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ANTHROPOLOGY

The Châtelperronian Neanderthals of Cova Foradada (Calafell, Spain) used imperial eagle phalanges for symbolic purposes

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Evidence for the symbolic behavior of Neanderthals in the use of personal ornaments is relatively scarce. Among the few ornaments documented, eagle talons, which were presumably used as pendants, are the most frequently recorded. This phenomenon appears concentrated in a specific area of southern Europe during a span of 80 thousand years. Here, we present the analysis of one eagle pedal phalange recovered from the Châtelperronian layer of Foradada Cave (Spain). Our research broadens the known geographical and temporal range of this symbolic behavior, providing the first documentation of its use among the Iberian populations, as well as of its oldest use in the peninsula. The recurrent appearance of large raptor talons throughout the Middle Paleolithic time frame, including their presence among the last Neanderthal populations, raises the question of the survival of some cultural elements of the Middle Paleolithic into the transitional Middle to Upper Paleolithic assemblages and beyond.

INTRODUCTION

Archeological personal ornaments such as beads and pendants have traditionally been recognized as direct evidence of symbolic behavior. Their confection and use have been further related to the emergence of "behavioral modernity" (*1*). Through analogies with recent societies, specialists interpret Paleolithic personal ornaments as encoding elements of nonverbal communications, most often carrying messages about the social identity of the bearer (*2*). This current paradigm indicates a long-lasting and widespread bead working tradition of marine shells, having emerged in Africa and the Levant among anatomically modern humans (AMHs) well before their arrival in Europe [100 to 75 thousand years (ka)] (*3*). Presumably in later times (50 to 37 ka), this expression appears among western European Neanderthals independently or by a process of acculturation, being particularly relevant for Châtelperronian (CP) assemblages found in archeological layers from Le Grotte du Renne (Arcy-sur-Cure) and La Grande Roche de la Plématrie (Quinçay) (*4*). From this point of view, recent investigations in Cueva de los Aviones (Spain) have proposed the use of marine shells by Iberian Neanderthals as beads and pigment containers as early as 115 ka, predating any expression of symbolism by AMH in Eurasia (*5*). These findings, together with new dates for some rock art motives in three Spanish caves anteceding the arrival of *Homo sapiens* in Europe (*6*), have generated a heated debate regarding the origin of symbolic behavior, cultural modernity, and the appearance of art in Europe.

Focusing on Neanderthal technocultural traditions, associated with the Middle Paleolithic (MP), Late MP (LMP), and transitional technocomplexes, other more controversial evidence of symbolism such as abstract engravings, body painting, use of feathers, funerary practices, and grave goods have been historically claimed as evidence for Neanderthal symbolic complexity (*1*, *7*). The debate, however, does not stop at this. On the one hand, alternative explanations to this evidence of advanced symbolic thinking such as intervention of natural processes, purely functional character of symbolic items (e.g., pigments/ochre), stratigraphic mixtures, and even the lack of Neanderthal innate cognitive capacities have been proposed. On the other hand, the authorship of some of the European transitional industries, such as those of CP and Uluzzian, in which some of the most notable manifestations of modern behavior are inserted, is still a subject of debate (*8*). In the case of the CP, most of the studies show a clear cultural continuity of this transitional complex with the MP. Moreover, the CP is found with diagnostic fossils or biological traits typical of Neanderthals rather than those of modern humans (*4*, *9*, *10*). Notwithstanding, this statement is far from being universally accepted among researchers (*11*, *12*).

Assuming that Neanderthals were responsible for the CP, the use of raptor talons as bead-like objects seems to be one of the most widespread evidence of symbolism among the MP and CP populations in Europe. At least 23 large raptor phalanges from 10 sites, dated between ~130 and 42 ka, present traces of anthropic manipulation in the form of cut marks (Table 1). The main arguments supporting the symbolic nature of these elements are (i) the anatomical distribution of cut marks, related with non-alimentary handling of animal resources, as contrasted through actualistic experiments; (ii) the scarcity or complete lack of nutritional value of a bird's lower extremities; (iii) the rarity of large raptors in certain ecosystems (namely, their selective hunting/gathering); (iv) the established analogy with other cut-marked phalanges and talons from late Prehistoric contexts; and (v) their comparison with the ethnographic register (*13*–*24*). The lack of formal criticism of these interpretations indicates the plausibility of hypotheses regarding the anthropic modification of large raptor's pedal phalanges by Neanderthals as their use for

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Table 1. Sites and layers with cut-marked raptor phalanges interpreted as symbolic elements associated with Neanderthals or transitional MP/UP populations. CP, Châtelperronian; CM, Classic Mousterian; L, Levallois; M, Mousterian; MTA, Mousterian of Acheulean Tradition; N, Neronian; N/A, not applicable/unknown.

Site	Layer	Age (ka)	Cultural attribution	Taxa CM	Common name	CM NISP	Bird NISP	Raptor NISP	Reference
Baume de Gigny*	XV	50	MP	*Cygnus cygnus*	Whooper swan	1	N/A	N/A	(*13*, *14*)
Combe Grenal	52	90	MP-CM	*Aquila chrysaetos*	Golden eagle	1	7	1	(*13*)
Fumane	A12	MIS3	MP-L	*Aquila chrysaetos*	Golden eagle	1	N/A	1	(*15*, *16*)
Fumane*	A9	38–42	MP-D	*Tetrao tetrix*	Black grouse	1	N/A	N/A	(*17*)
Grotte de L'Hyene	N/A	MIS3	MP	*Aquila chrysaetos*	Golden eagle	1	N/A	N/A	(*13*, *16*)
Grotte du Renne	IX-X	44–42	CP	*Haliaetus albicilla*	White-tailed eagle	1	N/A	N/A	(*18*)
Grotte du Renne	IX-X	44–42	CP	*Bubo bubo*	European eagle-owl	1	N/A	N/A	(*18*)
Krapina	N/A	100–130	MP-M	*Haliaetus albicilla*	White-tailed eagle	5	29	12	(*19*)
Les Fieux	I/J	60–40	MP-DM	*Haliaetus albicilla*	White-tailed eagle	1	81	3	(*13*, *20*)
Les Fieux	Jbase	60–40	MP-MTA	*Haliaetus albicilla*	White-tailed eagle	1	42	4	(*13*, *20*)
Les Fieux	Ks	MIS3	MP-MTA	*Haliaetus albicilla*	White-tailed eagle	2	97	8	(*13*, *20*)
Les Fieux	Ks	MIS3	MP-MTA	*Aegypius monachus*	Cinereous vulture	1	97	8	(*13*, *20*)
Les Fieux	Rec. clean	MIS3	MP-MTA	*Haliaetus albicilla*	White-tailed eagle	2	>2	2	(*13*, *20*)
Mandrin	E	52–56	MP-N	*Aquila chrysaetos*	Golden eagle	1	11	1	(*15*)
Pech de l'Azé I	4	44–48	MP-MTA	*Aquila chrysaetos*	Golden eagle	2	92	5	(*14*, *21*)
Pech de l'Azé IV	8	100	MP-M	*Medium-sized raptor*	N/A	1	1	1	(*22*)
Rio Secco	7	48–49	MP-M	*Aquila chrysaetos*	Golden eagle	1	15	1	(*15*)
Cova Foradada	IV1	>39	CP	*Aquila* [*heliaca*] *adalberti*	(Iberian?) Imperial eagle	1	41	12	This work, (*23*)

*The cases of Baume de Gigny and Fumane A9 correspond to other birds than raptors.

personal ornaments. Considering the large geographical distribution and temporal context of Neanderthals across Eurasia, this phenomenon seems to be concentrated in a very specific area of southern Europe (Fig. 1). Nevertheless, the relative novelty of these discoveries demands further investigation. Here, we present a new case of large raptor pedal phalanges associated with a CP context, thus expanding the geographical and chronological limits of this kind of evidence and providing new insights into the symbolic practices in pre–Upper Paleolithic (UP) European populations.

RESULTS

Site stratigraphy, chronology, and archeological record

Cova Foradada [Calafell, Catalonia, Spain; UTM (ETRS89) 381027.6–4562447.9] is a small karstic tunnel, 1.8 km far from the actual shoreline of the Mediterranean coastline of northeast Spain (Fig. 1 and fig. S1) (*23*). The morphology of the cave is defined by a circular entrance, yielding direct access to the "excavation hall" of ca. 14 m^2. Stratigraphically, the excavated area consists of a 2.5-m section presenting four major lithostratigraphic units and 10 archeopaleontological layers, 8 with evidence of human occupation/use of the cave from the mid-Holocene to the Upper Pleistocene (Supplementary Materials) (*23*). Units I and II correspond to the Holocene epoch. The middle part of the sequence corresponds to the lithostratigraphic Unit III, formed by three different archeological layers. Layer IIIn has been associated with the Early Gravettian, followed by the almost sterile layer IIIg and layer IIIc, each corresponding to the Early Aurignacian. The basal part of the stratigraphic column corresponds to Unit IV, with layers IV, IV1, and IV2 being associated with the CP occupation. Found underneath these layers is an almost archeologically sterile unit (Unit V). Unit V has been further documented to be in contact with a thick basal flowstone (fig. S2).

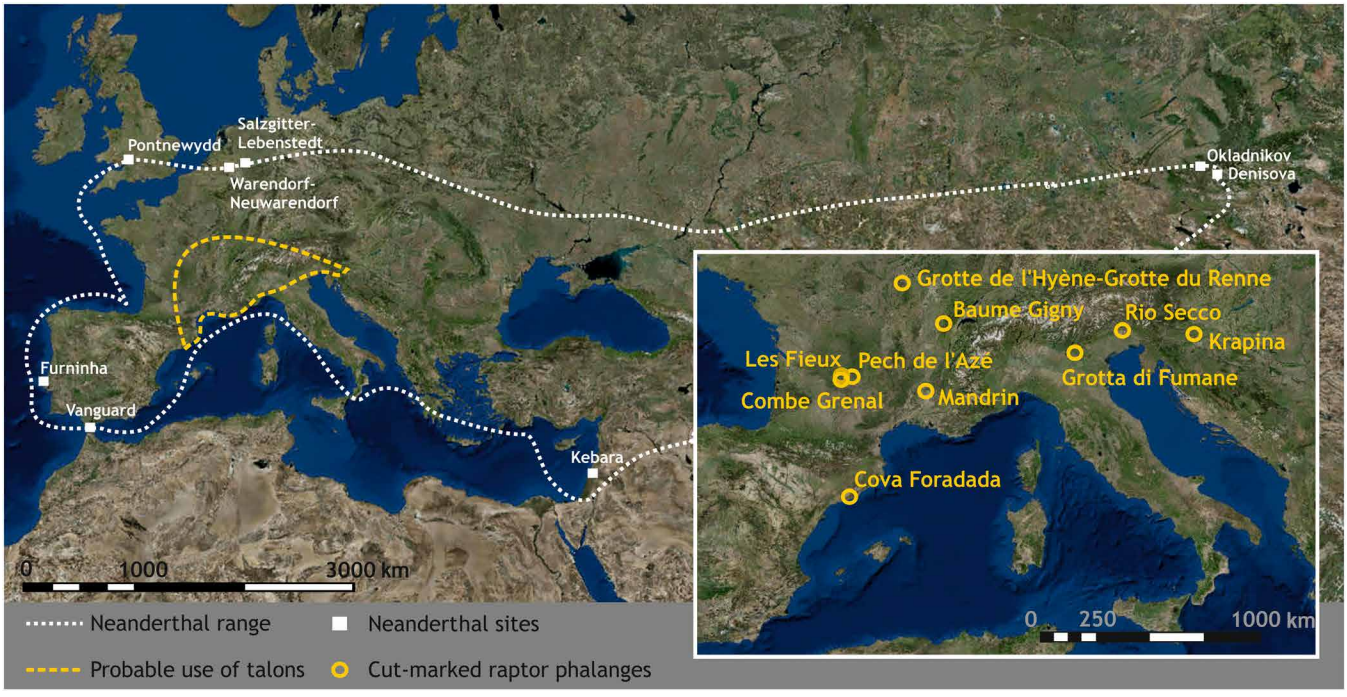

Fig. 1. Pre-UP symbolic use of raptor talons. Geographical range of Neanderthal populations and sites with raptor cut-marked phalanges. The line of white dots roughly marks the probable range of Neanderthals in Eurasia, based on paleogenetic data and fossil remains. The yellow dotted line suggests the common cultural territory for the use of raptor talons before the arrival of the UP. The extended map indicates the location of all MP/CP sites, with raptor phalanges interpreted as symbolic elements, including Cova Foradada. Baume Gigny is included for the sake of clarity.

Archeological patterns shared by layers IIIn and IIIc and Unit IV suggest that the cave was only occasionally occupied by human groups, leaving a very scarce archeological record, formed mainly by shell ornaments in layer IIIn and hunting-related tools in both layers IIIc and IV. Fortunately, the lithic remains recovered from layers IIIc and IV are typologically diagnostic and, aside from the chronological context, are useful indicators attributing these occupations to their associated cultural technocomplexes (*23*).

Layer IV provided a small lithic assemblage highlighting the almost exclusive presence of CP points (fig. S1B). This represents the southernmost expression of this particular tool class in Europe, exclusively related with the CP culture and supposedly associated with the Neanderthals (*4*, *10*).

The faunal assemblage of Unit IV is composed of 1289 remains [number of species (NSP)]; 1076 [number of identified species (NISP)] dominated by leporids (63.8% NISP), small bird remains (16.5% NISP), and Iberian lynx (9.4% NISP) (table S1). Twelve elements correspond to medium- and large-sized raptors, namely, that of the Iberian or Spanish imperial eagle (*Aquila adalberti*) (Table 2). Bone surface modification (BSM) analysis indicates scarce anthropogenic intervention, except for 31 burned bones (2.4% of NSP), 19 long bone shaft cylinders of leporids (11% of the total humerus, femur, and tibia NISP), and one fragment of a leporid tibia showing cut marks (fig. S4). The interpretation of the occupational dynamic in Unit IV suggests a very sporadic use of the cave by human groups, probably related to its use as a hunting shelter where they could rest, repair, and fine-tune certain hunting tools (*23*). Moreover, layer IV1 presents the remains of an imperial eagle with a cut-marked phalange. This find is horizontally and vertically associated with typical elements of the CP culture. Radiocarbon evidence currently places the occupations of Unit IV >39 ^{14}C ka cal B.P. (calibrated years before the present) (fig. S3) (*23*).

The FO15/IV1/E6/1339 specimen

The FO15/IV1/E6/1339 specimen (Fig. 2, STL S1, and movie S1) corresponds to the phalanx 1 of the first digit (the thumb or *Hallux*) from the left foot of a large eagle. The general morphology of the phalanx is stylized and svelte, as in the genus *Aquila*, thus different from the more robust morphology of *Aegypiinae* (subfamily of vultures) and *Haliaeetus* (genus including white-tailed eagle). The palmar surface of the body is deeper than in vultures, presenting a well-marked attachment to fibrous sheaths of flexor tendons. The distal trochlea and the groove between them are well pronounced as in the genus *Aquila*. Studies regarding general morphology, dimensions, principal components analysis (PCA) results, as well as the distribution of past, extant, and Pleistocene large eagles in the Mediterranean Basin (*25*) all concur that *A. adalberti*, the Iberian imperial eagle, or an earlier ancestor, is the most plausible taxonomic match for the case of Foradada (Fig. 3).

Nevertheless, the origin and evolution of this species are controversial. *A. adalberti* and *Aquila heliaca* (Eastern imperial eagle) are currently considered to be not only separate species but also subspecies, allospecies, or semispecies. On the basis of molecular data, some authors date the divergence between these two raptors to at least ca. 1 million years (Ma), while other authors propose the split to have occurred in the Holocene or terminal Pleistocene (<13 ka B.P.) (*26*, *27*). Moreover, there seems to have been male-mediated gene flow after the divergence, complicating the scenario (*26*). Solving this problem is far from the objectives of this paper, although the Foradada specimens can contribute to our knowledge of the evolutionary

Table 2. Raptor remains from Unit IV of Cova Foradada. ID, unique identification number of each specimen; BSM, bone surface modifications; CM, cut marks; Dg, diagenetic breakage.

ID	Layer	Element	Side	Taxon	Common name	BSM
FO14/IV/ F8/2848 + 3453	IV	Tarsometatarsus	R	*Aquila* [*heliaca*] *adalberti*	(Iberian?) Imperial eagle	Broken-Dg
FO15/IV/G8/C1	IV	Phalange 2 toe II	L	*Aquila* [*heliaca*] *adalberti*	(Iberian?) Imperial eagle	–
FO14/IV/F9/1971	IV	Talon	–	Accipitridae sp.	–	–
FO14/IV/ F6/306 + 307	IV	Tibiotarsus	R	*Aquila* [*heliaca*] *adalberti*	(Iberian?) Imperial eagle	Broken-Dg
FO15/IV/D7/C1	IV	Humerus	L	Accipitridae cf. *Milvus milvus*	cf. Red kite	Broken-Dg
FO14/IV/D8/1018	IV	Phalange 2 toe III	R	*Gyps fulvus*	Griffon vulture	–
FO15/IV/E6/C1	IV	Phalange	–	Accipitridae cf. *Accipiter* sp.	–	–
FO14/IV1/F8/2864	IV1	Phalange 2 toe III	R	*Aquila* [*heliaca*] *adalberti*	(Iberian?) Imperial eagle	–
FO14/IV1/F8/2862	IV1	Phalange 2 toe III	L	*Aquila* [*heliaca*] *adalberti*	(Iberian?) Imperial eagle	–
FO14/IV1/F8/3129	IV1	Phalange 1 toe I	–	Accipitridae cf. *Aquila* sp.	–	Broken-indet.
FO15/IV1/E6/1339	IV1	Phalange 1 toe I	L	*Aquila* [*heliaca*] *adalberti*	(Iberian?) Imperial eagle	CM
FO15/IV2/D7/C1	IV2	Ulna	R	Accipitridae cf. *Milvus milvus*	cf. Red kite	Broken-indet.

history of imperial eagles. If the specimens presented in this paper belong to *A. adalberti* or their ancestor, then they would be the oldest recorded find of the species so far. If these remains belong to the species *A. heliaca*, then it would be the first occurrence of this species in the fossil record of Iberia (for the whole of the Quaternary, Pleistocene, or Holocene periods). Nonetheless, at this current point in time, this problem cannot be resolved for this case; therefore, the Foradada specimen will be referred to throughout the rest of this study following González's use of semispecies classification (*27*), expressed in brackets and trinomially as *A.* [*heliaca*] *adalberti* and as imperial eagle sensu *lato* when we refer to the vernacular name.

The phalange presents 12 cut marks on the dorsal side of the diaphysis, appearing along approximately two-thirds of the phalanx's total length (Fig. 2 and Supplementary Materials). Most of the cuts (n = 11) are oriented obliquely to the principal axis of the bone, ranging from the proximal epiphysis to distal extremity of the bone. These striae are found oriented parallel among themselves. All these oblique cuts are deep and present both composed striae and associated shoulder effect as deep as the principal groove like those produced by retouched stone tools (*28*). An additional incision can be observed, presented obliquely oriented with a longitudinal tendency. This last mark is more superficial than the previous marks and superimposes all other incisions. The 12 incisions observed present an average length of 3.67 mm and width of 0.23 mm. As can be seen in table S2, a general increase in the opening angle of each groove can be observed, while a similar pattern is observed through a decrease in depth of each profile along the groove. This variation, however, is relatively subtle and gradual, most likely explained by the physical properties and pressure exerted when making an incision (*29*). The homogeneity of the groove's shape, however, is clearly represented by the cross-section morphology and its development along the course of the incision. Procrustes analysis indicates that all these marks present an asymmetrical \/-shaped cross section (Fig. 4A and STL S2). This feature is one of the key characteristics described by multiple authors when diagnosing a taphonomic trace as a cut mark (*28*). Considering only the profile shape, these taphonomic traces are clearly comparable with cut mark samples studied by a great deal of taphonomists [e.g., (*30*)], as opposed to the morphology of other linear traces such as tooth scores (*31*).

Three-dimensional (3D) analysis (Fig. 4B and Supplementary Materials) indicates that the depth and shape of the linear marks are clearly more pronounced than what would be expected of a trampling mark. Combined with a clear lack of a rounded base, as well as other features, this also rules out the possibility that these marks can be confused as a product of other natural agents, carnivores, humans, or even herbivores (*32*). While these marks are associated with some other taphonomic alterations such as biochemical BSM, they do not prevent the morphological study of these traces to a degree where equifinality is overly present (*33*). Mark location and depth all agree with experimental works presented by Romandini *et al.* (*15*), associating these striae with the disarticulation of the claw and the entire digit from the tarsometatarsus. Other than FO15/IV1/E6/1339, no other specimen of eagle or raptor remains shows anthropic modifications. It should be noted, however, that all the remains of *A.* [*heliaca*] *adalberti* are from appendicular elements, of which only one talon has been recovered. This unusual skeletal element representation can be further considered important when comparing with the case of other abundant small bird remains in this site (tables S1 and S3 and fig. S5) (Supplementary Materials).

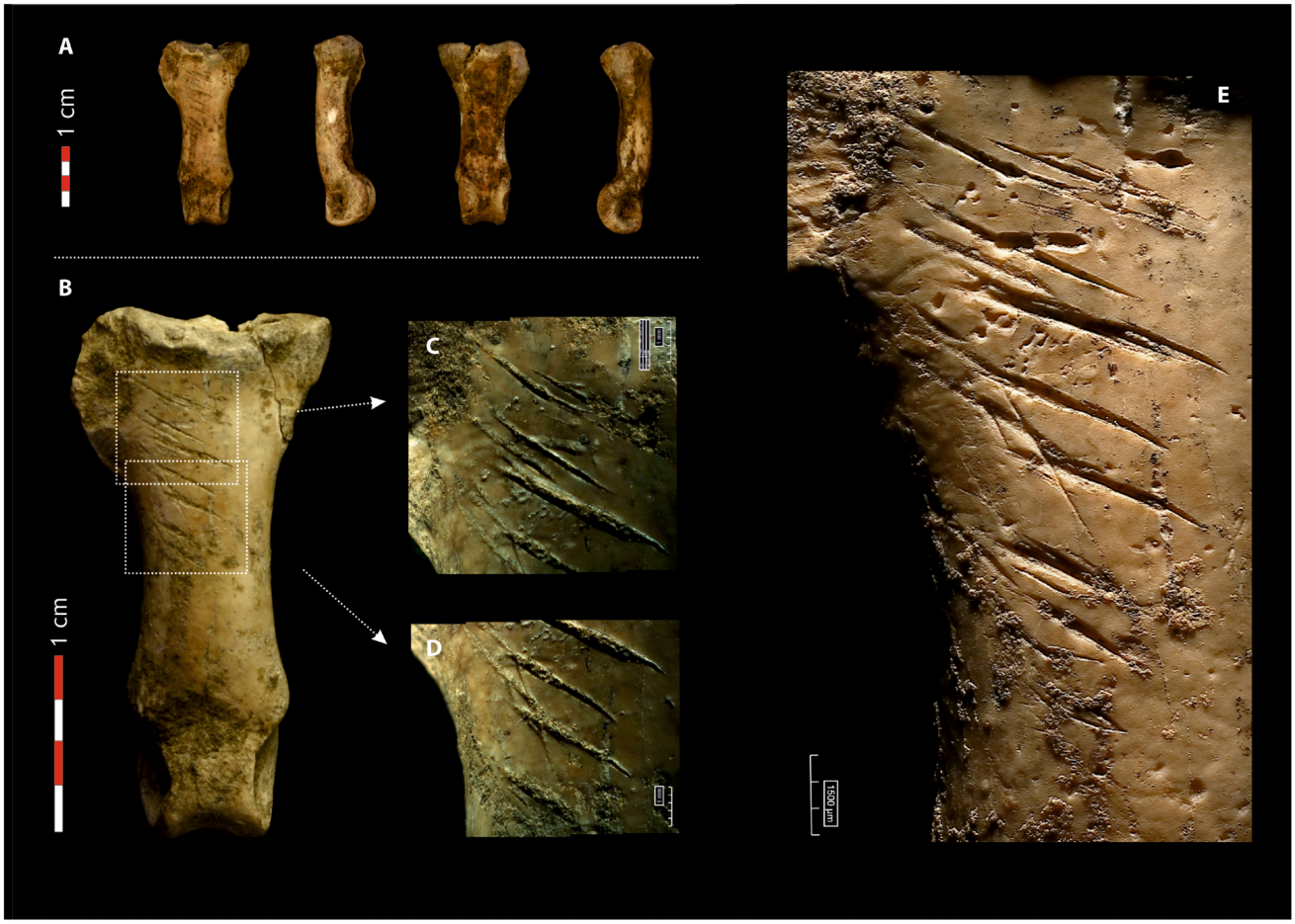

Fig. 2. FO15/IV1/E6/1339 specimen. (**A**) Dorsal, medial, plantar, and lateral views of the phalange (from left to right, respectively). (**B**) Detail of the cut marks in the dorsal view and dotted-line squares with the area amplified in photos (**C**) and (**D**). (**E**) Detailed photo of all the cut marks after cleaning and restoration. Photo credit: Antonio Rodríguez-Hidalgo, IDEA.

DISCUSSION

The exploitation of birds as an alimentary and non-alimentary resource has been proven through several zooarcheological investigations, suggesting that the trapping of birds formed a part of the behavioral variability of Neanderthal populations (*7*, *34*, *35*). While not being a frequent practice, the consumption of raptors among hunter-gatherers has further been confirmed through ethnographic data (*36*) and supported by the archeological record, including other Neanderthal sites (*37*, *38*). Non-nutritional use of bird bones in Neanderthal sites is almost exclusively related to symbolic purposes (*7*), while their use as a raw material for creating domestic tools is extremely scarce (Supplementary Materials) (*39*).

In the case of talons, their non-nutritional value has been exhibited to support the claim of their symbolic use by Neanderthals, as opposed to their association with alimentary purposes (*13*, *15*). Nevertheless, while the obvious consumption of talons can be considered a poor idea, according to current Spanish, Latin-American, and oriental recipes, the edibility of the raptor's feet may just be a question of cooking and taste to appreciate the skin and cartilaginous tissues present on these bones. Needless to say, cut marks are only indicators of anthropogenic manipulation. Their presence may simply indicate the butcher's removal of non-inedible areas.

The present study demonstrates how a combination of traditional and newly developed methodological approaches in cut mark analysis can be a powerful tool when classifying BSMs. Our results lean strongly toward the classification of the marks on FO15/IV1/E6/1339 as cut marks. Their presence is a fundamental and unique find when constructing the hypothesis and reasoning behind the manipulation of these elements by ancient humans. For this reason, the combination of old and new methods and tools for BSM analysis is essential when the presence of cut marks may lead to relevant evolutionary hypotheses. Furthermore, we strongly agree with the interpretation of these cut marks as a product of talon extraction, or claw sheath removal, independent of the phalanx in which the traces are present (*13*–*24*). This observation is especially supported by neo-taphonomical experimentation, thus aiding in the construction of our interpretation (*15*). The additional arguments leading us to discard the alimentary nature of these remains are (i) the scarcity of raptor remains in the Foradada assemblage, namely, the selection of the species for anthropogenic handling; (ii) the high anatomical bias in favor of phalanges, thus presenting a selection of anatomical parts; and (iii) the absence of other BSMs related to anthropogenic consumption. This includes human chewing, green breakage, burning, and any traces of cooking BSMs on raptor bones or any other element in most of the faunal assemblage.

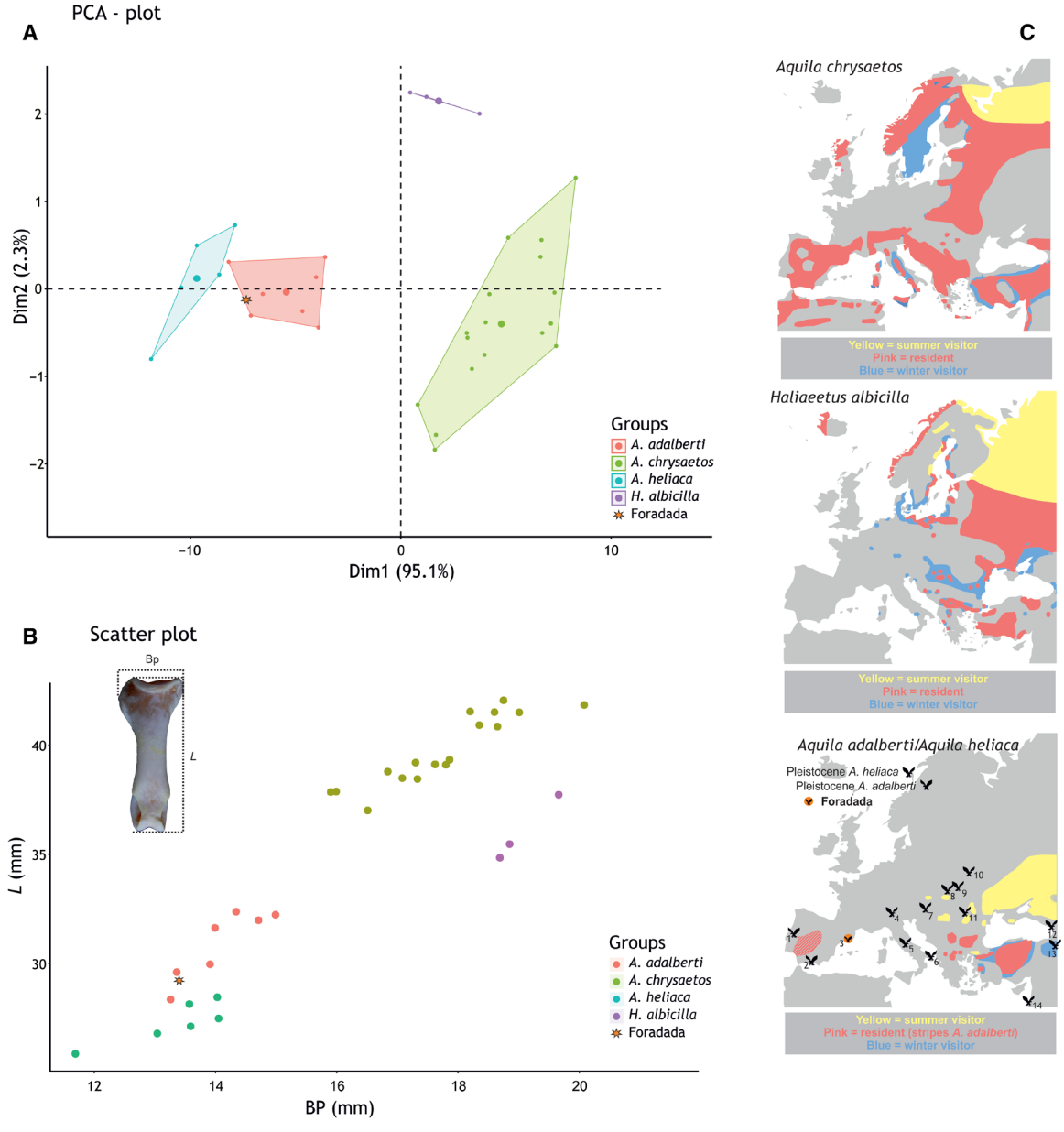

Fig. 3. Data supporting species identification. (**A**) PCA analysis of six measurements of the first phalanx of the toe I of different species of large eagles documented in the Iberian Pleistocene fossil record and *A. heliaca*. (**B**) Diagram with comparative measurements of the total length (*L*) and proximal breath (Bp). (**C**) Current distribution of the three large eagles documented in the Iberian fossil record and European/Middle Eastern localities with the presence of imperial eagles (*A. adalberti/heliaca*) during the Pleistocene (references and dates of occurrences in the fossil record can be consulted in table S5).

Regarding species and anatomical selection, to date, cut marks are yet to be found on the pedal phalanges of other birds, except for raptors, excluding the case of Baume Gigny and Fumane A9 (*14*, *17*). This can be further extended to the case of large carnivore claws, which would be more common if they were to be used as tools. This exceptional find reinforces their interpretation as symbolic elements, supporting and further suggesting that Neanderthals transmitted similar symbolic connotations to large raptors as current traditional societies (*35*, *40*). The symbolic meaning of majestic eagles as large predators could thus be transmitted to some parts of their bodies as talons and feathers. While most archeological cases have presented this use in large eagle's talons, other species, however, are also represented including vultures and eagle owls. Following the same logic, the talons of other species should also convey other meanings, considering that both traditional and current societies associate vultures and eagles with opposing concepts. The same can be said for the swan of Baume Gigny, where the modest claw of a duck can hardly express the same symbolic message as a white-tailed eagle talon. Similarly, the talon of the black grouse from Fumane A9 presents another interesting case. Our finds from Foradada increase the number of cases where large eagles have specifically been exploited for their talons. In this sense, the selection of the larger eagles available in the Palearctic ecosystems dominates during the Middle and Middle to Upper Paleolithic archaeological record, making up 91.3%

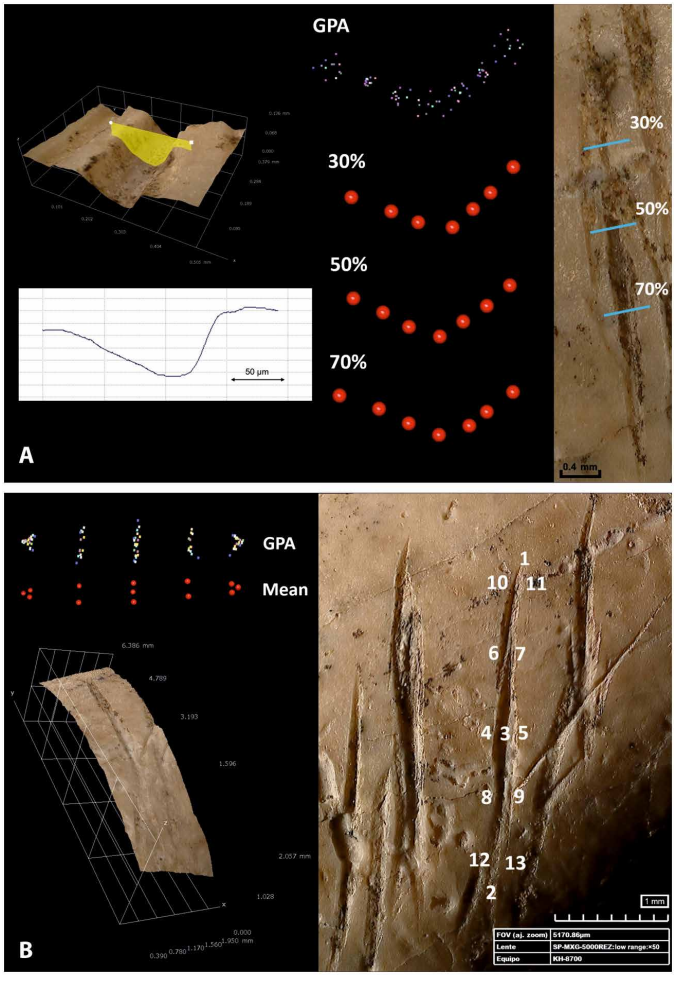

Fig. 4. Analysis of cut mark morphology using the HIROX KH-8700 3D digital microscope. (**A**) 2D GPA and mean shape of cut mark cross-section profiles across 30, 50, and 70% of each incision. (**B**) 3D GPA and mean shape of the entire incision. Photo credit: Antonio Rodríguez-Hidalgo, IDEA.

of the total cases documented (21 cases of 23). This suggests a correlation between the chosen taxon and the processed object. Moreover, the example of Foradada also sees an increase in the number of represented species. Consequently, while some authors may have proposed a specific symbolic meaning behind the use of large eagle "ornamental talons" (*13*), as well as large diurnal raptors associated with scavenging habits (*20*, *35*), at least in the case of talons, the increase in the variety of taxa documented in these sites, including imperial eagle in Cova Foradada and cinereous vulture and eagle-owl in other MP/CP sites (*13*, *18*, *20*), suggests a greater complexity in terms of the symbolic nature of these elements. Current inferences regarding talons interpreted as ornaments highlight them to be "surviving traces of ancient human communication" (*2*), and precisely because of this, talons of different birds with different appearances and behaviors could transmit different messages about the identity of the bearer. In contrast, these archaic populations might not have needed to taxonomically differentiate between large raptor species, regardless of whether they could or not.

Archeological parallels documented specifically among hunter-gatherers of the late Pleistocene and Holocene support the symbolic character of these types of elements (*38*, *41*–*44*). Faced with the same type of zooarcheological and taphonomic evidence, the interpretation of specimens as fully symbolic in contexts associated with AMH leaves little space for speculation. This is enforced when the same elements and evidence are found within MP/CP sites, such as the case of Foradada. Peculiarly, manipulated talons are not very abundant among UP assemblages, commonly found only in the Magdalenian (17/12 ka) (*24*). Furthermore, the cases documented during the early UP appear to be extremely rare. Only two have been published, a talon of *Bubo scandiacus* from La Quina Aval (associated with early Aurignacian) (*42*) and a talon of probable *Gyp fulvus* from Üçağizli (associated with Ahmarian) (*41*). Again, this can be applied to the case of Foradada, where no early or late UP layer has provided anthropogenically modified raptor phalanges. Seashell beads, on the other hand, are in abundance. Currently, UP sites in the Iberian Mediterranean region and the rest of the Iberian Peninsula also fail to present similar finds, except for the case of Santa Catalina, Biscay (Spain), where snowy owl (*Bubo scandiacus*) talons were recovered associated with Magdalenian archeological layers (*24*).

In addition to archeological parallels, the ethnographic data prove that different cultural groups of all continents have used raptor claws/talon for the elaboration of a great variety of elements associated with rituals, dances, personal adornments, grave goods, etc. (*38*, *44*). Only the case of the National Eagle Repository (NER) in Colorado (United States) currently provides more than 600 eagle carcasses to American nations every year for religious and cultural purposes. The most used elements are feathers and the limbs of these animals (with between 1200 and 1500 eagle limbs delivered on a yearly basis). In all cases, carcasses belong to two species, the bald eagle (*Haliaeetus leucocephalus*) and the golden eagle (*Aquila chrysaetos*), because these species contain the highest symbolic meaning for most of the Native American people.

Once having ruled out a nutritional and utilitarian use of raptor talons and considering the interpretation of similar objects in contexts associated with modern humans, the final interpretation of their use as symbolic is both plausible and probable. Although researchers tend to agree on the symbolic nature of talons, their definition of these elements as personal ornaments has been explored with prudence. Most have advocated defining the talons as "supposed ornaments," while others have opted to refer to these finds directly as an example of "Neanderthal jewelry" (*19*). In accepting the use of talons as personal ornaments, this can be considered a tradition that predates any other manifestation of symbolism among Neanderthals or AMH, especially those in which seashells play a central role (*5*). If not, this manifestation also entails important implications for the emergence of symbolism and behavioral modernity, although further investigation is necessary to establish the functionality behind these objects. Regardless of whether the talons were hanging "beads," part of necklaces, earrings, or any other elements for which there are no current parallels, the case of Foradada indicates the symbolic use of talons to be a well-rooted tradition among the Neanderthals of southern Europe for more than 80 millennia. Furthermore, our research suggests the presence of a common cultural territory in which the meaning conveyed by these large-raptor talons could probably be recognized by individuals from different groups. To date, the total absence of raptor talon exploitation in the African Paleolithic record (*35*, *40*) forces us to ask ourselves for the direction of cultural interactions between Neanderthals and modern humans.

Neanderthal origins are currently situated around the second half of the Middle Pleistocene, while classic forms of these populations appear somewhat later during the MIS 5/4. Moreover, the archeological record indicates that they were very close to modern humans in behavioral terms, especially considering their tools, use of fire technology, foraging/hunting strategies, organization of living areas, and mobility. Hybridization between Neanderthals and AMH has been recently proven, highlighting how close both species were (*45*). Encephalic evolution also supports that the fundamental components needed for symbolic and abstract thinking are likely to be present during the end of the Middle Pleistocene (*46*). Nevertheless, evidence of symbolic behavior among Neanderthals is still scarce, especially if we compare this with the subsequent inflation of symbolism of modern humans (*2*, *47*). Even so, the claims for symbolism among Neanderthals are much more frequent than among any other human species (*1*, *4*–*7*, *13*–*20*).

The use of raptor talons in Foradada must be added to the scarce pieces of evidence of symbolism among premodern humans in Europe. The symbolic and non-utilitarian meaning of raptor talons implies that Neanderthals would have had the ability to create and understand fully abstract concepts. The standardization and recurrent use of this kind of element can be interpreted as a nonverbal code and could indicate part of a communicative technology (*2*). If we accept this interpretation, then Neanderthals would have had social and cultural structures complex enough to convey the use and meaning of these codes both in time, from generation to generation, and through space. This represents a remarkable advance with respect to our knowledge about the symbolic behavior of the Neanderthals because, in many occasions, such evidences are unique, sporadic, or little standardized facts.

The case presented in this paper is evidence of the last occurrence of the use of raptor talons among Neanderthals, immersed in a cultural movement in which other jewelry traditions, developed independently or not, are documented (*1*, *5*, *39*). This practice, which emerged in the early MP, appears from time to time but recurrently in the Neanderthal world surviving on one of the last expressions of their material culture, the CP, and probably extinguishing with them forever.

MATERIALS AND METHODS

Excavation methods

Cova Foradada was systematically excavated in extension according to an artificial subdivision of the site in 1 m × 1 m squares, following the natural inclination of the geological layers. Regarding faunal remains, all ≥2-cm and all identifiable specimens, regardless of size, were recovered and their coordinates were documented on a 3D plot. In addition, all the excavated sediment previously recovered by square, layer, and relative depth (5-cm ranges) were water-sieved using superimposed 1-, 0.5-, and 0.05-mm mesh screens. These finds were then bagged. Microfossils were then sorted and classified.

Zooarcheological and taphonomical methods

Anatomical and taxonomic determination of mammalian and bird remains were carried out in the Zooarcheological and Taphonomical Laboratory of the Catalàn Institute of Human Paleoecology and Social Evolution (IPHES). Avian reference collections from the Nat-Museu de Ciències Naturals de Barcelona in Barcelona, Muséum National d'Histoire Naturelle in Paris, Laboratório de Arqueociências—LARC-DGPC in Lisbon, Estación Biológica de Doñana in Seville, and Naturhistorisches Museum Wien were used for comparative purposes. The osteological measurements were taken using a digital caliper with a precision of two decimal places in six specified anatomical points: proximodistal length (L), proximal mediolateral width (BP), mediolateral width at midshaft (SD), distal mediolateral width (Bd1), distal mediolateral width at the beginning of the trochlea (Bd2), proximal dorsopalmar height (Bapp), and the distal dorsopalmar height at the beginning of the trochlea (Badp). The comparative data can be consulted in table S4. Bone surfaces of all faunal remains were inspected macroscopically and microscopically with a stereomicroscope (OPTHEC, 120 Hz model), using magnifications from ×15 to ×45.

Cut marks and their relationship with specific butchering activities were identified on the basis of the criteria of Domínguez-Rodrigo *et al.* (*28*) and Romandini *et al.* (*15*). In addition, 3D reconstructions of the marks were carried out following the methodological protocol established by Courtenay *et al.* (*48*). This approach digitalizes each trace using the HIROX KH-8700 3D Digital Microscope with an MXG-5000REZ triple objective revolving lens. First, cross sections of each mark were produced using the midrange lens at a ×600 magnification. A fixed high-intensity light-emitting diode light source was placed above each sample, combining the use of coaxial and ring illumination. 3D digital reconstructions were produced using a combination of quick auto focus and depth synthesis functions that are provided by the HIROX's system, generating a 3D display of each mark where measurements could be taken and cross-section profiles could be extracted. To construct each digital image, between 110 and 130 photos were taken for each profile. The capturing and assessment of the morphology of each mark's profile were carried out using a total of three cross sections, taken at 30, 50, and 70% of the total length of each mark. As described by Maté González *et al.* (*30*), this range along the groove is suggested to be the most representative for cut mark morphological analysis.

These profiles were then exported to the free tpsDig2 (v.2.1.7) software where the allocation of seven homologous landmarks was carried out following the geometric morphometric models described by Maté González *et al.* (*30*). The resulting files produced through landmark allocation were then edited and imported into the free software R [www.r-project.org; (*49*)], where a full Procrustes fit was performed using the Geomorph library (*50*). This package can be used to prepare the sample for multivariate statistical analysis and is commonly referred to as a generalized Procrustes analysis (GPA). Through GPA, each individual is standardized through a series of superimposition procedures involving the translation, rotation, and scaling of each shape. Any differences in structure can thus be studied through patterns of variation and covariation, which can then be statistically assessed (*51*). The library Shapes (*52*) was then used to calculate and plot the mean shape of each cross section. Additional measurements concerning the depth and opening angle of each of the profiles were later taken. To capture the entire shape of these incisions, further digital reconstruction was carried out on the entire mark using the low-range lens at ×100 or ×150 magnification, depending on the necessities of the analyst with regard to resolution (*48*). To capture the entire length of each mark, the HIROX's tiling function was used to create a mosaic and complete digital reconstruction of each groove. Thirty photos were taken for each tile, while any number between 15 and 32 tiles was used to create the final image. With the use of a high-pixel resolution and the consequential

stacking of photos produced by the microscope, the entire shape of the taphonomic trace could be reproduced digitally. A 13-landmark model, as developed by Courtenay *et al.* (*53*), was then used to capture the entire shape of the groove. The position of each landmark was recorded through a series of measurements. This was done first using the "*xy*-width" function to measure and plot the location of each landmark across a 2D graph, followed by the measurement of depth using the "point height" function to establish each landmark's position along the *z*-axis of a 3D plot. Landmark coordinates were recorded and processed in the same manner as the 2D profiles.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/5/11/eaax1984/DC1

Supplementary Text

Fig. S1. Different views of Cova Foradada and CP points.

Fig. S2. Stratigraphic column.

Fig. S3. Horizontal and vertical location of the phalange FO15/ IV1/E6/1339.

Fig. S4. Anthropogenic modifications on leporid bones in Unit IV of Cova Foradada.

Fig. S5. Anatomical representation of large raptors versus small birds.

Table S1. NISP, percentage and minimal number of individuals (MNI), and number of specimens for Unit IV and layer IV, IV1, and IV2 faunal assemblage at Cova Foradada.

Table S2. Average measurements of the opening angle and depth of incision profiles at 30, 50, and 70% of the groove's total length.

Table S3. Skeletal representation of small birds from Unit IV of Cova Foradada.

Table S4. Measurements of the first phalanx of digit I used for comparative purposes and data from the specimen of Cova Foradada.

Table S5. Pleistocene/Early Holocene fossil remains of *A. adalberti* and *A. heliaca* in Europe and Near East.

Movie S1. Animation of the 3D model of eagle phalanx with cut marks recovered in Cova Foradada.

STL S1. www.morphosource.org/Detail/MediaDetail/Show/media_id/44124

STL S2. www.morphosource.org/Detail/MediaDetail/Show/media_id/44124

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