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Insects in the far West: Burial practices on El Hierro Island (Canary Islands, Spain; ca. 6th-11th centuries) reconstructed via funerary archaeoentomology☆

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A B S T R A C T

The Canary Islands were first settled by North African groups in the first millennium CE and, after a few centuries of interconnections with the mainland and between islands, remained isolated until the late medieval European expansion into the Atlantic. El Hierro is a small island located in the westernmost part of the archipelago that was inhabited by the *bimbapes* from the 2nd century CE until the 15th century European conquest. The archaeological records, including marine food processing sites and cave burials, illustrate their adaptation to the environment: the dependence on marine resources for its economy owing the island's isolation and the scarcity of arable land and the use of the natural landscape to dispose of deads. La Lajura Cave, a collective burial site used from the 6th to 11th centuries CE, revealed significant anthropological and entomological findings. The archaeoentomological analysis of the sediment samples revealed 5816 insect remains, primarily Diptera and Coleoptera, with relatively small numbers of Hymenoptera, Heteroptera, Lepidoptera, and Arachnida. These findings shed light on decomposition processes and funerary practices as well as the distribution of the cadaveric entomofauna present in the western limit of the Palearctic region before the modern era. This study highlights the role of insects in cadaveric decomposition and their ecological behaviors, offering valuable insights into the funerary practices of *Bimbape* society in a unique ecological context.

1. Introduction

When the decomposition of a corpse occurs, multiple organisms are involved, ranging from bacteria (e.g., *Bacillus subtilis* Cohn, 1872; Carter et al., 2007) to large scavengers such as vultures (Barton et al., 2013). However, a significant part of this process is attributable to insects, which play roles in various decomposition stages, responding primarily to the olfactory signals emitted by the decaying remains (Putman, 1983; Goff, 1988). Forensic entomology endeavours to analyse insect evidence to estimate the postmortem interval (PMI), pinpoint the location of death, and uncover other pivotal clues pertinent to criminal investigations (Amendt et al., 2011; Vanin, 2016; Vanin and Huchet, 2017). This discipline relies on the established principles of entomological succession, which delineate the predictable sequence in which various insect groups colonize and decompose a dead body or carrion over time. The pattern of succession is influenced by several factors, such as environmental conditions, geographic location, season, and the accessibility of the body to insects (Mégnin, 1894; Mondor et al., 2012). Within funerary archaeological contexts, the analysis of insect remains from tombs or those associated with human remains provides critical insights into the taphonomy of the grave and, consequently, the funerary practices of past populations. This specialized field of research, originally defined by Huchet (1996) as "Funerary Archaeoentomology," is now gaining recognition and being further developed globally (e.g., Fugassa et al., 2008; Vanin and Huchet, 2017; Huchet, 2014, 2017; Giordani et al., 2018; Pradelli et al., 2019).

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In the Canary Islands, the preservation of entomological remains in archaeological contexts is not uncommon and is often sustained through desiccation (Henríquez-Valido et al., 2019; 2020). However, the majority of insects from funerary contexts have been recovered from materials stored in museums since the late 19th and early 20th centuries (Mathiesen, 1960; Sánchez-Pinto and Ortega, 1995; López-dos Santos et al., 2021), with very few direct data obtained from systematic excavations (Trujillo-Mederos and González-Toledo, 2011). Our paper presents the first funerary archaeoentomological investigation in the Canary Islands on the basis of direct data from insect remains recovered during a controlled and systematic archaeological excavation in a natural cave used as a collective burial place by the indigenous population of El Hierro.

The Canary Islands were populated by North African human groups in the early years of the first millennium CE (Santana et al., 2024). After several centuries of interaction with the rest of the archipelago and from the continent, they remained isolated until the onset of late medieval European expansion (Fregel et al., 2019; Serrano et al., 2023). These populations have developed adaptive responses to ecologically diverse islands, leading to the emergence of distinct island cultures (Navarro, 1997). The easternmost islands are heavily eroded and more arid, whereas the western islands have greater orography and a humid climate due to contact with trade winds (Fernández-Palacios and Whittaker, 2008). This led to a different development of agricultural practices, which was more pronounced on central islands such as Gran Canaria (Morales et al., 2023). The most intriguing case is El Hierro, the smallest inhabited island in the archipelago (287 km^2) and the furthest from the African continent. It was first colonized between the 2nd and 4th centuries cal CE (Santana et al., 2024). The way of life of the *Bimpape* population is conditioned by the absence of metals and their reliance on volcanic stone materials, which affects the development of cereal cultivation, animal husbandry, or the gathering of plant and marine resources essential for their subsistence (Jiménez González and Jiménez Gómez, 2007; Morales et al., 2023). The archaeological record highlights food processing sites, such as shell middens, as well as the use of caves for habitation and burial purposes (Ordóñez et al., 2017, 2021; Trujillo-Mederos, 2018; Cockerill and Rodríguez Caraballo, 2022; Morales et al., 2023).

The site of La Lajura is a natural cave used for collective burial. Located in a volcanic area on the southern slope of the namesake volcanic cone 600 m above sea level, it is situated at the southern end of the island (Fig. 1). This cave has functioned as a funerary space for more than six centuries (6th–11th century cal CE) (Table 1). Within a volcanic lapilli matrix, this geological formation was highly unstable, potentially leading to the collapse of the cave roof during or after its period of use for funerary purposes (Velasco-Vázquez et al., 2005). This circumstance kept the site buried and inaccessible until road construction in the 1990s cut through part of the volcano's slope, revealing its existence. This discovery triggered an emergency archaeological excavation conducted between June 1998 and January 1999 (Fig. 2).

The archaeological fieldwork at Lajura identified four stratigraphic units corresponding to distinct phases of occupation:

Surface level: The first and most recent layer consisted of a sterile sedimentary deposit formed from the accumulation of livestock excrement. This suggests that after the *Bimbapes* abandoned its use as a funerary site, the cave was repurposed as a shelter for the animals. This extended reuse resulted in the complete coverage of anthropological remains by this sedimentary layer. Importantly, this layer also mitigated the impact of the subsequent collapse of the cave vault.

SU 1: This layer holds the last and most intense phase of funerary activity in the cave. Many of the human remains were found in anatomical positions with articulated labile persistent joints, suggesting primary inhumation. Furthermore, certain human remains exhibit displacement, likely caused by the repeated use of funerary space over

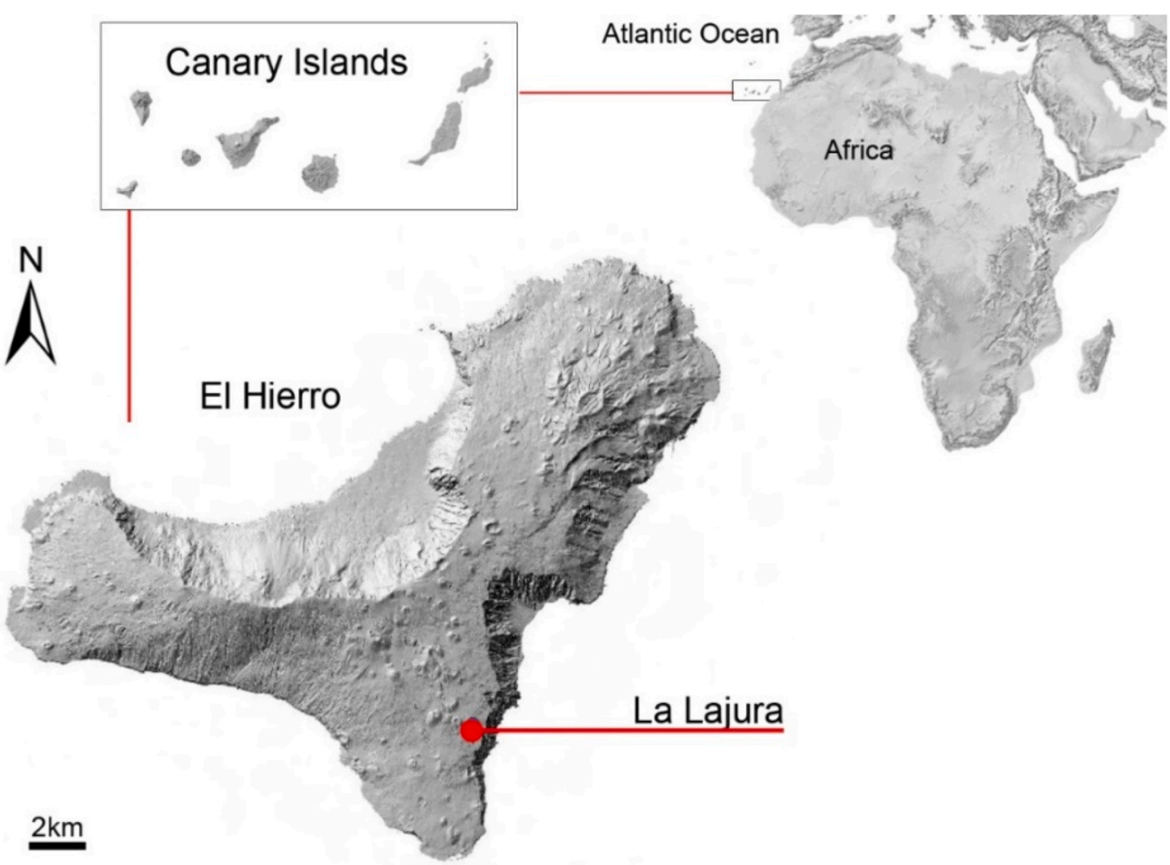

Fig. 1. Location of the island of El Hierro on the North African coast and the location of the site.

Table 1
Chronological data of La Lajura.

Lab. ID	Type material	Identification (common designation)	CRA	Error	Modelled (BCE/CE)					Reference
					median	68%		95%		
Boundary Start SU3					535	475	595	295	640	
Beta-261244	seed	*Hordeum vulgare* (barley)	1530	40	570	540	600	440	640	Morales et al. (2023)
Beta-261245	seed	*Visnea mocanera* (mocán)	1490	40	580	550	605	480	650	Morales et al. (2023)
Interval SU3					105	0	180	0	450	
Boundary End SU3					630	555	680	540	875	
Boundary Start SU2/ SU1					910	850	990	735	1020	
Beta-691438	insect	*Mezium americanum (*American spider beetle)	1010	30	1020	990	1035	980	1120	This study
Beta-128882	bone	*Homo sapiens* (Human)	1220	40	945	865	995	815	1025	Velasco et al., 2005
SUERC-98551	bone	*Homo sapiens* (Human)	1137	27	975	940	1020	890	1030	Santana et al. (2024)
SUERC-98552	bone	*Homo sapiens* (Human)	1108	27	990	960	1030	895	1040	Santana et al. (2024)
SUERC-98547	bone	*Homo sapiens* (Human)	1085	27	1005	985	1035	895	1055	Santana et al. (2024)
Beta-173704	bone	*Homo sapiens* (Human)	970	50	1040	990	1070	980	1145	Velasco et al., 2005

Lab. ID	**Type material**	**Identification (common designation)**	**CRA**	**Error**	**Modelled (BCE/CE)**					**Reference**
					median	from_68_3	to_68_3	from_95_4	to_95_4	
Interval SU2/SU1					165	45	255	0	405	
Boundary End SU2/SU1					1065	1010	1110	995	1210	
Difference phase SU3 to SU2/SU1					255	165	380	20	415	

time, influencing their condition. The primary deposition of bodies lacked a standardized pattern; the remaining materials were found in both the supine and flexed lateral positions. Primary deposits were distributed throughout the cave, whereas disturbed human remains were relocated to a secondary position at the southern end of the space. The site did not feature compartments, although the remains of wooden planks used to elevate bodies above the ground and separate them from the soil were documented.

SU 2: This layer stands for a phase characterised by the deposition of human corpses that were affected by a single episode of burning at the end of the depositional period. Fire-induced modifications of human remains indicate that burning occurred when the bodies were in an advanced stage of decay. This phase encompasses both primary and secondary depositions, showing prolonged and intense funerary activity over time.

SU 3: The deepest layer reveals evidence of five minor fires scattered throughout the cave, along with several marine shells. This level represents the earliest evidence of human activity in the cave, predating the onset of funerary practices. These hearths were interpreted by excavators as both ritual fires and prophylactic fires (Velasco-Vázquez et al., 2005). However, Bayesian analysis of the radiocarbon dates reveals a notable divergence between SU3 and SU2/SU1, spanning from 20 to 415 years with 95% probability. This disparity suggests that this early phase was likely distinct and separate from the subsequent phase associated with funerary activity (Table 1).

The presence of primary burials indicates that decomposition of some corpses occurred within the cave. The arrangement of bone fragments also suggests that decomposition occurred in an open-air area (Velasco-Vázquez et al., 2005). This scenario involves the disarticulation of anatomical joints both within and beyond the confines of the body, with bone elements displaced according to the slope of the deposition surface (Duday et al., 1990; Santana, 2020). Interestingly, this pattern of decomposition facilitates the access of animals and insects to the corpse during the decay process, resulting in diverse taphonomic processes affecting human remains (Dirkmaat and Cabo, 2016). In both open and enclosed spaces, insects play a pivotal role in the decomposition of corpses (Huchet, 2014) and are influenced by local biodiversity, climatic conditions, and methods of preparing corpses and funerary spaces. The archaeoentomological analysis of the Lajura funerary cave offers an opportunity to investigate the entomofauna involved in cadaveric decomposition at one of the westernmost points of the Palaearctic region.

This study represents an archaeoentomological analysis of a primary funerary context in the Canary Islands renowned for its ecological biodiversity (Fernández-Palacios and Whittaker, 2008). The primary objectives of this study are as follows: 1) to characterize the entomofauna associated with the decomposition of human remains; 2) to identify and interpret funerary practices through the study of entomological biodiversity and its ethological patterns; and 3) to analyse the historical distribution of species before the tricontinental trade among Europe, Africa, and the Americas on the westernmost edge of the Palearctic region.

2. Materials and methods

Nine litres of sediment, distributed across twenty-six samples from SU1, were processed to extract archaeoentomological remains. These samples were systematically collected around the skulls of at least twenty-four different individuals from the same stratigraphic unit. Information on the origin of each sample as well as the sample volume can be found in Supplementary Table 2. The sedimentary matrix of these samples consists of volcanic lapilli resulting from erosion of the cave walls and ceiling. Additionally, the matrix contains fine sediment deposited by aeolian activity and the degradation of organic matter.

The sediment samples were dry sieved through a series of mesh sizes (10, 5, 2, 1, 0.5, and 0.25 mm) to recover desiccated entomological remains. This method avoids potential damage that can occur with paraffin flotation in subsequent analyses (e.g., radiocarbon dating). Paraffin flotation would require the storage of entomological material under alcoholic conditions, which could compromise the AMS dating of the chitin (Panagiotakopulu et al., 2015). The sediments were then examined at the PACEA Laboratory (University of Bordeaux). Materials retained in meshes larger than 2 mm were analysed visually, while the finer meshes were scrutinized via a Nikon SMZ-2T binocular microscope at 8–80x magnification.

The taxonomic identification of the entomological remains was carried out by comparing them with the reference collection housed at the PACEA Laboratory. The distribution of species in the Canary Archipelago was determined by referencing the List of Wild Species of the Canary Islands (Arechavaleta et al., 2010). The minimum number of individuals (MNI) for entomological specimens was determined via three criteria: 1) counting the number of fly puparia, 2) identifying the

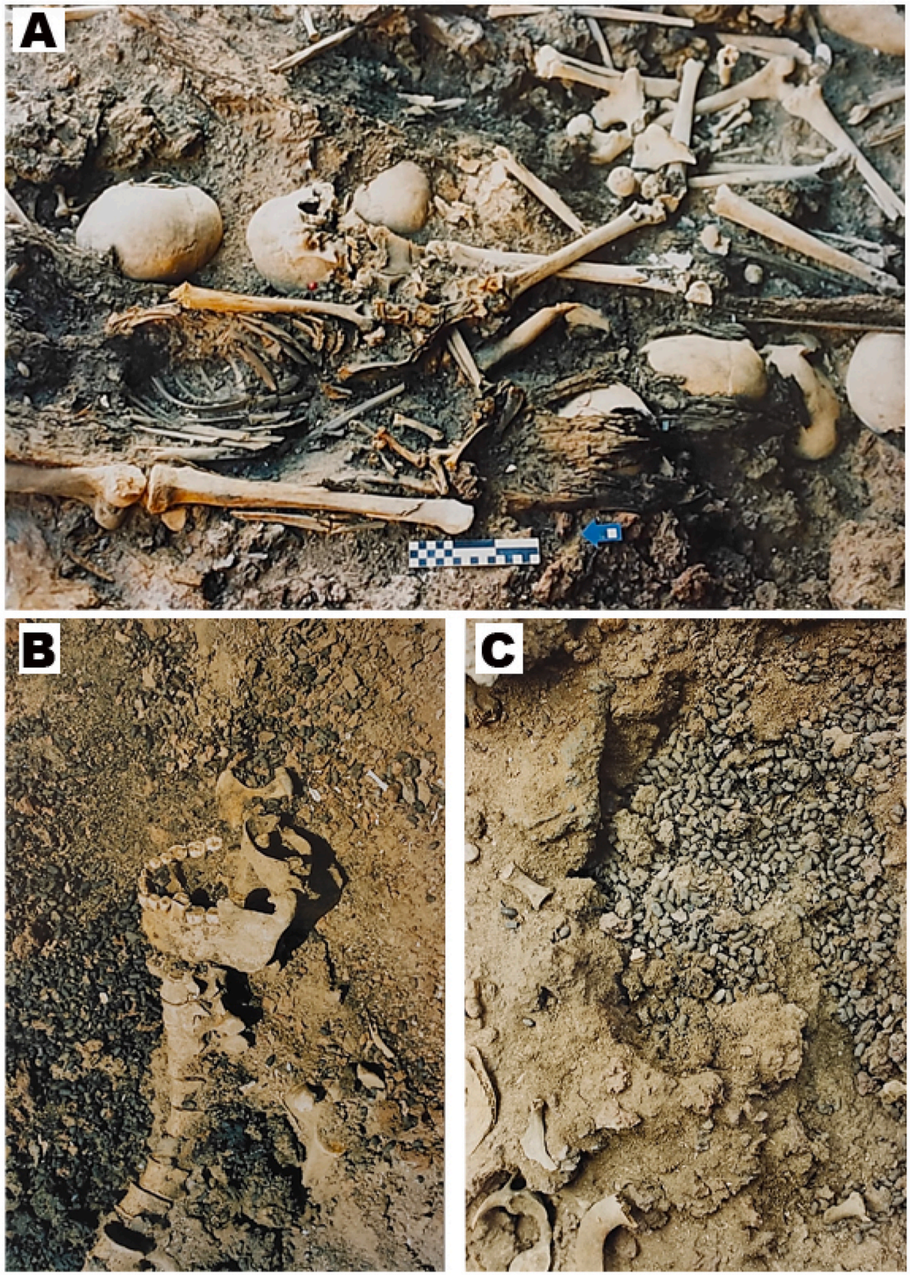

Fig. 2. Excavation process of the Necropolis of La Lajura. A) General view of the human remains; B) Detail of the mandible and spine next to the remains of cadaveric fauna; C) Detail of the puparium documented under the skeletal remains. Author: Sixto Sánchez.

most abundant anatomical unit of each taxon from adult samples found in each sediment sample, and 3) determining the lateralization of each anatomical unit if replicated in beetles (such as elytra or cerci). Additionally, the ubiquity index of each species was computed by dividing the number of samples in which the taxon was present by the total number of analysed samples (Huchet, 2014).

2.1. Radiocarbon dating and Bayesian analyses

This study considers eight AMS radiocarbon dates obtained from Beta Analytic Laboratory (Miami, USA) and SUERC (Glasgow University, United Kingdom) to establish the chronological framework of the site (Supplementary 1 and 2). These radiocarbon dates were subjected to Bayesian modelling to increase precision and credibility in estimating the onset, conclusion, and duration of the periods of human activity within the cave. The uncalibrated radiocarbon dates were analysed via a multiphase model (Bronk Ramsey, 2009). This model incorporates the radiocarbon dates into a continuous distribution under the assumption that all dated events have an equal probability of occurring at any point within the phase. We utilized the two-sigma probability interval (95.4%) to interpret the radiocarbon dates, with the inclusion of the one-sigma probability interval (68.2%) and medians in the tables and figures (Millard, 2014).

Two radiocarbon dates from charred seeds and one from an insect were calibrated via the IntCal20 atmospheric calibration curve (Reimer et al., 2020), whereas the five dates from human remains were calibrated via both Marine20 (Heaton et al., 2020) and terrestrial curves, as recommended by Santana et al. (2024). The analyses were conducted via OxCal online software version 4.4 (Bronk Ramsey, 2021).

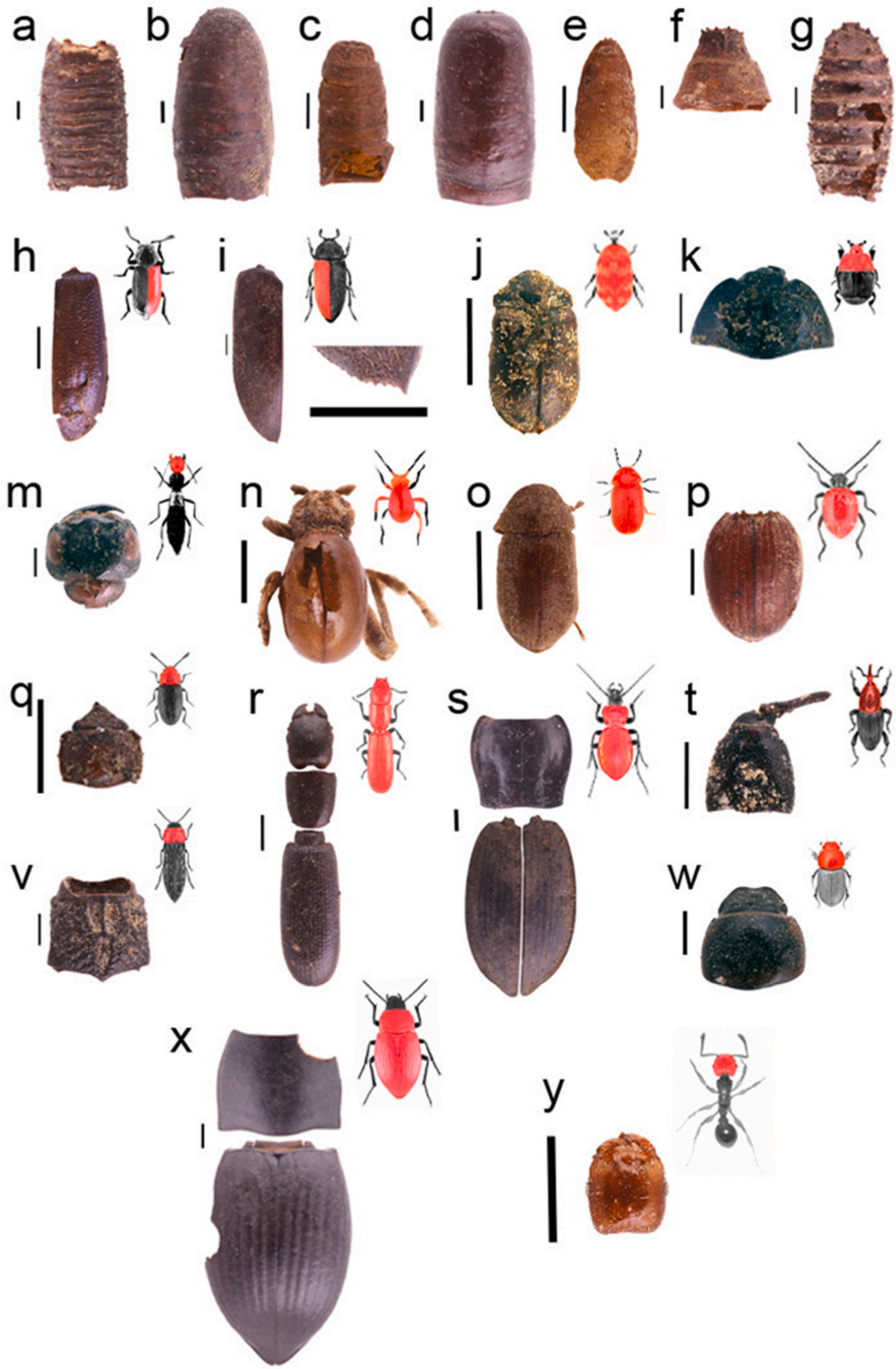

Fig. 3. *Entomological remains identified at La Lajura: a)* Chrysomia albiceps, *puparia; b)* Calliphora sp., *puparia, c)* Hydrotaea sp., puparia; *d)* Muscina sp.*, puparia; e)* Megaselia sp. *puparia; f)* Sarcophaga africa, puparia; *g)* Fannia sp.*, puparia, h)* Dermestes cf. frischii, *right elytra; i)* Dermestes maculatus, *left elytra and detail of distal segment of elytra; j)* Attagenus wollastoni*; k)* Saprinus, *head and pronota; m) Staphylinidae, head; n)* Mezium americanum*; o)* Stegobium paniceum*; p)* Casapus subcalvus, *pair of elytra; q)* Cryptophagus sp.*, head and pronota; r)* Leipaspis sp.*, head, pronota and abdomen; s) Carabidae, pronotum and elytra, t) Curculionidae, head and pronota, v)* Acmaeodera sp.*, pronota; w)* Aphodius sp.*, head and pronota; x)* Hegeter sp.; y) Tetramorium depressum, worker's head. *Scale bar:* 1 mm.

3. Results

A total of 5817 entomological remains were recovered (MNI = 4521). Taxonomically, these include two classes, seven orders, 19 families, and 31 different taxa (Supplementary 3; Fig. 3). Diptera appears as the predominant order in the Necropolis of La Lajura, identified primarily through puparia, constituting 60% of the identified specimens. Notably, only two of the samples analysed did not belong to this order. Coleoptera represented the second most abundant order (36%) and demonstrated significant taxonomic diversity. The insect remains consist of various anatomical segments (sclerites) of adult beetles, with some remaining immature stages also documented (e.g., *urogomphi* of the Dermestid larvae). While most samples in this order belong to carrion beetles, taxa from diverse ecological niches were also identified. This biodiversity enriches the archaeological record of the cave, offering valuable insights into its historical ecology. The remaining orders identified (4%) included moth cocoons (Lepidoptera: Tineidae), cerci of earwigs (Dermaptera), and pronota of field bugs (Heteroptera). Additionally, remains of the class Arachnida, identified as mites (Oribatida), were recovered. The taxonomic classification of each identified taxon can be found in Table 2, which summarizes the entomological remains identified.

Table 2
Summary of the entomological remains identified in La Lajura.

ID.	TOTAL	MNI	Ubiquity index
INSECTA			
DIPTERA			
Calliphoridae			
Calliphora sp.	458	458	0,58
Chrysomia albiceps (Wiedemann, 1819)	1596	1596	0,54
Muscidae			
Muscina sp.	187	187	0,46
Hydrotaea sp.	423	423	0,31
Phoridae			
Megaselia sp.	22	22	0,15
Sarcophagidae			
Sarcophaga africa (Wiedemann, 1824)	20	20	0,15
Fanniidae			
Fannia sp.	14	11	0,12
COLEOPTERA			
Cleridae			
Necrobia rufipes (De Geer, 1775)	516	188	0,88
Dermestidae			
Dermestes cf. *frischi* Kugelann, 1792	1	1	0,04
Dermestes maculatus De Geer, 1774	119	36	0,62
Attagenus wollastoni Mroczowsky, 1964	10	10	0,27
Histeridae			
Saprinus sp.	110	50	0,38
Staphylinidae			
Staphylinidae (s.l.)	17	10	0,27
Ptinidae			
Mezium americanum (Laporte de Castelnau, 1840)	1784	1163	1,00
Casapus subcalvus Wollaston, 1862	68	36	0,58
Stegobium paniceum (Linnaeus, 1758)	1	1	0,04
Cryptophagidae			
Cryptophagus sp.	1	1	0,04
Trogossitidae			
Leipaspis sp.	123	40	0,54
Carabidae			
Carabidae (s.l.)	28	13	0,27
Curculionidae			
Curculionidae (s.l.)	26	26	0,38
Buprestidae			
Acmaeodera sp.	6	6	0,08
Scarabaeidae			
Aphodius sp.	10	7	0,15
Tenebrionidae			
Hegeter sp.	38	16	0,35
Pimelia laevigata costipennis Wollaston, 1864	17	10	0,19
ID.	**TOTAL**	**MNI**	**Ubiquity index**
HYMENOPTERA			
Formicidae			
Lasius sp. (worker)	7	7	0,23
Tetramorium depressum Forel, 1892 (worker)	76	76	0,50
DERMAPTERA			
Dermaptera (s.l.), cerci	73	41	0,38
HETEROPTERA			
Heteroptera (s.l.)	9	9	0,08
LEPIDOPTERA			
Tineidae			
Tineidae (s.l.), coccoon	49	49	0,19
ARACHNIDA			
Acari, Oribatida	8	8	0,27
TOTAL	**5817**	**4521**	

4. Discussion

4.1. Insects of forensic interest

The archaeoentomological analysis of La Lajura revealed exceptional preservation of Diptera puparia, encompassing a diverse array of species observed at distinct stages of the decay process. This diversity aligns with archaeological findings indicating that primary burials were initially placed in an open space inside the cave and gradually skeletonized over time. However, taxon distributions are influenced by both the ecology and life cycles of each species (intrinsic conditions) and the climatic oscillations caused by seasonal changes (extrinsic conditions) (Hwang and Turner, 2005). In the context of Lajura, the environmental conditions of the cave likely influenced the timing of the decay process. Natural caves typically maintain constant temperature and humidity throughout the year, which can impact the presence and activity of insects.

4.1.1. Diptera (flies)

- Calliphoridae

Among the Diptera, the most prominent taxon is Calliphoridae, a family of insects that are among the earliest colonizers of corpses during the decay process. These insects typically lay their eggs on exposed cadavers within hours or even minutes after death (Sharma et al., 2015). In La Lajura, remains of *Chrysomya albiceps* were the most abundant taxon identified (n = 1596). This blowfly is attracted by the scent of decaying flesh, especially in warm conditions and urban environments (Grassberger et al., 2003). During its larval phase, *C. albiceps* acts as a voracious predator, often displacing other species of calliphorids from decomposing bodies (Faria et al., 2004; Szpila et al., 2008). Another taxon identified within this family belongs to the genus *Calliphora* Robineau-Desvoidy, 1830. Although the state of preservation did not allow for precise identification, the remaining species were attributed to one of the following two species: *C. vicina* or *C. vomitoria* (n = 458). The former is known to prefer urbanized areas, whereas the latter tends to favour more rural and shaded environments (Hwang and Turner, 2005; Gołębiowski et al., 2013). Like *C. albiceps*, both species are among the earliest flies to visit a corpse (Leclercq and Verstraeten, 1988). They are known for their ability to access bodies exposed on the surface or buried at shallow depths (Gunn and Bird, 2011), as well as their ability to adapt to cold and winter climates (Faucherre et al., 1999; Martín-Vega et al., 2017).

- Muscidae

The second most abundant family within this order is Muscidae, which is often prevalent in urban environments (Hwang and Turner, 2005). *Hydrotaea armipes/ignava* and *Muscina prolapsa/stabulans* were the taxa identified in La Lajura. These species are recognized for their active participation in the decay process (Grzywacz et al., 2017). The former were the most numerous, totaling 423 samples. This genus is typically found in warm environments (Marshall, 2012) and feeds on decaying organic matter along with other sapro-sarcophagous Diptera insects, particularly Calliphoridae and Sarcophagidae (Grzywacz et al., 2014). They can reach corpses both early in the decomposition process and during the ammoniacal fermentation stage, which typically occurs between 20 and 32 weeks after death, depending on the environmental conditions (Wyss and y Cherix, 2013). Puparia of *M. prolapsa/stabulans* were also recovered (n = 187). Typically, this species is found in livestock facilities, latrines, and landfills (Wang et al., 2019; Grzywacz et al., 2017). Smith (1986) argues that the forensic relevance of Muscidae is less pronounced than that of Calliphoridae representatives, as they typically arrive later, along with other species. This genus primarily pupates in the surrounding environment or under corpses during the initial stages of decomposition (Wang et al., 2019).

- Phoridae

The current analysis revealed a limited number of puparia belonging to this family (n = 22). Only the genus *Megaselia* was found in La Lajura. Species within this genus exhibit a wide range of ecological habits and can be observed at distinct stages of the decay process, beginning as early as the third week after death (Leclercq and Verstraeten, 1988). These insects are typically associated with decaying corpses during the winter season (Bugelli et al., 2015).

- Sarcophagidae

This family is represented by *Sarcophaga africa*, identified on the basis of the morphological characteristics of puparia (Wiedemann, 1824), and is among the less abundant families than other Diptera (n = 20). This species is found in both urban and rural environments (Fremdt and Amendt, 2014). They are known to colonize corpses shortly after death, feed on fresh tissue and oviposit in situ (Fu et al., 2016).

- Fanniidae

Few puparia of flies attributed to *Fannia* sp. were recovered (n = 14). These insects typically appear in the initial stages of cadaveric decomposition but are also present in more advanced stages in both urban and rural environments (Grzywacz et al., 2017). Larval development of this family typically occurs in decaying organic matter, although it is also attracted to nitrogen-rich animal manure, particularly from birds (Steve, 1959; Murillo et al., 2021).

4.1.2. Coleoptera (beetles)

- Cleridae

Necrobia rufipes (n = 516) is extensively represented among all the samples from La Lajura. This species is a cosmopolitan saprophagous insect associated with protein-rich food storage (Hasan et al., 2020). However, it is also present on corpses once fresh tissues have decomposed and the dry phase begins (Grassberger and Frank, 2004). Larval development involves decomposed matter, and adults feed on both dry tissues and the larvae and pupae of Diptera. The timing of *N. rufipes* arrival varies with climatic conditions, potentially occurring earlier in warmer periods (Hu et al., 2020), although it is seldom observed in funerary contexts (Gaudry, 2010).

- Dermestidae

Most of the remaining individuals (n = 37) in this family were identified as *Dermestes maculatus*. However, one elytron appears to belong to a specimen of *D. frischii*. Both larvae and adult insects of these species feed on the dry skin of corpses and the remains of other insects (Hoermann et al., 2011). They can directly modify bones, causing characteristic osteolytic lesions and borings (Huchet et al. 2013a,b,c; Huchet, 2014). Additionally, *Attagenus/Anthrenus* sp. (n = 10) were documented in the larval stage, during which they consume very dry remains of soft tissues. Interestingly, this species is quite common in mummified materials stored in museums (Vanin and Huchet, 2017).

- Histeridae and Staphylinidae

The entomological composition of La Lajura also includes remains of *Saprinus nobilis/proximus simillimus* (n = 110). These insects consume both desiccated skin and the larvae and puparia of Diptera (Szelecz et al., 2018). Additionally, the presence of Staphylinidae (n = 10), which are ecologically related to distinct stages of cadaveric decomposition, such as the bloating phase, was identified (Dekeirsschieter et al., 2013). Staphylinid beetles are also necrophilous species that prey on the larvae of flies and other beetles (Payne and King, 1970).

Overall, the ecological data from the cadaveric entomofauna documented at La Lajura strongly suggest that the decomposition process occurred within the cave, as the majority of documented insects are primary colonizers of corpses. Furthermore, the presence of specific species indicates that skeletonization occurred prior to the natural sedimentation that filled the funerary space. These findings notably align with the archaeological data gathered during the fieldwork, which was based on an archaeothanatological approach (Velasco-Vázquez et al., 2005). However, the identification of species typically associated with urban environments (e.g., Muscidae) also suggests that La Lajura was situated near anthropized areas used by the *Bimbape* population, if these species' behaviours have remained consistent over time.

4.2. Archaeoentomological insights into the ecological conditions within and around the cave

The archaeoentomological analysis of La Lajura revealed the presence of ecological groups of insects not exclusively linked with the decay process. Notably, *Mezium americanum* (Ptinidae) was prominently represented across all the examined samples (n = 1784). Previously documented in mummified remains of the indigenous population of Gran Canaria as an incidental finding (López-Dos Santos et al., 2021), its substantial presence in sedimentary samples alongside direct radiocarbon dating (Table 1) suggests an association with funerary practices at La Lajura. The dietary habits and temporal occurrence of this polyphagous species are complex because of its various food sources. As a storage pest, *M. americanum* typically consumes food waste and materials of both animal and plant origin (Hagstrum and Subramanyam, 2017). Interestingly, it has also been identified in the cave granaries utilized by the indigenous population of Gran Canaria (Henríquez-Valido et al., 2020).

Similarly, an additional representative of the Ptinidae family, *Casapus subcalvus* (n = 68), was also identified. The ecological habits of this genus remain poorly understood. However, specimens of this genus have been recovered from other archaeological contexts associated with food storage in the Canary Islands and are often found alongside *M. americanum* (Henríquez-Valido et al., 2020). Other storage pests, such as *Stegobium paniceum* (Ptinidae) (n = 1), were present in the cave. This species is recognized as a significant secondary pest of stored products, typically affecting processed cereals and legumes (Kučerová et al., 2005; Hagstrum and Subramanyam, 2017). In addition, the remains of *Cryptophagus* sp. (Cryptophagidae) (n = 1) could point in the same direction, although this fungivorous species is also documented in other contexts not related to stored products (Bouchard and Hébert, 2016).

The presence of *Leipaspis* sp. (Trogossitidae) (n = 40) further suggests the presence of natural organic materials undergoing decomposition within the cave. Larvae of this genus, which are endemic to Macaronesia, typically consume xylophagous insects inhabiting pine forests, fayal-brezal (*Morella faya* (Aiton) Wilbur and *Erica canariensis* Rivas-Mart et al.), and laurel forest formations (Hernández-Teixidor et al., 2020). These vegetation formations are currently situated in the central massif of the island, at elevations ranging from 400 to 900 m above sea level (Pérez de Paz et al., 1981), approximately 3–6 km from La Lajura.

The coprophagous guild is further represented by remains attributable to the Aphodiinae subfamily (Scarabaeidae) (n = 7). These insects are typically associated with livestock dung, where they play a crucial ecological role in its decomposition (Cárdenas-Castro and Páez-Martínez, 2017). Given that the superficial layer of the site served as a livestock pen, it is plausible that these insects were accidently introduced from above into SU1, where the sample originated. Other species, such as *Hegeter amaroides/tristis* (Tenebrionidae) (n = 16) and *Pimelia laevigata costipennis* (Tenebrionidae) (n = 10), are commonly found in caves, including those in the Canary Islands, often in association with bird droppings (Martín et al., 1987; Gnaspini and Trajano, 2000); however, other factors cannot be ruled out, so their presence in the archaeological record may be fortuitous.

The various other entomological taxa found within the cave cannot be definitively linked to its funerary use. These included specimens of Carabidae (n = 28), Curculionidae (n = 26), and Buprestidae (*Acmaeodera bipunctata plagiata/lugubris fracta*) (n = 6), which could be native entomofauna. These specimens may have appeared in the cave accidently and formed part of the biocenosis and subsequent taphocenosis at the site (Vanin and Huchet, 2017). In the same way, remains of Hymenoptera (Formicidae) belonging to the genus *Lasius* sp. (n = 7) as well as workers of the species *Tetramorium depressum* (n = 76) may have appeared in the archaeological record because of biocenosis/taphocenosis processes. Both species are granivorous, consuming small seeds (Xavier Espadaler, pers. comm. 2022). These remains are likely related to the presence of more recent seeds introduced alongside the upper layer of dung left from its subsequent use as a livestock pen. Similarly, the remains of Dermaptera, Lepidoptera, and Hemiptera present at the site cannot be linked with the cadaveric decomposition process or other materials deposited in the cave. Incidentally, remains of oribatid mites were documented, potentially introduced into the cave through aeolian processes involving sediment. However, their role as part of the necrofauna cannot be entirely discounted.

4.3. Forensic entomology on the edge of the Palearctic region before European colonization of the Americas

The archaeoentomological analysis of La Lajura has not only enabled the identification of the taxa associated with the human remains of the *bimbape* population but also provided insights into species of forensic interest at the westernmost point of the Palearctic region prior to the Columbian voyages. In this context, our discussion centers exclusively on necrophagous and necrophilous species, which offers valuable insights into the dispersal of cadaveric entomofauna over time.

Among the Diptera identified, the species *Calliphora vicina/vomitoria* and *Chrysomya albiceps* have also been documented in other archaeological contexts worldwide. The oldest puparia of *Calliphora* sp. (cf. *vicina*) associated with funerary spaces have been documented in the Roman catacombs of Rome, dating between the 1st and 3rd centuries CE (Huchet and Castex, 2022). Furthermore, this species has been identified in the Medieval cemetery of Kildimo, located at the westernmost extent of the Palearctic region, in Limerick, Ireland (Lynch and Reilly, 2011). These blowflies are recognized as primary colonizers of the decomposition of human remains in Europe (Niederegger et al., 2013). They are now well established throughout the American continent (Hildebrand et al., 2021). However, their absence in pre-Columbian archaeological contexts of the Americas implies that their distribution was limited to the Palearctic before the onset of European expansion across the Atlantic. Therefore, the results of the present study suggest that La Lajura represented the westernmost extent of this species before the 15th century CE.

With respect to *C. albiceps*, the earliest documented remains are from Egyptian contexts (e.g., Curry, 1979; Harrison, 1986; Huchet, 2010; Huchet et al. 2013a,b,c). In Europe, the species has been identified only in human samples derived from Egyptian materials housed in museums (e.g., Huchet, 2016). In addition to Egypt, *C. albiceps* has been recorded exclusively in the shrouds of mummies from Tenerife and Gran Canaria on the Canary Islands, which are stored in local museums (Fernández, 1960; López-dos Santos et al., 2021). This distribution pattern suggests that *C. albiceps* has been present across North Africa and Europe since at least medieval times (Szpila et al., 2008), extending to its westernmost point at La Lajura. Currently, *Chrysomya albiceps* is present in South America (Greenberg, 1988), where it competes with and displaces native calliphorids such as *Cochliomyia macellaria* (Fabricius, 1775)

(Reigada and Godoy, 2005; Pujol-Luz and Barros-Cordeiro, 2012). This species is capable of travelling considerable distances, drawn by the odors of decaying animal matter, particularly at warm temperatures, to lay its eggs (Carvalho-Queiroz, 1996; Omar, 1995; Szpila et al., 2008).

Similarly, the transport of animal skins, furs, and other foodstuffs has significantly facilitated the anthropic dispersal of highly specialized fauna, with numerous keratinophagous and/or necrophagous species achieving cosmopolitan distributions. This is particularly evident for the beetle *Necrobia rufipes* (Cleridae), a notorious pest of fish and stored animal products. Currently, cosmopolitanly, *N. rufipes* is sometimes utilized in forensic entomology to establish the post-Mortem interval (PMI) (Arnaldos et al., 2004; Gennard, 2007). This beetle has greatly benefited from human movements, enabling its spread worldwide. *N. rufipes* has been documented throughout the Mediterranean, from the catacombs of Rome (Huchet and Castex, 2022) to the Capuchin Catacombs of Palermo (Baumjohann and Benecke, 2019), and in Egyptian mummies (e.g., Huchet, 2016). In the Canary Islands, *N. rufipes* has been identified in mummies from Gran Canaria (López-dos Santos et al., 2021). Today, it is a globally distributed pest (Hasan et al., 2020), although it has not been documented at archaeological sites on the American continent. Consequently, La Lajura represents the westernmost point of the Palearctic region where this species was present prior to the 15th century.

In addition to these findings, the distributions of Dermestidae species in other archaeological contexts are noteworthy. *Dermestes frischii* has been identified exclusively in Egyptian mummies (e.g., Panagiotakopulu, 2003), whereas *D. maculatus* has been recovered not only from Egyptian contexts but also from mummies in Gran Canaria (López-Dos Santos 2022), as well as pre-Columbian sites in Mexico and Peru (Centeno et al., 2009; Huchet et al. 2013a,b,c; Giordani et al., 2020). While the Egyptian and Canarian remains come from relocated mummies housed in museums, the specimens from La Lajura unequivocally situate the species in the Old World prior to European contact with the Americas. Therefore, the presence of *D. maculatus* at sites predating European colonization of the American continent is striking, implying that the species may have been introduced through other human or animal population movements. The lack of direct radiocarbon dating of these entomological species limits our ability to pinpoint the exact timing of their arrival in America. Nevertheless, the evidence from La Lajura suggests that *D. maculatus* was widespread in the Old World prior to the Columbian voyages. This challenges traditional biogeographical narratives, proposing a more intricate scenario of faunal exchange that may involve earlier human migrations or natural dispersal routes that are not yet fully understood (Michaud et al., 2010; Lutz et al., 2019).

5. Conclusion

The archaeoentomological analyses of La Lajura provide direct insights into the funerary practices associated with this collective burial cave. Although this analysis was limited to a 9-L sample of sediment recovered during the archaeological excavation, the assemblage of insect remains is notable for its abundance and preservation, attributed to the site's environmental conditions. Previous research has demonstrated the effectiveness of the volcanic substrate in the Canary Islands for preserving insect remains within caves (Henríquez Valido et al., 2019). However, those studies focused primarily on cave granaries where insects are linked to the storage of cereals, fruits, and other foodstuffs. The findings of the present study suggest that insect remains from funerary contexts are exceptionally well preserved in volcanic caves.

This study shows that the decomposition of some corpses occurred inside the cave. The presence of puparia remains of Diptera is indicative of the initial stages of decomposition, whereas the remains of beetles (*N. rufipes, D. maculatus, D. frischii*, and *S. nobilis/proximus*) are related to the later phases of the putrefaction process. These findings are consistent with the archaeothanatological analysis of the archaeological assemblage, which interpreted the evidence as indicative of a collective funerary practice involving the primary deposition of corpses that decayed inside the cave over time (Velasco-Vázquez et al., 2005). This interpretation is further supported by the extensive colonization by pioneer flies and insects associated with the later stages of decomposition.

The presence of other beetle species suggests the possible inclusion of plant remains as grave goods or offerings during the funerary use of the cave. The archaeological deposit at La Lajura included wooden planks on which the corpses were laid in a primary position. These planks were associated with *Leipaspis* sp. and xylophagous species such as *Acmaeodera plagiata/rubromaculata*, Carabidae, and Curculionidae. Interestingly, insect remains associated with storage pests, including *S. paniceum*, *Cryptophagus* sp., and *Mezium americanum*, were also found. These species have previously been documented in food storage cave facilities on the island of Gran Canaria (Henríquez et al., 2020). However, there is no evidence of such features in La Lajura Cave. Therefore, the presence of these insects might indicate the inclusion of plant grave goods in caves as part of the funerary practice.

This study enhances our understanding of the taphonomic processes at work from the deposition of corpses to sedimentation within the funerary cave site of La Lajura Necropolis. This study elucidates both anthropogenic and natural factors that contribute to the degradation of materials in caves. These insights are significant not only for a deeper comprehension of the La Lajura site but also for other funerary caves in the Canary Islands. Finally, this analysis reveals the diversity of insects involved in organic decomposition at the westernmost edge of the Palearctic region before European expansion across the Atlantic Ocean. Notably, *Dermestes maculatus*, a species documented on both sides of the Atlantic Ocean prior to European colonization, was present.

CRediT authorship contribution statement

Pedro Henríquez-Valido: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jonathan Santana:** Writing – review & editing, Resources, Project administration, Funding acquisition, Data curation, Conceptualization. **Aarón Morquecho-Izquier:** Writing – review & editing, Methodology, Data curation. **Amelia Rodríguez-Rodríguez:** Writing – review & editing, Visualization, Supervision, Resources, Funding acquisition, Conceptualization. **Jean-Bernard Huchet:** Writing – review & editing, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jas.2024.106120.

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