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Lead provenance study in medieval metallic materials from Madinat al-Zahra (Medina Azahara, Córdoba)

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ABSTRACT

The objective of this study is to provide insight into the origin of the lead present in the 10th-century. AD Islamic city of Madinat al-Zahra, both as unalloyed metal and as a component of the copper-based alloys, as well as a first approach to technological details related to the production of these materials. Recycling lead is argued to be a common practice but, nonetheless, the lead isotope analysis suggests a single origin for all the lead at the site. Two main options are discussed as lead sources: mines in the Linares district (100 km east) or in Villanueva del Duque (75 km north). Other interesting features are the use of lead-tin solder and fire gilding on a copper–zinc alloy.

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1. Introduction

The aim of this work is to make a first approach to the analysis of metallic materials from the 10th century. AD archaeological site of the Islamic city of Madinat al-Zahra (known nowadays as Medina Azahara, in Córdoba, Spain). The original Muslim city was established ca. 936 four miles west of Córdoba (Fig. 1) by the first Caliph of Al-Andalus, Abd al-Rahman III, following a long tradition with its origins in the Eastern Islamic world that associated the Caliph's status with the creation of large urban nuclei adjacent to the old cities.

For the whole length of its existence, this city was an extraordinary focus of production, import and export of all kind of goods, from the plain and quotidian to the most luxurious and sumptuary. It was in Madinat al-Zahra where the official workshops that produced, consumed and/or distributed all kind of goods in the name of the Caliph were established, in order to supply the Court, the army or to provide presents and elements of political propaganda.

Despite its early destruction, which occurred during the so-called second *fitna*, between the years 1010 and 1013, Madinat al-Zahra is one of the most representative archaeological sites of the Islamic presence in the Mediterranean (For a general overview about the site and the research performed on it see Vallejo, 2007, 2010). Its extension, with a surface of 1500 by 750 m, its historical significance, the urban and architectural solutions used in its construction, and the quality of its decorative programs and artistic productions, all make Madinat al-Zahra a truly unique reference for the study of the history of Islam.

Furthermore, as the city has not undergone any major occupation after its abandonment and destruction, we have in Madinat al-Zahra a site with an extraordinary potential in multiple fields of the research of the Al-Andalus Caliphate and the Mediterranean area in the Middle Ages.

Since the beginning of the archaeological efforts, which started in 1911, the range and significance of the different materials recovered and documented in the excavations have been constantly increasing. This paper focuses on a very specific group: the non-ferrous metallic materials found at the site over a century of fieldwork, and now in custody at the Museum of Madinat al-Zahra. The objective of this study is to provide insight to the origin of the lead present at the site, both as unalloyed metal and as a component of the copper-based alloys, as well as a first approach to technological details related to the production of these materials. This information is used to better understand the historical, cultural and social processes associated to the context that produced these objects.

The technology of metals was one of the staple points of Islamic culture and it influenced the production practises of the areas that came under Muslim control. As such, it became one of the

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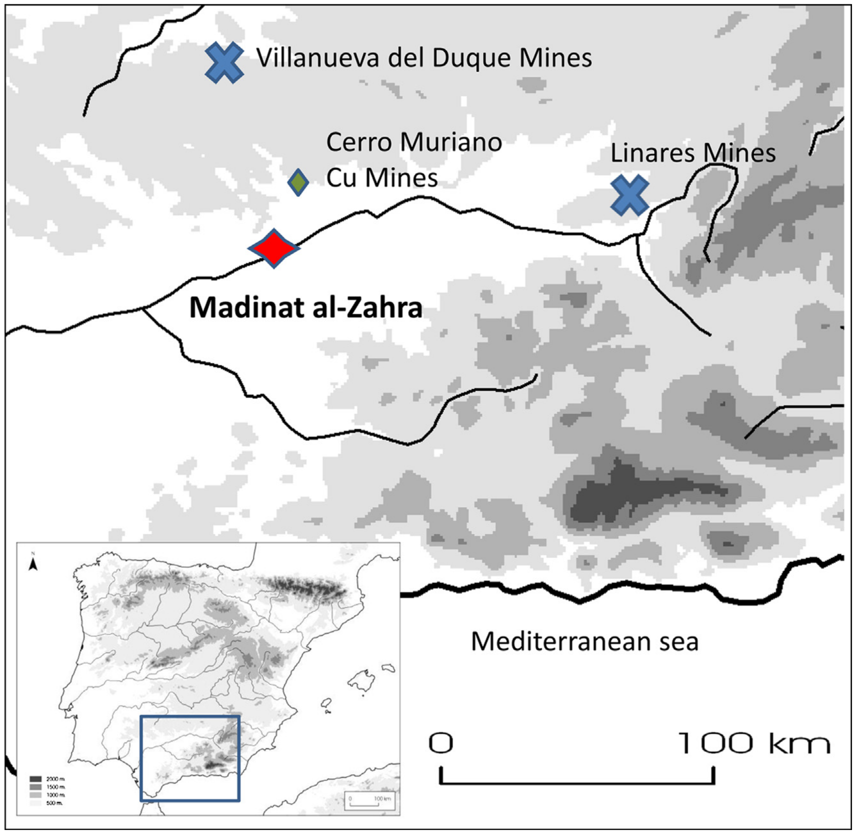

Fig. 1. Map showing the location of the Madinat al-Zahra site and the main mining areas cited in the text.

characteristic traits that allows for the identification of Islamic cultural influence over a given territory (Al-Hassan and Hill, 1986). Hence the importance of characterising the metallic materials of a site like Madinat al-Zahra, given its geographical situation, chronology and particular archaeological features.

2. Materials and methods

The materials used in this study were selected in order to offer a significant range of results to characterise the use and provenance of lead at the site and at the same time provide a broad view of the metals technology. These materials, some of which are illustrated in Fig. 2, are:

- two lead pipe fragments (Ref.: 0.25715 and 0.25745).
- one fragment of lead extracted from a repair in a capital stone (Ref.: 24090).
- one fragment of lead from a sewer grate (Ref.: Caja Y-51a).
- one shapeless and unidentified fragment of lead (Ref.: Caja 2045)
- one fragment of a decorative nail's head made of a copper-based alloy (Ref.: C-13/B-244)
- one fragment of a scabbard's chape made of a copper-based alloy (Ref.: (31) SAL-43).
- one fragment of a decorative embossed metal sheet (*appliqué*) made of a copper-based alloy (Ref.: C62/10446).
- one fragment of an embossed and gilt metal sheet, probably a decorative cover for a door or window (Ref.: LC-1990/HA).

Different analytical techniques were applied to these materials in order to obtain the most meaningful information from them. Electronic microscopy and microanalysis were carried out at the Laboratory of Electronic Microscopy: Microlab, at the *Centro de Ciencias Humanas y Sociales* (CCHS-CSIC, Madrid, Spain), using a variable pressure scanning electron microscope (SEM) HITACHI 3400N-II, with secondary (SE) and backscattered (BSE) electron detectors (SEM resolution: 3 nm-30 KV (HV); 10nm-3 KV(HV), 4 nm-30 KV (LV)) and an energy-dispersive X-ray (EDX) spectrometer for microanalysis, with a Bruker Quantax 200 Xflash 4010 (133eV) silicon drift detector (SDD), and a signal processing unit Bruker SVE III. The results of the analysis of gold and copper-based materials were processed with the Bruker Quantax ESPRIT v. 2.1 software, using P/B-ZAF algorithms. The detection limit for this technique is 0.8–1%, so minor or trace elements cannot be evaluated.

When metallographic analysis was required, samples were extracted from the objects, embedded in resin and then ground and polished following the standard procedures for metallographic analysis (Rovira and Gómez, 2003; Scott, 1991). After that, they were etched with an aqueous ferric chloride solution (H_2O, HCL, $FeCl_3$) and studied by optical microscopy (OM) using a Leica DMLM microscope equipped with a Leica DFC480 digital camera. Some of these samples were also studied by SEM-EDX before etching. All these procedures were carried out at the Laboratory of Archaeometry of Materials (CCHS-CSIC, Madrid, Spain).

For the lead objects, the elemental analysis was performed by inductively coupled plasma-sector field mass spectrometry (ICP-SFMS) with a Thermo Scientific ELEMENT XR spectrometer. Sample 1:1000 solutions in 5% HNO_3 were used for the detection of major components, and 1:10 dilutions for trace elements. The study was carried out with a SC-FAST system, a ST 5532 PFA μ-FLOW nebulizer, a Peltier-cooled PFA spray chamber and a 1.8 mm sapphire injector

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