



## Provenance evidence for Roman lead artefacts of distinct chronology from Portuguese archaeological sites



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### ARTICLE INFO

#### Keywords:

Pb isotope ratios  
Sn content  
*Glandes plumbeae*  
*Fistulae aquariae*  
Hispania Ulterior  
Lusitania

### ABSTRACT

In the present study, a set of 24 *glandes plumbeae* found at Alto dos Cacos, a Roman Republican military camp located in the Tagus valley, Portugal, was analysed by a quadrupole based ICP-MS to determine the tin (Sn) content and lead (Pb) isotope ratios. Results were compared with similar data previously obtained for *fistulae plumbeae aquariae* from Conimbriga, an important Lusitanian Roman centre during the Empire. Low Sn contents ( $\leq 0.01$  wt%) were observed in 25% of *glandes plumbeae* indicating that were probably made with non-recycled lead. A similar situation was perceived for the set of *fistulae aquariae*, although most of the remaining *fistulae* present systematically higher Sn concentrations than those of *glandes* suggesting that lead recycling increased during the Empire. Pb isotope ratios distribution differentiated the analysed samples into two distinct groups: one composed by most of *glandes plumbeae* (15) and the other by the remaining *glandes plumbeae* (9) and all *fistulae aquariae*. The comparison with Pb isotope ratios of the published data for several lead ore deposits, exploited by the Roman in Iberian Peninsula, suggests that lead used in the manufacture of most of the *glandes plumbeae* would come from Linares-La Carolina, Alcudia Valley and Ossa Morena Zone. Also, some *glandes* could have been made using these ores, probably mixed with lead ores from *Gallia Narbonensis* (Southern France) or from Sardinia in the Mediterranean region. On the other hand, lead used in most *fistulae aquariae* came from Iberian mines, namely from Sierra Morena (Alcudia Valley and Linares-La Carolina mines) and Ossa Morena mining district, although in some cases, probably mixed with lead from the Iberian Pyrite Belt.

### 1. Introduction

Lead (Pb), an unaesthetic metal, became of great economic importance during Roman times due to its large scale use in silver production (cupellation process). Besides, it was widely used in architectural and hydraulic structures, and also in containers, sarcophagi and military weapons, as sling bullets used by Roman legions.

The Romanization of Iberia started during the 2nd century BCE becoming *Hispania* an important source of silver and lead, but also of copper, tin and gold (Edmondson, 1989; Rodà de Llanza, 2009). During the Republic, the mining district of Cartagena (*Carthago Noua*)/Mazarrón turned out to be the most important source of silver and lead in the Iberian Peninsula, exporting to other Roman regions as testified by lead ingots found in several shipwrecks ascribed to this period (Domergue et al., 1974, 2012; Trinchèrini et al., 2001, 2009). With the end of the Republic, the mines of Linares-La Carolina, Alcudia Valley, Fuente Obejuna and Los Pedroches, located in Sierra Morena region,

replace Cartagena/Mazarrón as the most important source of lead and silver, supplying high amounts of these metals to the Roman Empire. Later on, during and after the Flavian period, Riotinto mining region, in the Iberian Pyrite Belt, became the region with the most productive silver mines in Iberia. However, it was necessary to import lead from other regions, since in Riotinto there was not enough lead to proceed with the silver cupellation process (Edmondson, 1989). It must be noted that other lead mines beyond those either during the Republic or during the Empire were exploited although on a smaller scale than those referred to above.

The abundance of lead made possible a diversity of applications including the manufacture of military weapons as sling bullets (*glandes plumbeae*) used by slingers of the Roman legions. *Glandes plumbeae* were long-distance light weapons widely used by legionaries mainly during the Republic and also during the Augustan-Tiberian period. These weapons, having diverse sizes, shapes, and weights, were usually made by casting lead in moulds (Dohrenwend, 2002; Rihll, 2009; Laharnar,

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Fig. 1. Geographical location of the Roman Republican military camp of Alto dos Cacos (Almeirim) and of the town of *Conimbriga*.

2011). On the other hand, high amounts of this metal were used to the manufacture of plumbing hydraulic systems (*fistulae plumbeae aquariae*) at public buildings and private houses, as occurred in *Conimbriga* or *Pompeii*, for instance. These two kinds of artefacts, *glandes* and *fistulae*, which have distinct chronology, but both found in the Portuguese territory, were subjected to analysis for this study.

Chemical analysis of lead artefacts, namely Pb isotopic ratios and elemental content determinations, may provide significant information on sources and trade routes of lead. In the particular case of the tin (Sn), a higher content may indicate the recycling of lead materials, since tin solders were largely used for joining components of lead artefacts or to seal the joints of lead pipes, (e.g. Gomes et al., 2016). Usually, lead obtained from galena ores and consequently lead from ingots has a Sn content < 0.01 wt% (Wytenbach and Schubiger, 1973; Asderaki and Rehren, 2006). However, galena ores from the Iberian Northeast (Molar-Bellmunt-Falset mining district, Catalonian region) can present much higher Sn contents, which may reach c. 0.4 wt% with an average of 0.08 wt%, following analyses of 46 samples (Montero-Ruiz et al., 2008, 2009, 2009). Therefore, when using Pb isotope ratios to assess an Iberian provenance of leaden raw materials, the first step is to see if a Catalonian source can be ascribed to the raw material. If not, only those artefacts with a Sn content  $\leq 0.01$  wt% (lead probably not recycled)

can give the most reliable information. Nevertheless, it must be taken into account that, in some cases, a mixture of primary leaden raw materials or the recycled lead may also give some indication about the origins of the raw materials used in the manufacture of the artefact, if Pb isotope ratios of the respective ore sources are known (Durali-Müeller et al., 2007).

The present work is focused on variations of the Sn content and Pb isotope ratios distributions of *glandes plumbeae* found at Alto dos Cacos, ascribed to the Roman Republican period with a chronology of c. 60 BCE. Results were compared with those from a previous study of *fistulae plumbeae* from *Conimbriga* ascribed to the Empire (Gomes et al., 2016), intending to investigate whether the source of leaden raw materials changed over the time and, if so, trying to identify those different sources.

## 2. Archaeological collections

The first collection is composed by 24 *glandes plumbeae* of different typologies (biconical, truncated biconical, oblong or with an olive shape) and manufacturing processes (most of them cast in moulds but some seem to have been hammered into the desired shape), found at Alto dos Cacos (AC). This archaeological site (Fig. 1) is a Roman

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