



Burial taphonomy and megalithic ritual practices in Iberia: the Panoría cemetery

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Abstract

Our ability to build precise narratives regarding megalithic funerary rituals largely depends on an accurate understanding of bone assemblage formation. The cemetery of Panoría offers an excellent opportunity for exploring the ritual variability through the study of funerary taphonomy, as four of the nine recently excavated dolmens are remarkably well-preserved. Based on a multi-proxy approach that includes the contextual archaeological features, skeletal preservation and representation indexes, taphonomic processes, and radiocarbon chronology, three main ritual practices can be outlined: (i) primary sequential inhumations followed by the differential in situ decomposition of skeletal remains; (ii) the selective removal of crania and long bones; and (iii) the curation of subadult crania and probably long bones. The use-life of tombs, the intensity of mortuary depositions, and the intentional protection of specific bones appear as key aspects for understanding the variability in bone assemblage formation.

Keywords Megalithic societies · Burial taphonomy · Funerary ritual · Radiocarbon chronology · Iberian Peninsula

Introduction

Ritual and funerary practices in megalithic monuments normally appear to archaeological observation as complex palimpsests. The frequent use of these funerary spaces has

created mortuary deposits consisting of masses of stratified, fragmented, mixed skeletal remains that are found piled on top of each other. The formation of these contexts can be attributed to many social, physical, chemical, and biological factors, some of which may have interacted in very complex ways (Chambon 2003; Bello et al. 2002; Baxter 2004; Bello and Andrews 2006; Duday 2006; Manifold 2012; Robb 2016; Knüsel and Robb 2016). The deposition of human remains is the first step in assemblage formation. Skeletal remains can be deposited as articulated bodies (primary deposition) or disarticulated bones that have been buried previously or defleshed elsewhere (secondary deposition). Human remains deposited in megalithic tombs may subsequently have been removed as the result of social decisions or by non-human forces such as scavenging animals. Bone remains can also be destroyed in situ as a result of chemical dissolution by local ground conditions, damage caused by plant roots, bone fragmentation during subsequent depositional events, mechanical compression from sediment pressure, etc.

Since megalithic palimpsests are created by overlapping depositional events during variable periods of time and the variable erasing of previous material traces (Lucas 2005; Bailey 2007), our ability to build precise narratives for these societies largely depends on an accurate understanding of bone assemblage formation. Their study is a challenging task that is additionally hindered by the fact that undisturbed

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megalithic burials are either unusual or were excavated many years ago without the use of systematic recording techniques. These drawbacks have affected the skeletal parts preserved and, consequently, the potential to investigate funerary taphonomy. This is the case of the Iberian Peninsula, where only very recently has the bone assemblage formation of megalithic burials been incorporated into the research agenda (Silva, 2003; Fernández-Crespo and De la Rúa 2015; Mack et al. 2015; Silva et al. 2017; Díaz-Zorita Bonilla 2017; Evangelista 2019; Evangelista and Godinho 2020, Aranda Jiménez et al. 2020a).

The recent excavation of the megalithic cemetery of Panoría offers an excellent opportunity for exploring ritual variability through bone assemblage formation (Benavides et al. 2016; Aranda Jiménez et al. 2017, 2018, 2020a, 2022; Díaz-Zorita Bonilla et al. 2017, 2019). During fieldwork in 2015 and 2019, nine tombs were excavated, four of which were remarkably well-preserved without major post-ritual disturbances. Meticulous recording techniques, including trained bioarchaeologist excavators, produced detailed archaeological information on the skeletal remains deposited in these tombs. This paper is specifically aimed at discussing bone assemblage formation based on a multi-proxy approach that includes the contextual archaeological features, differing skeletal preservation and representation indexes, taphonomic processes, and radiocarbon chronology. In the following sections, the general background of the cemetery and especially of Tombs 3, 10, 11, and 15 will be analyzed before discussing how the specific features of each bone assemblage can be associated with particular funerary rituals.

Archaeological background: The Panoría cemetery

The megalithic cemetery of Panoría is located in the south-east of the Iberian Peninsula (Fig. 1). Discovered in 2012, it is the latest addition to the known megalithic cemeteries spread across the Guadix Basin. This region stands out as one of the most important megalithic concentrations in Western Europe. Archaeological fieldwork since the end of the nineteenth century has led to the discovery of more than 400 megalithic tombs (Siret 1891 (2001), Leisner and Leisner 1943; García and Spahni 1959; Ferrer et al. 1988). Intensive surveys at Panoría have found 19 dolmens with polygonal or trapezoidal chambers and short corridors. They are aligned at regular intervals and orientated towards the sunrise at the equinox. All these funerary structures were dug into limestone bedrock and were formed by large standing stones that range in number from 9 to 11 (Aranda Jiménez et al. 2017, 2018, 2020a, 2022). From a typological point of view, these tombs belong to passage dolmens, the most common type of megalithic monument, not only in Iberia but

also in Western Europe (Leisner and Leisner 1943; Laporte and Scarre 2016). In addition to the general features of their construction, these passage dolmens also share complex funerary rituals based on multi-depositional events through variable periods of time. As mentioned above, at Panoría cemetery, four of the nine excavated tombs preserved largely undisturbed ritual deposits whose analysis will contribute to a better understanding of this Pan-European Neolithic funerary behavior.

These include Tomb 3, which consists of a passage grave with a trapezoidal chamber and a short corridor (Fig. 2). Inside the funerary chamber, two different phases of mortuary and ritual depositions were clearly separated by a paved floor that sealed in the earliest depositions and created a new space for mortuary practices. In the most recent phase of funerary depositions (Phase A), skeletal remains were recovered in an articulated position, although some minor displacements could be identified. All the individuals were placed on their left sides (left lateral decubitus¹) with their upper and lower limbs flexed. Bodies were arranged parallel to one another, oriented from west to east and aligned with the main axis of the chamber. There were five articulated individuals, all adults: two males, one female, and two of undetermined sex. Below the paved floor, in the earlier phase of mortuary deposition (Phase B), all the skeletal remains were found disarticulated, commingled and usually fragmented. The MNI was 17, calculated on the basis of tooth 42 for adults, 38 for a juvenile, 75 for infants, and a phalange for a perinatal individual.

Tomb 10 is a passage-type dolmen with a trapezoidal-shaped burial chamber and a short corridor (Fig. 3). Skeletal remains were found scattered in a single compact layer of mixed bones. Although most of the bones had lost their anatomical connections, five individuals were found in articulated or semi-articulated positions ranging from almost complete skeletons to only the upper or lower limbs. In all the latter cases, the bodies were found in a flexed and left lateral decubitus position. Articulated individuals were also found oriented from west to east and aligned with the major axis of the tomb. The MNI was 24, calculated on the basis of permanent tooth 45 for adults and deciduous tooth 63 for subadults.

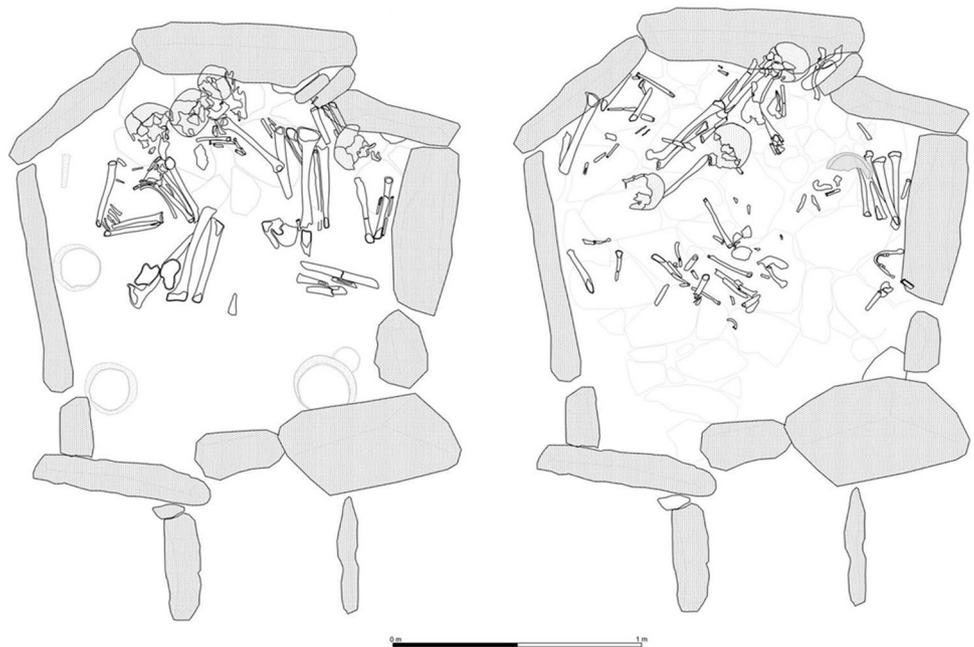
Tomb 11 is also a dolmen with trapezoidal-shaped funerary chamber and a short corridor (Fig. 4). Post-depositional activity in the form of an intrusive pit affected the right-hand side of the chamber. One of the three orthostats on this side was missing and another two were broken. The pit also affected the mortuary deposits, albeit only partially. As in Tomb 3, two different phases of mortuary activity were identified. In this case, the megalithic societies sealed the earliest

¹ Decubitus consists in a position in which the body lying on its left or right side.



Fig. 1 Orthophotography with the location of the 9 excavated tombs at Panoría cemetery

Fig. 2 Human bone remains of Phases A (left) and B (right) from Tomb 3



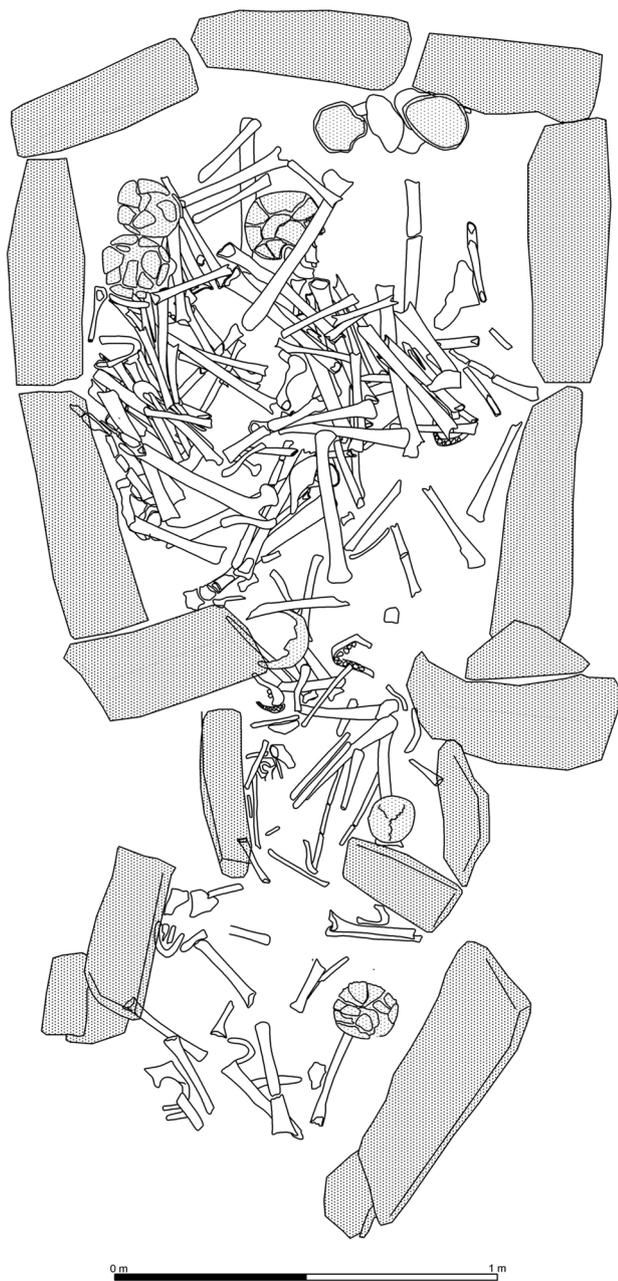


Fig. 3 Human bone remains from Tomb 10

depositions with a soil layer to differentiate the beginning of new burial practices. The most recent phase of ritual activity (Phase A) consisted of a compact layer of articulated individuals found together with other skeletal remains that had lost their anatomical connections. Nine individuals were identified in articulated or semi-articulated positions. All the anatomically connected skeletons were found in a flexed and left lateral decubitus position, except for Individual 4 who had been placed on its right side. The MNI was 13, based on the temporal bone for adults and tooth 17 and a left humerus for subadults.

The earliest phase of interments (Phase B) consisted of a layer of skeletal remains found scattered, mostly fragmented and disarticulated, except for two cases: the left upper limb of a subadult placed in the left lateral decubitus position, and the upper and lower limbs of an adult, probably female, found in the right lateral decubitus position. Particularly remarkable was the concentration of four crania next to the orthostat that formed the southern side of the mortuary chamber. The MNI was estimated as 9 individuals, a figure calculated using tooth 42 for adults and teeth 36 and 47 for subadults.

Tomb 15 also matches a passage-type dolmen with similar features to those of the previous graves (Fig. 5). This is the only tomb with skeletal remains outside the chamber and the passage. An adult female cranium (18–25 years old) and two long bones—a humerus and a tibia—carefully placed above the cranium were recovered from a pit. In the funerary chamber, human remains were found as a layer of highly fragmented and mixed bones. Only the remains of an adult male laid in the right lateral decubitus position were found in an articulated and flexed position. The MNI of 14 was calculated from the right femur for adults and teeth 28 and 37 and a clavicle for subadults.

Materials and methods

The entire assemblage from Tombs 3, 10, 11, and 15 totals 54,539 bone fragments, 1150 teeth, and 41 teeth roots. Thanks to careful recording techniques, including the systematic sieving of the sediments, we are very confident that 100% of the skeletal remains from each tomb was recovered. The distribution of the bone assemblage by tomb shows a balance in the number of skeletal remains, except for Tomb 11, which contained the largest number at 19,260 remains. In the case of Tombs 3, 10, and 15, the number ranged from 11,140 in Tomb 10 to 13,346 in Tomb 15 (Table 1).

The identification and classification of each fragment followed standard bioarchaeological methods. These included discriminating between human and non-human remains, adult and subadult bones, identifying the skeletal bone element or tooth, the laterality, the segment and anatomical area, the fraction present, and the degree of completeness of each element. Sex was assessed following Buikstra and Ubelaker (1994). Adult age was assessed in relation to changes of the auricular surface of the pelvis (Lovejoy et al. 1985), closure of the cranial sutures (Meindl and Lovejoy 1985), and dental wear (Scott, 1979; Smith 1984; Lovejoy 1985). Subadult age was assessed using skeletal development and epiphyseal fusion (Brothwell 1987; Buikstra and Ubelaker, 1994; Scheuer and Black 2000), as well as dental development (AlQahtani et al. 2010). Inter-observer error was calculated using the guidelines outlined in Buikstra and Ubelaker (1994).

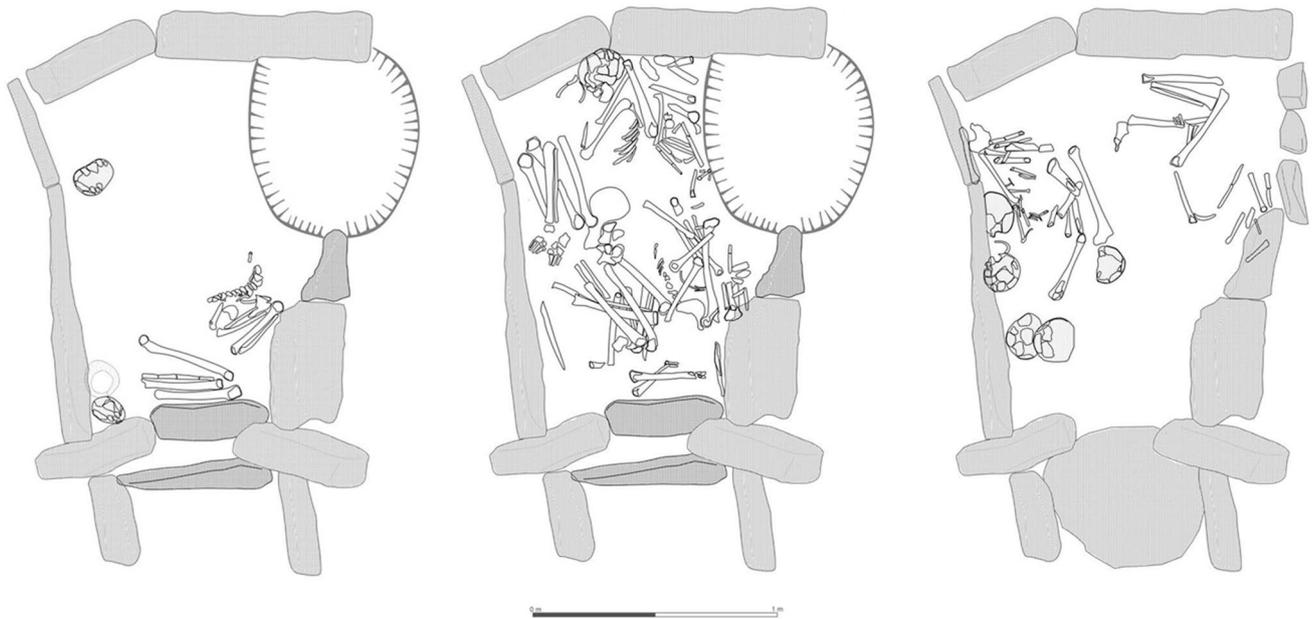


Fig. 4 Human bone remains from Tomb 11 (left, top of the Phase A; center, Phase A; right, Phase B)

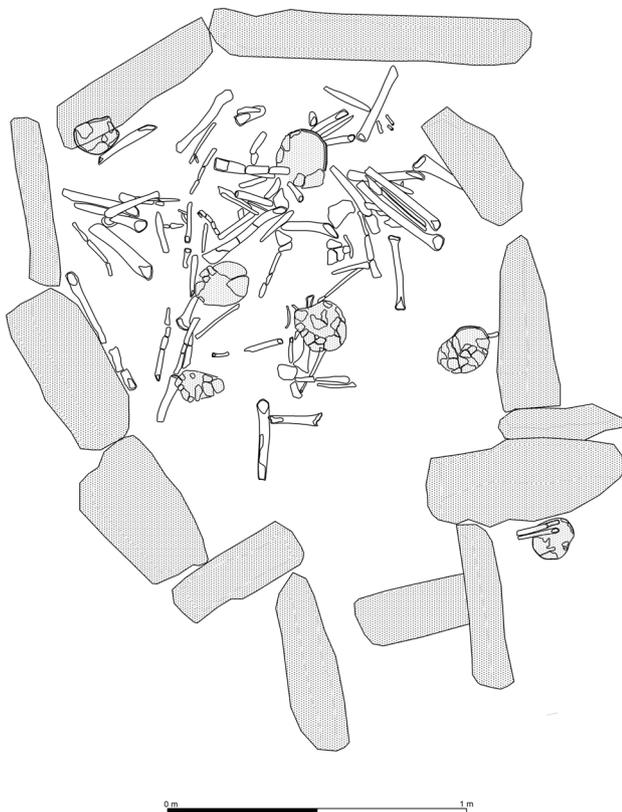


Fig. 5 Anthropological remains from Tomb 15

For the study of bone assemblage formation, several statistical indexes adapted from Bello et al. (2003, 2006) were considered. These indexes are based on bone preservation, the degree of fragmentation, how different bones are represented proportionally, and the degree of cortical surface degradation. The Anatomical Preservation Index (API) measures the percentage of bone material preserved for each bone according to the expected minimum number of elements (MNEs). Four categories were considered: more than 75% of bone preserved (Grade 1); between 25 and 75% (Grade 2), less than 25% (Grade 3), and non-preserved bone (Grade 4). The Bone Fragmentation Index (BFI) establishes the ratio between the number of fragments and the preserved MNE. A percentage index close to 100% would mean bones with little fragmentation and vice versa (Modini, 2003). The Bone Representation Index (BRI) calculates how many of the minimum number of elements are present in comparison to how many there should be according to the MNI. The Qualitative Bone Index (QBI) assesses the degree of cortical surface of each bone affected by taphonomic processes. Three categories were recorded: less than 25% of the bone surface damaged (Grade 1), between 25 and 75% (Grade 2), and more than 75% (Grade 3). These statistical indexes provide a good approach to the selective bone preservation. Nevertheless, the accurate understanding of these indexes requires the identification of the specific taphonomic agents and their degree of influence on the bone assemblage. For

Table 1 Distribution of skeletal remains found in Tombs 3, 10, 11, and 15

Type		Tomb 3	Tomb 10	Tomb 11	Tomb 15	Total
Bone	Identified	7.940	6.981	16.180	10.372	54.539
	Undetermined	3.748	3.793	2.745	2.780	
Tooth		281	352	329	188	1.150
Dental root		15	14	6	6	41
Total		11.984	11.140	19.260	13.346	55.730

this purpose and as part of the bioarchaeological study, different taphonomic agents were recorded in accordance with the methods described by Buikstra and Ubelaker (1994), Fernández-Jalvo and Andrews (2016), and Lyman (1994).

For analytical purposes, adult and subadult bone remains were clustered in nine anatomical regions: cranium, mandible, thorax, vertebral column, upper limbs, pelvic girdle, lower limbs, hands, and feet (Online Resource 1). These groups are consistent with the bone resistance to surviving taphonomic damage. The size, shape, and mineral density of skeletal remains are key factors that determine the uneven rates of bone preservation (Henderson 1987; Guy et al. 1997; Bello et al. 2006). Subadult skeletons are generally less well-preserved due to their low mineral density. In adult skeletons, those bones also characterized by low density and a high cancellous proportion and the smaller bones are also less likely to survive. The uneven decay rates are related to the nature of bone itself and to the complexity of the skeletal structure. It is expected that the nine anatomical regions will show distinct representation and preservation signatures.

Based on our previous experience (Aranda Jiménez and Lozano Medina 2014; Aranda Jiménez et al. 2022, 2021, 2020a, 2020b, 2018), we decided to radiocarbon date the minimum number of individuals identified in each tomb as the best way of ensuring that no individual was dated twice. Bearing this criterion in mind, a radiocarbon series of 66 dates was obtained for Tombs 3, 10, 11, and 15 (Online Resource 2). All samples were dated using Accelerator Mass Spectrometry (AMS) at the Scottish Universities Environmental Research Centre (SUERC) and the Swiss Federal Institute of Technology (ETH). The radiocarbon measurements were calibrated using the IntCal20 atmospheric curve (Reimer et al. 2020) and the OxCal v4.4.4 program (Bronk Ramsey 2001, 2009, 2017). The new chronological series was modelled in a Bayesian framework, and the results have been discussed in-depth elsewhere (see Aranda Jiménez et al. 2018, 2020a, 2022).

Results and discussion

Tomb 3

Tomb 3 presented two phases of mortuary depositions separated by a chronological hiatus. The most recent (Phase

A) was characterized by a high percentage of bone remains found in anatomical connection with 86.8% belonging to five articulated individuals, all adults. The remaining 13.2% were bones consistent with these articulated bodies. None of the skeletal remains recorded was those of subadults. Phase A occurred between the last decades of the twenty-sixth century and the first decades of the twenty-fifth cal BC for a very brief period, between *1 and 30 years (68% probability)*, which is approximately one generation² (Aranda Jiménez et al. 2022) (Online Resource 3).

The anatomical preservation index (hereinafter the API) revealed that more than 90% of small, low-mineral-density, and cancellous bones had not survived (Grade 4) (Table 2). This contrasts with robust and dense skeletal remains, such as cranium, mandible, and lower and upper limbs, which had better preservation percentages, most of them concentrated in Grades 1 and 2. The bone representation index (hereinafter BRI) was also very consistent with these differences in bone type. Hands, feet, vertebral column, and thorax were very poorly represented anatomical regions with percentages below 10% (an average of 5.1%). In contrast, cranium, mandible, and long bones were well-represented with at least 50% of the MNE. Especially remarkable is the 80% reached by the mandible. The difference between robust and small/fragile bones is statistically highly significant ($X^2=57.167$, p value=0.000).

The qualitative bone index (hereinafter QBI) reveals that the cortical surface of upper/lower limbs, cranium, and mandible is the least affected by taphonomic processes with a mean of 37% in Grade 1 and only 4.9% in Grade 3. In contrast, small/fragile bones are concentrated in Grades 2 and 3, which fits in with their very low degree of preservation (see API values). The taphonomic processes identified were mainly plant roots that affected 59.6% of the MNE, followed by weathering (38.5%), fungi (24.7%) and, to a lesser extent, rodent gnawing (6.4%) (Table 3 and Fig. 6). All these factors caused the physical and chemical degradation of the bone remains. Especially destructive were the plant roots that crept into the bones, producing progressive chipping and fragmentation. At the same time, excreting humic acid roots causes the dissolution of the mineral

² We assume that a generation represents 25 years (for further discussion see Whittle et al. 2007).

Table 2 Preservation, fragmentation, and representation statistical indexes of Phases A and B in Tomb 3 according to adult and subadult age groups. Minimum number of elements (MNEs); number of identified specimens (NISP)

Anatomical region	MNE	NISP	BFI%	BRI%	API%				Total API	QBI%			Total QBI
					Grade 1	Grade 2	Grade 3	Grade 4		Grade 1	Grade 2	Grade 3	
Phase A (Adults)													
Cranium	29	1148	3%	64.4%	26.7%	31.1%	6.7%	35.6%	2.5	44.8%	44.8%	10.3%	1.7
Mandible	4	116	3%	80.0%	20.0%	60.0%	0%	20.0%	2.2	25.0%	75.0%	0%	1.8
Thorax	14	232	6%	9.7%	2.1%	3.4%	4.1%	90.3%	3.8	21.4%	57.1%	21.4%	2
Vertebral column	5	59	8%	4.2%	0%	3.3%	0.8%	95.8%	3.9	20.0%	60.0%	20.0%	2
Upper limb	15	405	4%	50.0%	20.0%	26.7%	3.3%	50.0%	2.8	40.0%	60.0%	0%	1.6
Pelvic girdle	4	288	1%	26.7%	6.7%	0%	20.0%	73.3%	3.6	25.0%	25.0%	50.0%	2.3
Lower limb	21	1168	2%	52.5%	17.5%	27.5%	7.5%	47.5%	2.9	38.1%	52.4%	9.5%	1.7
Hand	16	70	23%	5.9%	0.4%	5.2%	0.4%	94.1%	3.9	0%	81.3%	18.8%	2.2
Foot	2	2	100%	0.8%	0.4%	0.4%	0%	99.2%	3.9	0%	100%	0%	2
Total	110	3628	3%	11.8%	3.4%	6.5%	1.9%	88.2%	3.7	30.0%	57.3%	12.7%	1.8
Phase B (Adults)													
Cranium	38	833	5%	22.2%	24.1%	5.6%	5.6%	64.8%	3.1	76.3%	21.1%	2.6%	1.3
Mandible	3	243	1%	25.0%	8.3%	16.7%	0%	75.0%	3.4	33.3%	33.3%	33.3%	2
Thorax	34	626	5%	9.8%	0.3%	2.9%	6.6%	90.2%	3.9	11.8%	88.2%	0%	1.9
Vertebral column	15	245	6%	5.2%	0%	0.7%	4.5%	94.8%	3.9	0%	66.7%	33.3%	2.3
Upper limb	22	545	4%	30.6%	20.8%	5.6%	4.2%	69.4%	3.2	59.1%	40.9%	0%	1.4
Pelvic girdle	2	239	1%	5.6%	0%	2.8%	2.8%	94.4%	3.9	0%	100%	0%	2
Lower limb	16	841	2%	16.7%	9.4%	3.1%	4.2%	83.3%	3.6	56.3%	25.0%	18.8%	1.6
Hand	101	204	50%	15.6%	6.2%	9.0%	0.5%	84.4%	3.6	36.6%	57.4%	5.9%	1.7
Foot	77	237	32%	12.3%	6.3%	4.6%	1.4%	87.7%	3.7	32.5%	58.4%	9.1%	1.8
Total	308	4136	7%	13.8%	5.9%	5.2%	2.7%	86.2%	3.7	38.3%	54.2%	7.5%	1.7
Phase B (Subadults)													
Cranium	0	0	0%	0%	0%	0%	0%	0%	4	0%	0%	0%	-
Mandible	2	6	33%	4.0%	0%	4.0%	0%	96.0%	3.9	0%	100%	0%	2
Thorax	5	7	71%	3.4%	0%	0%	3.4%	96.6%	3.9	0%	100%	0%	2
Vertebral column	1	1	100%	0.8%	0%	0%	0.8%	99.2%	3.9	100%	0%	0%	1
Upper limb	3	83	4%	10.0%	0%	3.3%	6.7%	90.0%	3.9	0%	33.3%	66.7%	2.7
Pelvic girdle	0	0	0%	0%	0%	0%	0%	100%	4	0%	0%	0%	-
Lower limb	3	45	7%	7.5%	2.5%	5.0%	0%	92.5%	3.8	33.3%	66.7%	0%	1.7
Hand	20	22	91%	7.4%	1.5%	5.9%	0%	92.6%	3.8	0%	100%	0%	2
Foot	10	10	100%	3.8%	1.9%	1.9%	0%	96.2%	3.9	0%	100%	0%	2
Total	44	175	25%	4.7%	1.1%	2.8%	0.9%	95.3%	3.9	4.5%	90.9%	4.5%	2

component of bones and produces a progressive erosion of the cortical surface that leads to the dissolution of bone tissues (Andrews and Armour-Chelu, 1996; Bello et al., 2006). The variety and intensity of taphonomic agents would have led to the almost complete destruction of the small and low-mineral-density bones (API values $\geq 90\%$ in Grade 4) and a highly fragmented assemblage (3% of the fragmentation Index, hereinafter BFI). If the very brief period of use and the high percentage of bones in anatomical connection are considered, the rates of bone decay were the result of in situ decomposition of primary sequential inhumations. The unequal representation and preservation of skeletal remains would have depended principally on the structural features of the bones, such as their shape, size, and density.

In contrast, the earliest phase of mortuary depositions or Phase B revealed a very different picture. None of the bone remains was found in articulated positions. They appeared as a mass of fragmented and mixed human bones in which only 4% of the skeletal remains belonged to subadults. The tomb was intensively used during the last decades of the thirty-fifth century and the thirty-fourth century cal BC for a period of 75–145 years (68% probability), which means between three and six generations. After this primary period of interments, there was a brief reuse, between 1 and 25 years (68% probability), in the twenty-ninth century cal BC (Aranda Jiménez et al. 2022).

The representation and preservation indexes for adults show more balanced values than in Phase A (Table 2 and

Table 3 Taphonomic processes of Phases A and B in Tomb 3 according to adult and subadult age groups

Type	MNE	No. affected	Frequency (%)
Phase A (Adults)			
Weathering	109	42	38.5%
Root marks	109	65	59.6%
Rodent tooth marks	109	7	6.4%
Fungal colony	109	27	24.7%
Phase B (Adults)			
Weathering	308	108	35%
Root marks	308	53	17.2%
Rodent tooth marks	308	22	7.1%
Insect marks	308	5	1.6%
Carnivore marks	308	1	0.3%
Fungal colony	308	206	66.8%
Phase B (Subadults)			
Weathering	45	23	51.1%
Root marks	45	5	11.1%
Rodent tooth marks	45	3	6.6%
Fungal colony	45	39	86.6%

Fig. 7). This is especially noticeable in the prevalence attained by the representation of small bones. Hands and feet present 15.6% and 12.3% of BRI values, which is very contrasting and statistically significant ($X^2=6.429$, p value=0.011) in comparison with the 5.9% and the 0.8% of hands and feet in Phase A. Furthermore, lower limbs revealed a BRI value of 16.7%, similar to the small bones ($X^2=0.153$, p value=0.696). Other robust bones, such as

cranium, mandible, and upper limbs, present higher BRI values, 22.2%, 25%, and 30.6%, respectively. Nevertheless, in comparison with Phase A, their representation is significantly lower (Fig. 7). The differences between cranium, mandible, and upper/lower limbs in both phases are highly significant ($X^2=15.068$, p value=0.000). The API scores are also more balanced. All anatomical regions present a poor state of preservation, with percentages of bones that have not survived ranging from 64.8% of cranium to 94.8% of vertebral column elements (Grade 4).

The cortical surfaces (QBI) present slightly better states of preservation than the bone assemblage of Phase A, with 38.3% of the skeletal remains classified in Grade 1 and only 7.5% in Grade 3 (Table 2). In contrast, in Phase A, 30% of remains were clustered in Grade 1 and 12.7% in Grade 3. By anatomical region, cranium and long bones show the least affected cortical surface with an average of 63.9% in Grade 1. The most important taphonomic agent was fungi, which affected 69.6% of the MNE, followed by weathering (37.2%), plant roots (16.4%), and rodent gnawing (16.4%) (Table 3). In the case of Panoría, fungi are not among the most aggressive taphonomic agents. As a result of tomb reopening, fungal colonies developed producing pigment accumulation (staining) and the microbial degradation of bone tissue.

Unlike Phase A, the intensity of funerary depositions, with an MNI of 17, and the period of use, between three and six generations, should also be considered as a relevant source of bone disturbance and destruction. The sequential deposition of many individuals over a period of 75–145 years would imply that each new deposition would have

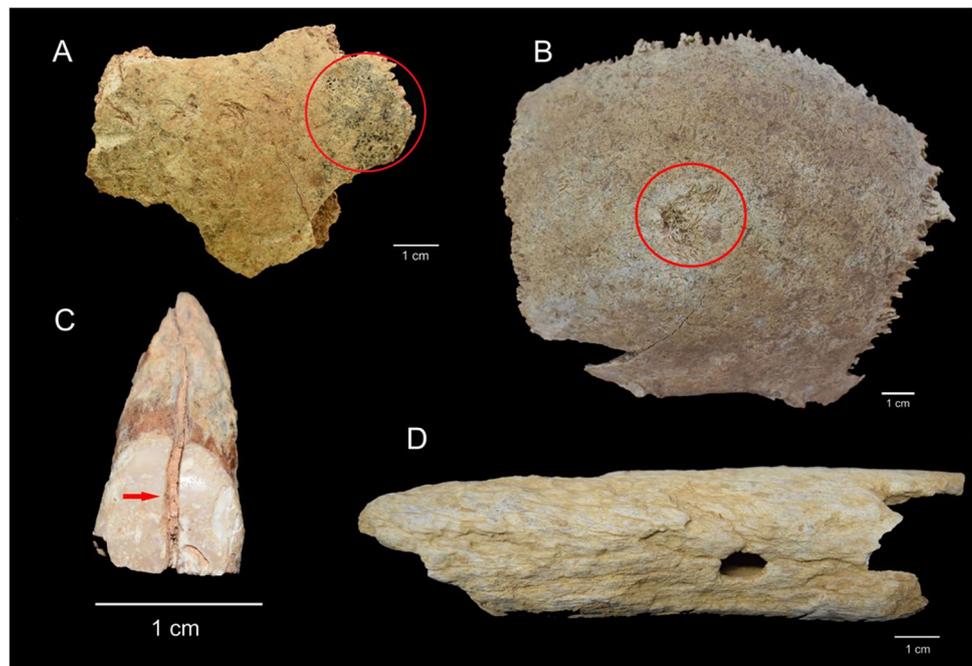
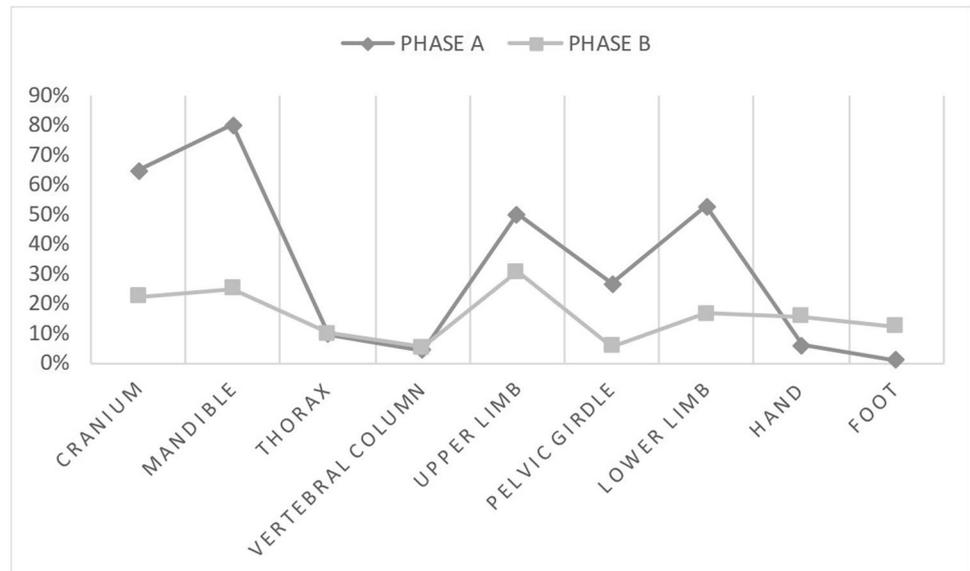
Fig. 6 Taphonomic processes identified in the bone collection. **A** fungal colony; **B** rodent marks; **C** the root of a plant chipping a tooth; **D** weathering marks

Fig. 7 BRI values of the different anatomical regions of Phases A and B of Tomb 3



damaged to some extent the previous ones. The manipulation, trampling and re-arrangement of earlier bone remains would have contributed to their physical degradation. The complex interaction of environmental, biological, and human taphonomic agents and their cumulative effect over long periods would have produced a highly fragmented bone assemblage (BFI 7%), an absence of articulated skeletal remains, and a poor state of preservation. In this scenario, the skeletal representation (BRI) differs from what would be expected, i.e., a clearer bias towards robust rather than fragile/small bones. Particularly informative is the similar representation of small bones (feet/hands) and lower limbs, as well as the under-representation of crania and mandibles. These discrepancies can be explained as the result of a selective removal of femora, crania, and probably also mandibles, a ritual practice also found in other European megalithic monuments (Beckett and Robb 2006; Beckett 2011).

Tomb 10

In Tomb 10, only a single layer of bone remains was found, 10.5% of which belonged to five articulated individuals ranging from an almost complete body to only the upper or lower limbs. Also noticeable was a very low representation of subadult bones, only 0.5% of the skeletal remains. Tomb 10 was intensively used in the twenty-fifth century and, after a hiatus, was reused for a few interments in the twenty-first century. In both cases, the period of use was short, not more than one generation (Aranda Jiménez et al. 2022).

The API index shows that those anatomical regions of small, low-mineral-density, cancellous bones were non-preserved in large percentages, around 90% (mean of 91.3% in Grade 4) (Table 4). Crania and long bones also presented high percentages of non-preserved bones with an average

of 69.2% (Grade 4). None of the anatomical regions scored above 15% of bones in Grade 1 (>75% of bone preserved). The BRI values also presented a poor representation of the different anatomical regions. It is remarkable the low percentages of crania and lower limbs with 23.3% and 28.6%, respectively. These values are similar to those found in Phase B of Tomb 3 with which there are no differences ($X^2=0.000$, p value=1). The same occurs with the comparison of fragile and small bones ($X^2=0.056$, p value=0.814), which means very similar osteological profiles.

According to the QBI values, the cortical surface was heavily affected by taphonomic agents. Only 12.1% of bones scored in Grade 1, which contrasts with the 30% and 38.3% of Tomb 3 Phases A and B. Weathering was the main type of taphonomic agent, affecting 40.5% of bones, followed by fungal colonies (16.1%) and root and rodent marks at 9.3%, respectively (Table 5). Weathering can be considered as one of the most powerful environmental factors causing the cracking and splitting of bones (Behrensmeyer 1978; Lyman and Fox 1989; Knüsel and Robb 2016). Tomb 10 shows very poor bone preservation as it is intensively affected by taphonomic agents. In this scenario, greater differences would be expected in the rate of decay between robust and small bones. As occurred in Phase B of Tomb 3, mainly crania and femora were under-represented, which could be explained by their selective removal. This possibility has been explored through comparative radiocarbon chronology elsewhere (Aranda Jiménez et al. 2020a). For this purpose, the chronological differences between teeth and bones were tested. According to the radiocarbon series for teeth, the earliest human remains were placed in the tomb in the last centuries of the 4th millennium, which contrasts with the brief period of use shown by bone remains in the twenty-fifth century cal BC. The dates on teeth present a long period

Table 4 Preservation, fragmentation, and representation statistical indexes of Tomb 10 according to adult and subadult age groups. Minimum number of elements (MNEs); number of identified specimens (NISPs)

Anatomical region	MNE	NISP	IFO%	BRI%	API%				Total API	QBI%			Total QBI
					Grade 1	Grade 2	Grade 3	Grade 4		Grade 1	Grade 2	Grade 3	
Adults													
Cranium	44	1654	3%	23.3%	7.9%	9.0%	6.3%	76.7%	3.5	18.2%	56.8%	25.0%	2.1
Mandible	12	174	7%	57.1%	14.3%	38.1%	4.8%	42.9%	2.8	16.7%	66.7%	16.7%	2
Thorax	41	490	8%	6.7%	0.7%	1.1%	4.9%	93.3%	3.9	4.9%	70.7%	24.4%	2.2
Vertebral column	34	371	9%	6.7%	0.6%	1.2%	5.0%	93.3%	3.9	23.5%	61.8%	14.7%	1.9
Upper limb	51	890	6%	40.5%	7.9%	26.2%	6.3%	59.5%	3.2	2.0%	86.3%	11.8%	2.1
Pelvic girdle	7	261	3%	11.1%	0%	3.2%	7.9%	88.9%	3.9	0%	28.6%	71.4%	2.7
Lower limb	48	2016	2%	28.6%	3.0%	22.6%	3.0%	71.4%	3.4	18.8%	70.8%	10.4%	1.9
Hand	137	214	64%	12.1%	4.5%	7.0%	0.6%	87.9%	3.7	5.8%	87.6%	6.6%	2
Foot	99	164	60%	9.1%	2.0%	6.1%	0.9%	90.9%	3.8	19.2%	63.6%	17.2%	2
Total	473	6945	7%	12.1%	2.9%	6.6%	2.6%	87.9%	3.8	12.1%	73.2%	14.8%	2
Subadults													
Cranium	0	0	0%	0%	0%	0%	0%	100%	4	0%	0%	0%	-
Mandible	0	0	0%	0%	0%	0%	0%	100%	4	0%	0%	0%	-
Thorax	1	1	100%	1.1%	0%	1.1%	0%	98.9%	3.9	0%	100%	0%	2
Vertebral column	0	0	0%	0%	0%	0%	0%	100%	4	0%	0%	0%	-
Upper limb	2	7	29%	11.1%	5.6%	5.6%	0%	88.9%	3.7	0%	100%	0%	2
Pelvic girdle	0	0	0%	0%	0%	0%	0%	100%	4	0%	0%	0%	-
Lower limb	1	15	7%	4.2%	0%	4.2%	0%	95.8%	3.9	0%	100%	0%	2
Hand	10	10	100%	6.2%	3.7%	2.5%	0%	93.8%	3.8	10.0%	70.0%	20.0%	2.1
Foot	3	3	100%	1.9%	0.6%	1.3%	0%	98.1%	3.9	0%	100%	0%	2
Total	17	36	47%	3.0%	1.4%	1.6%	0%	97.0%	3.9	5.9%	82.4%	11.8%	2.1

of funerary use before the deposition of the bone remains that would have been the most recent interments. It seems very plausible that these teeth provide the evidentiary link to skeletal depositions subsequently being removed.

Tomb 11

This tomb presented two phases of ritual activity separated by a long chronological hiatus. The most recent phase (Phase

A) was characterized by a high percentage of bone remains found in anatomical connection: 49.8% belonged to nine individuals ranging from almost complete skeletons to specific anatomical parts, such as lower or upper limbs. It is also remarkable that only 4.2% were attributable to subadults. Funerary activity was concentrated principally in the twenty-fifth and twenty-second centuries cal BC, in two short events spanning between 1–120 years and 1–95 years (68% probability), respectively (Aranda Jiménez et al. 2022).

Table 5 Taphonomic processes of Tomb 10 according to adult and subadult age groups

Type	MNE	No. affected	Frequency (%)
Adults			
Weathering	473	192	40.5%
Root marks	473	45	9.5%
Rodent tooth marks	473	44	9.3%
Calcareous concretions	473	7	1.4%
Fungal colony	473	76	16%
Subadults			
Weathering	17	9	52.9%
Rodent tooth marks	17	1	5.8%
Fungal colony	17	8	47%

The preservation index (API) shows a clear bias in favor of robust rather than fragile bones. The 81% of anatomical regions such as the thorax, vertebral column, hands, and feet have disappeared (Grade 4), a figure that falls to the 35.6% for robust bones (Table 6). Especially informative were the high percentages of upper (47%) and lower (36.4%) limb bones in Grade 1. The BRI values revealed a well-represented bone assemblage. Robust bones scored above 50% in all cases (average 64.3%), and around 20% of small and fragile bones (average 19%). Again, the difference between robust and small/fragile bones is statistically very highly significant ($X^2=33.476$, p value=0.000).

The quality bone index (QBI) also revealed a well-preserved assemblage, as the 39.1% of bones were concentrated in Grade 1, with no differences between robust and fragile bones ($X^2=0.087$, p value=1). Weathering (65.6%) and

Table 6 Preservation, fragmentation, and representation statistical indexes of Phases A and B in Tomb 11 according to adult and subadult age groups. Minimum number of elements (MNEs); number of identified specimens (NISPs)

Anatomical region	MNE	NISP	BFI%	BRI%	API%				Total API	QBI%			Total QBI
					Grade 1	Grade 2	Grade 3	Grade 4		Grade 1	Grade 2	Grade 3	
Phase A (Adults)													
Cranium	65	2892	2%	65.7%	27.3%	18.2%	20.2%	34.3%	2.6	63.1%	20.0%	16.9%	1.5
Mandible	8	194	4%	72.7%	18.2%	54.5%	0%	27.3%	2.4	37.5%	37.5%	25.0%	1.9
Thorax	57	1943	3%	17.9%	3.4%	3.1%	11.3%	82.1%	3.7	33.3%	49.1%	17.5%	1.8
Vertebral column	59	749	8%	22.3%	1.9%	10.2%	10.2%	77.7%	3.6	35.6%	49.2%	15.3%	1.8
Upper limb	38	661	6%	57.6%	47.0%	3.0%	7.6%	42.4%	2.5	28.9%	52.6%	18.4%	1.9
Pelvis girdle	18	1403	1%	54.5%	3.0%	9.1%	42.4%	45.5%	3.3	16.7%	38.9%	44.4%	2.3
Lower limb	54	2345	2%	61.4%	36.4%	10.2%	14.8%	38.6%	2.7	31.5%	55.6%	13.0%	1.8
Hand	123	252	49%	20.7%	14.5%	5.9%	0.3%	79.3%	3.4	41.5%	51.2%	7.3%	1.7
Foot	85	436	19%	14.9%	7.9%	5.6%	1.4%	85.1%	3.6	37.6%	43.5%	18.8%	1.8
Total	507	11683	4%	25.0%	11.7%	7.0%	6.1%	75.2%	3.4	39.1%	45.4%	15.6%	1.8
Phase A (Subadults)													
Cranium	6	471	1%	30.0%	10.0%	10.0%	10.0%	70.0%	3.4	0%	33.3%	66.7%	2.7
Mandible	0	0	0%	0%	0%	0%	0%	0%	4	0%	0%	0%	-
Thorax	3	5	60%	5.2%	0%	1.7%	3.4%	94.8%	3.9	0%	100%	0%	2
Vertebral column	0	0	0%	0%	0%	0%	0%	100%	4	0%	0%	0%	-
Upper limb	2	22	9%	16.7%	8.3%	8.3%	0%	83.3%	3.6	0%	50.0%	50.0%	2.5
Pelvis girdle	0	0	0%	0%	0%	0%	0%	100%	4	0%	0%	0%	-
Lower limb	1	1	100%	6.3%	0%	0%	6.3%	93.8%	3.9	0%	100%	0%	2
Hand	2	2	100%	1.9%	1.9%	0%	0%	98.1%	3.9	0%	50.0%	50.0%	2.5
Foot	4	4	100%	3.8%	1.0%	2.9%	0%	96.2%	3.9	25.0%	75.0%	0%	1.8
Total	18	518	3%	4.8%	1.6%	1.9%	1.3%	95.2%	3.9	5.6%	61.1%	33.3%	2.3
Phase B (Adults)													
Cranium	13	708	2%	28.9%	2.2%	15.6%	11.1%	71.1%	3.5	23.1%	15.4%	61.5%	2.4
Mandible	1	8	13%	20.0%	0%	0%	20.0%	80.0%	3.8	0%	0%	100%	3
Thorax	7	79	9%	4.8%	0%	0.7%	4.1%	95.2%	3.9	0%	57.1%	42.9%	2.4
Vertebral column	4	9	44%	3.3%	0%	0%	3.3%	96.7%	3.9	25.0%	25.0%	50.0%	2.3
Upper limb	6	178	3%	20.0%	10.0%	10.0%	0%	80.0%	3.5	0%	83.3%	16.7%	2.2
Pelvis girdle	4	305	1%	26.7%	0%	0%	26.7%	73.3%	3.7	0%	0%	100%	3
Lower limb	12	893	1%	30.0%	12.5%	0%	17.5%	70.0%	3.5	16.7%	58.3%	25.0%	2.1
Hand	15	30	50%	5.6%	3.1%	2.7%	0%	94.4%	3.9	20.0%	80.0%	0%	1.8
Foot	5	26	19%	1.9%	0.4%	0.4%	1.2%	98.1%	3.9	20.0%	20.0%	60.0%	2.4
Total	67	2482	3%	7.3%	1.9%	2.0%	3.2%	92.8%	3.9	14.9%	47.8%	37.3%	2.2
Phase B (Subadults)													
Cranium	19	350	5%	52.8%	8.3%	19.4%	25.0%	47.2%	3.1	5.3%	26.3%	68.4%	2.6
Mandible	3	89	3%	75.0%	0%	50.0%	25.0%	25.0%	2.8	33.3%	0%	66.7%	2.3
Thorax	22	268	8%	19.0%	6.9%	0.9%	11.2%	81.0%	3.7	0%	59.1%	40.9%	2.4
Vertebral column	3	58	5%	3.1%	0%	0%	3.1%	96.9%	3.9	33.3%	66.7%	0%	1.7
Upper limb	12	125	10%	50.0%	25.0%	8.3%	16.7%	50.0%	2.9	8.3%	16.7%	75.0%	2.7
Pelvis girdle	1	4	25%	8.3%	0%	0%	8.3%	91.7%	3.9	0%	0%	100%	3
Lower limb	12	392	3%	37.5%	21.9%	12.5%	3.1%	62.5%	3.1	8.3%	8.3%	83.3%	2.8
Hand	7	20	35%	3.2%	2.8%	0.5%	0%	96.8%	3.9	42.9%	42.9%	14.3%	1.7
Foot	4	8	50%	1.9%	1.0%	1.0%	0%	98.1%	3.9	0%	100%	0%	2
Total	83	1497	6%	11.3%	4.3%	2.6%	4.3%	88.8%	3.8	9.6%	36.1%	54.2%	2.4

Table 7 Taphonomic processes of Phases A and B in Tomb 11 according to adult and subadult age groups

Type	MNE	No. affected	Frequency (%)
Phase A (Adults)			
Weathering	507	333	65.6%
Root marks	507	56	11%
Rodent tooth marks	507	190	37.4%
Fungal colony	507	335	66%
Calcareous concretions	507	35	6.9%
Phase A (Subadults)			
Weathering	18	12	66.6%
Root marks	18	2	11.1%
Rodent tooth marks	18	5	27.7%
Fungal colony	18	17	94.4%
Calcareous concretions	18	2	11.1%
Phase B (Adults)			
Weathering	67	52	77.6%
Root marks	67	13	19.4%
Rodent tooth marks	67	25	37.3%
Fungal colony	67	56	83.5%
Calcareous concretions	67	13	19.4%
Phase B (Subadults)			
Weathering	83	60	72.2%
Root marks	83	19	22.8%
Rodent tooth marks	83	42	50.6%
Fungal colony	83	70	84.3%
Calcareous concretions	83	37	44.5%

fungi (66%) were the most significant taphonomic agents, followed by root and rodent marks that affected 37.4% and 11% of bones, respectively (Table 7). Although there is a better preservation, it is also true that there are clear biases towards certain anatomical regions. Robust bones appeared well-represented in comparison to the poor representation of small and fragile bones. As in the Phase A of Tomb 3, if the high percentage of articulated bones is taken into account, the bone assemblage formation seems to be mainly the result of the in situ decomposition of primary burials. The different rates of bone decay would have been the outcome of their differing structural nature.

The earliest phase of mortuary activity (Phase B) presents very contrasting features. Most of the bone remains (84.6%) were found disarticulated, commingled, and fragmented. The remaining 15.4% belonged to two partially articulated individuals, a figure that contrasted with the 49.8% of Phase A. Nevertheless, the most striking feature was the high percentage of subadult bones: 37.6% were from that age group compared to only 4.2% in Phase A. These differences can be extended to the other tombs in the cemetery in which subadult bones do not score above 6%. From a chronological point of view, the funerary activity occurred during the

second half of the 4th millennium cal BC (Aranda Jiménez et al. 2022).

The preservation index (API) reveals that most of the bones in the adult age group were not preserved (Grade 4) with small differences between small/fragile bones (mean 96.2%) and robust bones (mean 74.8%) (Table 6). The BRI values show an under-representation of robust and small/fragile bones with percentages $\leq 30\%$ and $\leq 6\%$, respectively, although these differences are statistically highly significant ($X^2=17.127$, p value=0.000). Regarding subadults, the good representation of robust bones is remarkable, with percentages $\geq 50\%$ for crania, mandibles, and upper limbs (mean of 59.2%). In fact, the differences with the adult group are statistically very significant ($X^2=9.104$, p value=0.003). This better subadult representation is also supported by ritual practices that would have involved the intentional preservation of four crania—three of them from subadults—that appeared concentrated next to the orthostat that formed the southern side of the mortuary chamber.

The cortical surfaces (QBI) revealed a poor state of preservation with percentages of 37.3% for adults and 54.2% for subadults in Grade 3 (Table 6). These figures reveal clear differences with Phase A that are especially noticeable in the adult age group with a concentration of 39.1% of bones in Grade 1 and only 15.6% in Grade 3. These differences between phases are highly significant ($X^2=10.268$, p value=0.001). Taphonomic agents such as fungal colony, weathering, and rodent marks affected adults (mean 66%) and subadults (mean 69%) equally (Table 7). The cumulative effect of taphonomic processes, including the destruction of earlier bone remains during the sequential burial depositions, would have produced a very poor preservation and representation of small and fragile bones in both adults and subadults. In contrast, crania, mandibles, and upper/lower limbs were well-represented in subadults and under-represented in adults. It seems that these anatomical regions could have been manipulated in different ways. For subadults, crania appear to have been intentionally collected and protected, which would explain their good state of preservation. In the case of adults, this ritual practice has not been observed and their under-representation could be the result of a selective removal of crania, mandibles, and long bones.

Tomb 15

Tomb 15 presented a single layer of highly fragmented (2% of BFI) and mixed bones that amounted to 91.8% of the bone assemblage. The remaining 8.2% were from a partially articulated adult male. Only 6% of the skeletal remains came from subadults. Outside the tomb, a pit was found with a carefully deposited cranium and two long bones from a reuse event dated to the fifth century cal AD. For that reason, these remains were not included in

Table 8 Preservation, fragmentation, and representation statistical indexes of Tomb 15 according to adult and subadult age groups

Anatomical region	MNE	NISP	BFI%	BRI%	API%				Total API	QBI%			Total QBI
					Grade 1	Grade 2	Grade 3	Grade 4		Grade 1	Grade 2	Grade 3	
Adults													
Cranium	49	2129	2%	54.4%	8.9%	28.9%	16.7%	45.6%	3	26.5%	30.6%	42.9%	2.2
Mandible	4	156	3%	40.0%	0%	20.0%	20.0%	60.0%	3.4	0%	25.0%	75.0%	2.8
Thorax	10	355	3%	3.4%	0.3%	0.7%	2.4%	96.6%	3.9	40.0%	50.0%	10.0%	1.7
Vertebral Column	9	221	4%	3.8%	0%	0.8%	2.9%	96.3%	3.9	11.1%	33.3%	55.6%	2.4
Upper limb	20	1466	1%	33.3%	10.0%	13.3%	10.0%	66.7%	3.3	15.0%	25.0%	60.0%	2.5
Pelvis girdle	5	682	1%	16.7%	0%	3.3%	13.3%	83.3%	3.8	20.0%	20.0%	60.0%	2.4
Lower limb	32	3469	1%	40.0%	6.3%	20.0%	13.8%	60.0%	3.3	18.8%	25.0%	56.3%	2.4
Hand	22	84	26%	4.1%	1.1%	2.6%	0.4%	95.9%	3.9	9.1%	54.5%	36.4%	2.3
Foot	22	41	54%	4.2%	1.5%	1.9%	0.8%	95.8%	3.9	13.6%	31.8%	54.5%	2.4
Total	173	9494	2%	9.3%	1.8%	4.4%	3.1%	90.7%	3.8	19.1%	32.9%	48.0%	2.3
Subadults													
Cranium	9	232	4%	25.0%	2.8%	11.1%	11.1%	75.0%	3.6	22.2%	44.4%	33.3%	2.1
Mandible	2	50	4%	50.0%	0%	25.0%	25.0%	50.0%	3.3	0%	50.0%	50.0%	2.5
Thorax	1	19	5%	0.9%	0%	0.9%	0%	99.1%	3.9	0%	0%	100%	3
Vertebral Column	0	0	0%	0%	0%	0%	0%	100%	4	0%	0%	0%	-
Upper limb	6	230	3%	25.0%	4.2%	8.3%	12.5%	75.0%	3.6	16.7%	33.3%	50.0%	2.3
Pelvis girdle	0	0	0%	0%	0%	0%	0%	100%	4	0%	0%	0%	-
Lower limb	0	0	0%	0%	0%	0%	0%	100%	4	0%	0%	0%	-
Hand	1	1	100%	0.5%	0.5%	0%	0%	99.5%	3.9	0%	100%	0%	2
Foot	1	1	100%	0.5%	0.5%	0%	0%	99.5%	3.9	100%	0%	0%	1
Total	20	625	3%	2.7%	0.5%	1.1%	1.1%	97.3%	3.9	20.0%	40.0%	40.0%	2.2

this study. Mortuary rituals occurred in the thirty-fifth and thirty-fourth centuries cal BC, with a later reuse in the twenty-ninth century cal BC (Aranda Jiménez et al. 2022).

The API and BRI values revealed a very poor preservation (>95% in Grade 4) and representation (<4%) of small and fragile bones (Table 8). The cranium is the only type of anatomical region that surpasses 50% of BRI values. Upper limbs and lower limbs present 33.3% and 40% anatomical representation, respectively. The differences between small/fragile and robust bones remain very significant ($X^2=24.695$, p value=0.000). The QBI shows that 48% of the bones present more than 75% of their cortical surface affected by different taphonomic agents, among which weathering (89%), fungi (76.8%), and root marks (46.2%) were the most significant (Table 9). Tomb 15 had the poorest preserved bone assemblage in the cemetery. Unlike the previous tomb, the ritual behavior that produced this osteological profile is unclear.

Conclusions

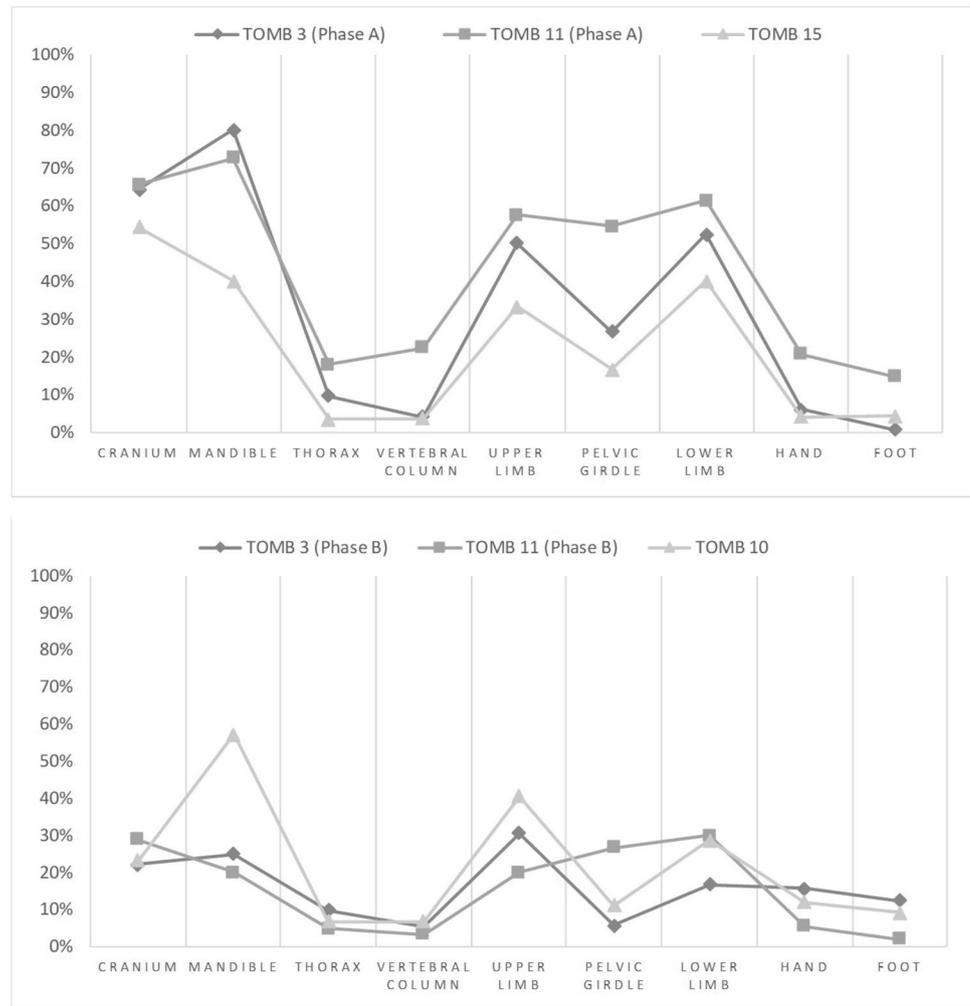
Understanding bone assemblage formation is a very complex matter, as different social, environmental, and biological taphonomic factors interacted in complex ways. The

deposition of human remains in megalithic tombs was followed by their differential in situ destruction and the potential removal of all or part of the skeletal remains. Deposition, removal, and destruction are key aspects that would imply complex events involving the addition and extraction of bone remains. Due to this complex sequence of depositions

Table 9 Taphonomic processes of Tomb 15 according to adult and subadult age groups

Type	MNE	No.affected	Frequency (%)
Adults			
Weathering	173	154	89%
Root marks	173	80	46.2%
Rodent tooth marks	173	38	21.9%
Carnivore marks	173	1	0.5%
Fungal colony	173	133	76.8%
Calcareous concretions	173	12	6.9%
Subadults			
Weathering	20	19	95%
Root marks	20	14	70%
Rodent tooth marks	20	6	30%
Fungal colony	20	19	95%
Calcareous concretions	20	4	20%

Fig. 8 Osteological profiles of sequential primary inhumation (up) and selective removal (bottom) according to the BRI values of the different anatomical regions



and the variable erasing of previous material traces, we will probably never fully understand the ritual and mortuary practices that took place at every megalithic tomb. Nevertheless, the bone assemblages recovered during excavations provide multiple avenues for exploring megalithic rituals, even if they can only be partially perceived.

In the case of Panoría cemetery, the bone assemblages can be characterized as highly fragmented and very poorly preserved. As expected for burials that share similar environmental conditions, the same taphonomic processes, principally weathering, plant root activity, fungal invasion, and rodent gnawing, were identified in all tombs, although their intensity varied from tomb to tomb. All these factors caused the physical and chemical degradation of bone remains that were amplified by the damage produced by the repeated manipulation and trampling of the earlier remains, especially in those tombs with longer and more intensive periods of use.

In addition to these general trends, important differences can be found between tombs and within them between different phases of mortuary deposition. According to the previous

multi-proxy discussion, three main ritual practices can be identified. The sequential primary inhumation followed by the differential in situ decomposition of bone remains would be one of these practices. The osteological profiles of Phase A of Tomb 3, Phase A of Tomb 11, and probably also of Tomb 15 are consistent with this scenario. Crania, mandibles, and long bones are well-represented, which contrasts with the clear under-representation of small and fragile bones (Fig. 8). The differences in the rate of decay between tombs can be related to the preservation of each assemblage. Phase A of Tomb 11 shows the highest frequencies of representation in all the anatomical regions, but also the best preservation rates, with the low degree of bone cortical surface degradation being especially remarkable. At the opposite end of the scale, Tomb 15 reveals the poorest representational values and also the lowest rates of preservation.

As John Robb (2016) has claimed, osteological profiles characterized by the low representation of fragile and small bones form a common preservational baseline rather than indicating specific mortuary practices. Sequential primary inhumation and secondary depositions would have produced

similar representation patterns. In our case study, the archaeological contextual information provides critical evidence for distinguishing between them. Phases A of Tombs 3 and 11 are characterized by a very short period of use spanning just a few decades, which means that the disturbance caused by tomb reuse was limited. In fact, most of the bones were recorded in articulated positions—86.8% in Tomb 3 and 49.8% in Tomb 11—ranging from largely complete bodies to specific anatomical parts. Both brief periods of use and articulated bodies suggest a ritual practice consisting of primary sequential inhumations followed by in situ decomposition. In the case of Tomb 15, the archaeological evidence does not offer reliable information to distinguish between different funerary practices. With the exception of one partially articulated body, all the bone remains were found scattered and disarticulated. Although the intensity and period of use could have been responsible for this bone assemblage from primary inhumations, the possibility of secondary depositions cannot be ruled out.

The selective removal of crania and long bones was also an important ritual practice at Panoría cemetery. This would be the case of Phase B in Tomb 3, Phase B in Tomb 11, and Tomb 10. The three bone assemblages share with primary inhumations the low representation of fragile and small bones, but differ in the proportions of crania and long bones, which show lower frequencies than would be expected (Fig. 8). This under-representation of crania and upper/lower limbs would be the result of a selective removal that could have occurred before or after deposition in the funerary chamber. In the first case, crania and long bones could have been collected prior to deposition, which would have implied that human remains were skeletonized elsewhere and were incomplete when placed in the dolmens. This scenario would be consistent with secondary depositions, whereas the opposite would be true if the removal had occurred after the skeletons had been deposited in the tombs. In these cases, primary depositions would have been followed by the selective extraction of crania and long bones. In both cases, the osteological profile will be characterized by an under-representation of those anatomical regions that better survive taphonomic damage.

Nevertheless, at Panoría, as at other European megalithic monuments, such as the Poul nabrone portal tomb in Ireland (Beckett and Robb 2006; Beckett 2011) and West Kennet Long Barrow in Great Britain (Piggott 1962), selective removal after deposition appears to be the most plausible scenario. Two main aspects support this statement. Firstly, in secondary depositions it is expected that fragile and small remains, especially labile bones from the upper and lower limbs, would have been lost during their transfer from the primary deposition site. However, this is not the case of funerary deposits with an under-representation of crania and long bones. The preservation and representation indexes of hands and feet are especially noticeable when compared to those ritual practices of primary depositions only followed

by in situ decomposition. Tomb 3 is the best example of this: during Phase B hands and feet represent 15.6% and 12.3% respectively, which is very contrasting and statistically significant ($X^2=6.429$, $p\text{-value}=0.011$) in comparison with the 5.9% and 0.8% of hands and feet in Phase A.

Secondly, the contextual archaeological information would also appear to support selective removal after deposition. The under-representation of crania and long bones was only associated with long and intensive periods of use, over three to six generations. In contrast, crania and long bones are well-represented in those deposits formed over brief periods of a few decades, in which most of the bone remains are found articulated. It seems that the longer use-life and the more intensive ritual depositions could be the main reason behind the removal of crania and long bones. The space needed for new interments could explain these socially motivated actions, although other cultural reasons and complex beliefs cannot be ruled out.

The third type of ritual behavior was the manipulation and re-arrangement of specific bones, a common ritual practice found at many European megalithic monuments, including El Pendón (Díaz-Navarro et al. 2022) and Alto Reinoso (Alt et al. 2016) in Iberia; Fussell's Lodge (Shanks and Tilley 1982), Ascott-under-Wychwood (Benson and Whittle 2006) in Great Britain; and Les Peirrières (Duday 1988) in France. At Panoría, this was the case of the Phase B of Tomb 11, in which subadult crania and probably mandibles and long bones were intentionally collected and protected, as their BRI values and location inside the tomb suggests. These bones were either treated differentially as part of unknown cultural beliefs or were just more carefully handled than other remains to avoid damaging them. Whatever the explanation, the critical influence of these social actions in bone assemblage formation is remarkable. It is very informative that 37.6% of the bone remains in Phase B of Tomb 11 belonged to subadults. This contrasts with the other tombs in Panoría cemetery in which that age group does not score above 6%. The fact that all the tombs share similar environmental conditions and taphonomic agents also adds relevance to these differences and supports a specific ritual behavior in Tomb 11.

Funerary practices are a mainstay in explanations of Iberian Neolithic and Chalcolithic societies. Surprisingly, however, very little attention has been paid to the study of bone assemblages. Their informative potential has been overlooked for many years. However, the characterization of mortuary rituals can only be accessed through an accurate understanding of the taphonomic factors affecting bone remains. The Panoría cemetery offers an excellent example of how the variability in ritual practices can be explored through the characterization of different patterns of skeletal preservation and representation. It seems clear that a fine-grained understanding of megalithic rituals needs to rely on a systematic analysis of bone assemblage formation.

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Declarations

Conflict of interest The authors declare no competing interests.

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