Pottery production in Santa Ponsa (Majorca, Spain) from the Late Bronze Age to the Late Iron Age (1100–50 BC): Ceramics, technology and society

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Abstract - The present paper represents a study of hand-made ceramics from different Late Bronze Age to Late Iron Age (1100–50 BC) archaeological sites located in Majorca (Spain), combining petrography, X-ray powder diffraction, X-ray fluorescence, and scanning electron microscopy. The analysis of the ceramic samples focused on the establishment of specific chaînes opératoires. As such, this analysis represents a useful tool for assessing different technological traditions of pottery production throughout prehistory. This theoretical and methodological approach, in agreement with the historical context, has permitted the interpretation of significant social and technical practices related to pottery production. As the data suggest, the preparation of pottery pastes underwent great changes during the periods under consideration, and especially between the sherds from the different archaeological sites studied. The changes may have occurred in response to new dynamics in the social organisation of pottery production, knowledge transmission systems, and learning contexts in the investigated area.

1. Introduction
For the purposes of the present paper, we have undertaken a macroscopic and archaeometric study of 87 prehistoric hand-made ceramics samples from Santa Ponsa (southwest Majorca, Spain). The archaeological sites from which these samples were collected are located in a territory of 3500 ha with a topography marked by the contrast between the mountains and other flatter areas (Fig. 1). The hills are composed of Triassic and Jurassic materials, mainly limestone and dolomite, with marl as well. The rest of the territory is relatively flat, with broad valleys filled by a wide range of sedimentary calcareous clay deposits. The geodiversity of the clay resources in the area corresponds to specific sedimentary depositional environments, with characteristic qualities, compositions, and plasticity (Albero Santacreu and García Rosselló 2010).

We selected 50 samples from Tower I and Tower III of the prehistoric fortified site of Puig de Sa Morisca (SM), located on a hill in the Santa Ponsa area (Guerrero Ayuso et al. 2002). Potsherds from the Late Bronze Age (LBA) (1120–920 cal BC, KIA- 33825), Early Iron Age (EIA) (750–400 cal BC, KIA- 33609), Late Iron Age II (LIA2) (2nd–1st century BC), and primarily the Late Iron Age I (LIA1) (410–350 cal BC, KIA- 33826) were selected from this location (Table 1). In addition, 37 potsherds from the Turo de les Abelles (TSB) site were selected (Table 1). This archaeological site is located 1 km north of Puig de Sa Morisca, and the wheel-shaped ceramic materials found at TSB suggest that the site was occupied in the Late Iron Age II, between 250–75 BC (Camps and Vallespir 1998).

The objective of the sampling strategy was to compare ceramic technologies identified as corresponding to different time periods or sites, but that were developed or used in the same hinterland. The goal of using this procedure was to answer the following questions: 1) What changes occurred in ceramic technology in the Santa Ponsa area during prehistory? 2) Is there any connection between the pottery found in Turo de les Abelles and the pots obtained from Puig de Sa Morisca? 3) Can the features observed in the pots be related to social dynamics involved in the organisation of production?

2. Methods
We carried out X-ray powder diffraction (XRPD) studies on all potsherds. Measurements were performed with a Siemens D5000 diffractometer using Cu Kα radiation (λ=1.5405Å) and a monochromator goninum in the diffracted beam (at 45 kV and 40 mA). Spectra were...
taken in the interval 3–70° 2θ at a rate of 3 s per step. We also used the X-powder software to evaluate the crystalline phases according to the intensity tables found in the data bank from the Joint Committee of Powder Diffraction Standards (JCPDS 2003). The semi-quantification of phases was achieved using the normalised Reference Intensity Ratios method (Martín 2004).

The exploration of the chemical composition of 87 pottery samples was carried out by X-ray fluorescence (XRF). Samples were prepared by pulverisation and furnace-drying at 80°C for 4 h, and pressed pills were made using 1.5 g of the powder. The analysis was performed in an X-ray spectrometer Philips MagiX Pro-PW2400, while the qualitative analysis was carried out using the SuperQ software. The measurement of the dust sample was conducted in a helium atmosphere supported in a polyester film (Mylar®). The semi-quantification of the samples was normalised to 100% and achieved using the IQ + software.

We used thin sections of 36 of the potsherds for optically-based mineralogical and textural studies. The amount of each compound in each section was established using comparative charts (Matthew et al. 1991). The optical examination was performed using petrographic micro-

Figure 1. Geographic location of the studied area within the island and simplified geological map of the studied area showing the location of the two archaeological sites (source: Conselleria de Medi Ambient, Govern de les Illes Balears).
scopes Leica DM-RX and Olympus BX 60, which incorporate colour filters and micrometers. The lenses used varied from 16x to 400x. Photomicrographs of the samples were taken with a Leica DC500 digital camera.

Finally, some images of paste microstructures and elemental analysis of specific inclusions and slips were taken of the thin sectioned pottery and sherds with a Hitachi S-3400-N scanning electron microscope equipped with a liquid-nitrogen-cooled detector system Brooker RX-EDS using 15 Kv of tension. In addition, a Jeol Jsm-840 scanning electron microscope with 25 Kv of tension was used in the examination of some samples. For analysis via the latter instrument, the sample was adhered to the microscope slide with colloidal silver and covered with a carbon film in a high vacuum atmosphere.

3. Results

3.1. Ceramics

The mineralogical composition of pottery samples, as detected by XRPD, did not show any qualitative difference in major peaks between different sites or periods. Most of the analysed samples were characterised by the presence of peaks of illite-muscovite, quartz, calcite, and some traces of feldspars. These are also the main minerals present in all the clay soils analysed in the area (Albero Santacreu and García Rosselló 2010). No high-temperature minerals, such as gehlenite or anorthite, appeared in the diffraction data. Despite one sample (TSB-6/65) presenting montmorillonite (15Å) and others (TSB-6/61, SM-426) showing the presence of dolomite (2.88Å), the diffractograms vary primarily in the peak intensities of quartz and calcite.

Preliminary statistical explorations of chemical data combined with petrological observations of ceramic samples showed clear differences between the pots of the two archaeological sites. Evident groupings depending on the amount of CaO, Fe₂O₃, TiO₂, and Zr were easily identified in dispersion plots. A strong correlation was found between the amount of Fe₂O₃ and TiO₂ (r Pearson = 0.839), Zr and TiO₂ (r Pearson = 0.804), and Zr with Fe₂O₃ (r Pearson = 0.735). These oxides have been revealed to be very helpful for establishing distinctions in the ceramic record. In addition, the petrological data appears to correlate well with the chemical differences detected by XRF (Fig. 2). We were therefore able to divide most of the pots into four main groups, while some pots from each site were considered as outliers and did not fall into any of these groups. Although scarcely represented, these loners, mainly from the Late Iron Age, indicate the use of different recipes or provenance: e.g., Petro-fabric 5 (Grog tempered), Petro-fabric 6 (Carbureted matrix without temper), Petro-fabric 7 (Brecillas temper), Petro-fabric 8 (Clay mixing + calcareous rocks), Petro-fabric 9 (Carbureted carbureted very low fired), Petro-fabric 10 (Groundmass with ferruginous veins), Petro-fabric 12 (Clay mixing + crushed calcite).

(a) Puig de Sa Morisca (SM)

All the analysed samples from SM were low in Fe₂O₃ (<7.5%), TiO₂ (<2%), and Zr (<250 ppm), and grouped together well on the plots. The sherds from this location also show high and widespread levels of CaO (25–55%). This group is characterised by a very rich and optically active clay matrix with

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less than a 10% composition of poorly sorted, micritic, anhedral calciumudstone up to 1400 μm in length. All of the samples of this group presented a very low content of sub-rounded and rounded mono-crystalline quartz, consistently less than 5% and small in size (<350 μm); polycrystalline quartz is rare. We have identified accessory inclusions (<3%) of K feldspar, small muscovite flakes (<100 μm), and pure to amorphous iron nodules (up to 1500 μm in length). These data, along with observations on some clay pellets found in the clay matrix, suggest the utilisation of highly plastic clays with some limes and very fine sands for vessel construction. We observed molluscs and foraminifera, mainly planktonic, in several pots of this group (Fig. 3a). In some cases, Globigerinidae could be identified, while other samples presented benthic foraminifera such as Elphidium, Planorbulina, rotalids, bivalves, and red algae. The foraminifera, chemical, mineralogical, and textural data were well correlated with the characteristics observed in Tertiary clays (Table 1) located close to the site (Albero Santacreu 2011; Albero Santacreu and Mateu Vicens 2012).

Beyond the basic raw material composition, we can distinguish between different petro-groups...
primarily on the basis of the presence of different tempers, such as crushed calcite (spathic crystals of calcite) and calcarenites. Although other tempers, such as breccias (Petro-fabric 7) or grog (Petro-fabric 5) (Fig. 3f), were found in some pots, these other tempers are represented only by isolated samples; thus, we did not consider these cases when establishing petro-groups.

– Crushed Calcite Fabric (Petro-group 1): A large number of samples (n=14) had variable

Figure 3. Photomicrographs of ceramic thin sections: (a) Planktonic foraminifera (Globigerinidae) in sample SM-468 (XPL); (b) Crushed Calcite Fabric (SM-TIII, XPL); (c) Fe-rich paste (TSB-9/81, PPL); (d) Quartz-rich Fabric in sample TSB-17/23 (XPL); (e) Calcarenite Fabric showing a grain with coralline red algae traces (Rodoficies) in sample SM-181 (XPL); (f) Grog fragment added as temper in sample SM-659 (XPL).
amounts (15–40%, but generally 30%) of oriented euhedral, spathic, rhombohedral, and prismatic crystals of calcite, sometimes thermally altered to micrite. The grains showed a polymodal distribution and rarely exceeded 1500 μm in size (Fig. 3b). Finally, we were also able to observe in LIA1 samples the presence of oriented elongated voids related to the addition of organic matter, probably Poaceae, in some pots. Usually, the organic matter remains partially unburned, and the pots that contain this temper are characterised by higher levels of porosity.

– Calcarenite Fabric (Petro-group 3): This LIA1 group (n=3) is defined by non-oriented well-rounded and sorted micritic calcite grains of about 1000 μm that sometimes occur in aggregates cemented by micro-sparry calcite. Bivalves and other bioclasts are also present in the aggregates. Some of these calcareous grains showed surface traces that were strongly related to the presence of coralline red algae (Rodoficies). In this petro-group, the amount of quartz is increased as much as 15%, but the particles are still small in size (<400 μm), similar to the particle sizes that characterise Petro-group 1. We can conclude that a small number of pots from this location were tempered by bioclastic calcarenites rather than by crushed calcite (Fig. 3c). Only one sample had a low amount of spathic calcite (5%) of medium size (650 μm). Finally, we also detected the isolated occurrence of sandstone and calcareous sandstone rock fragments in some samples. The higher levels of quartz and the presence of rock fragments in Petro-group 3 can be related to accidental introduction, occurring when the rock was crushed to make temper for use in pottery production.

Figure 4. (a) Spathic calcite crystals that have been thermally altered (Sample SM-665, XPL); (b) BSEI-SEM with well-conserved laminated structure of clay minerals in sample SM-665; (c) Unburned organic matter in sample SM-472 (XPL); (d) XRD diffractogram showing the main mineralogical phases documented in Petro-group 3 (sample SM-246). Note the absence of high-temperature minerals.
that are compositionally dissimilar.

– Iron-rich Fabric (Petro-group 2): Chemically, the TSB pots made from this fabric were found to have a more random chemical dispersion than the samples tested from the SM site. The samples from the two different sites are clearly distinguishable by the higher content of Fe$_2$O$_3$ (8.5–17%), TiO$_2$ (2–5%), and Zr (250–550 ppm) found in the TSB pots. The examination of the matrix of some TSB samples under SEM-EDS revealed that the high levels of these elements are related to abundant ferric and titanium oxides and the presence of zircon. Divergences from the SM pots were also evident in the CaO levels; in the TSB samples these levels consistently remained below 25%. Petrographic analysis (n = 8) revealed an optically active matrix that was very red and/or black (XPL-PPL), with an abundance of circular pure amorphous nodule up to 2400 μm in size (Fig. 3c). The paste of the ceramics from the Iron-rich Fabric group seemed poorly mixed and had abundant clay pellets of up to 800 μm in size. These features suggest the utilisation of dirty or poorly-homogenised clays for vessel construction. Moreover, no microfossils were found in the matrix. Finally, some muscovite flakes and laths of about 100 μm were also observed. The coarse fraction is characterised mainly by fragments of micritic limestone and mono-crystalline sub-rounded quartz (5–10%) of less than 400 μm. As in some pots from the SM site, the vessels from the TSB site also had oriented, elongated, and large pores; this aspect is related to the presence of organic temper, which usually remains unburned in the core of the pots. Finally, we have documented the accessory (5%) presence of spathic, rhombohedral, and prismatic grains of calcite between 300 and 900 μm in size. The minority presence of this temper in the pots can explain why the TSB vessels have lower CaO and calcite levels (Table 1). Thin section analysis suggests that the main differences between the samples from the TSB Iron-rich Fabric group are related to the amounts of calcium-udestone, amorphous inclusions, quartz, and the presence/absence of spathic crystals of calcite.

– Quartz-rich Fabric (Petro-group 4): This fabric group, consisting of only two pots, is divergent from the other TSB and SM pots due to their low Fe$_2$O$_3$ (5–6%) and CaO (2–3%) content, respectively. This last aspect is well correlated with XRPD analysis, where calcite peaks were not detected. Nevertheless, the mineralogical composition of these two pots is characterised by high quartz content (25–30%), as confirmed by XRPD. The optical analysis reveals an optically active groundmass with low amounts of organic temper, where no foraminifera or calcite compounds could be identified. However, the pots have many non-oriented, but well-sorted monocrystalline sub-angular and sub-rounded quartz grains, with a maximum size of 600 μm (Fig. 3d). Finally, some pure amorphous nodules could be identified that were up to 600 μm in size. These data suggest the use of border calcareous clays. As it frequently occurs with sandy quartz fabrics (Riederer 2004), it is extremely difficult in these cases to establish whether these inclusions are of natural or artificial origin.

3.2. Chaîne opératoire and techniques
The chaîne opératoire represents an adequate concept for establishing an explicit distinction between objects and techniques. Objects possess physical character, while techniques are strongly related to human actions, carried out in accordance with the production of these objects. This distinction permits us to infer broad questions that exceed the material composition and allow us to approximate the social organisation and activities ‘hidden’ behind these actions. Techniques and materials represent technological choices made by the potters that define the formal properties and attributes of the artefacts. Furthermore, material capabilities also affect both the production process and the potential uses of the vessels, thus affecting human practices. By this reasoning, we understand that there can be strong interactions between people and the processes of fabrication, use, maintenance, and deposition of pottery (Lemonnier 1993; Dietler and Herbich 1998; Calvo Trias et al. 2004; Livingstone-Smith 2007).

3.2.1. Clay procurement
We have documented the use of raw materials consisting mainly of secondary illite-muscovite clays with K feldspars and quartz. Moreover, we have been able to distinguish three different types of clay deposits using chemical and thin-section analyses. The main clays employed in the production of pottery at the SM site were local calcareous fine-grained clays with low amounts of silt and fine sand, but rich in foraminifera (such as _Globigerinidae_). In contrast, we have documented that most TSB samples from the Late Iron Age 2 are usually rich in Fe$_2$O$_3$ and TiO$_2$, and are characterised by abundant amorphous inclusions and low carbonate content that are highly related to Fe-rich soils. We also detected the utilisation of border calcareous clays with low iron and high quartz content in some TSB pots.

3.2.2. Temps
Thin-section studies have documented the intentional addition of different materials for tempering pots. Crushed calcite is commonly identified by variable amounts (<40%) of rhombohedral grains in a large number of vessels. Sometimes, in LIA sherds, these crystals are combined with elongated voids related to the addition of organic matter (probably _Poaceae_). In a few LIA1 vessels we have documented the presence of peloids and traces of red algae (_Rodoficies_), usually associated with the utilisation of local calcarenites. In addition, we have assessed the use of small grains of crushed calcite-composed grog and calcareous rocks such as breccias in some LIA1 pots.

3.2.3. Firing strategies
By considering a precise composition of the base clay material and specific firing experiments (Albero Santacreu 2010), we observed the following results regarding the firing methods used for these artefacts: 1) an absence of high-temperature minerals as shown by XRPD (Fig. 4d); 2) no thermal decomposition of calcite crystals as shown in thin-section slides; and 3) evidence of un-vitrified matrix as shown by SEM and petrological studies (Fig. 4b). Our analysis suggests a low or very low firing temperature, never exceeding 800°C. This low-temperature firing
strategies are undoubtedly related to the required conditions for controlling the decomposition of calcareous bodies. By this firing method, potters could prevent fractures and burst processes from occurring as the calcite turns to calcium oxide and then rehydrates post-firing (Albero Santacreu 2007; 2010).

Optical analysis permits the division of the ceramics according to two dissimilar strategies of firing, based on the temperature, atmosphere, and duration of the firing process (García Rosselló et al. 2011). On the one hand, we documented LBA/EIA pots without organic matter and high amounts of spathic crystals of calcite, fired mainly in a reducing atmosphere. In these cases, the identification of thermal alterations in the calcite crystals (Fig. 4a), and the higher hardness of the product obtained provide evidence of higher firing temperatures (<800°C) and/or a longer duration. On the other hand, we also documented tempered LIA vessels containing unburned organic matter (Fig. 4c) that confirm that these samples were fired at very low temperatures (<700°C) and/or for a short duration. In these latter cases, the reduced cores of the samples suggest sluggish oxygen diffusion within the pottery, which was produced with organic-rich pastes under an oxidising atmosphere during the firing process (Maritan et al. 2006). These firings proceed in open fires and very quickly, normally in less than one hour, and the high amount of organic matter in the pastes allows the formation of only thin oxidised margins (García Rosselló et al. 2011).

4. Technological traditions
Technological traditions can be defined as the utilisation of concrete technical solutions and specific chaînes opératoires that existed in specific historical and social contexts. This way, technological traditions can be representative and characteristic of particular necessities in a given society. Continuous repetition of practices, technical gestures, and sequences in time and place developed the establishment of technological traditions strongly related to savoir faire, habitus, and rationale schemes. The advancement of technology thus requires both technical and social knowledge for developing and ensuring its continued survival. The persistence of technological traditions is strongly related to specific knowledge transmission processes, learning contexts, and the skill of the individuals. People learn how to get raw materials, as well as the ‘correct ways’ for producing and using material from their social interactions. By identifying recipes, technological traditions, and the quality of the final products in their cultural context, we can understand why pottery undergoes change or remains unchanged. Technological recipes therefore constitute rules that favour cultural identity and control over the fabrication processes, as well as the social organisation involved in the production of pottery vessels (Lemonnier, 1993; Dobres and Hoffman 1994; Gosselain 2000).

4.1. LBA/EIA: Late Bronze Age/Early Iron Age (1100–550 BC)
Pottery from LBA/EIA is extremely homogeneous and is characterised by the use of calcareous fine-grained clays and the addition of high amounts of spathic crystals of calcite (20–40%), which provides a very coarse texture to the pottery (Petro-group I). The homogeneity of the raw materials and tempers also reflects firing strategies; for these artefacts, we found that the firing temperature was kept below 800°C. Only thermally altered calcite tempered samples would have been seen with a firing temperature of 800°C. These data is in accordance with the existing knowledge pertaining to the ceramic technology observed in several archaeological sites of the Balearic Islands dating from the Middle Bronze Age (1400 BC), when these types of technological solutions were generalised amongst all potters. All of the archaeometric studies regarding Balearic pottery during the LBA/EIA period have noted the low variability of the ceramic record, suggesting the presence of relatively specialised potters in this era (Waldren 1982; 1991; Gómez-Gras and Risch 1999; García Orellana et al. 2001; Risch and Gómez-Gras 2003; Andreu et al. 2007; Lull et al. 2008).

All the data suggest that, in many settlements and territories of the Balearic Islands, potters in the LBA/EIA used the same strongly normalised recipes, techniques, and typologies (Guerrero Ayuso et al. 2007; Lull et al. 2008) to advance the processes related to the production of pottery. The potters’ use of the same technology and production strategies over long periods of time and over a broad territory suggests the presence of efficient communication networks among the potters and the diverse communities of the island and the archipelago.

This uniformity can also be observed among other technologies of this period, such as architecture, bone industry, and metallurgy (Guerrero et al. 2006; 2007). The homogeneous character of the pots suggests well-transmitted traditions and well-defined learning contexts, probably related to the existence of collective production spaces where information could be easily shared between all individuals. The existence of communal production spaces has also been detected in many sites of these periods (Salvà and Hernández 2009).

When using the extremely calcareous pastes that were produced during LBA/EIA, the control of the firing temperature and atmosphere becomes crucial to achieve an adequate final product. This last stage of the chaîne opératoire requires a high level of skill from the potters, and thus the utilisation (by all the artisans) of the same paste becomes relevant for the pottery survival of the entire community. Here, pottery becomes a reflection of the diverse social communication strategies within the community, as well as of the possible organisation of labour in communal areas. In this type of productive organisation, the vessels could acquire their highest social value between the members of the group, and thus represent a significant tool for establishing identity (Albero Santacreu 2008).

4.2. LIA1: Late Iron Age I (500–250 BC)
For LIA1 artefacts, our evidence supports the hypothesis of important changes in Majorca with regard to the preparation of pastes and the fabrication of pots. The changes coincide with the arrival of significant amounts of Punic materials to the island, especially after the 4th century BC (Guerrero Ayuso et al. 2002). At the same time, we observe the widespread introduction of variable amounts of organic matter to the pastes, usually in conjunction with crushed calcite. Phenomena such as the addition of organic matter as temper have been well documented, not only in the analysed record, but also at
vast amounts of raw materials and clay preparations at the SM site reveals the utilisation of the same type of clay involved in this delicate process.

The variability of paste composition also increased in these pottery samples, and new tempers such as calcarenites (Petro-group 3), breccias (Petro-fabric 7), and grog (Petro-fabric 5) are found to be occasionally introduced. The substitution of crushed calcite and the utilisation of other organic and inorganic materials for tempering pots were previously noted for this time period (Albero Santacreu 2007).

Potters used diverse tempers (organic tempers, calcite, calcarenites, breccias, limestone, grog, etc.) and recipes for preparing the pastes. These actions increased the number of fabrics documented in LIA1. While in previous periods only one type was documented, here we see the simultaneous use of seven different fabrics (Table 1). Thus, we witness during this period the widespread exploitation of the biotic and non-biotic resources available in the territory.

All these aspects suggest changes in the system of knowledge transmission, where the production begins to be more individualistic and the learning contexts are revealed to be more private. This hypothesis is closely related to the observations of Salvà and Hernández (2009), who argue that people developed productive activities in more private-domestic and less visible contexts during the LIA. In this era, the domestic space shrank and the tasks performed in those spaces were necessarily undertaken on a smaller scale. In contrast, productive activities were carried out in public and collective spaces during the LBA/EIA; consequently, people pursued such activities on a larger scale. This change correlates with a restructuring of domestic areas in many settlements from the beginning of the LIA (Palomar 2005; Lull et al. 2008).

The knowledge that was previously shared by all the artisans seems at this point to have been progressively restricted to low-scale producers with low specialised skills. In our opinion, these features are also evident in the firing strategies and raw materials selections during LIA1. Likewise, these samples are usually found to contain unburned organic matter, providing evidence of very low firing temperatures (<650°C) and short firing duration. We hypothesise a change in the firing strategy to more oxidised atmospheres developed in open firings. In ethnographic communities, these types of firing strategies are normally related to low-scale production (Livingstone-Smith 2007). The characteristics of the ceramics from the LBA/EIA period suggest that progressive changes were occurring in the social organisation systems. Pastes with increased levels of organic matter were likely utilised to ensure a minimum firing of pots in conditions where low-skilled potters could not control the high number of variables involved in this delicate process.

Likewise, the petrological analysis of the LIA1 samples from the SM site reveals the utilisation of the same type of clay deposits as those used at the site during LBA/EIA. In the microfossil analysis of the LIA1 samples, we also reported the presence of benthic (such as Discorbididae and red algae) and planktonic foraminifera (Globigerinidae) that attests to the continuity of the Tertiary clays as the main raw material. Even though certain changes occurred in terms of ceramic production strategies at the Puig de Sa Morisca site, the potters’ recipes show a certain continuity in the use of calcareous raw materials, rich in foraminifera, and the additional of crushed calcite (Petro-group 1). Thus, the CaO and calcite values obtained by XRF and XRPD analyses are still very high, as also observed in LBA-EIA ceramics (Table 1). This fact could indicate a certain continuity of social phenomena related to technology, especially its capacity of reinforcing identity bonds.

### 4.3. LIA2: Late Iron Age II (250–50 BC)

The high variability observed in the pottery production during LIA1 increases in LIA2. This later period is characterised by the discontinuation of extremely calcareous pastes in the TSB site and the introduction of pastes rich in Fe₂O₃ and TiO₂ (Petro-group 2). We have also detected the introduction of another new fabric, composed mainly of quartz (Petro-group 4). With regard to the tempers, we documented the preservation of organic matter that at this point represented the main non-plastic material of the pastes. The use of spathic crystals of calcite decreases (<15%) and becomes symbolic or trivial, so that fine textures become common in a large number of vessels. Firing temperatures and strategies remain very similar to those observed in the previous period.

Thus, it can be concluded that a change in the raw materials exploited and in the recipes mentioned earlier occurred at this time. Also, it can be proved that at TSB, located in the same territory as SM, different strategies for the collection of the raw materials and the preparation of the pastes were put into practice. Therefore, it can be shown that different production strategies were employed at each of these two sites.

Regarding production, we observe the highest variability in the raw materials, tempers, and techniques the artisans used to produce pots in the entire period under consideration. Potters from LIA2 expanded the number of clays (calcareous, siliceous, and ferruginous) and tempers (organic tempers, calcite, quartz-sands, calcarenites, breccias, limestone, grog, etc.) they used to produce ceramics.

This variability also becomes patent in the modelling techniques and surface treatments (García Rosselló 2010), as well as in the application strategies of slips (Albero Santacreu et al. 2012) and in the typology (García Rosselló et al. unpublished). Regarding pastes, the main technological choices of former periods, such as the use of highly calcareous resources and crushed calcite, lost their validity. This becomes evident in the lower CaO and calcite percentages (Table 1). All these data show that new social dynamics were affecting the production of pottery, in contrast with the homogeneity observed in the practices of former eras.

On the one hand, we observe in TSB samples the radical abandonment of the technological choices that characterised the production developed during the LBA/EIA (and partially in the LIA1 samples from the SM site). On the other hand, we note that these technical changes are correlated with the...
appearance in LIA2 of typological innovations (García Rosselló et al. unpublished), such as the production of hand-made ceramics that are inspired by foreign materials (Guerrero Ayuso 1985; Plantalamor and Rita 1986; Pons Homar 1991; Palomar 2005). In our opinion, these artefacts represent the development of new ideas and necessities that are materialised in new technological choices. The Punic contact with indigenous communities took place under unequal conditions and favoured the rise of a hierarchical social organisation, in stark contrast to the collective strategies observed in previous periods. This disruption of technology could be considered as the definitive establishment of new forms of pottery production. Collective productions seem to have been completely dismantled into small-scale firings and individualised production systems that developed in private contexts. The increased variability, worsened quality, and new pottery production contexts suggest that pots had a low social value. The social value of local wares may have been replaced by new Punic wheel-made vessels.

5. Conclusions

The ceramic characterisation suggests some interesting technological differences between the Late Bronze/Early Iron Age (1100–550 BC) and the Late Iron Age (500–75 BC) ceramics, particularly evident in the LIA2. This change becomes more obvious if we consider the pots of the two different sites under consideration here, both of different chronology, but situated in the same hinterland. The ceramic pastes, as well as the typology, the modelling strategies, and the surface treatments, increase their variability in this era.

As we already mentioned above, the changes may have been in response to new dynamics in the social organisation of pottery production, knowledge transmission systems, and learning contexts. These changes are congruent with historical processes, and with the changing necessities and rationale schemes of the people who lived in the Santa Ponsa area. They allow us to suggest different social, ideological, and economic functions inherent in the technological choices made by the potters from both settlements and periods studied. These traditions and their degree of variability are the result of different habits acquired by knowledge transmission in specific day-to-day social contexts.

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