

**The pre-burning condition of Chalcolithic cremated human remains from the Perdigões enclosures (Portugal)**

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## Abstract

The Iberian Chalcolithic displayed a remarkable variety of funerary practices, which has been related to inter-population differences, intra-population social-cultural differences and complex multistage funerary rituals. Perdigões, a Chalcolithic set of ditched enclosures, reflects such diversity including a wide array of funerary practices. Among those practices is cremation, which, despite relatively rare, is represented in different structures in Perdigões. One of these structures (Pit 40) presents an unparalleled high minimum number of individuals ( $n=240$ ), contrasting with nearby and coeval structures. In this study we analyse heat-induced bone changes and other archaeoanthatological variables to tentatively assess the pre-burning condition of the human remains. The results of Pit 40 are also compared to other comparable contexts to assess if this unique context presents further funerary differences relative to those other contexts in, e.g, body processing. Our results suggest preferential cremation of fleshed human remains, but burning of at least a minority of skeletonised remains and deposition of possibly unburned remains also likely occurred. Body processing appears to be comparable to that of the cremation contexts of Perdigões but contrasts with that of another nearby context (Dolmen of Olival da Pega 2b) in which burned bones were also found.

Keywords: Bioarchaeology; cremation; burned bone; funerary practice.

## 1 Introduction

Funerary practices in the Chalcolithic vary markedly in Southern Portugal and include both primary and secondary deposition of human remains in dolmens, tholoi, pits, ditches and hypogea (Valera et al. 2010). Although cremation has also been reported (Cataroche and Gowland 2015; de Becdelievre et al. 2016; de Becdelievre et al. 2015; Gatto 2007; Geber et al. 2017; Silva et al. 2015b; Silva et al. 2008), it appears to have been restricted to a relatively low number of individuals per structure/site and thus be a marginal funerary practice in recent pre-history (for a review see Weiss-Krejci, 2005). Such diversity in funerary practices has been related to inter-population differences (Fernández-Crespo and de-la-Rúa 2016; Fernández-Crespo and Schulting 2017; López-Onaindia et al. 2017), intra-population social-cultural differences (Fernández-Crespo and de-la-Rúa 2016; Fernández-Crespo and Schulting 2017; Fontanals-Coll et al. 2015; Valera 2017b), or complex multistage sequences of funerary rites (Hutchinson and Aragon 2002).

This topic is of acute relevance in Perdigões, a complex set of ditched enclosures in southeast Portugal that was occupied from the late Middle Neolithic to the early Bronze Age (3500-2000 BC) and which is interpreted as an aggregation centre of social-culturally differentiated groups (Valera 2017b). In Perdigões, different funerary practices coexisted, including cremation and deposition of unburned human remains in collective tombs, pits and ditches (Silva et al. 2015a; Silva et al. 2017; Silva et al. 2015b). Of particular interest in Perdigões is a circular pit (Pit 40) containing mostly cremated remains (cremains). Just next to Pit 40, associated contexts (Ambiente 1 and Cista) contain the cremated remains of many individuals (a minimum of 77 individuals; Pereira, 2015). Additionally, another nearby pit (Pit 16) in Perdigões exclusively contains the cremains of 9 individuals (Silva et al. 2015b; Valera and Godinho 2010). All these cremation contexts contrast with the remaining non-cremation funerary contexts not only in body processing but also because the funerary structures and the associated grave goods differ completely. As a result, such funerary differences have been hypothesized to relate to social-cultural differences and processes of social emulation (Valera 2017b; Valera et al. 2015). Although there are some more Neolithic/Chalcolithic funerary contexts in Portugal containing burned human remains, such as Cabeço de Moínhos (Silva et al. 2013), Eira da Pedrinha (Corrêa and Teixeira 1949), Anta das Castelhanas (Oliveira 2000) and Olival da Pega 2b (Silva et al. 2008), it is unclear whether those remains were intentionally burned as part of a funerary practice

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3 or burned post-depositionally due to other non-funerary processes. As such, Pit 40,  
4 Ambiente 1, Cista and Pit 16 of Perdigões are some of the very few confirmed outdoor  
5 cremation funerary contexts from the Late Neolithic/Chalcolithic found in Portugal.  
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7 Thus, it is of interest to understand the funerary rite (i.e. body processing) from Pit 40 in  
8 detail and compare it to the associated contexts (Ambiente 1 and Cista), the somewhat  
9 similar funerary rite from Pit 16 of Perdigões and to another nearby context involving  
10 burned skeletal remains that have been studied (Olival da Pega 2b; OP2b).  
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15 In this study we examine the remains of stratigraphic unit (SU) 193 of Pit 40.  
16 While this is not the whole sample, it accounts for ~60% of the whole sample and ~80%  
17 of Phase 1 (see **Error! Reference source not found.**) and so it provides critical  
18 information about the funerary behaviours associated with Pit 40 and adopted in recent  
19 prehistory, thus enhancing our knowledge about these past populations and providing  
20 information to guide future studies. Further, ongoing analysis of the remaining sample  
21 reveals no meaningful differences between contexts, and so expanding the sample is  
22 unlikely to impact our interpretations.  
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29 One of the most common and critical questions regarding contexts involving  
30 burned skeletal remain is related to the pre-burning condition of the remains. This is  
31 because burning of dry bones implies a complex multistage sequence of funerary rites  
32 that burning of complete bodies (i.e. cadavers) may not. Thus we aim to infer if the  
33 cremated remains from Pit 40 correspond to the outcome of i) exclusive cremations of  
34 complete bodies, ii) exclusive cremations of dry and disarticulated skeletons or iii) both  
35 (as has been hypothesised for Pit 16, Ambiente 1 and Cista). To that end, we attempted  
36 to infer the pre-burning condition of the remains using heat-induced bone changes and  
37 archaeothanatological and taphonomic data. Also, to better outline the vast spectrum of  
38 cremation-related funerary practices adopted during this chronological period in the  
39 current Portuguese territory, we compared our results with those from the coeval  
40 contexts of the contexts associated with Pit 40 (Ambiente 1 and Cista), Pit 16 of  
41 Perdigões and OP2b (for which comprehensive anthropological studies have been  
42 undertaken).  
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### 56 **1.1 The Perdigões and Pit 40 archaeological context**

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58 Located in the municipality of Reguengos de Monsaraz, Évora district, in South  
59 Portugal, Perdigões is a large ditched enclosure that has been investigated for the last 21  
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3 years, in a long term program of research led by the Archaeological Research Group  
4 (NIA) of ERA Arqueologia S.A., and has an extensive list of publications (Valera  
5 2017a). It comprises a set of ditched enclosures (and thousands of pits) with a long  
6 period of construction and use, and is implanted in a natural amphitheatre open to the  
7 East. The actual image is one of a progressive but arrhythmic growth, starting with  
8 smaller enclosures in the centre of the natural amphitheatre at the late Middle Neolithic,  
9 followed by an accelerated enlargement of the enclosed area during the Late  
10 Neolithic/transition to the Chalcolithic, in the early 3<sup>rd</sup> millennium BC, until the site is  
11 abandoned around 2000 BC. During this time span, funerary practices and body  
12 manipulation were always present, but revealing diversified procedures: primary  
13 depositions in pits (rare) and secondary depositions in ditches and in several funerary  
14 structures. Pit 40 is one of these structures.

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16 Pit 40 is a circular pit with 2.5m diameter and 0.50m deep, located in the central  
17 area of Perdigões ditched enclosures. It presents two post holes in the centre, so it must  
18 have had a roof in perishable materials and recent excavations suggest it may have had a  
19 wood passage. Therefore, this feature was intentionally built to function as a tomb, thus  
20 not corresponding to a reused pit. It was used for successive secondary depositions of  
21 mostly human cremated remains (three phases of deposition were detected) which were  
22 commingled (although some partially articulated remains were also found; Figure 1).  
23 Associated with the human remain, burned faunal remains and votive materials, where  
24 ivory anthropomorphic schematic and naturalistic figurines and marble betiles punctuate  
25 were also found (Valera 2015; Valera and Evangelista 2014; Valera et al. 2014). Several  
26 radiocarbon dates under publication place this context in the middle of the 3<sup>rd</sup>  
27 millennium BC (2600-2400).

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## 2 Materials and methods

The study of the cremains of Pit 40 is currently underway. Here we present the results from a recently fully examined stratigraphic unit (SU 193; integrated in phase 1 of the depositions) and compare it with the results of another study that fully examined other stratigraphic contexts located just next to Pit 40 (Ambiente 1 and Cista; see above; Pereira, 2015). Altogether, these represent approximately 75% of the full sample from Pit 40 and associated outer contexts. We further compared the results from Pit 40 to other similar funerary contexts; Pit 16 also from Perdigões (Silva et al. 2015b), and the

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3 burned human remains from OP2b (Silva et al. 2008). The latter is a Chalcolithic tholos  
4 connected to the corridor of the Dolmen of Olival da Pega 2, 15km distant from  
5 Perdigões, from which skeletal remains were recovered. Of those, a small subset  
6 displays heat-induced changes which were originally interpreted as the result of a  
7 sanitization process of OP2b (Gonçalves 1999; Gonçalves 2003).  
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11 Because of the size of the sample from Pit 40, it was not possible to perform a  
12 systematic inventory of each bone fragment. As such, we inventoried bone fragments  
13 that hold relevant information for the estimation of the minimum number of individuals  
14 (MNI), age-at-death, sex and paleopathology. In such cases, an individual inventory  
15 number was allocated to each fragment, the fragment was anatomically identified and  
16 information about heat-induced changes and paleobiology was systematically recorded.  
17 All data and interpretation about heat-induced changes and paleobiology were thus  
18 based on the inventoried bones. When the fragments did not present relevant  
19 information for the above mentioned variables, they were identified by bone whenever  
20 possible or anatomical category when specific bone identification was not possible.  
21 When fragments were too small to be allocated to an anatomical region they were  
22 classified as unidentified.  
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32 To infer the pre-burning condition of the remains, we analysed five parameters  
33 that are theoretically correlated to it: i) proportional mass of anatomical regions; ii)  
34 frequency of specific bones of labile joints; iii) heat-induced colour pattern; iv)  
35 frequency of heat-induced fractures; and v) frequency of heat-induced deformation (i.e.,  
36 warping).  
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41 Because SU 193 accounts for the majority of the full sample of Pit 40 (~60%)  
42 and no meaningful differences exist between this SU and other contexts of the ongoing  
43 study, the results presented are considered representative of the whole sample.  
44 Nonetheless, future publications will address this prediction.  
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## 50 51 **2.1 Proportional mass of anatomical regions**

52 This approach is based on the premise that atypical representativeness of  
53 anatomical regions is more likely in cremation of dry skeletons than in cremation of  
54 bodies with soft tissues. This is because in the latter the soft tissues preserve the bones  
55 in their anatomical location when the body is handled and so bone loss or selection is  
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3 theoretically minimized. Conversely, this may not be the case in dry skeletons and so  
4 bone loss, or deliberate selection, is more likely. Specifically, if fleshed bodies are  
5 cremated bone loss or selection is likely after cremation, (i) during recollection of the  
6 remains from the pyre and transport to the final depositional site and (ii) the use of the  
7 final deposition site, which may include removal of sediments and bones. If dry bones  
8 are cremated, bones may be lost or selected during these processes *and* also before  
9 cremation, when the bones are recovered from their original depositional place. Thus,  
10 the probability of changing the natural representativeness of anatomical regions is  
11 higher when burning dry remains than when burning bodies with soft tissues.  
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19 Proportional mass of different anatomical regions was used here to assess  
20 skeletal representativeness (Silva et al. 2009). To that end, each bone fragment is  
21 usually allocated to anatomical categories (e.g. head; trunk; limbs; limb extremities) and  
22 each of these is weighed. Because a large portion of bone fragments could only be  
23 identified as fragments of diaphyses of long bones, we favoured the use of an overall  
24 category of limbs instead of two separated categories for upper limbs and lower limbs  
25 (even though bones were identified according to that classification whenever possible).  
26 To provide more resolution to the analysis, we also weighed the first distal phalanges of  
27 the feet separately. These phalanges are relatively easy to identify and are part of a  
28 labile joint. As such, a proportional mass of the first distal phalanges of the feet  
29 comparable to reference studies is most likely if cremation of fleshed remains occurred.  
30 Bone fragments that were not identifiable due to their reduced size were classified as  
31 unidentified. Proportional mass was then compared with the expected proportions  
32 calculated via regression equations developed by Gonçalves et al. (2015a). The  
33 proportional mass of the first distal phalanges of the foot of Pit 40 were compared to  
34 reference values obtained on a sample of 12 unburned skeletons (5 females and 7 males)  
35 from the 21<sup>st</sup> Century Identified Skeletal Collection of the University of Coimbra  
36 (Ferreira et al. 2014). This was carried out to determine if atypical proportional mass  
37 was present, which may have resulted from pre or post-burning selection of anatomical  
38 regions (intentional or non-intentional).  
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## 2.2 Bone frequency

The atypical frequency of specific skeletal elements may relate to the funerary rite and thus this criterion has been previously used to infer primary vs secondary depositions (Andrews and Bello 2006; Bello and Andrews 2006; Duday and Guillon 2006; Gonçalves et al. 2016; Roksandic 2002). This is because secondary depositions often involve deliberate selection of specific skeletal elements (e.g. crania and long bones) or because collection and transport of skeletal elements often occur after decomposition, hence resulting in the loss of small bones from labile joints such as the ones from the hands and feet (Duday 2006; Duday and Guillon 2006; Roksandic 2002). Thus, larger frequencies of these skeletal elements are more likely in primary than in secondary depositions.

While the cremation deposits in pit 40 are clearly secondary, small differences between the most frequent bone and bones that are commonly poorly represented even in primary depositions may suggest cremation of fleshed individuals and not of fully skeletonised bones. Thus, the frequency of the most frequent skeletal element was compared to that of the first distal phalange of the foot. The latter was chosen because i) it integrates a labile joint and so is likely to be lost in secondary depositions; ii) it is one of the most poorly represented bones in primary burials (Bello and Andrews 2006; Waldron 1987); iii) it is relatively easy to identify; and iv) preserves well whenever present. The frequency of the first distal phalange of the foot was calculated in function of the MNI. To that end, individually identifiable bone fragments were inventoried and the MNI estimated is based on the Minimum Number of Elements (MNE). Thus, the most frequent element corresponds to the MNI (Robb 2016). Differences in frequency were then interpreted based on studies that quantify the representativeness of this bone in primary burials (Bello and Andrews 2006; Waldron 1987).

## 2.3 Heat-induced changes

When exposed to heat, bone undergoes several stages of transformation that lead to heat-induced changes in colour (Ellingham et al. 2015; Munro et al. 2007; Shipman et al. 1984), formation of fractures (Binford 1963; Buikstra and Swegle 1989; Gonçalves et al. 2011; Spennemann and Colley 1989; Whyte 2001) and warping

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3 (Binford 1963; Buikstra and Swegle 1989; Gonçalves et al. 2011). We analysed such  
4 changes because they have been related to the pre-burning condition of the bones.  
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### 9 **2.3.1 Heat-induced colour changes**

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11 Exposure to heat leads to colour changes that are correlated with burning  
12 temperature (Shipman et al., 1984; Etxeberria, 1994; Mayne Correia, 1997; Devlin and  
13 Herrmann, 2008; Walker et al., 2008; but see Walker et al. (2008) and Reidsma et al.  
14 (2016), who show similar heat-induced colours may occur when bones are burned at  
15 different temperatures due to differences in oxygen availability and duration of  
16 exposure to heat). Thus, heat-induced colour changes were used to tentatively infer the  
17 intensity of the cremation. Most important, to infer the pre-burning condition of the  
18 remains, heat-induced colour changes were compared in the internal and external  
19 surface of bones to determine if they might have been fragmented before burning. Thus,  
20 evidence of burning at higher temperatures in the internal surface than on the external  
21 surface of bones probably relates to pre-burning fragmentation, which is most likely in  
22 skeletonised remains. To tentatively approximate the intensity of burning, the scale of  
23 Buikstra and Ubelaker (1994) was used.  
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### 37 **2.3.2 Heat-induced fractures**

38 Exposure of bone to heat leads to changes in size (usually in the form of  
39 shrinkage) and formation of different fractures, including curved, linear, patina and  
40 delamination (Binford 1963; Buikstra and Swegle 1989; Gonçalves et al. 2011).  
41 Although early studies suggest curved fractures only occur in fleshed/wet bone (Binford  
42 1963), several authors demonstrated that this type of fractures may also occur in dry  
43 bones and so it is not a conclusive indicator of the pre-burning condition of bones  
44 (Gonçalves and Pires 2016; Gonçalves et al. 2011). Yet, such fractures occur more  
45 frequently in bones burned with soft tissues than in completely skeletonised remains  
46 (Gonçalves et al. 2011). Thus, we quantified the presence of curved fractures relative to  
47 other types of heat-induced fractures (linear, patina and delamination).  
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### 2.3.3 Warping

When exposed to heat, bones may warp. Although this morphological change has, for quite some time, been said to occur only in wet or fleshed bones (Baby 1954; Binford 1963; Etxeberria 1994), it has also been identified in dry cremated bones (Gonçalves et al. 2015b; Gonçalves et al. 2011; Vassalo et al. 2016; Vassalo et al. 2017). Thus, presence/absence of warping is an inconclusive indicator of the pre-burning condition of bones (Gonçalves et al. 2011). Yet, warping is more frequent in bones that were burned after being buried for shorter periods than in bones burned after being buried for longer periods (Vassalo et al. 2016), and so high frequencies of warping may reflect absence or short periods of burial before cremation. Here we quantify the presence of warping and use its frequency to infer if bones were likely buried for long periods prior to cremation.

## 3 Results

### 3.1 Proportional mass

A total of 137 kg of bone was sorted by anatomical category. Because 38 kg were unidentified, the regression equations to predict the expected proportions of each anatomical region were implemented using a 72% value for the part of anatomically identified bone fragments (corresponding to 99kg of bone).

Table 1 shows the proportional mass of the different skeletal regions of the skeletal remains from pit 40 is within the intervals estimated using the regressions of Gonçalves (2015a), which account for the predicted mass of each region taking into account the presence of anatomically unidentified bone fragments. Thus, the results suggest no atypical proportional mass in any of the anatomical regions. When applying the regressions of Gonçalves (2015a), the proportional mass of Ambiente 1 is within the predicted range. Nonetheless it should be mentioned that the original study of Ambiente 1 presents different anatomical categories, which had to be converted to the ones used in this study. Specifically, Pereira (2015) uses skull, hands/feet, long bones, other bones (which includes vertebrae, ribs and flat bones) and unidentified. Thus, to render the results comparable, the category 'other bones' was converted into trunk because it includes vertebrae and ribs. While probably not meaningful, this inevitably overestimates the proportional mass of the trunk and underestimates that of the limbs,

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3 because this category also includes flat bones (which in this study are allocated to  
4 limbs).  
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6 The mean proportional mass of the two first distal phalanges of the foot in  
7 function of the total skeletal mass was 0.03%, thus slightly lower than the 0.05% (S.D.:  
8 0.01) derived from the reference sample (minimum: 0.04%; maximum: 0.07%).  
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### 14 **3.2 Bone frequency**

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17 The most frequent bone element from SU 193 was the right pars petrosa  
18 (n=147), followed by the left pars petrosa (n=144) and the left (n=71) and right (n=70)  
19 mandibular condyles. In the study of Pereira (2015) the right pars petrosa was also the  
20 most frequent element (n=77), followed by the left pars petrosa (n=43), the right  
21 mandibular condyle (n=29) and the left mandibular condyle (n=28).  
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26 We favoured not siding the first distal phalange of the foot because this is not  
27 always straightforward. We also only selected the distal phalange and not the proximal  
28 as well because the latter is less dense, and so more prone to heat induced fragmentation  
29 (as was clear during the cleaning of the bones) and so less represented/identifiable in the  
30 sample. Because there were 147 right petrosals and 54 distal phalanges of the first digit  
31 (thus meaning that at least 27 are necessarily from the same side) the frequency of the  
32 latter was larger than 18% when compared to the most frequent skeletal element in the  
33 sample. Waldron (1987) reported frequencies of 11 - 13% for the left and right  
34 phalanges of the first digit of the foot in the primary burials of 88 adult individuals from  
35 the Romano-British site at West Tenter Street (London). That study did not specify the  
36 values of the proximal and distal phalanges (and so the frequency of the distal phalange  
37 is most probably lower than the 11 - 13% because it is smaller and more difficult to  
38 preserve/retrieve, while that of the proximal phalange is most probably higher), and so  
39 we assume the frequency found in SU193 of Pit 40 was considerably higher than that  
40 observed by Waldron (1987). Bello and Andrews (2006) provided frequency intervals  
41 for the distal phalange of the first digit of the foot in two primary burial sites.  
42 Unfortunately, reported frequencies were given in somewhat large intervals  
43 corresponding to 1% - 24% and 25% - 49% in St. Estève le Pont (8<sup>th</sup> Century AD) and  
44 in Observance (1722 AD), respectively. Therefore, the frequency in unit 193 of Pit 40  
45 was comparable or higher than in St. Estève le Pont and lower than in Observance.  
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3 cremations, so our comparisons are tentative. Our results were not compared to  
4 Ambiente 1, Cista, Pit 16 and OP2 because this analysis was not undertaken in those  
5 studies.  
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### 11 **3.3 Heat-induced colour changes**

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13 Analysis of the heat-induced colour changes suggests most remains were  
14 cremated at generally high temperatures and only a residual part of the remains did not  
15 display this heat-induced feature suggesting they were not burned. Most observable  
16 internal surfaces of bones did not display evidence of burning at higher temperatures  
17 than the external surfaces. Nonetheless, several bone fragments (mainly cranial)  
18 displayed evidence of burning at higher temperatures in the internal surface than on the  
19 external surface (Figure 2).  
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### 30 **3.4 Heat-induced fractures**

31 Of the 4516 inventoried bone elements, 1519 (34%) displayed clearly visible  
32 heat-induced macro-fractures. Of the latter, only a small percentage displayed curved  
33 fractures (6%; Figure 3), which were almost absent in bone elements of the trunk and  
34 were most frequent in bones of the head (Figure 4).  
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38 In Ambiente 1 and Cista, 7% of the bones displayed heat-induced fractures, and  
39 12% of those presented curved fractures (Pereira 2015). In OP2, 39% of the sample  
40 displayed heat-induced fractures, of which 19% were curved (Silva et al. 2008). In Pit  
41 16, coexistence of different fractures is reported, but no quantification of results was  
42 performed (Silva et al. 2015b).  
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### 49 **3.5 Warping**

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51 Only 150/4516 (3%) of the inventoried bone elements displayed warping (Figure  
52 5), which was most frequent in bones of the head ( $61/1430 = 4\%$ ) followed by bones of  
53 the limbs ( $86/2708 = 3\%$ ) and almost absent in bones of the trunk ( $3/378 = 1\%$ ).  
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3 In OP2b, 8% of the sample displayed warping (Silva et al. 2008). No such data  
4 is reported for the nearby Ambiente 1 and Cista (Pereira 2015) and Pit 16 (Silva et al.  
5 2015b).  
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#### 10 11 **4 Discussion**

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13 SU 193 of Pit 40 (MNI=147) and associated outer contexts (MNI=77) of  
14 Perdigões present an unparalleled total high number of cremated individuals (N=224) in  
15 an archaeological context of this chronology. If we further include data of the ongoing  
16 study, Pit 40 alone includes 240 left and 239 right petrosals. Thus, Pit 40 and associated  
17 contexts total a minimum number of 316 individuals, largely surpassing the comparable  
18 nearby funerary contexts of Pit 16 of Perdigões (MNI=9) and OP2b (MNI=16). Further,  
19 it also largely surpasses the MNI of comparable contexts from other countries as well,  
20 such as Dolmen 2 in San Sebastian (which, to the best of our knowledge, is the next  
21 archaeological structure with a commingled collective burial containing the highest  
22 minimum number of cremated individuals of this chronology (N=78; Gatto, 2007).  
23 Regardless, the combined analyses of the five criteria we assessed, which are relatively  
24 correlated with the pre-burning condition of the remains, provide somewhat conflicting  
25 results regarding the pre-burning condition of the human remains  
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##### 38 **4.1 The pre-burning condition of the skeletal remains from Pit 40**

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41 Despite a conclusive assessment of the pre-burning condition of skeletal remains  
42 is very difficult to attain, our results, combining several approaches, suggest most  
43 remains were likely cremated while fleshed, although this practice probably coexisted  
44 with secondary cremations, *i.e.*, the burning of fully skeletonised remains.  
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48 The proportional mass of different skeletal regions suggests cremation of fleshed  
49 individuals. This is because the proportional mass found in Pit 40 is generally consistent  
50 with regression predictions (Gonçalves et al. 2015a). Thus, selection of different regions  
51 such as crania and long bones, as would be more probable in fully skeletonised remains,  
52 is unlikely. While the anatomical categories we used (head, trunk, limbs) may lack  
53 resolution for this analysis because they lump several bones in single anatomical  
54 regions, the proportional mass of the first distal phalange of the foot, which is part of a  
55 labile joint, is also generally consistent with burning of fleshed remains. First phalanges  
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3 are small and so their full recovery from a cremation pyre after burning (which causes  
4 size changes, deformation and fragmentation) is a quite difficult and unlikely task.  
5 Therefore, its high representation in SU 193 is not supportive of an interpretation of this  
6 context as being mainly the result of secondary cremations. Moreover, the frequency of  
7 this bone also approximates that found in some primary burial sites and so appears to  
8 suggest cremation of fleshed rather than skeletonised remains. Additionally, we  
9 identified bones that are very small, such as distal phalanges of feet, hyoids, epiphyses  
10 of metacarpals and metatarsals, sesamoids and unfused centra of vertebrae. Because  
11 such bones are extremely small and difficult to retrieve, this appears most likely as a  
12 result of burning of fleshed remains. However, they were collected after cremation and  
13 transported and deposited in Pit 40 with the rest of skeletal remains, showing a  
14 significant care in the process and documenting that their presence in a funerary  
15 contexts cannot axiomatically be ascribed to primary depositions. Lastly, several  
16 partially articulated remains were found (Figure 1), including a lower limb, two upper  
17 limbs, a head and partial trunk, a thoracic vertebral segment, and a cremated right  
18 temporal bone with the right mandibular condyle still in the glenoid fossa (Figure 6).  
19 While only the latter shows unequivocal heat-induced bone changes (although absence  
20 of heat-induced macroscopic bone changes in the other remains does not preclude low  
21 intensity burning), such partial anatomical connections evidence the clear deposition of  
22 fleshed remains in Pit 40.  
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37 Most bones evidenced heat-induced colour changes suggestive of burning at  
38 high temperatures. Most such changes are suggestive of burning at higher temperatures  
39 of the external surfaces than of the internal surfaces of bones. While this is consistent  
40 with burning of whole bones (and so possibly cadavers), the presence of a minority of  
41 cranial bones evidencing burning at higher temperatures of the internal surfaces  
42 suggests otherwise. This is because, during the soft tissue pyrolysis caused by  
43 cremation, the outer tabula tends to become exposed sooner to heat than the inner tabula  
44 (Bohnert et al. 1998). In consequence, the latter tends to present signs of less intense  
45 exposure. The small portion of bones displaying the inverse colour pattern thus supports  
46 the interpretation of SU 193 being the result of cremation practices targeting remains in  
47 different stages of decomposition, with an emphasis on primary cremation. As an  
48 additional element of support, while most bones from Pit 40 presented no signs of  
49 erosion, some displayed non heat-induced erosion of the periosteal and endosteal  
50 surfaces, suggesting pre-burning deposition/burial (Figure 7).  
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3 While the interpretation of the above mentioned criteria appear to be relatively  
4 straightforward and useful for the estimation of the pre-burning condition of remains,  
5 the interpretation of heat-induced curved fractures and warping is less clear. In Pit 40,  
6 only 6% of the inventoried bones with heat-induced fractures show curved fractures and  
7 only 3% of the inventoried bones displayed warping. In their study comparing the  
8 frequency of heat-induced curved fractures between cremated cadavers and dry bones,  
9 Gonçalves et al. (2015b) report curved fractures in 96% of the cadavers and 22% of dry  
10 skeletons. Vassalo et al. (2016) compared the frequency of heat-induced warping  
11 between bones cremated after buried for less than 20 years and bones cremated after  
12 being buried for at least 80 years. The former displayed warping in 67% of the cases  
13 and the latter in 18%. Yet, the study of Gonçalves et al. (2015b) quantifies heat-induced  
14 curved fractures per individual, the study of Vassalo et al. (2016) quantifies warping per  
15 bone and the results of this study for Pit 40 inevitably quantify both per bone fragment  
16 (due to extreme fragmentation and commingling of a minimum of 147 individuals).  
17 Thus, while our results of heat-induced curved fractures and warping appear more  
18 consistent with burning of dry skeletons, differences in quantification methodology  
19 prevent a direct comparison of results and so our results are inconclusive due to lack of  
20 appropriate comparative reference studies. This is consistent with the conclusions of  
21 Gonçalves et al. (2011; 2015b) that, on their own, curved fractures and warping are not  
22 very useful indicators of the pre-burning condition of skeletal remains, especially when  
23 used to assess contexts with multiple individuals.

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39 Thus, most criteria used in this research suggest SU 193 was mainly composed  
40 of elements resulting from the burning of fleshed remains. However, the presence of  
41 some bones with eroded surfaces and evidencing burning at higher temperatures of the  
42 internal surfaces than of the external ones also suggests that a smaller part of the  
43 assemblage resulted from the burning of skeletonised remains. This cremation diversity  
44 adds to the apparent inclusion of skeletal remains not subjected to burning. As such, Pit  
45 40 reveals the adoption of very different body treatments by this population (consistent  
46 with the funerary diversity in the whole Perdigões enclosure). Such diversity may  
47 reflect different belief systems, which is commonly observed within segmented  
48 communities, different stages of complex multistage funerary rites, or even different  
49 procedures according to social status.  
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## 4.2 Comparison of Pit 40 and other coeval contexts

Results from Pit 40 are generally comparable to the other cremation contexts from Perdigões, which evidence intentional cremation of the human remains with subsequent retrieval of the cremains and transport to a final secondary deposition place. Further, all contexts have been suggested to include cremations of individuals in different stages of decomposition (although mainly of fleshed individuals).

The results from all cremation contexts from Perdigões contrast with those from OP2b. In that tholos, only a minority of the bones were burned and most evidence burning at low temperatures (Silva et al. 2008). Thus, researchers have suggested the human remains were burned inside the tholos to sanitize the structure rather than intentional cremation of human remains (Gonçalves 1999; Gonçalves 2003). In fact, most bones (61%) display evidence of no burning or burning at low temperatures (Silva et al. 2008), which may in fact suggest funerary differences in the burning process of OP2b and the cremation contexts from Perdigões. The latter probably consist mainly of primary cremations commingled with secondary cremations and, in Pit 40, with articulated remains that have apparently not been exposed to heat.

The main differences between Pit 40 and the other cremation contexts from Perdigões is the unparalleled high MNI, which in SU 193 is 147, in Ambiente 1 and Cista is 77, in Pit 16 is 9 and in OP2b is 16 (although the MNI in OP2b only includes the burned remains, thus excluding the majority of the sample). The other is that all remains from Pit 16 were reported to show heat-induced changes, while in Pit 40, Ambiente 1 and Cista a minority did not display heat-induced colour changes (despite the majority showing evidence of burning at high temperatures; also, this does not exclude incomplete burning or at low temperatures which caused no macroscopic heat-induced bone changes). In contrast, most of the human remains from OP2b were unburned.

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9 **Declaration of interest statement**

10 The authors declare no competing interests.  
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## Figure captions

Figure 1: Partially articulated skeletal remains in Pit 40 of Perdigões, deposited in the middle of the cremated remains of SU193. (A) General overview of the partially articulated skeletal remains and of Pit 40. (B) Detailed view of some of the partially articulated remains in A. (C) Computer Assisted Design (CAD) drawing of some of the partially articulated remains from Pit 40.

Figure 2: Examples bone fragments with apparent lower burning exposure of the external surface (A) when compared to the internal surface (B).

Figure 3: Example of curved fractures in a long bone from SU 193 of pit 40.

Figure 4: Heat-induced fractures (curved vs other fractures) by anatomical region in SU 193 of pit 40.

Figure 5: Example of heat-induced warping in SU unit 193 of pit 40.

Figure 6: Right temporal bone with partially rotated right mandibular condyle in the glenoid fossa. Note the compatibility of the heat-induced changes of both bone fragments. This most likely reflects cremation of fleshed remains.

Figure 7: Example of erosion in the endocortical surface of a long bone from SU 193 of Pit 40 of Perdigões.

**Table captions**

Table 1: Comparison of the mean proportional mass (in %) of different skeletal regions from SU 193 with Ambiente 1, near Pit 40 (Pereira 2015) and the reference study of Silva et al. (2009). OP2 is not included in because that information was not included in the study.

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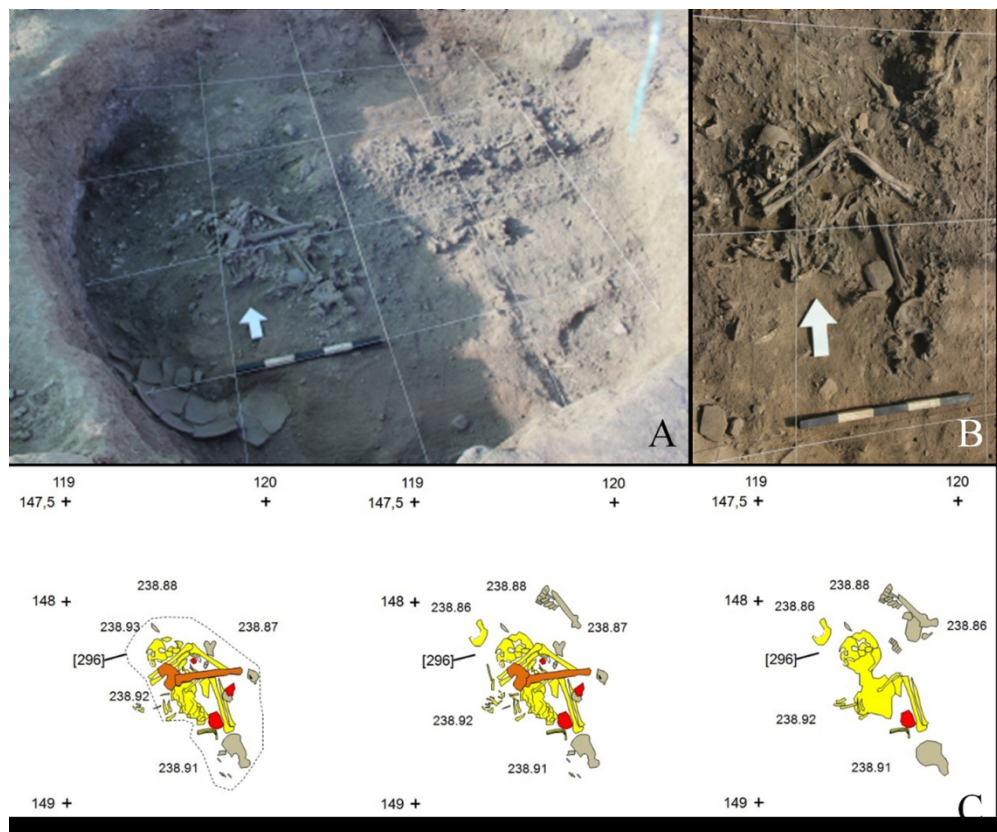


Figure 1: Partially articulated skeletal remains in Pit 40 of Perdigões, deposited in the middle of the cremated remains of SU193. (A) General overview of the partially articulated skeletal remains and of Pit 40. (B) Detailed view of some of the partially articulated remains in A. (C) Computer Assisted Design (CAD) drawing of some of the partially articulated remains from Pit 40.

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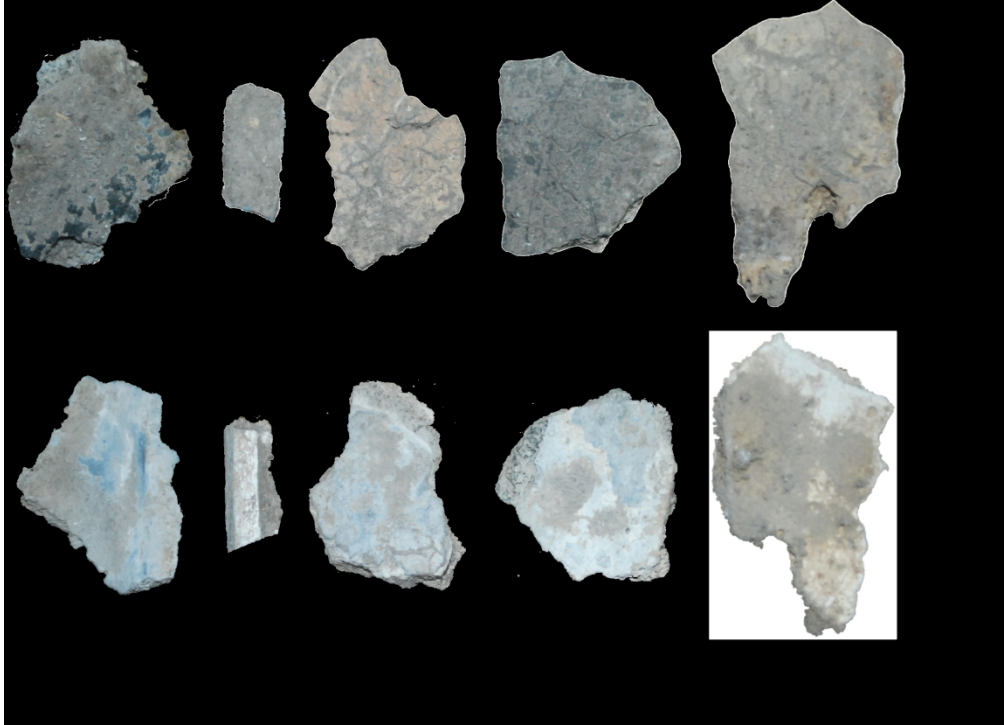


Figure 2: Examples bone fragments with apparent lower burning exposure of the external surface (A) when compared to the internal surface (B).

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Figure 3: Example of curved fractures in a long bone from SU 193 of pit 40.

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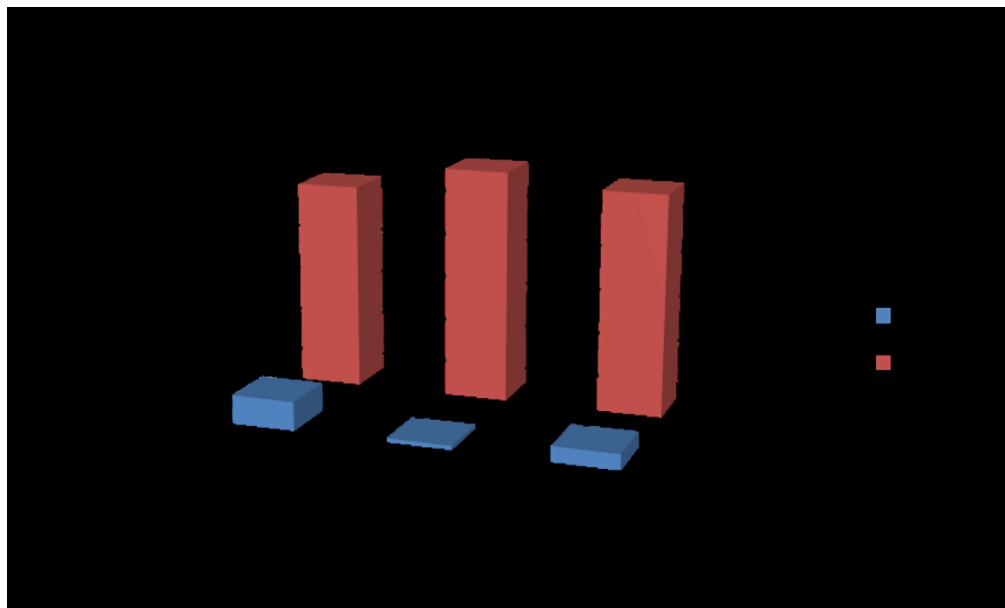


Figure 4: Heat-induced fractures (curved vs other fractures) by anatomical region in SU 193 of pit 40.

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Figure 5: Example of heat-induced warping in SU unit 193 of pit 40.

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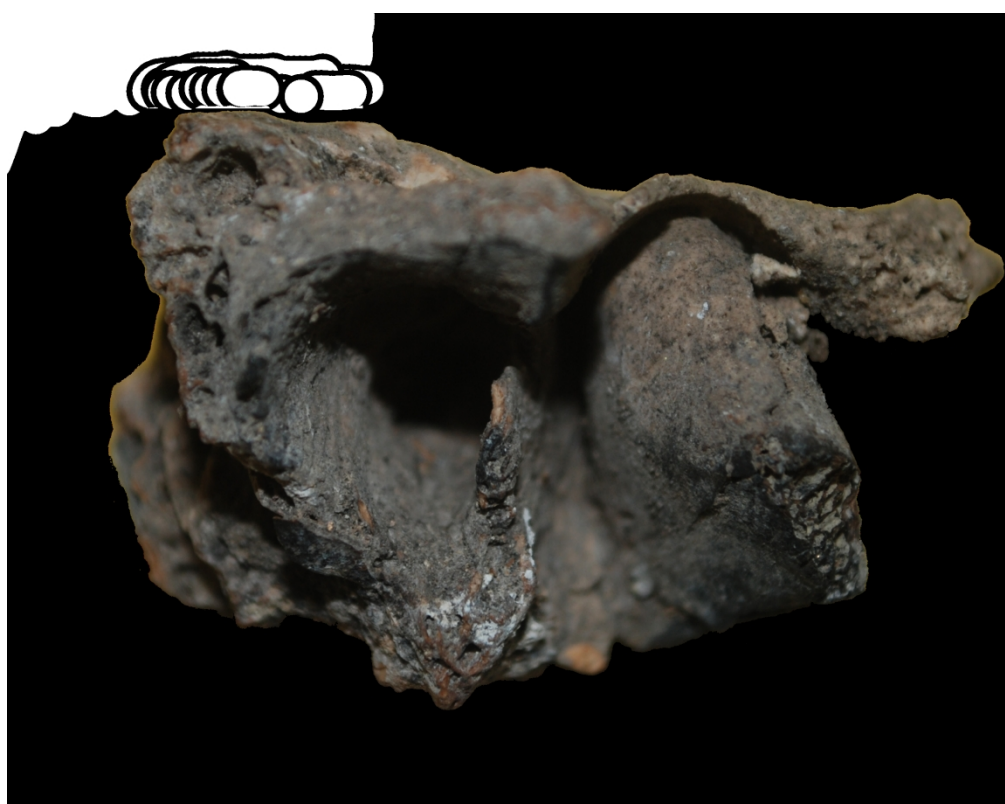


Figure 6: Right temporal bone with partially rotated right mandibular condyle in the glenoid fossa. Note the compatibility of the heat-induced changes of both bone fragments. This most likely reflects cremation of fleshed remains.



Figure 7: Example of erosion in the endocortical surface of a long bone from SU 193 of Pit 40 of Perdigões.

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Pit 40	18.98	8.10	45.35	27.57
Predicted mass (Gonçalves et al., 2015a)	10.58 - 25.30	8.26 - 12.60	31.75 - 51.85	
Silva et al. (2015; Pit 16)	26.49	16.81	49.59	7.11
Predicted mass (Gonçalves et al., 2015a)	12.48 - 29.70	11.31 - 21.47	43.50 - 67.01	
Pereira (2015; Ambiente 1)	25.28	13.95	42.73	18.04
Predicted mass (Gonçalves et al., 2015a)	11.46 - 27.35	9.68 - 19.06	37.22 - 58.91	

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