlements of Los Castillejos (Vico et al. 2018: 44-45) and Cerro de la Virgen (Pinillos de la Granja 2019: 43). Smoothing, in turn, is the most common surface treatment at Santa Bárbara for most of the plates, pots and crucibles, as well as for the external surfaces of certain bowls.

It is nonetheless necessary to highlight that certain surfaces were treated with red slip so as to yield features differing from other productions. Applying a thin layer of very fine clay had a double objective: it sealed the pores of the vessel while simultaneously affording it with an aesthetic value (Echallier 1984; Balfet 1991; Garcia Rosselló and Calvo Trias 2013:66). Its mineralogical composition obtained by XRD indicates the presence of haematite (Fe_2O_3) and maghemite ($Fe^{3+}{}_2O_3$) in respective proportions ranging from 12.20 to 14.30% and 14.40 to 17.70%. These minerals, not recorded in the pulverised sample, are behind the unique reddish appearance of the vessel which is characteristic for the period in spite that the technique has roots in earlier times (Capel et al. 2006; Gámiz Caro 2018). It is not uncommon to find it in other contemporary settlements such as Les Moreres (González Prats et al. 1992-94), Valencina de la Concepción (López Aldana et al. 2001: 627), São Pedro (Costeira and Mataloto 2019) or associated with painted vessels such as those of Cerro de la Virgen (Pinillos de la Granja 2019: 44, fig. 8). The study by Galván Martínez and Galván García (1993) at Almizaraque, the site thought to be a "mother" settlement of Puente de Santa Bárbara (González Quintero et al. 2018; Dorado et al. 2020), offers evidence of their strong relationship since the red-slipped ware of Almizaraque also contains the same two minerals suggesting a common provenance of the raw materials. Moreover, the petrographic study of one of the Santa Bárbara's vases implies an allochthonous source.

It is probable that red-slipped ware was restricted to certain members of Chalcolithic society as was the case of Bell Beaker or other vessels bearing symbolic decors. This is argued in studies such as those of Los Millares where this type of ware is restricted to certain domestic areas and funerary spaces (Arribas and Molina 1987; Molina and Cámara 2005; Afonso et al. 2011). Reticulated incised decors can be traced throughout almost all the large settlements of the Late Copper Age of the SE of the Iberia such as Los Millares (Arribas and Molina 1987), Terrera Ventura (Gusi and Olaria 1991: 179 fig. 106-2) and Ciavieja (Carrilero and Suárez 1989–90: 127, fig. 11a). They are likewise present at even more distant settlements in the area of Granada such as Cerro de la Encina (Dorado et al. 2017: 280, fig. 2-2) and El Manzanil (Fresneda Padilla 1980: pl. XVIII, Fresneda Padilla 1983: 137; Carrilero 1991).

To conclude, the current study turns to firing techniques, one of the final steps of the c*haîne opératoire* (although not for crucibles). The alterations generated by exposure to fire begin with variations of surface tone depending on the raw material and a relative regular oxidising atmosphere in the firing chamber. The perception of colour by the potters and the strategies they followed to generate it also serve to evaluate certain social and cultural behaviours. In this sense, the definition of colour is not absolute and neither refers to or defines a ceramic in the same way among different cultures or communities (Berlin and Kay 1969; Davies and Corbett 1997; Roberson et al. 2005; Rosch Heider 1972). Surface tonalities must therefore be considered a reflection of productive behavioural conducts from an ample perspective, and respond, more or less, to the origin of the raw material and firing strategies. The differing tonalities at Santa Bárbara allow identifying at least five groups independent from a direct relation between colour and form.

The exceptions are the two crucibles of groups IV and V which were altered, as noted by the XRD analyses, due to exposure to high temperatures during the reduction processes. The alterations are likewise due, according to the microstructural SEM analyses, to the viscosity of the material, as well as the scarce activity identified during the petrographic study. The remaining assemblages, on the contrary, were in firing atmospheres with lower temperatures, and correspond to chromatic groups I, II and II. Those under 700 °C are classification based on the presence of paragonite (Comodi and Zanazzi 2000), whereas those under 800 °C are due to the presence of muscovite (Buxeda and Tsantini 2009). These groupings are also ratified by SEM and petrographic analyses.

The lack of finds of firing structures such as kilns during the archaeological excavations requires prudence when interpreting the firing strategies adopted by the potters. The findings are nonetheless clear and allow to advance a series of considerations when they combined with data from ethnoarchaeological research. Thus, it appears evident that there is no control of the oxidising atmosphere in the firing chamber thus yielding pottery with irregular tones and a combination of both oxidised and reduced areas. Furthermore, certain reduced areas visible on the surfaces suggest that the fuel and the vessels were arranged together in the firing chamber. With these elements in mind, the kilns could have been either open or closed, on the surface or in a pit, or with/without permanent features (García Rosselló and Calvo 2006). Generally speaking, these kilns could not produce temperatures exceeding 700 °C and the potters usually resorted to low-calorie fuels such as manure, dry wood and/or dry scrubs. Certain research argue nonetheless that kilns may have exceeded this temperature in the Neolithic and Chalcolithic (Gámiz Caro 2018; Amicone et al. 2020), a notion bolstered by ethnographical examples in Cameroon (Gosselain 1995: 153-155), Pakistan (Rye and Evans 1976: 13-16) and different areas of South America (e.g. Litto 1976: 12-17; Ravines 1978: 413-415; Shimada 1994: 307-311; Camino 2009).

Conclusions

The results of the different studies to date bear evidence that the site of Puente de Santa Bárbara (Huércal-Overa, Almería, Spain) was established during the Middle Chalcolithic period in the framework of a series of sites spread throughout the Lower Almanzora around the settlement of Almizaraque (González Quintero et al. 2018; Dorado et al. 2020). The raising of a defensive wall at Puente de Santa Bárbara with semicircular bastions served to fortify the settlement is in line with the semicircular bastions known elsewhere throughout the Lower Almanzora Valley such as Campos (Siret and Siret 1890: pl. 9; Camalich et al. 1998: 402-403, fig. 5) and Almizaraque (Delibes et al. 1986: pl. 1b). The genesis of these walled settlements must be placed in the framework of the need to control the different communication routes linking the Lower and the Upper Almanzora River (Mederos Martín 1993), especially in the period of metallurgy intensification (Ruiz Taboada and Montero 1999; Müller et al. 2004; Delgado Raack et al. 2014; González Quintero et al. 2018) during the Middle–Late Chalcolithic (c. 3100-2200 BC) and the outset of the Bronze Age (Montero Ruiz 1994; Lull et al. 2010).

The current study focusing on the ceramics of a Bell Beaker site offers the possibility to advance a series of considerations regarding production strategies during the Middle and Late Chalcolithic in the Almanzora Valley and Vera Basin of southeastern Iberia. It is a subject that with the exception of the study of the Lower Aguas River area during the Early and Middle Chalcolithic (Del Pino et al. 2019) has benefitted from little research. It has shed light on the strategies for selecting raw materials, procured presumably from the nearby River Plain of the Almanzora Valley to the north of the settlement. It has likewise identified the strategies adopted by the local potters treating clay by eliminating or adding temper and has identified different modelling techniques such as simple hollowing out, moulding, moulding in combination with coiling and coiling after fashioning a base from a lump of clay. Potters when making cups, in this sense, preferred the simple hollowing out technique. For forms such as pots, on the contrary, they resorted to coiling which allowed raising more vertical walls. Similar traditions are identified in other areas of the south and southeast of Iberia (Vico et al. 2018; Pinillos de la Granja 2019).

Worth highlighting among the samples are the crucibles that point to metallurgical specialisation at Santa Bárbara. Similar features are recorded at Almizaraque (Müller et al. 2004) and Las Pilas (Murillo-Barroso et al. 2017; Del Pino et al. 2019). Their surface reveals that they were modelled in moulds which leads to two interpretations. Either the workers specialised in the metal working possessed an advanced knowledge of making ceramics or the potters destined part of their products to meet the demands of metal working. The variability recorded among the raw materials of the crucibles follow the same patterns as other local products (storage vessels, plates, vessels...) and relate to technological choices adopted by the potters during their manufacture. In addition, the different functions of the crucibles during metal working may have led to them to be subjected to higher temperatures. Quartz (SiO_2) was added in various proportions (e.g. SB-91-21/248) to withstand the higher temperatures required for metal production. Adding quartz supposes a great amount of silicate typical of ancient technical ceramics (Freestone and Tite 1986). Other studies from the southeast of Iberia suggest the existence of different types of fabrics and the addition of silicon-rich minerals and rocks. This is the case of finds at the Chalcolithic site of Las Pilas (Murillo-Barroso et al. 2017) and the Bronze Age site of Peñalosa (Rovira et al. 2015; Moreno et al. 2017).

To conclude, the different internal relations that must have existed within the Almanzora Valley led to the circulation of finished artefacts such as metal and ceramics. This appears to be the case as evidenced by the presence of certain potential prestige goods such as red-slipped ware that was acquired by the local elites. In fact, the great amount of production of these types of vessels at the nearby settlement of Almizaraque (Galván Martínez and Galván García 1993; Galván Martínez 1995) since the Late Neolithic-Early Chalcolithic could be the origin of the finds identified at Puente de Santa Bárbara. The link between the two sites goes nevertheless further than the simple application of red slip as both lots also share maghemite, gypsum and fossils (foraminifera), minerals which are not identified among other local productions.

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