ROMAN AMPHORAE AROUND THE CHANGE OF ERA: PRODUCTION AND CONSUMPTION PATTERNS IN THE NORTH-EAST OF THE IBERIAN PENINSULA

[1,2]L. Vila - [2]J. Buxeda i Garrigós - [3]V. Kilikoglou - [3]A. Hein

[1]Elements. Centre de gestió i difusió de Patrimoni Cultural, Palma de Mallorca, lvila@catalonia.net
[2]Cultura Material i Arqueometria (ARQ|UB), Facultat de Geografia i Història, Departament de Prehistòria, Història Antiga i Arqueologia de la Universitat de Barcelona, jbuxeda@ub.edu
[3]Institute of Materials Science, National Centre of Scientific Research-„*Demokritos*", kilikog@ims.demokritos.gr, hein@ims.demokritos.gr

Abstract: *This paper focuses on technological change concerning the first Roman amphorae designs produced along the Citerior Roman province. Archaeometrical research has been conducted in order to characterize the material properties of the ceramic material and evaluate several performance characteristics of these different designs. The results so far reveal different technical choices among workshops and different distribution patterns in the main Roman cities of the area.*
Keywords: *technological change, archaeometry, Roman amphorae, consumption, production*

INTRODUCTION

Parameters that define technological changes have always been a key issue of research in archaeology. In this paper we present a case study dealing with amphorae design variations that took place between the 1st century BC and the 1st century AD along the coast of the *Citerior* Roman province —renamed *Tarraconensis* after Augustus' political reorganization. The area roughly corresponds to the nowadays coast of Catalonia.

During that period, most of the coastal territory in the north-east of the Iberian Peninsula was devoted to the mass production of wine and, likewise, to the production of amphorae to serve as wine containers in overseas trade. As a substitution of the previous Iberian amphora, whose design had been derived from Phoenician models, the first type to be produced was an imitation of the typical Roman amphorae design, Dressel 1. Its production began in the middle of the 1st century BC, but shortly afterwards was replaced by two new designs peculiar to the Catalan area: Laietana 1 (also called Tarraconense 1) and Pascual 1 (**Fig. 1**). Yet, the archaeological evidence shows a wider distribution for the latter type as well as a longer life span, until the first third of the 1st century AD.

Both archaeological and historical sources available have traditionally been used to fashion explanatory narratives about the economic phenomenon represented by this Roman trade of wine, but few words have been written about the technological change stemmed from the so-called *Romanization* process — at least concerning these amphorae productions. In trying to bridge this gap we suggest to apply the concept of *behavioral chain* (*Skibo & Schiffer 2001*) and, thus, focus the analytical effort on the specific activities in which these vessels were involved. In so doing, a combination of analytical techniques has been devised to measure some material properties of the ceramic. Moreover, this combination of techniques has also served to simulate and evaluate a set of performance characteristics of these amphorae. This strategy should shed light on the set of compromises that configured amphora technology as well as on the most relevant situational factors involved in the production and consumption of the vessels (*cf. Sillar & Tite 2000*).

MATERIALS AND ANALYTICAL PROGRAMME

A set of 970 amphorae have been sampled for this study. Shards were recovered at 13 main production centres located along the Catalan coast, and 14 consumption centres located in that area, as well as in the recent territories of France, Germany and Tunisia. Criteria for the sampling of the individuals included representativeness of the range of macroscopic fabrics and the different amphora types recovered at the site.

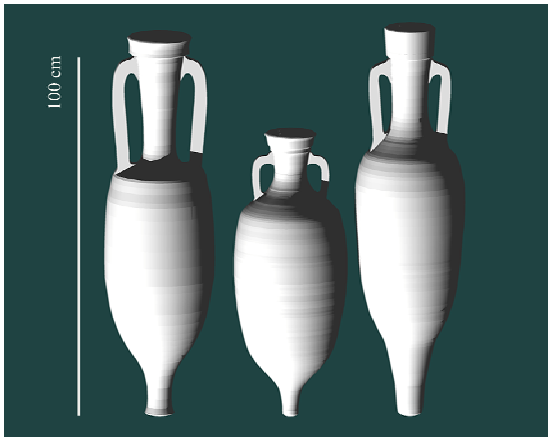

Fig. 1 Representative models of the Roman amphorae. Form left to right: Dressel 1, Laietana 1/Tarraconense 1 and Pascual 1

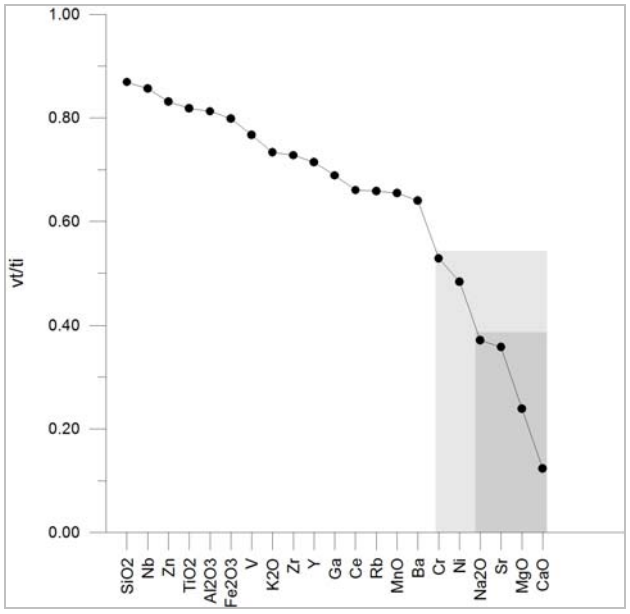

Fig. 2 Bivariate plot with chemical elements in rank order of increasing contribution to total variability, in abscises, versus vt/τ_i values, in ordinates

Chemical composition of the individuals has been determined by X-Ray Fluorescence (XRF) analysis and mineralogical characterization has been achieved by X-Ray Diffraction (XRD) analysis. In some cases Scanning Electron Microscopy (SEM) has been used to characterize the microstructure and the stage of sintering of the ceramic matrix (*Vila et al. 2006; Hein et al. 2002*). Additionally, a series of mechanical properties tests have been performed in order to study the strength and toughness of the materials. Furthermore, material properties have been evaluated taking into account the different shapes of these amphorae, by Finite Element Methods (FEM). This methodology enables us to evaluate the mechanical performance of the vessels under different kind of loads and simulating transport conditions (*Kilikoglou et al. 1998; Vekinis & Kilikoglou 1998; Kilikoglou & Vekinis 2002; Vila et al. 2008*).

RESULTS AND DISCUSSION

Following the statistical approach proposed by *Aitchison (1986), Buxeda (1999), and Buxeda & Kilikoglou (2003)*, total variation is used as an estimation of the existing chemical variability of the whole data set. As expected, the resultant value (vt=1.97) might be considered high as a reflection of the heterogeneous nature of the assemblage, representing different workshops and consumption centres. As shown in **Fig. 2**, the chemical elements that introduce most of the existing variability are mainly calcium, magnesium, strontium, and sodium. This variability can be attributed, mainly to the different technical choices during pottery-making (*Vila et al. 2006; Schwedt et al. 2006*, and references therein), and to a lesser extent to several contamination and alteration processes usually observed in this kind of productions. Whereas some workshops seemingly change from using low calcareous to calcareous pastes during its activity period and roughly in parallel to the change of shape designs (for example, Cabrera de Mar), others made up all the amphora types from low calcareous pastes (for example, El Mujal) (*Vila et al. in press-b*).

Furthermore, if attention is focussed on individual workshops, total variation still provides high values despite the fact that all individuals were recovered either inside the same kiln or in its immediate surrounding and, therefore, a monogenic assemblage should be expected. The general trend seems to be represented by chemical groups delimitated by end-members with an array of intermediate compositions through a continuum. The reason for these relatively high chemical spread even within the same workshop can be traced up to the situational factors in which the production of these vessels were embodied. In this regard, the normal expectation (see *Kingery 2001*) of these containers must be kept in mind. These Roman amphorae were primarily designed for shipping goods (wine) in a single use fashion. Hence, the main value of the trade would not be the vessel itself but its content. It would be the final selling of the wine what would produce the benefit for all actors involved in this long chain of wine and amphorae production and distribution. Moreover, it must be noticed that shipping, of this great volume of trade, would be restricted to few months along the Mediterranean Sea, as mentioned by classical sources. Thus, taking into account the constraints imposed by the wine production-schedule (see *Paterson 1982*), this would also contribute to this hurried fashion production. As a consequence of the previous considerations, the chemical trend observed in these productions might be the result, at some extent, of a paste preparation not following rigorously standardized processes.

In spite of this, one of the basic performance requirements in amphora technology is avoidance of failure. Otherwise, catastrophic cracking would cause the content to spill out, resulting in a partial lost of the investment, or affecting boat's buoyancy at worst. For that reason, some mechanical properties of the ceramic material have been studied. First of all, equivalent firing temperatures (EFT) of the individuals were estimated. In that sense, the mineralogical characterization reveals a tendency to achieve high temperatures (950-1000ºC), which is especially clear in Pascual 1 productions. In the case of calcareous productions, a fair amount of vitreous phase is produced at this range of temperature and remains stable between 850-1050ºC. Thus, if a higher strength associated with and extensive vitrification is to be produced, the control over the firing process would be less critical than in low-calcareous productions, something that might be desirable in pottery-making in a hurried fashion.

Furthermore, mechanical properties of fracture strength and toughness have been estimated. The results show a typical unstable crack propagation mode (*Kilikoglou et al. 1998*) in most of the individuals tested. The general trend is high fracture strength values but lower energy dissipation from crack initiation until final failure. This behaviour is the result of a combination of factors, but it has to be stressed that, in any case, the high EFT of the individuals analyzed is certainly playing an important role. The increased strength in the expense of toughness is compatible with the use of the amphorae to carry liquids. From the engineering point-of-view the goal is to avoid crack initiation (high strength), because if this happens then the liquid will be lost even if the vessel does not fail completely.

In studying technological change, it is crucial to discern among the properties of the material the artefact was made of, and the performance characteristics that should be evaluated in the context of a specific activity (*Schiffer & Skibo 1997: 31-32*). For this reason, a quantitative model of each amphorae type has been created using the FEM approach (*Vila et al. 2008*). By using FEM, different mechanical loads can be applied to each model in a computer simulation and predict which conditions would cause vessel failure.

Following this approach, the loading conditions of common activities have been simulated. In the case of filled amphora lifted by the two handles (**Fig. 3**), the results show a maximum strain at the joint of the handles and the body of the vessel, representing just 3% of the total fracture strain of the material for the Dressel 1 type, and 6% for the Laietana 1 and Pascual 1 types.

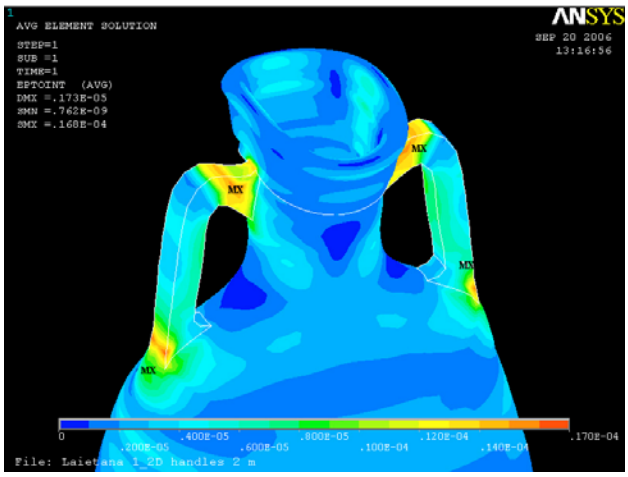

Fig. 3 Strain in Laietana 1 model as calculated by FEM. Loading conditions represent the amphorae being lifted simultaneously by the two handles and the full weight being equally distributed. The weight of this type is estimated to be about 15 kg and its capacity around 25 l. Location of maximum strain is indicated with MX.

As expected, these results are not critical in any case and, therefore, all designs considered could have been lifted by the handles without failing. Conversely, the loading conditions for the amphora at the bottom, when stacked for shipping or storage, appear to be critical for Dressel 1 type (maximum strain corresponding about 86% of fracture strain), but neither do for Laietana 1, nor for Pascual 1 (maximum strain representing 49% and 48% of the fracture strain, respectively). These results certainly reveal great differences in the mechanical performance of the three shape designs. Further investigation will provide more criteria for assessing the role played by these different performances in driving forward shape design changes.

Finally, and as far as provenance is concerned, it has to be stressed that discrimination at the inter-regional level is possible by chemical analysis despite the fact that many workshops were located in a very similar geological environment (*Vila et al. in press-b*) and that the reference groups of the production centres are not tightly homogeneous, as has already been pointed out. However, the chemical trend discussed above points to the definition of reference groups of the production sites as an essential starting point in provenance studies concerning these vessels. In this sense, **Fig. 4** illustrates the dendrogram resulting from the cluster analysis of the chemical data representing all the production centres and two main consumption centres: the Roman cities of *Baetulo* and *Emporiae*. As can be observed, the results so far reveal different distribution patterns concerning both cities. The amphorae recovered at the city of *Baetulo* seems to be mainly produced in workshops located in its surrounding, while the city of *Emporiae* seems to be supplied by many of the production centres that operated along the coast. In any case, again it is hoped that further investigation will shed light on these seeming distribution patterns.

CONCLUSIONS

The results so far suggest that the production of the first Roman amphora types recovered in the north-east of the Iberian Peninsula (Dressel 1, Laietana 1, and Pascual 1) did not follow a highly standardized paste preparation process. This could be related to the mass production process and, especially, to the very important fact that wine would heavily weigh the whole chain of production and distribution. Important differences in the mechanical performance of the three amphora shape designs have been observed. It is worth pointing out that the typical Roman amphorae design, Dressel 1, would be especially problematic during shipping, when the vessels used to be piled up. On the contrary, this specific activity should not cause any problem affecting vessel integrity in later Laietana 1 and Pascual 1 shape designs.

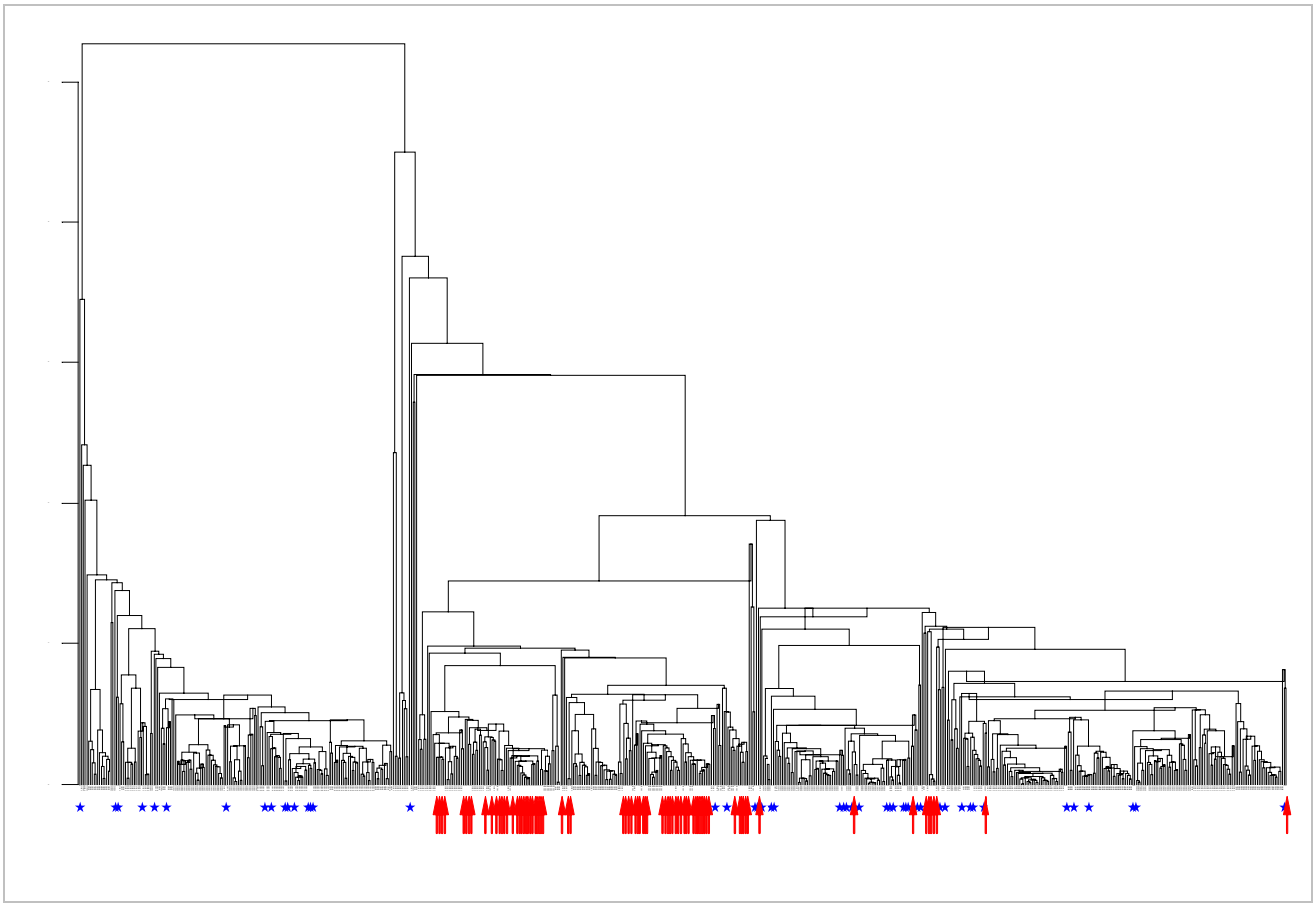

Fig. 4 Dendrogram resulting from the cluster analysis of XRF data using the centroid method and the squared Euclidean distance as a dis-similarity measure on the subcomposition Fe_2O_3 (as total Fe), Al_2O_3, MnO, TiO_2, MgO, CaO, Na_2O, K_2O, SiO_2, Ba, Rb, Nb, Zr, Y, Sr, Ce, Ga, V, Zn, Ni and Cr, using SiO_2 as divisor in logratio transformation. Stars=amphorae recovered at *Emporiae*. Arrows=amphorae recovered at *Baetulo*

Besides this, significant technological differences have also been observed within and among production centres, sometimes related to changes in shape designs. In some cases, a change can be observed from using low calcareous pastes, border calcareous pastes, to high calcareous pastes roughly in parallel to shape design changes (Dressel 1, Laietana 1, and Pascual 1, respectively). However, this is far to be the general pattern. All this high complexity is already pointing to the fact that although shape design seems to be an easy lineal historical development, in terms of technology, potter's tradition, and technology transfer, it is not. And only archaeometrical approaches, integrating provenance, technology, mechanical properties and FEM, embodied on appropriate theoretical grounds, would shed light on this complex phenomenon.

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