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Strength of pre-Roman amphorae: Comparison of the different types

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ABSTRACT

Given that amphorae were used for storage or for long and/or short distance transport, they must have been able to retain their content and, at the same time, be able to resist important load during transport. This paper concerns aspects of the techno-functionality of pre-Roman Iberian amphorae. The basic performance requirement concerned here is the mechanical strength (transverse rupture strength: TRS). Strength is related to the adequacy for storage or short and/or long distance transport that, up to now, is only assessed by typological identification or archaeological evidence. Experimental implementation on actual archaeological material has confirmed that strength increased with higher firing temperatures, less porosity, finer texture, less calcareous composition and a more siliciclastic component. The general conclusion is that only specific types of Iberian amphorae were appropriate for short distance and occasional transport.

1. Introduction

The mechanical properties of ceramic materials are decisive when manufacturing items that will suffer from impacts and different kind of loadings during usage. While this is fully understood in advanced ceramics, it is sometimes overlooked in archaeological ceramics, probably due to the difficulty in testing these properties. Mechanical resistance offers information on the maximum stress that the pottery can stand without breaking, which is directly related to its homogeneity and texture.

Pottery generally can be considered a brittle material with low tolerance to crack propagation. Its mechanical properties depend on the exact microstructure of the material, and, consequently, on the different aspects of manufacture. On one hand, the nature of the clay particles and, on the other, the relative abundance (packing), type, size, shape and distribution (hard or soft) of the natural inclusions and/or the temper are of considerable importance with respect to the mechanical properties of the ceramic product. Finally, the size, shape and distribution of the pores, the firing conditions (temperature and atmosphere) and, consequently, the extension and kind of developed vitrification all contribute to the final properties.

There are a number of important experimental studies on mechanical properties simulated in artificially prepared material similar to ancient pottery that, in a few cases, also involve alternative tests on archaeological pottery with small size sample requirements (Hertzian fracture stress) (Kilikoglou et al., 1995, 1998; Vekinis and Kilikoglou, 1998; Kilikoglou and Vekinis, 1998, 2002; Tite et al., 2001; Müller et al., 2010, 2015). Nevertheless, there are only a few published articles on mechanical properties through studies carried out directly on ancient pottery. They concern mainly the resistance of Roman amphorae to sustain load (Martínez et al., 2007) or deal with the importance of shape as a functional requirement in transport jars (Vila, 2008).

The effect of temper on the mechanical performance of ceramics has been studied and explained with the development of appropriate models by Kilikoglou et al. (1995, 1998), Vekinis and Kilikoglou (1998), and Kilikoglou and Vekinis (1998, 2002). Strength in replica materials has, generally, proved to be inversely related to quartz content. Meaning that, higher quartz tempering displays significant energy dissipation during fracture, since the presence of relatively elevated quartz inclusions (more than 20%) in a ceramic leads to the development of extensive micro-damage networks through drying and firing. This results in a substantial reduction of the strength that can be controlled by keeping the amount of temper to around 20%.

The effects of the shape and the form of the porosity and the tempering, on the one hand, and microstructure and texture, on the other, on the mechanical performance of a pottery were further assessed by Müller et al. (2010, 2015). These latter studies developed on experimental briquettes, testing replica material prepared with calcareous and low calcareous clays (probably used for ancient pottery), tempered with material of different shapes (bulky and platy) and fired under different temperatures. The differences in strength were semi-quantitatively

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measured by applying an improved damage zone model which was previously proposed by Kilikoglou et al. (1998). Both studies showed that platy phyllitic temper normally greatly improves the strength, but also reduces fracture energy and toughness. To preserve relatively high strength without loosing toughness, finally, the addition of bulky siliciclastic temper more suitable, though, nevertheless, maintaining the proportions at under 20%.

These experimental results had and have an important influence on the understanding of past technological choices. In the case of transport amphorae, for example, strength plays a significant role in their mechanical performance, since they receive continuous knocks and pressure during transportation (bending stress). For utilitarian vessels such as cooking pots, in contrast, fracture energy and toughness of is much more important, given that they have to stand repetitively high firing temperature without breaking. Eventually, in accordance with the results of the previously mentioned works, for amphorae, higher firing temperatures, finer and quite homogeneous texture containing less and soft platy tempering (such as phyllites) would be preferable. Nevertheless, since the increase in strength is, generally, accompanied by a decrease in fracture toughness, adding only platy tempering could result in its immediate collapse during transport.

Until recently, archaeologists believed that Iberian amphorae were used principally for storage, since there was no significant archaeological evidence of their presence far beyond the borders of the Peninsula: this in contrast to the significant presence of Punic and Greek amphorae in the Iberian Peninsula, demonstrating the existence of an organised trade network between Iberians, Phoenicians and Greeks. Recent archaeometrical evidences, however, have demonstrated the export of Iberian amphorae from the Catalan and Valencian coasts to the Balearic Islands and southern France, indicating the consumption of these types of amphorae, at least, through short-distance occasional transports (Tsantini, 2007; Tsantini et al., 2005a,b; Ribera and Tsanini, 2008).

In the present work the strength of the different types of pre-Roman Iberian amphorae is measured and the relationship between their strength and their chemical and mineralogical composition, firing temperature and microstructure is interpreted. The main goal is to evaluate the suitability of the different Iberian amphora types for storage and/or for short or long distance transport. The indirect aim is to determine the level of technological knowledge of the inhabitants of the Iberian Peninsula before the Romanization process. To expand the conclusions further, a comparison was made with studies on the strength of contemporary Punic amphorae studied elsewhere (Vekinis and Kilikoglou,

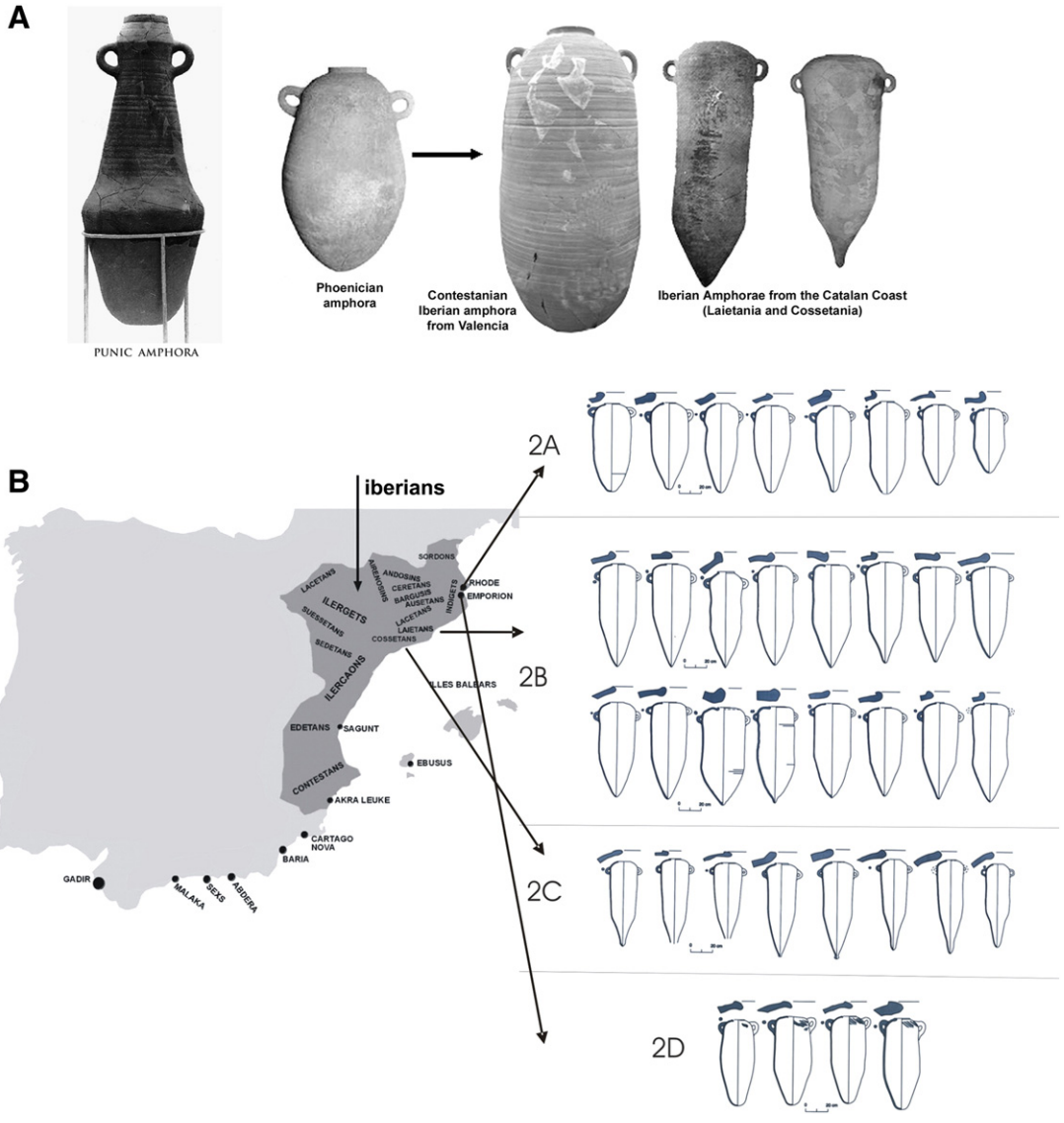

Fig. 1. A: Punic amphorae and the evolution of Phoenician amphorae into the basic Iberian types. B) Different Iberian amphorae types, defined mainly for the studied areas.