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WHAT THE FIRE SAYS: FIRING STRATEGIES IN BRONZE AGE POTTERIES FROM THE BALEARIC ISLANDS (1700-850 B.C.)

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Archaeological context and goals

The work[1] comprises the analytical study of the firing processes used on 32 pots from different Bronze Age archaeological sites located in Majorca (Balearic Islands, Spain) (Figure 1). We have undertaken the study of 14 Late Bronze Age (ca. 1120-920 B.C., KIA- 33825) hand-made ceramics from the prehistoric site of *Puig de Sa Morisca* which is located on a hill in the Santa Ponsa area (Guerrero *et al.* 2007). In addition, we have also selected 18 samples from the Navetiforme I (boat-shaped house) of the Bronze Age village of *Closos de Can Gaià* which is located in the Porto Colom area (Guerrero *et al.* 2007).

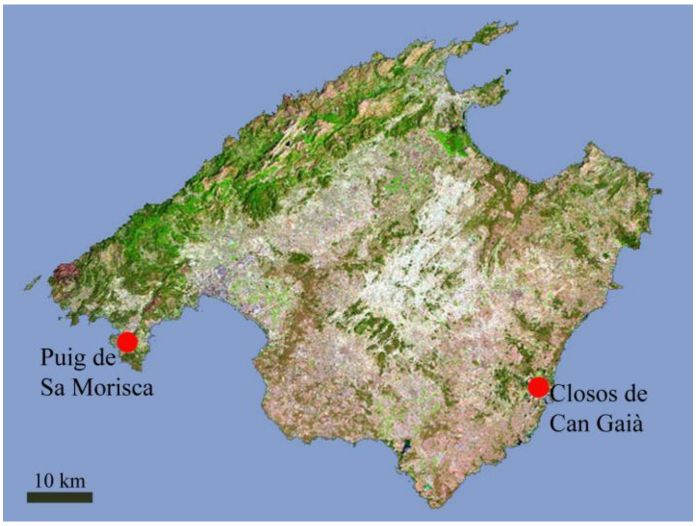

Figure 1. Map of Majorca showing the location of the archaeological sites under study.

Pots from the Early Bronze Age (ca. 1760-1610 B.C., KIA- 11221), the Middle Bronze Age (ca. 1420-1250 B.C., KIA- 11233) and primarily the Late Bronze Age (ca. 1040-840 B.C., KIA- 11232) were selected from this location. We have carried out X-ray powder diffraction (XRPD) analysis to evaluate the crystalline phases of the pots developed during firing and petrographic analysis for optically-based mineralogical studies. Finally, features of paste microstructures were taken by means of scanning electron microscopy (SEM). The main goals of the analysis were to determine temperatures, firing times and phase changes in the pots.

Results

Of the samples we analysed by means of XRPD, only Early Bronze Age and a few Middle Bronze Age sherds showed evidence of a slight over-firing (pottery that was fired either longer or at higher temperature than the average of the other types and, in consequence, presents high temperature mineral phases and an initial vitrification). This evidence is clearly visible in the high-temperature phases, as well as in the low intensity calcite peaks in the XRPD diffractograms (Figure 2a). Within the high-temperature phases detected, we find (insofar as can be expected, given that these samples are characterised by significant concentrations of CaO [13-25%]) the development of mineral phases typically associated with calcareous pastes, such as anorthite and ghelenite. We also find hematite peaks, a mineral phase that can crystallise in oxidising conditions starting at 775º C. Finally, we documented the presence of spinel, suggesting a firing temperature of between 775º to 875º C (Ortega *et al.* 2005; Maritan *et al.* 2006).

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The presence of a phyllosilicate peak at 4.45 Å reveals the survival of clay minerals in the paste, probably illite and muscovite, both of which have structures that survive in paste in temperatures up to 900º to 950º C (Murad and Wagner 1996; Albero 2010). This observation fits well with the absence of wollastonite and mullite in the XRPD diffractograms, as these mineral phases form in temperatures above 950º C, as was the case in the experimental firings (Albero unpublished). All the data available establish a firing temperature of between 850º and 950º C for these samples and the existence of two possible firing strategies, one consisting in a longer firing at 850º C and the other a faster firing at higher temperatures (900º to 950º C).

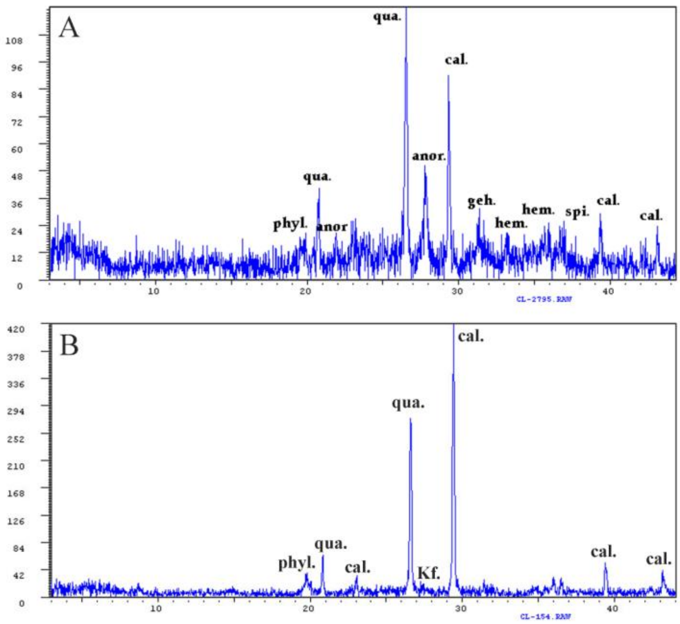

Figure 2. a) XRPD diffractogram showing the high-temperature phases identified in Bronze Age pot CLG-2795; b) XRPD diffractogram showing the mineral phases identified in Bronze Age pot CLG-154, Note the absence of high-temperature minerals.

The microstructure of the paste from these samples, which we examined by means of SEM on freshly-cut sections, also provides evidence of a clay matrix with smooth surfaces and rounded, soft fusion points between the boundaries of the clay flakes (Figure 3a). This state is typical of cell microstructures that appear in calcareous pastes with a degree of sintering related to an initial vitrification. The features of the microstructures observed in these pots fit well with the temperature suggested by the high-temperature mineral phases detected by means of XRPD, which also confirms a firing temperature of between 850º to 1000º C. Nevertheless, there are other samples from this period where there is no evidence, either in the XRPD (Figure 2b) or SEM (Figure 3b) analysis, of over-fired pots. Therefore these pots show firing temperatures up to 800º C.

In contrast with the Early Bronze Age, the majority of the Middle Bronze and all the Late Bronze Age samples analysed by means of XRPD are characterised by the absence of high-temperature minerals and very well-preserved calcite peaks. This suggests, according to some self-conducted experiments (Albero 2010), that the firing temperature never exceeded 800º to 850º C. The microstructure of various samples we studied by means of SEM is in agreement with the XRPD data. None of these samples present sintering evidence on the surfaces and boundaries of the clay minerals. The microstructure of the matrix also shows no signs of vitrification, suggesting that the potters fired the pots up to a temperature of 800º C. The MBA and LBA samples had variable amounts (generally 30%) of euhedral, spathic, rhombohedral and prismatic crystals of calcite sometimes thermally altered to micrite (Figures 4a and b). The grains showed a serialised distribution and rarely exceeded 1500 μm in size. Petrographic analysis suggested differences in the firing temperature between some samples. In many cases, the identification of thermal alterations in the calcite crystals gives evidence of firing temperatures between 750-800º C.

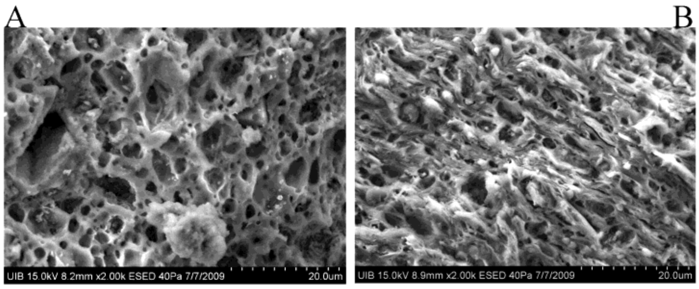

Figure 3. a) SEM image of the matrix microstructure in which clay flakes have smooth surfaces and soft and rounded fusion points on the boundaries (slightly over-fired sample CLG-2795); b) SEM image showing an early sintering state in the clay matrix of the sample CLG-154.

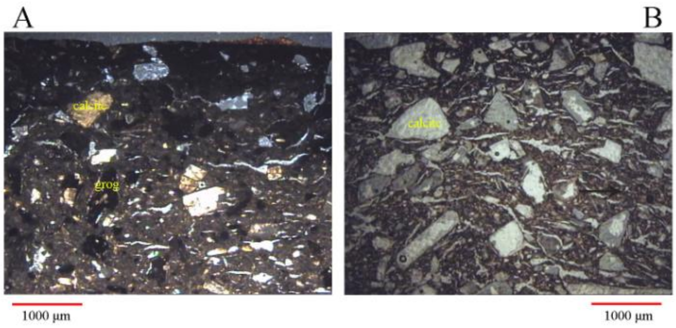

Figure 4. Photomicrographs of ceramic thin sections, a) Grog-tempered Fabric in the Early Bronze Age sample CLG-149 (XPL); b) Crushed Calcite Fabric showing calcite crystals that have been thermally altered in the Late Bronze Age sample CLG-1233 (PPL).

Conclusions

Analysis permits the Bronze Age ceramics to be divided according to two dissimilar strategies of firing depending on the temperature and duration of the firing process. The firing strategies are also in agreement with the utilization of different recipes.

On the one hand, the firing temperature of most EBA grog-tempered pots (Figure 3a) was between 850º and 950ºC, as corroborated by the low intensity of the calcite peaks and the presence of high-temperature mineral phases in the XRPD diffractograms. Also, the microstructure of these samples gives evidence of the highest degree of sintering. As with these samples, other studies have demonstrated the existence of slightly over-fired sherds with lower calcite values in EBA sites from Menorca, for example, in pots from the archaeological site at *Alcaidús* (Vendrell 2003) and at *Trebaluger* (Andreu *et al.,* 2007). Nevertheless, as in this case study, there are other sites from this period where there is no evidence of over-fired pots (García Orellana 2001: 59-60). The data from *Cova des Carritx* also suggest higher firing temperatures for grog-tempered samples with low amounts of calcite, although high-temperature phases could not be detected by means XRD (Gómez Gras and Risch 1999).

As the evidence of the variability in the firing atmospheres and temperatures suggests, the EBA potters were not interested in strictly controlling firing conditions. Most probably, these data can be related to the use of firing structures where the distribution of the pots and weather factors greatly influenced the firing process. However, the presence of slightly over-fired pots demonstrates that the firings sometimes had a longer duration and/or higher temperatures. Given the small quantity of crushed calcite potters added to the EBA vessels, the use of heterogeneous firing strategies would not pose a problem, as would be the case with pots from later periods. The potters were not forced to develop any specific firing strategy to produce adequate vessels.

On the other hand, we documented during MBA-LBA highly calcareous pots with high amounts of crushed calcite. The firing temperature we observed in these pots remained below that observed in EBA vessels. The absence of high-temperature mineral phases and intense peaks of calcite in the XRPD diffractograms and of well-preserved calcite crystals in the petrographic observations provide evidence that potters kept firing temperatures below 850º C. Such a low firing temperature would be an excellent strategy for firing highly calcareous pots, a feature that characterized the samples analysed (CaO 30-50%). By this firing strategy potters could prevent fractures and burst processes from occurring as the calcite turns to calcium oxide and then rehydrates post-firing. In conclusion, at the same time that potters introduced new recipes into the production of pottery, they employed new firing strategies to bake extremely calcareous pastes. The consistency in the ceramic record is evident in the regular use of low firing temperatures that clearly differ from the 850º to 950º C observed in many EBA pots.

Changes in firing strategies among the different periods could be related in different societies to social and economic phenomena (Pool 2000; Sillar 2000). The Middle Bronze Age period in the Balearic Islands (ca. 1500 B.C.) is typified by a long series of changes in wide aspects of the island's material culture, the introduction of new technologies and the intensification of interaction within the archipelago (Guerrero *et al.* 2007). In our case, it is possible to identify two technological firing traditions in the ceramics. One technological tradition originated in the EBA and was rooted in the Bell-beaker period, during which time potters infrequently used calcite temper and employed various firing strategies. The other tradition began to spread after the Naviform period (ca. 1500 B.C.), when potters depended on calcite temper (Albero 2008) and began to standardise firing temperatures.

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References

Albero, D., 2008, La calcita como desgrasante añadido en cerámicas prehistóricas: estado de la cuestión. *I Congreso de Jóvenes en Investigación Arqueológica*, Universidad Complutense de Madrid, pp. 93-100.

Albero, D., 2010, Pastas desgrasadas con calcita y pastas desgrasadas con materia vegetal: aproximación experimental. *Boletín del Laboratorio de Petrología y Conservación Cerámica* 2 (2), Universidad de Catamarca, Argentina, pp. 18-34.

Andreu, G., Badia, M., Gómez-Gras, D., Lull, V., Micó, R., Martín-Martín, J., Palomar, B., Rihuete, C., Risch, R., 2007, El desarrollo de la alfarería prehistórica en Menorca: Una primera aproximación. *L' arqueología a Menorca: Eina per al coneixement del passat*, Consell Insular de Menorca, pp. 125-141.

García Orellana, J., Molera Marimon, J., Vendrell Saz, M., 2001, *Caracterització de ceràmiques prehistòriques de l'illa de Menorca*. Treballs del Museu de Menorca, Govern de les Illes Balears.

Gómez-Gras, D., Risch, R. 1999, Análisis petrográficos de cerámicas de la Cova des Càrritx. In (Ed. V. Lull, R. Micó, R. Risch y C. Rihuete) *La Cova des Càrritx y la*

Cova des Mussol. Ideología y Sociedad en la Prehistoria de de Menorca, Consell Insular de Menorca. pp. 567-580.

Guerrero, V., Calvo, M., García, J., Gornés, S., 2007, *Prehistoria de las Islas Baleares: Registro arqueológico y evolución social antes de la Edad del Hierro.* BAR Internacional Series 1690.

Maritan, L., Nodari, L., Mazzoli, C., Milano, A., Russo, U., 2006, Influence of firing conditions on ceramic products: Experimental study on clay-rich inorganic matter. *Applied Clay Science*, 31, pp. 1-15.

Murad, E., Wagner, U., 1996, The thermal behaviour of an Fe-Rich illite. *Clay Minerals* 31, pp. 45-52.

Ortega, L., Zuluaga, M., Alonso, A., Olaetxea, C., 2005, El estudio arqueométrico de las producciones cerámicas. *Munibe* 57, pp. 365-388.

Pool, C., 2000, Why a kiln? Firing technology in the Sierra de los Tuxtlas, Veracruz (Mexico). *Archaeometry* 42 (1), pp. 61-76.

Sillar, B., 2000, Dung by preference: the choice of fuel as an example of how Andean pottery production is embedded within wider technical, social, and economic practices. *Archaeometry* 42 (1), pp. 43-60.

Vendrell Saz, M., 2003, Estudi analític de les ceràmiques del jaciment d'Alcaidús i comparació del conjunt. In (Ed. L. Plantalamor y J. Marqués) *El sepulcre megalític d' Alcaidús.* Treballs del Museu de Menorca 26, pp. 269-273.