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Can histomorphology enhance the analysis of cremated human bones in an archaeological context? A case from the Lagunita I archaeological site, Santiago de Alcántara (Cáceres), Spain

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ABSTRACT

Due to the effects of fire on bones, macroscopic observations of burned human remains are often insufficient to completely characterize an individual (age and sex determination). Herein we explore microstructure of bone fragments recovered in a funerary urn from the 1st millennium BC at Lagunita I archaeological site (Cáceres, Spain) in an attempt to determine if histomorphological analysis could complement macroscopic observation in anthropological study. Although histological analysis is a destructive technique, analyses making use of thin-sections has permitted us to unveil different stages of alteration in two pieces of the same bone despite both appearing to have similar major macroscopic alterations due to high temperatures reached by the fire (over 900 °C in some areas). Furthermore, the mid-shaft fragment suggested that the remains belonged to a young individual (between 12 and 20 years old). In light of the results, we conclude that bone histology could support and enhance inferences made from macroscopic observations improving the analysis of archaeological cremated remains.

1. Introduction

The anthropological analysis of archaeological cremations is typically very limited due to the stage of preservation of the skeletal remains (Hummel and Schutkowski, 1993). Burnt bones are frequently found as secondary deposits in which remains appear mostly fragmented, altered or even distorted (Duday et al., 2000). Under these conditions, taphonomic modifications could mask the effects of burning (Etxeberria, 1994; Lyman, 1994) and it is very difficult to achieve proper age estimation and/or sex determination (McKinley, 2000).

Many researchers have investigated the macroscopic appearance of burned bones trying to reveal how changes in colour, weight, shrinkage, deformations (warping) and fractures (Shipman et al., 1984; McKinley, 1993; Etxeberria, 1994; Correia, 1997; Devlin and Herrmann, 2008; Walker et al., 2008; Ubelaker, 2009; Gonçalves et al., 2011; Depierre, 2014; Ellingham et al., 2015; Gonçalves et al., 2015; Imaizumi, 2015) are related with burning conditions (presence of soft tissues, temperatures reached by fire, duration and intensity of heating, ventilation, etc.). Moreover, changes in microstructure (histology), chemical composition and ultrastructure have also been thoroughly investigated (Herrmann, 1977; Shahack-Gross et al., 1997; Cattaneo et al., 1999; Roberts et al., 2002; Hanson and Cain, 2007; Munro et al., 2007; Piga et al., 2008, 2009; Thompson et al., 2009; Figueiredo et al., 2010; Beckett et al., 2011; Gonçalves, 2012). However, being largely altered by fire externally does not imply being microanatomically poorly preserved (Hummel and Schutkowski, 1993). So, experimentation in microstructural alterations, taking into account age, sex or species, has been crucial to improve the interpretation of cremations (e.g., Shipman et al., 1984). Unfortunately, many of the results obtained are relatively ambiguous and difficult to interrelate, as is also the case with macroscopic observations (Thompson, 2005).

With regards to human bones, the first systematic experimentations were carried out by Van Vark (1970) who established that histological features are still observable with exposure to heat below 800 °C after which, shrinkage does not significantly increase. Herrmann (1976, 1977) agreed with Van Vark's observations but noted that above 800 °C fusion of bone crystals occurs. The existence of this critical temperature turned out to be very interesting for interpreting the remains from

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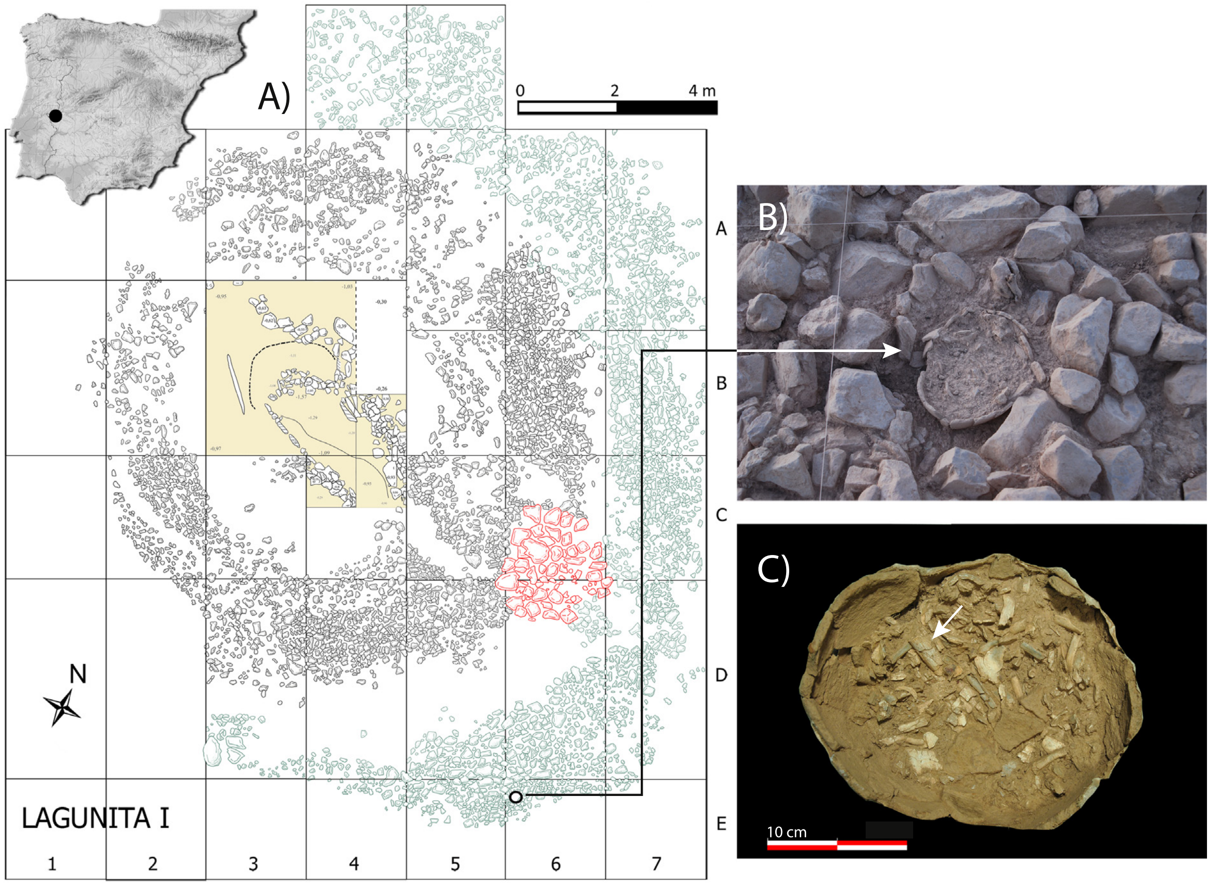

Fig. 1. Source of archaeological materials. A) Geographical location of Lagunita I (Santiago de Alcántara, Cáceres) and plan of the site with the location of Tomb 2. B) Detailed photograph of the Tomb 2 burial area. C) The funerary urn during the process of excavation. White arrow indicates the location of the two bone fragments analysed in this study.

cremations, however, later experimentations increased this limit even up to 1200 °C (Cattaneo et al., 1999; burning sections of humeri and femurs up to 1200 °C for 20 min). More recently, Squires et al. (2011), using 3 de-fleshed adult human femora (2 cm sections burned for 15 min at temperature up to 900 °C), described how temperature over 900 °C did not permit for any microstructure in the cortical bone (i.e., Haversian and/or Volkmann's canals) to be distinguished. But, why were different results obtained? As Fairgrieve (2008) started to unveil, differences in the chemical composition and/or microscopic configuration modulate the effects of fire on bone. In this sense, parallel experiments investigated how histological micro-transformations are caused by fire. For example, Bradtmiller and Buikstra (1984) measured how osteon diameters became increased due to heating using histomorphometric techniques in two, 10 cm long, pieces of bone from a human femur burned at temperatures up to 600 °C. The contrary effect was observed by Nelson (1992), using 8 segments of human femora extracted from cadavers of known age and sex burned for 30 min at 538–566 °C, and Hummel and Schutkowski (1993), who used 18 bone sections burned for 1 h at 1000 °C from individuals between 19 and 76 years of age. Nelson, as was previously pointed out in a non-controlled experimentation carried out by Forbes (1941), described how the osteon diameter decreased during burning and showed that it was actually the osteons canal which became increased. Afterward, Absolonová et al. (2012) used a sample of 148 histological sections of human ribs (burned for 30 min at temperatures up to 1000 °C) and observed a decrease in both parameters described above. Moreover, they described sex differences in the osteon alterations during burning (both sexes increase their compactness while they became more oval shaped in women).

So, could the histomorphological data actually enhance anthropological interpretations of human cremations? As Fairgrieve (2008) indicated, the effects of the cremation process are not homogenous in the body and we must assume that neither are the effects on bone. Anthropological interpretations (e.g., estimating age at death) must be inferred from multiple methodologies that probably will require, as Hummel and Schutkowski (1993) and Ellingham et al. (2015) later discussed, considerable experience. Nevertheless, histological analysis could be useful and all authors agree that much more experimental and descriptive work must be done in this area to unveil that which remains unresolved.

2. Tomb 2, Lagunita I

Lagunita I is a prehistoric megalithic monument located in Santiago de Alcántara in the province of Cáceres (south-west Spain) (Fig. 1A). This archaeological site, re-used during the Iron Age, forms part of a necropolis consisting of three dolmens, Lagunita I, II and III (Bueno Ramírez et al., 2008). Its chamber and tumulus, with several rings and buttresses (Fig. 1A), were built and reconstructed on various occasions from the Late Neolithic to the Bronze Age. In the Iron Age an external concentric ring of stones was added and this area was used for cremation burials (Fig. 1B). Of these, *Tomb 2* was selected because it was practically intact and enclosed by the outer ring of stones (Barroso Bermejo et al., 2012). It consisted of a small, 35 cm-deep, pit dug in the ground and held in place with stones in which a wheel-thrown urn was deposited. The rim had been lost but a small fragmented bowl found inside might have acted as a lid. Cremated human bone fragments (dated by radiocarbon to 2480 ± 40 BP, 780–410 cal. BC 2σ, Beta-