heritage

MDPI

Article

A Swan on the Water? Technical Execution and Graphic Strategy in an Epigravettian Portable Art Object from Grotta Paglicci

Simona Arrighi [1,2], Erika Moretti [1], Matteo Rossini [1], Jacopo Crezzini [1,2], Stefano Ricci [1], Annamaria Ronchitelli [1] and Francesco Boschin [1,2,*]

[1] Department of Physical Sciences, Earth and Environment, University of Siena, Strada Laterina, 8, 53100 Siena, Italy; s.arrighi@hotmail.com (S.A.); erykamor4@gmail.com (E.M.); matteo.rossini2@unisi.it (M.R.); jacopo.crezzini@unisi.it (J.C.); stefano.ricci@unisi.it (S.R.); annamaria.ronchitelli@unisi.it (A.R.)
[2] Centro Studi sul Quaternario ODV, via Nuova dell'Ammazzatoio, 7, 52037 Sansepolcro, Italy
* Correspondence: francesco.boschin@unisi.it

Abstract

Palaeolithic engraved portable art provides a valuable record for investigating the technical aspects of Palaeolithic graphic production. In this study, we analyse an engraved portable art object from the Epigravettian sequence of Grotta Paglicci (southern Italy): a *Bos primigenius* mandible bearing a figurative representation interpreted as a waterbird, possibly a swan. The analysis combines 3D digital microscopy and geometric morphometrics to reconstruct the sequence of engraving gestures and to quantitatively characterise the morphological variability of the incisions. Archaeological engravings are compared with experimentally produced marks obtained using different lithic tools displaying similar trihedral active edges (burins and unretouched flakes). In addition, experimental and archaeological cut marks from the same Epigravettian context are included for comparative purposes. The results allow the reconstruction of the sequence of gestures involved in the production of the figure, revealing a structured execution comprising contour engraving, internal filling and the addition of secondary elements. Morphological and morphometric analyses show low variability among the engravings, pointing to a high degree of motor control throughout the engraving process. The predominance of U-shaped cross-sections in the archaeological sample, compared with the experimental engravings, is consistent with the use of a previously used and/or partially smoothed cutting edge. These results highlight the potential of integrated technological and morphometric approaches for investigating gestures, technical choices and operational organisation underlying the production of Upper Palaeolithic portable art.

Keywords: portable art; engravings; 3D; geometric morphometrics; Epigravettian; Italy

Check for updates

Academic Editor: Grzegorz Osipowicz

Received: 30 March 2026
Revised: 9 May 2026
Accepted: 11 May 2026
Published: 13 May 2026

Copyright: © 2026 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license.

1. Introduction

Palaeolithic portable art provides a particularly suitable context for investigating the technical and behavioural dimensions of graphic production. Unlike parietal art, engraved portable objects are produced on small, manipulable supports, which allow close control over gesture, force application and tool–surface interaction. As a result, portable art offers a valuable record for exploring the relationships between engraving morphology, motor skills and technological choices at a fine analytical scale [1–3].

Early microscopic observations on engraved artefacts, including those carried out by Marshack [4,5], already highlighted the importance of studying engraving traces to

understand the processes involved in graphic production. Since then, research on Upper Palaeolithic art has increasingly focused on the technical actions and operational sequences underlying engraving practices [6–13].

More recently, high-resolution three-dimensional analytical approaches have provided new opportunities for investigating the technical characteristics of engraved marks. These methods allow the quantitative characterisation of engraving cross-sections and enable systematic comparisons between archaeological and experimental traces [14–23], making it possible to explore the relationships between groove morphology, tool edge properties and engraving gestures. These studies have shown that similar graphic outcomes may result from different tools and gestures, while conversely, tools belonging to the same techno-typological category may produce markedly different traces depending on the characteristics of their active edges and the gestures employed during their use [24–26]. This variability highlights the importance of analysing engraving marks through a combined technological and morphometric approach. Such approaches are now widely used in studies of cut marks and other bone surface modifications [27–30], where they have proven effective in distinguishing traces produced by different tools, actions and taphonomic processes. In contrast, their application to engraved portable art remains comparatively limited. In particular, the behavioural implications of morphological variability among artistic engravings—including the relationship between groove morphology, gesture control and tool familiarity—have rarely been explored in a systematic and quantitative way [31–33].

Beyond cross-sectional morphology, portable art also offers the opportunity to investigate the operational logic underlying graphic production. The analysis of superimpositions, stroke initiation and termination features, and groove orientation makes it possible to reconstruct the relative chronology of incisions and identify gesture sequencing within the composition [1–3,6–9]. This perspective is particularly relevant because the technical organisation of engravings, such as the order of execution, the presence of corrections or restarts, and the planning of contour versus internal filling, can be analysed independently from iconographic interpretation. In this sense, the engraving process itself becomes an important object of investigation, providing insights into the technical skills and motor control involved in graphic production. Moreover, its study can contribute to a better understanding of the behavioural organisation underlying the Palaeolithic engraving practices.

In this context, the present study offers an integrated technological analysis of an Epigravettian engraved portable art object from Grotta Paglicci (southern Italy), dated to about 18,000 years ago. By combining three-dimensional digital microscopy, morphometric measurements and geometric morphometrics, we reconstruct the sequence of engraving gestures and quantitatively assess the variability of incision morphology across the different elements of the composition. The archaeological engravings are compared with experimentally produced grooves obtained using different lithic tools characterised by similar trihedral active parts, as well as with cut marks identified on faunal remains from the same archaeological context.

1.1. Archaeological Context and Portable Art from Grotta Paglicci

1.1.1. The Site

Grotta Paglicci opens on the south-western slope of the Gargano Promontory (Apulia, southern Italy) at 143 m above sea level (Figure 1a). The site consists of a cave composed of several chambers [34], one of which is characterised by the presence of the only example of Palaeolithic wall paintings known in Italy so far [35,36]. Research directed by the Natural History Museum of Verona (from 1961 to 1963) and the University of Siena (from 1971 onwards), in collaboration with the local heritage office, brought to light a 12 m thick sequence in the cave's atrium [35,36]. The Upper Palaeolithic portion of this sequence spans

a time interval comprised from the Aurignacian with marginally backed bladelets through to the final Epigravettian [37–45]. Archaeological deposits were also excavated in other parts of the cave [46] and outside the present-day cavity, in areas that were part of the same hypogean system [47–49], revealing additional Upper and Middle Palaeolithic contexts.

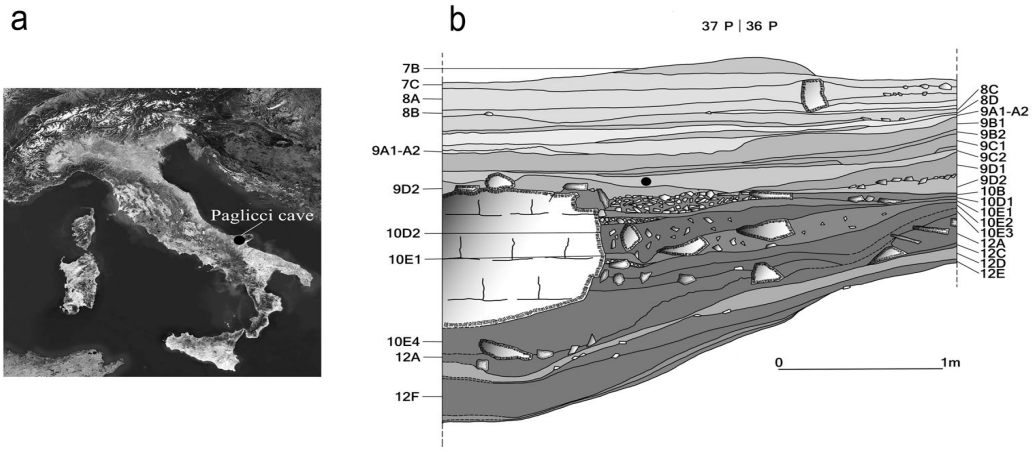


Figure 1. (**a**) Site position; (**b**) Stratigraphic sequence of the layers traditionally attributed to the Evolved Epigravettian at Grotta Paglicci. A black dot indicates the layer (9C2) and square (37P) in which the portable art object was found.

Grotta Paglicci is significant for its rich assemblage of artefacts and for its artistic evidence. It is the only example of Palaeolithic parietal paintings currently known in Italy. In an inner chamber, two painted horses and a series of handprints in a niche are preserved as part of the parietal art of the site [50–52].

Associated with the paintings is also a fragment of a limestone slab, recovered from the bottom of layer 14A (Early Epigravettian), on which a rear axle of a horse is depicted. This fragment likely originated from the ceiling of the atrial chamber, where the complete image was probably once present. The painting presents stylistic features comparable to those observed in the Lascaux cave complex [53].

Some engraved signs, located at the entrance of the cave, high up from the trampling level [54,55], are traditionally attributed to the Evolved Epigravettian. These consist of simple notches (along the edge of the rock) and straight or curved lines, sometimes arranged in pairs and possibly outlining stylised female figures. As suggested by some scholars, the position at the entrance of the cave suggests these signs had a symbolic value [55,56].

At Grotta Paglicci, in addition to the parietal art, an exceptionally rich assemblage of portable art has been documented [6,54,57–59]. It includes numerous stone and bone artefacts engraved with naturalistic or geometric motifs, mostly ascribed to the Epigravettian. The numerous finds recovered from the archaeological strata, and therefore their chrono-stratigraphical precise position, allow us to claim Grotta Paglicci as one of the most significant sites in Italy for the comprehension of the evolution of the styles and symbolism belonging to the Palaeolithic people. The well-documented stratigraphic context of most of these finds makes the site a key reference for understanding the development of stylistic and symbolic expressions in the Upper Palaeolithic of the Italian peninsula.

1.1.2. Contextual Portable Art from Grotta Paglicci

The specimen (ID no. 7553) analysed in this study was recovered from spit c2 of layer 9 at Grotta Paglicci. Layer 9, together with layers 8, 10 and 11, has traditionally been attributed to the Evolved Epigravettian, dated here between about 19,000 and 18,000 years ago (e.g., [55,60]). However, this attribution, based on the typological study of the lithic

industries at the site [43], is currently underway [61–63], integrating a techno-economic approach with use-wear analysis [64]. To better contextualise the analysed specimen, we present here the portable art from layer 9, from which it derives, together with that from layer 8, as both levels show broadly similar characteristics in their lithic assemblages and artistic productions, particularly in the emphasis on figurative representations expressed through engraved motifs on stone and bone artefacts.

These include: a bird, possibly an *Alca impennis* or *Alca torda* [53,54,58] represented on a limestone slab (layer 9); aurochs, red deer and horses engraved on both surfaces of a horse innominate (layer 8) [36,54,58]; the contours of an aurochs and a red deer represented on a limestone block (layer 8) [53,54,58]; a scene depicting a snake preparing to attack a nest of eggs with a bird nearby engraved on a fragment of the left radius of *Equus ferus* (layer 8) [53,54,58]; and unclear zoomorphic and anthropomorphic figures represented on both surfaces of a limestone pebble (layer 8) [36]. A limestone slab engraved with a horse pierced by arrows was recovered from a reworked context but has been tentatively considered contemporary with the material from layers 8 and 9 on stylistic grounds [55,59].

1.1.3. Stratigraphic and Paleoenvironmental Context of the Engraved Specimen

Layer 9, from which the specimen analysed in this study was recovered, was subdivided into several stratigraphic units during excavation [43]. Moving from the bottom to the top, the layer comprises the following sub-units (Figure 1b):

- 9d2: ashy level with stones bearing heat-induced alterations;
- 9d1: dark level reach in charcoal;
- 9c1: level rich in lithic artefacts and faunal remains.
- 9c2: dark brownish level with few rocks. The basal part is more yellowish.
- 9b2: reddish-yellowish level characterised, at the top, by the presence of well-defined and punctual depressions, probably due to dripping;
- 9b1: reddish-yellowish level with a concentration of charcoal and burned bones in the basal part;
- 9a2: brownish level reached in findings;
- 9a1: probably a living floor, rich in lithics, animal remains and rocks.

Layer 9 was dated between 18.002 and 18.956 cal. BP (date ID: F-67) [60]. The presence of *Microtus arvalis* among small mammals indicates arid conditions and open environments. This reconstruction is confirmed by the large amount of horse, ibex and aurochs specimens (which count respectively for the 23.5%, 36.5% and 10.5% of ungulate remains in the spit 9c) [65] and both by pollen and isotopic analyses [60,66–69].

2. Materials and Methods

2.1. The Art Object

Specimen no. 7553 was anatomically and taxonomically identified using the osteological reference collection at the Zooarchaeology Lab of the University of Siena (Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente).

The engraved motif, recognisable as a figurative subject, is composed of three graphic units: a group of curved lines, a main subject and a second, rounded one. The main subject is complete, delimited by a clear contour and consists of an ovoid form, with a kind of curved and pointed "neck". The figure is filled with dense engravings of various lengths. Some notches were engraved perpendicular to the contour. Near one side of this main unit, there are distinct single curved engravings. The second, rounded graphic unit is located near the "neck". It is a circular motif, composed of short lines delimiting small spaces filled by other dense engravings (Figure 2).

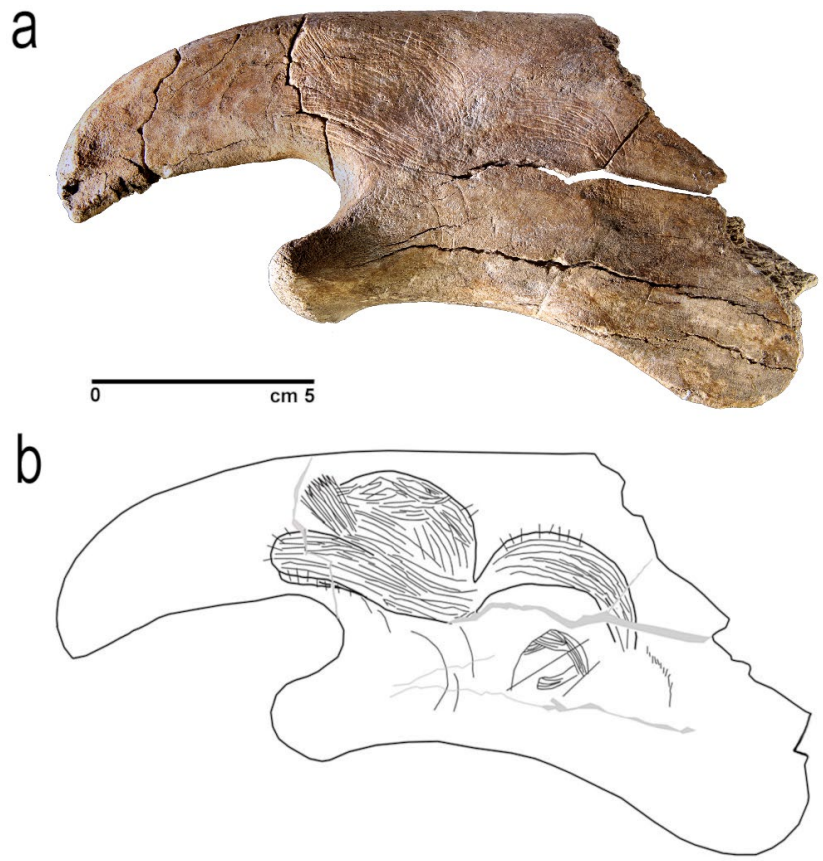


Figure 2. (**a**) Specimen no. 7553 from Grotta Paglicci; (**b**) Schematic drawing of the specimen with the tracing of the figurative units.

2.2. Technological Analysis of Engravings

To better study the portable art object from a technological point of view, the engraved motif was subdivided into several areas, according to Figure 3. In particular, the main figure was divided into the following areas: the contour, the filling, the fan and the notches.

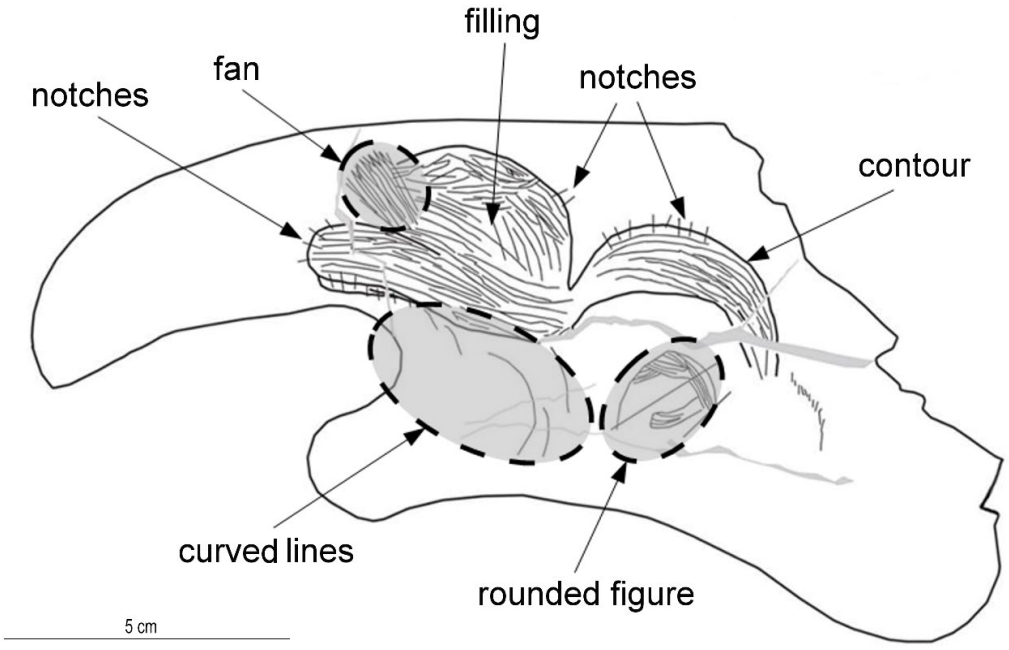


Figure 3. Subdivision of the engraved motif.

The artistic object was examined using a Hirox KH-7700 digital microscope (Hirox Co., Ltd., Koenji Minami Suginami-ku, Tokyo, Japan), which enables the 2D and 3D study of surfaces both by means of low magnification and higher magnification analysis. Analysis was conducted using two different optics: a MX-G 5040Z zoom lens equipped with an AD-5040 Lows objective lens (20–80×) and a coaxial vertical lighting MXG-10C zoom lens and an OL-140II objective lens (140–560×).

Before the technological analysis of the engravings, the art object was microscopically examined to detect evidence of surface preparation.

The execution of the engravings was investigated through the analysis of line superimpositions and specific microscopic indicators of stroke direction and sequence [3,70,71]. Morphological features distinguishing the initiation and termination of each incision were recorded when visible. Stroke initiation was identified by a micro-cavity or a widened contact surface producing the characteristic comet-head morphology. Stroke termination was recognised through the presence of final parasitic striations and tool exit striations. In addition, micro-detachments along the incision edges were documented to infer the orientation of tool movement. The relative chronology of overlapping incisions was established through superimposition relationships. All indicators were systematically recorded to reconstruct both the direction of strokes and the sequential order of engraving gestures, providing a detailed and reproducible framework for technological analysis.

2.3. Morphometric Analysis

3D models were generated directly by the Hirox digital microscope (140×), which acquires a series of images at different focus levels and automatically produces a multifocus image stack. These stacks provide precise 3D reconstructions of the engraved surfaces, enabling detailed morphometric and technological analyses [72]. The curved lines and the rounded figure were treated separately. A total of 82 cross-sections were analysed on the engravings.

Archaeological engravings were first morphologically subdivided into categories according to Boschin and Crezzini [17]. After this morphological study and after the preliminary study of the lithic assemblage from level 9c, four experimental tools were produced: two burins (respectively B1 and B2) and two unretouched flint implements (respectively UR5 and UR6), all of them presenting a trihedral active part. Tools were used to produce engravings on a cattle's fresh innominate to explore differences between intentionally and unintentionally produced marks. Engravings are linear and were inflicted by one of the authors (EM) with a single stroke, controlling hand movements and taking advantage of the trihedral active parts present on all implements; characteristics of these engravings were partially discussed in previous papers [24,25]; three engravings were produced with each tool and three cross-sections were analysed per each groove in this paper (respectively at 25, 50 and 75% of groove's length), for a total of 9 observations per each tool. The small size of this dataset must be considered, even if it can be useful for some considerations. Moreover, a set of experimental cut marks produced on cattle autopodials using unretouched flint flakes (n = 22), and a set of cut marks from the Epigravettian of Grotta Paglicci (n = 19) [13] were used for comparative analyses. The choice of different anatomic elements during experimentation, as well as the variety of archaeological specimens bearing analysed cut marks, does not affect results, as [73] demonstrated that the morphology of striations is not affected by bone type and size.

Measurements of cross-sections of analysed engravings were taken according to Boschin and Crezzini [17] and Duches et al. [74]. The following parameters were considered: depth of cut (DC); breadth at the top and at the floor of the groove (respectively BT and BF); greatest and smallest distances from the middle of the floor to the edges

(respectively GD and SD); opening angle (OA) (Figure 4). The ratio between the breadth at the top (BT) and at the floor (BF) of grooves (RTF index) was calculated for each profile. This index is related to the U/V shape of profiles [17]. Statistics on measurements were processed using the Past 5.3 software [75].

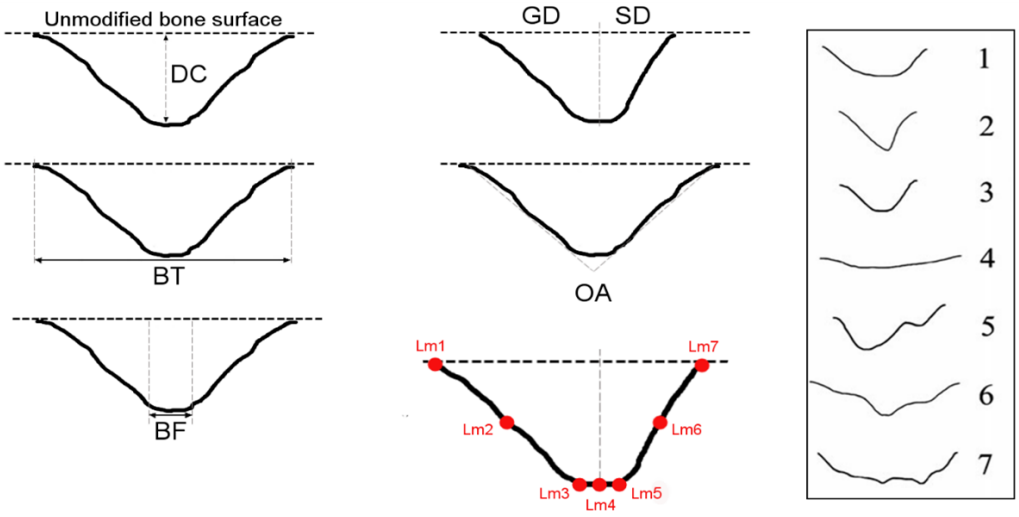


Figure 4. Measurements were taken on the grooves' profiles; DC: depth of cut; BT: breadth at the top; BF: breadth at the floor; GD and SD: greatest and smallest distances from the middle of the floor to the edges; OA: Opening angle; red dots indicate the position of the seven landmarks used for geometric morphometrics. The box on the right illustrates the seven morphological categories of mark cross-sections defined by Boschin and Crezzini [17].

2.4. Geometric Morphometric Analysis

A geometric morphometric analysis was also carried out on cross-sections of archaeological art engravings and on experimental ones. 7 landmarks were placed according to Maté González et al. [22] (Figure 4). Landmarks were placed using the software tpsUtil (v. 1.58) and tpsDig (v. 21.17) [76,77]. Raw coordinates were imported to the R software, version 4.6.0 [78]. After a Procrustes fit, a PCA was performed on the coordinates. A Procrustes ANOVA and pairwise comparison were performed to test the significance of shape differences among groups. Finally, the homogeneity of groups' variance along the two main PC scores was investigated using Levene's test.

3. Results

3.1. Blank and Execution Sequence of the Engravings

The artistic representation was engraved on the right mandible of *Bos primigenius* (Figure 5). The small size of the element and the porous appearance of some areas of the bone surface are consistent with a young individual. The only natural modifications of the specimen's surface are cracks that occurred after the engraving process.

The microscopic analysis of the bone surfaces did not detect any trace of surface preparation. Furthermore, no evidence that engravings may have erased earlier traces was found. Microscopic analysis allowed the reconstruction of the sequence of execution of the artistic representation. Regarding the main figure, the contour was engraved first, followed by the internal filling (Figure 6). Subsequently, the contour of the main figure was marked by short strokes engraved perpendicular to it (Figure 7b). It is not possible to establish when the curved lines located beneath the main figure were engraved, as they do not intersect with the other engravings.

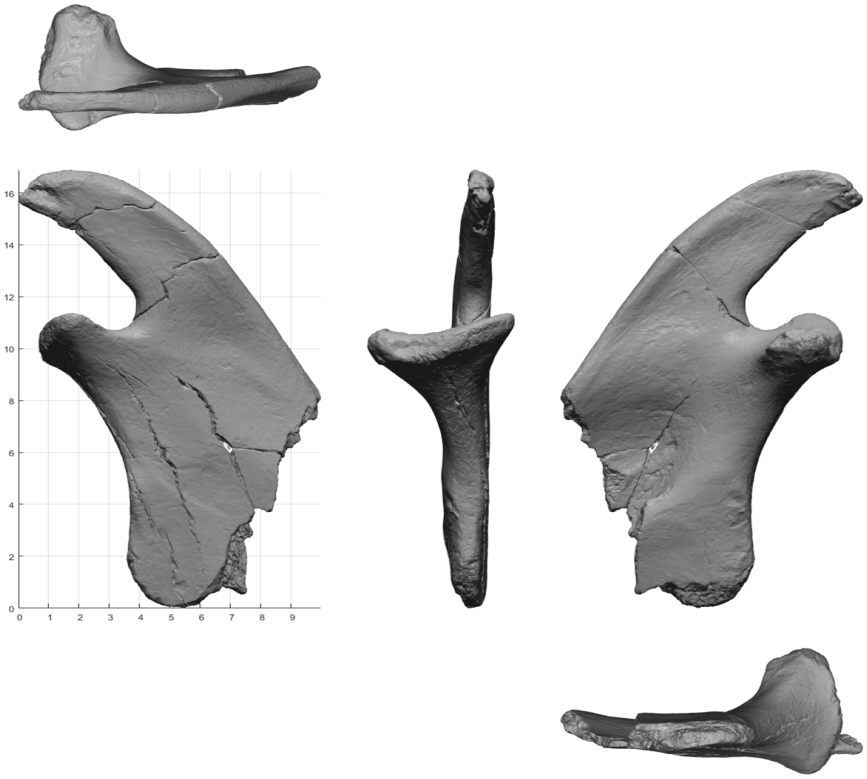


Figure 5. 3D model of the engraved *Bos primigenius* mandible (ID no. 7553) from Grotta Paglicci in anatomical position. The 3D model was produced with an Artec Micro II scanner (Artec 3D, Senningerberg, Luxembourg) with an accuracy of 5 microns. The open-source software Artifact3-D was used to produce the views [79].

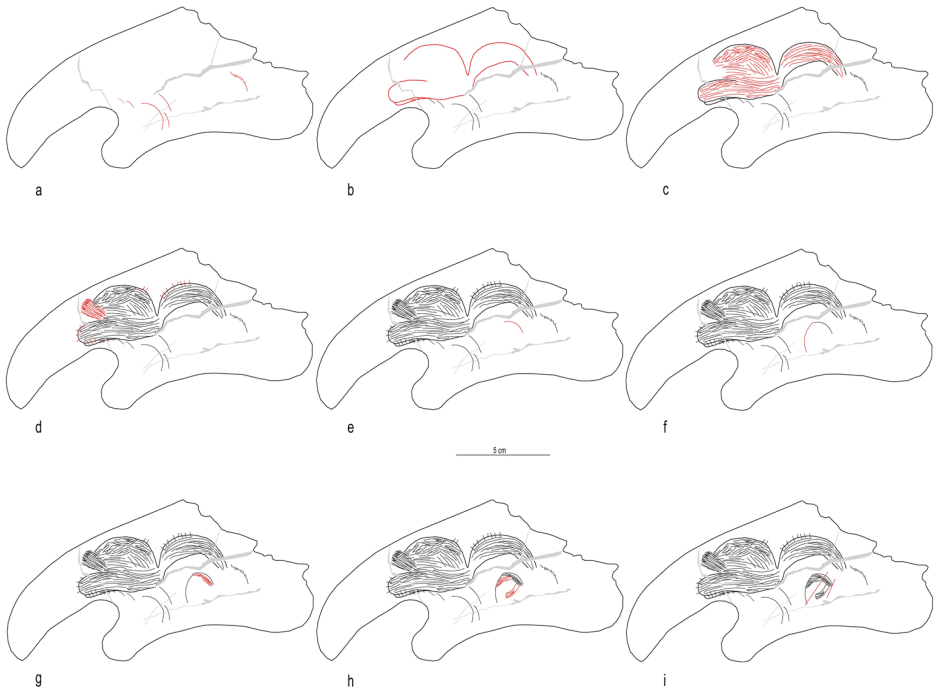


Figure 6. Reconstruction of the engraving sequence on the specimen. The lines added since the previous panel are in red. The panels illustrate the organisation of gestures within each graphic unit. The curved lines are shown separately, as their chronological position cannot be established. The sequences proposed for the main figure (**a**–**d**) and the rounded element (**e**–**i**) refer to their internal execution only. No chronological relationship between the units can be inferred.

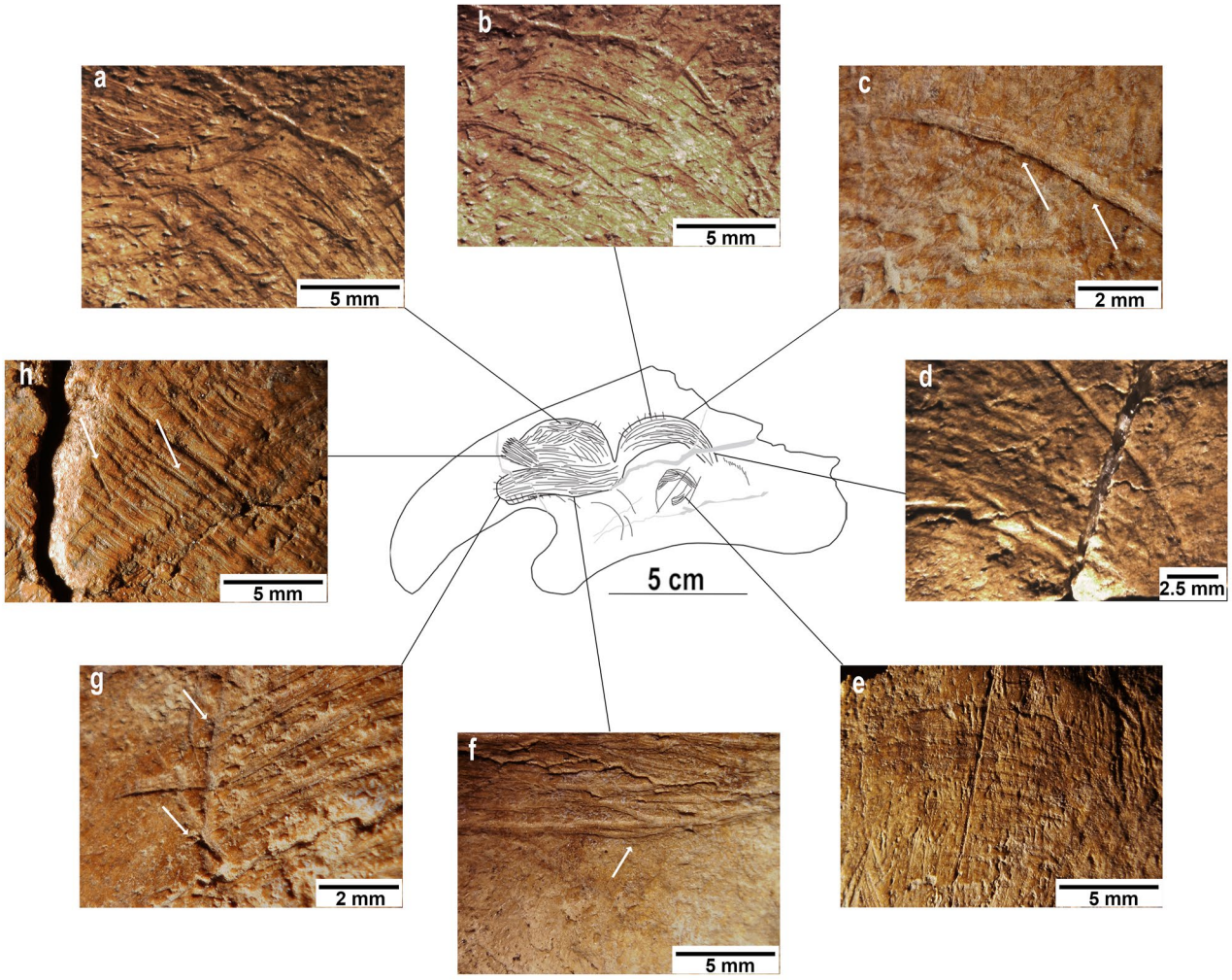


Figure 7. (**a**) Detail of the internal filling organised according to different orientations; (**b**) detail of the notches superimposed on the contour; (**c**) micro-detachments along the edges of the contour, indicated by arrows; (**d**) detail of the beak, where the strokes defining the contour do not overlap; (**e**) detail of the filling of the rounded figure; (**f**) restart in the lower part of the figure; (**g**) filling strokes extending beyond the contour, indicated by arrows; (**h**) superimposition of the strokes forming the fan-like motif, suggesting a top-to-bottom direction of execution.

The profile of the main subject was produced through two distinct gestures, one for the upper portion and one for the lower. The relative chronological order of these two strokes cannot be determined, as they do not overlap (Figure 7d). Both engravings likely start from the pointed end of the neck (the bird's beak). This inference is based on a small number of micro-detachments observed along the groove edges (Figure 7c), which may indicate the direction of the strokes, although their limited frequency does not allow definitive reconstruction. During the execution of the lower portion of the figure, the engraver appears to have restarted the stroke, possibly to correct the engraving (Figure 7f).

The internal filling occasionally appears imprecise where engraved lines overlap the contour (Figure 7g). In the neck area, the filling consists of dense, short strokes, engraved from right to left (considering the specimen oriented as in Figure 3). This directionality is suggested by the presence of initiation features on the left side of the strokes and by the superimposition of engravings, which also indicates a top-to-bottom motion. The filling of the body is organised into seven distinct groups of lines, each characterised by different orientations (Figure 7a). The chronological order of the engravings forming the

filling of the main subject could not be reconstructed, as the bone surface in this area is poorly preserved.

The fan-shaped motif was engraved last. These lines were produced from left to right and from top to bottom (Figure 7h). The short lines overlapping the contour appear to have been made by single strokes, most likely executed from top to bottom.

Regarding the rounded figure, it is unclear whether it was engraved before or after the main figure. Lines and filled areas were produced in an alternating sequence (Figure 7e). The upper engraving was executed first, followed by the left one. Subsequently, the groups of short lines interpreted as a form of filling were engraved, starting with the upper group and then the two lateral ones. The final engraving is the long vertical line that divides the rounded figure into two parts. All engravings appear to have been produced by single strokes.

3.2. Morphometry of Engravings

Engravings on the portable art object are mainly characterised by cross-sections with regular U-shaped profiles (categories 1 and 3), whereas regular V-shaped profiles (categories 2 and 4) are less common. Well-visible ancillary striations or secondary edges within the main grooves are also rare (categories 5, 6 and 7). This pattern differs markedly from that observed in experimental cut marks produced using long cutting portions of unretouched flint flakes [17]. Instead, it closely resembles the distribution observed in experimental engravings produced with trihedral active parts (Figure 8), although wide V-shaped profiles were also recorded in the latter.

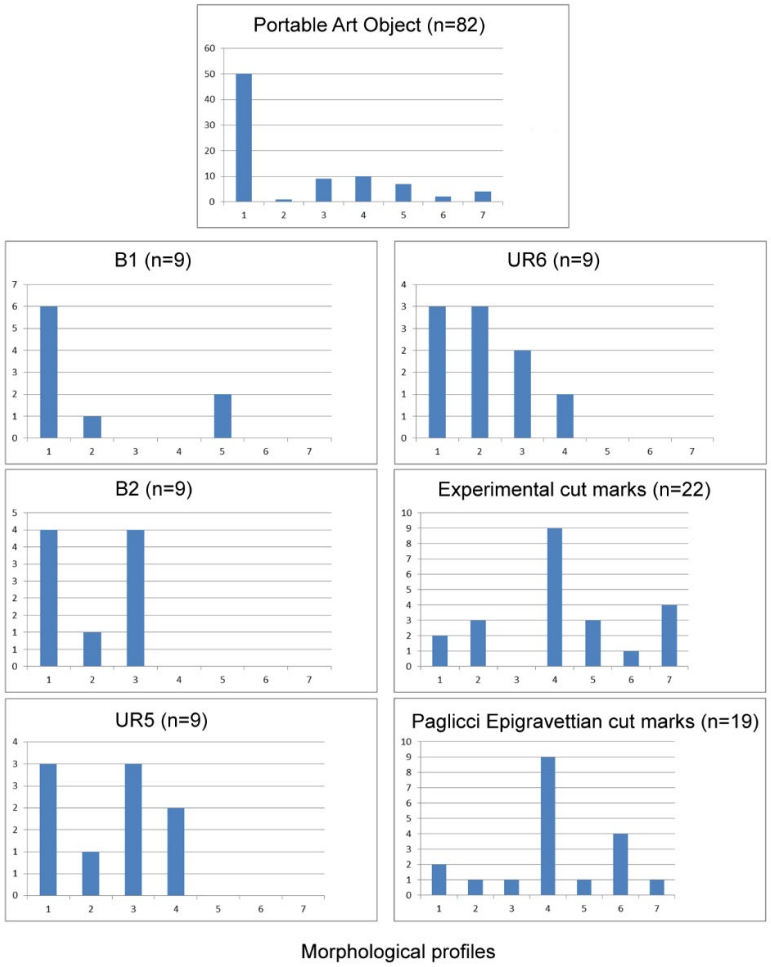


Figure 8. Frequencies of the different morphological categories across the analysed samples.

RTF index values measured on the artistic engravings are similarly distributed across the different areas of the object (i.e., contour, internal filling, notches, fan, curved lines and rounded figure), with comparable medians (Kruskal–Wallis test: p(same) = 0.5). When data from the whole engraving are pooled into a single sample, the resulting distribution differs significantly from both experimental engravings and experimental cut marks. Kruskal–Wallis test p(same) values range from 0.002 (art object vs. UR6) to 4.504×10^{-6} (art object vs. cut marks), indicating that the engravings from Paglicci are characterised by significantly more U-shaped profiles (Figure 9; Table S1).

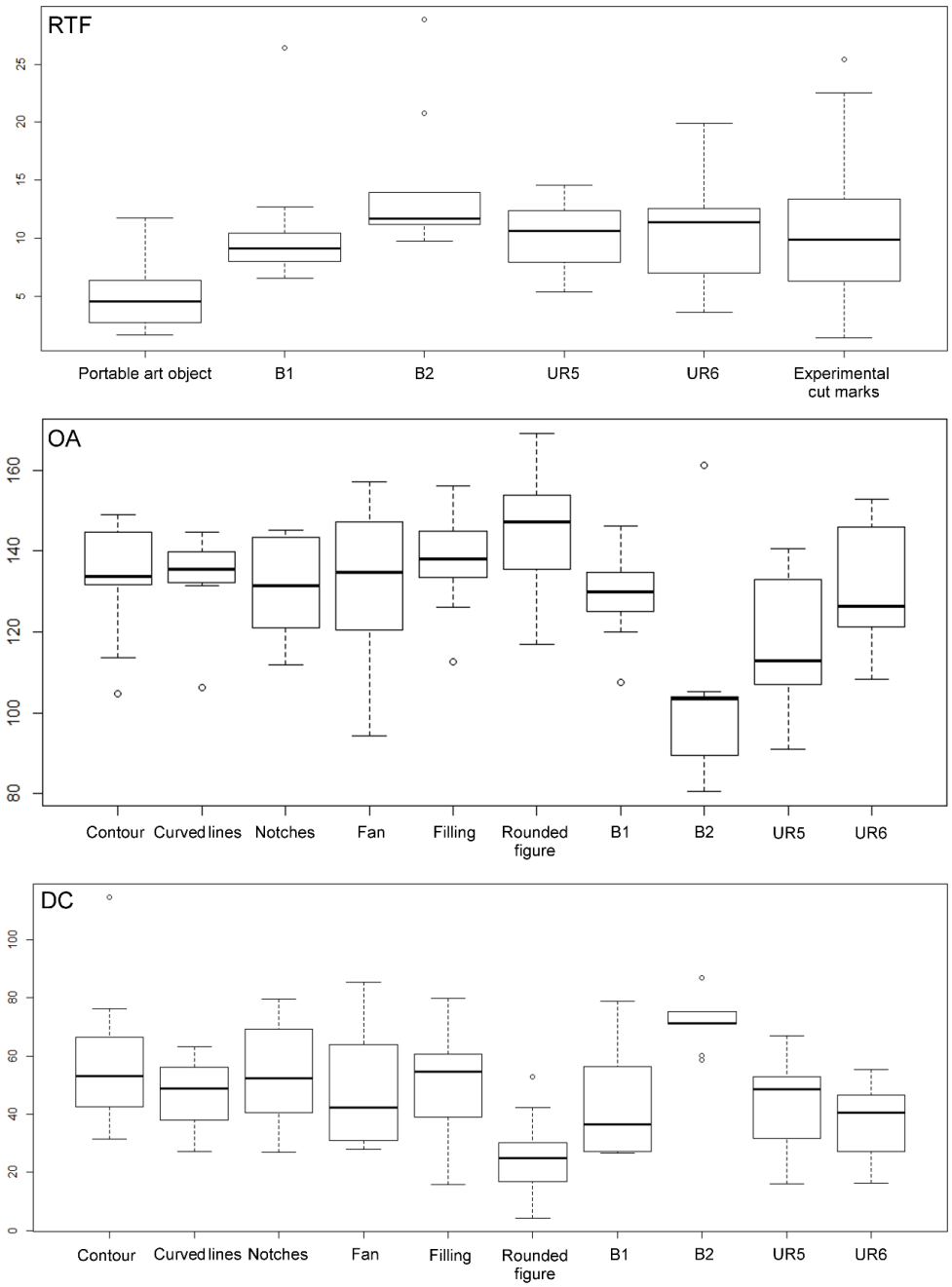


Figure 9. Distribution of values of RTF index, Opening Angle (OA) and Depth of Cut (DC) among considered samples. Regarding the RTF index, data from the portable art object are considered as a single sample. For OA and DC, data is split into 6 sub-samples (Contour, Curve lines, Notches, Fan, Filling, Rounded figure).

The opening angle (OA) shows limited variability, as no significant differences are detected among the various areas composing the main figure (Kruskal–Wallis test: p(same) = 0.6). Only the cross-sections associated with the rounded figure display broader opening angles than those observed in the other areas (rounded figure vs. other areas, Mann–Whitney test: p(same) = 0.0003). This overall homogeneity contrasts with the results obtained from experimental engravings. In that case, the four tools produced engravings with different opening angles: among the six possible pairwise comparisons, two are significantly different (B1 vs. B2: Mann–Whitney test p(same) = 0.006; B2 vs. UR6: p(same) = 0.006), while two are borderline (B1 vs. UR5: p(same) = 0.06; UR5 vs. UR6: p(same) = 0.09). Furthermore, when considering the entire set of cross-sections analysed on the Paglicci sample (n = 91), the coefficient of variation in the opening angle is significantly lower than that observed for engravings produced with B2 and UR5 (Fligner–Killeen test: p(same) = 0.01 and 0.05, respectively), and comparable to that of engravings produced with B1 and UR6 (p(same) = 0.4 and 0.2, respectively).

Depth (DC) values further differentiate the rounded figure from the other areas, as the former is systematically shallower (Figure 9). Comparison with experimental engravings and cut marks is again informative. Despite the complexity of its morphology, the contour of the main figure exhibits less depth variability than engravings produced with UR5 (Fligner–Killeen test: p(same) = 0.06, borderline result) and a variability comparable to that of engravings produced with B1 and UR6 (p(same) = 0.19 and 0.25, respectively). Only engravings produced with UR5 show a very constant depth, significantly less variable than that observed for the Paglicci engravings (p(same) = 0.02). As expected, the latter also displays a depth distribution that is significantly less variable than that of cut marks (p(same) = 0.009).

A different pattern emerges for the filling, the fan and the rounded figure, which are associated with multiple engraving actions. When considered separately, these three samples show higher depth variability, although of the same magnitude as that observed in engravings produced with B1, UR5 and UR6 (p(same) values ranging from 0.2 to 0.4). In contrast, engravings produced with B2 are characterised by a significantly more constant depth when compared with each of the three areas considered (p values ranging from 0.007 to 0.02).

Linking the analysis of cutting edges with that of engravings, a wider opening angle is expected when marks are shallow, and only the apical portion of the cutting edge is involved, as the angle increases toward the apex [24]. This expectation is supported by the relationship between OA and DC in engravings, which shows a significant negative correlation (art engravings: $p = 1.44 \times 10^{-52}$; experimental engravings: $p = 1.4352 \times 10^{-18}$). Accordingly, differences in opening angle values among the cross-sections of the rounded figure can be interpreted as a function of their depth.

A principal component analysis (PCA) was performed on the set of measurements (DC, BF, BT, GD, SD and OA) collected from archaeological groove cross-sections (art engravings and cut marks), experimental engravings and experimental cut marks. The first principal component, accounting for 63.4% of the total variability, is primarily related to cross-section size and was therefore excluded from further interpretation, as it does not convey information on shape variability. The second and third components, shown in the scatterplot in Figure 10, are more closely related to shape, but together they explain only 32.5% of the variability. Higher PC2 values (24.7% of variability) correspond to shallower, more U-shaped cross-sections with wider opening angles, whereas higher PC3 values (7.8% of variability) correspond to more V-shaped profiles. Notably, the cross-sections of the artistic engravings from Paglicci show limited variability. Moreover, comparison of PC2 scores (Figure 10) indicates that engravings on the portable art object are clearly distinct from cut marks, both experimental and archaeological.

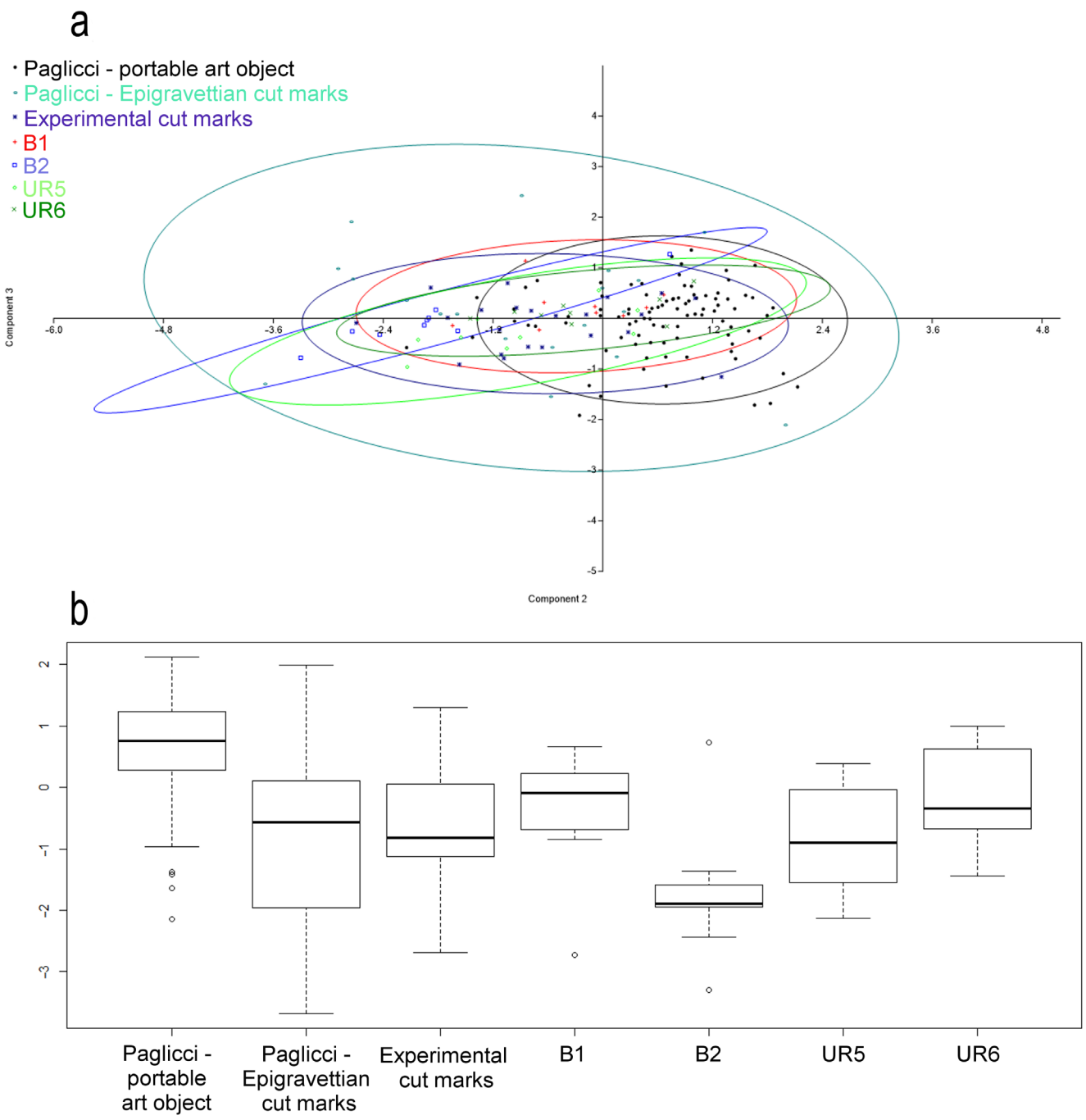


Figure 10. (**a**): graphic outcome of the PCA. PC2 (horizontal axis) accounts for the 24.7% of variance; PC3 (vertical axis) accounts for the 7.8% of variance. B1: burin 1; B2: burin 2; UR5: unretouched flake 5; UR6: unretouched flake 6; (**b**) boxplot of the PC2 values according to groups.

The geometric morphometric analysis, applied exclusively to the portable art object and the experimental engravings, yielded consistent results (raw data in Table S1). The principal component analysis (PCA) accounts for 71.6% of the total variance (Figure 11): the first axis (48.3%) is positively associated with deeper, V-shaped profiles, whereas the second axis (23.2%) is more related to symmetry of profiles; in particular, lower values indicate shallower and asymmetric shapes, whilst higher values are associated with deeper and more symmetric cross-sections. This variation has also been found in other studies to be related to hand position [80]. Analysis of Variance, using the Residual Radomization Permutation procedure, revealed a significant difference between groups ($p = 0.001$), and pairwise comparisons confirmed that Paglicci is significantly different from the other

groups (p ranges between 0.01 and 0.001). A Levene's test was performed separately on PC1 and PC2 scores to test homogeneity of variance. This is significantly different along PC1 ($p = 0.0079$), which confirms more U-shaped profiles characterising the Paglicci specimen. On the contrary, variance is not different along PC2 ($p = 0.16$). This is of great interest, as the whole dataset from Paglicci, despite its complexity, shows, along PC2, a variance comparable with that of a few regular striations produced with a single tool.

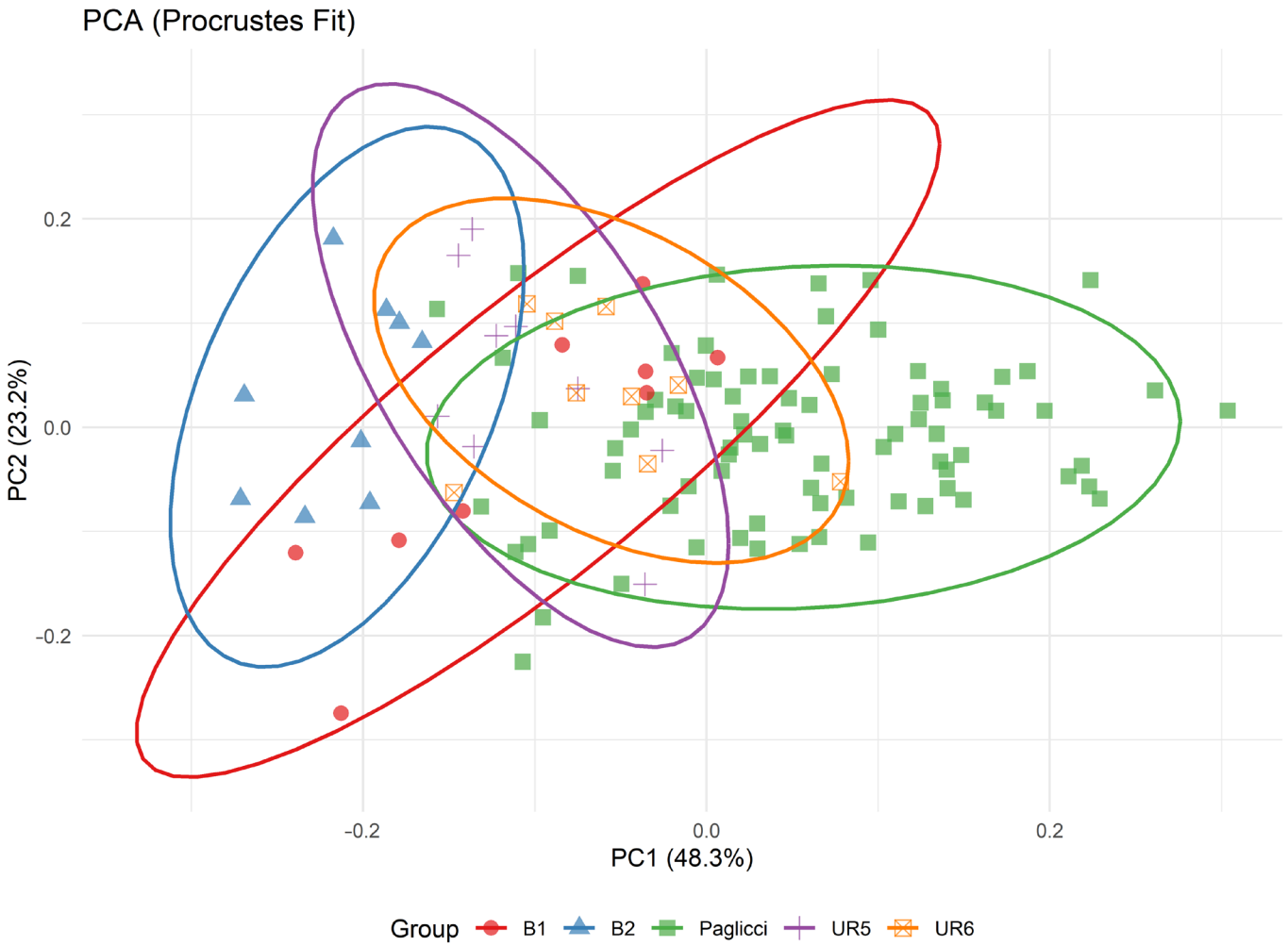


Figure 11. Graphical output of the PCA carried out on geometric morphometrics data. B1: burin 1; B2: burin 2; UR5: unretouched flake 5; UR6: unretouched flake 6. Paglicci: engraved motif.

4. Discussion

The general preservation of the portable art object no. 7553 from level 9c of Grotta Paglicci is that of a bone buried in a fresh state. Except for post-depositional cracks, no other surface alterations have been detected. The specimen bears a complete engraved figure delimited by a well-defined contour executed through controlled single strokes. Although its interpretation remains uncertain, the overall morphology of the main figure seems consistent, as a working hypothesis, with that of a swan. The curved element on the right may correspond to the long neck and head, the central portion to the body, and the dense engravings on the left to the plumage of the wings when the bird is swimming (Figure 12).

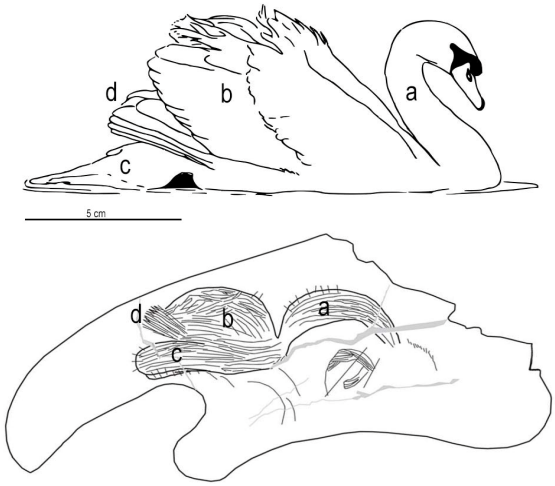


Figure 12. Schematic drawing of a waterbird (here a swan) compared with the engraved portable art object: (**a**) neck; (**b**) body and wings; (**c**) tail (in swimming posture); (**d**) part of the wing.

No specific interpretation is proposed for the associated rounded figure. It does not find close parallels in known Upper Palaeolithic representations and appears to be highly unusual in its composition. However, the short strokes composing it resemble those used to fill the body of the bird, suggesting a possible intention to represent a figurative element.

Bird representations are relatively uncommon in Palaeolithic art, although they are documented from the Aurignacian onwards, for example at Hohle Fels [81] and Grotte Chauvet [82], and become more frequent during the Final Upper Palaeolithic [83]. Although precise taxonomic identification is often difficult, waterbirds, particularly Anatidae, appear to be among the most commonly represented [84].

In the Italian Upper Palaeolithic record, bird representations are nevertheless relatively rare, although examples are documented in both parietal [85] and portable art [47–49,53]. Grotta Paglicci, however, has yielded a comparatively rich assemblage of portable depictions. In addition to the examples mentioned above (see Section 1.1.2), a probable wading bird engraved on a rib fragment has been documented in the Final Epigravettian levels [47]. The specimen analysed here differs stylistically from the bird depictions known from the site, as well as from the parietal example from Grotta Romanelli [85], in that the part we interpret as the body is filled with engraved lines, hypothetically intended to render the plumage. This feature recalls certain Upper Palaeolithic bird representations, such as the bustard depicted at La Madeleine and Gourdan [86]. However, the use of multiple strokes to fill figures is a broader feature of Late Upper Palaeolithic graphic conventions, not limited to the depiction of plumage, and is documented in a wide range of contexts [87–92].

Our interpretation is supported by the rounded body, as well as the long and curved neck, features commonly observed in Upper Palaeolithic depictions of swans, such as those documented at Grotte Margot [83], Malt'a [93,94], Teyat [95], Gourdan [96], La Croze [97] and Gönnersdorf [98].

The rendering of the plumage, obtained through strokes oriented in different directions, further supports this interpretation and is consistent with the naturalistic tendencies observed in Epigravettian art [99].

Swan's bone remains are recorded in the Late Glacial faunal record at several Italian sites, including Grotta delle Arene Candide, Grotta Romanelli, Grotta della Madonna and Grotta dell'Addaura [100]. Although they are not documented in the faunal assemblage of Grotta Paglicci, it is likely that these birds were familiar to the human groups occupying the site. Migratory species are among the most frequently represented birds in Palaeolithic art [101], suggesting that their seasonal presence may have held particular significance.

Beyond its iconographic interpretation, the figure provides a valuable case for exploring the relationship between representational choices and technical execution.

The reconstruction of the engraving sequence provides further insight into the technical organisation underlying the production of the figure. The execution follows a structured sequence, beginning with the engraving of the contour, followed by the internal filling and finally by the addition of secondary elements. This organisation suggests that the main features of the figure were established early in the process, with subsequent actions aimed at refining and completing the representation.

A restart is observed in the lower part of the figure, possibly reflecting a local adjustment during the execution of the engraving. Its isolated occurrence may suggest a generally controlled and confident execution of the figure. At the same time, the overall coherence of the sequence and the regularity of the main lines point to a well-mastered technical skill and a clear operational plan guiding the engraving process.

Complementing the reconstruction of the engraving sequence, the analysis of groove morphology provides further insight into the technical execution of the engraving.

It is known that marks' morphology is not influenced by the type of skeletal element on which they are produced [73]; the depth and opening angle may depend on the force applied (e.g., [14,24,74]), whilst the opening angle and symmetry depend on the changes in hand position (e.g., [80]); the opening angle and internal irregularities depend on the cutting edge.

As regards the technological aspects of the engravings, the grooves display a striking morphological homogeneity despite their structural complexity. The variables considered here are the opening angle (OA) and the depth of cut (DC). In several instances, these parameters appear more homogeneous in the archaeological engravings than in experimental cross-sections produced with a single tool under controlled force and hand movements. Also, the morphological variability described by the second axis on the PCA in Figure 11 is very homogeneous. The variability it displays is comparable to that depending on the hand movement described in [80]. This is of great interest, as our experimental engravings were linear, not complex, and produced by a single operator with only four tools. Even if these choices ensure consistency, they may result in a loss of complexity and variability in morphometric characters, not comparable with that of a complex archaeological engraved motif. This is the reason why the relative homogeneity of the studied specimen is so surprising.

At first glance, this pattern may appear counterintuitive, as experimental engravings produced with a single tool under controlled conditions often show greater variability. However, rather than representing a contradiction, this difference highlights the high degree of control achieved during the archaeological engraving process. In this perspective, the limited variability observed in the archaeological sample can be interpreted as the result of a stable and well-controlled gesture of a very skilled operator.

This observation is consistent with experimental research on surface modifications showing that differences in raw material or tool performance do not necessarily translate into diagnostic differences in groove morphology, which instead often reflects the dynamics of the gesture and the degree of control exerted during the action [30]. As previously demonstrated [24], the wider opening angles observed in the engravings composing the rounded figure can be just explained by their reduced depth.

Given the motor control required to maintain consistent depth, the systematically shallower incisions in this portion of the composition may reflect a deliberate technical choice. Maintaining such consistency in depth while engraving on an irregular bone surface requires a stable and well-controlled gesture throughout the action. The observed homogeneity is particularly noteworthy considering the complexity of the engraved rep-

resentation, which includes long, regular contour lines, dense groups of short strokes, notches, and isolated curved lines outside the figures.

These results indicate a high level of technical control, and, considering some parameters, morphometric variability is even comparable with that resulting when a single tool is used (Figure 11). Cross-sectional morphology (characterised by U-shaped profiles and a low frequency of ancillary edges or internal striations) is more typical of a trihedral active edge than of an elongated cutting edge, whether retouched or unretouched [17]. Nevertheless, the specific use of burins cannot be demonstrated, as similar functional edges occur on several other tool types, including unretouched flakes [25].

A clear distinction between the archaeological and experimental engravings lies in the more pronounced U-shaped cross-sections observed in the former. This feature can be consistent with the use of smoothed cutting edges, or more precisely, a previously used tool. Experimental studies show that grooves become progressively more U-shaped when actions are repeated with the same implement [14], and the archaeological engravings display more U-shaped profiles than those produced experimentally. Moreover, the similarity of RTF values across the different areas of the figure suggests that the edge of the tool(s) was already smoothed when the first grooves were executed.

Two non-mutually exclusive hypotheses may account for this pattern: tools may have been used for multiple tasks before engraving, or specific implements may have been repeatedly used for engraving activities. Whether such tools were shared within the group or belonged to individuals possessing particular technical skills cannot be determined. However, the latter possibility finds some support in the presence of distinctive ownership-like incisions on certain objects from the Epigravettian of Grotta Paglicci, such as retouchers [6].

When considered together, the reconstruction of the engraving sequence and the low variability observed in the morphometric data point to a highly controlled and consistent execution. The structured organisation of gestures, clearly distinguishing between contour, filling and secondary elements, combined with the regularity of groove morphology, suggests that the engraver was able to maintain stable motor behaviour throughout the entire process.

Such consistency is unlikely to result from occasional or unskilled engraving. Instead, it indicates a well-mastered technical practice, in which both the gesture and the interaction between tool and surface were finely controlled. In this sense, the engraved figure not only reflects representational intent, but also embodies a learned and stabilised technical skill, possibly acquired through repeated engagement with similar actions.

This interpretation is further supported by the limited variability of cross-sectional profiles across different areas of the composition, which is comparable to that observed in experimental series produced using a single tool under controlled conditions. Together, these elements suggest that the production of the engraving was guided by both a planned sequence of actions and a high degree of motor expertise.

The integration of iconographic and technological evidence reveals a deliberate representational strategy supported by refined technical control.

5. Conclusions

This study provides an integrated technological analysis of an engraved portable art object from the Epigravettian of Grotta Paglicci, combining microscopic observations, 3D morphometry and experimental comparisons.

The reconstruction of the engraving sequence shows that the figure was produced through a structured series of gestures, involving contour engraving, internal filling and the addition of

secondary elements. Morphometric analyses reveal a remarkably low variability among the incisions, pointing to a high degree of motor control throughout the engraving process.

The predominance of U-shaped cross-sections and the homogeneity of morphometric values across different parts of the composition are compatible with results obtained with the use of a single tool with a previously used and partially smoothed cutting edge. Anyway, this interpretation remains speculative due to the lack of more robust experimentation.

Taken together, these results indicate stable and well-controlled technical execution, consistent with a learned and practised engraving behaviour. More broadly, this study highlights the potential of integrated technological and morphometric approaches for investigating gesture organisation and technical choices in Upper Palaeolithic portable art.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/heritage9050188/s1, Table S1: Measurements and coordinates.

Author Contributions: Conceptualization, S.A. and F.B.; methodology, S.A. and F.B.; software, F.B. and J.C.; validation, S.A., E.M. and F.B.; formal analysis, S.A., E.M. and F.B.; investigation, S.A., E.M. and F.B.; resources, A.R.; data curation, S.A. and E.M.; writing—original draft preparation, S.A. and F.B.; writing—review and editing, S.A., E.M., M.R., J.C., S.R., A.R. and F.B.; visualisation, S.A., E.M., F.B., M.R. and S.R.; supervision, A.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The dataset created and analysed during the current study is included in the Supplementary Materials, as well as codes for the R software.

Acknowledgments: We would like to pay tribute to Arturo Palma di Cesnola, whose dedication and professionalism made this study possible. We are grateful to the Soprintendenza Archeologia Belle Arti e Paesaggio BAT e Foggia for their support and permission over the years. The authors are grateful to Daniele Aureli for his contribution to the already published experimental component of this project.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Crémades, M. Analyse et reconstitution technologiques en art mobilier paléolithique. L'exemple du glouton gravé sur bâton perforé de La Madeleine (Dordogne). *L'Anthropol* **1992**, *96*, 319–336.
2. d'Errico, F. Technology, motion and the meaning of Epipalaeolithic engraved stones. *Curr. Anthropol.* **1992**, *33*, 94–109. [CrossRef] [PubMed]
3. Fritz, C. *La Gravure Dans L'art Mobilier Magdalénien, du Geste à la Représentation*; Édition de la Maison de Science de l'Homme: Paris, France, 1999; 218p.
4. Marshack, A. Upper Paleolithic notation and symbol. *Science* **1972**, *178*, 817–828. [CrossRef] [PubMed]
5. Marshack, A. Some implications of the Palaeolithic symbolic evidence for the origin of language. *Curr. Anthropol.* **1976**, *17*, 274–828. [CrossRef]
6. Arrighi, S.; Borgia, V.; d'Errico, F.; Ronchitelli, A. I ciottoli decorati di Paglicci: Raffigurazioni e utilizzo. *Riv. Sci. Preist.* **2008**, *58*, 39–58.
7. Arrighi, S.; Borgia, V.; d'Errico, F.; Ronchitelli, A. Manifestazioni d'arte inedite e analisi tecnologica dell'arte mobiliare di Grotta Paglicci (Rignano Garganico—Foggia). *Preist. Alp.* **2012**, *46*, 49–58.
8. d'Errico, F. L'art gravée azilien. In *De la Technique à la Signification*; CNRS Édition: Paris, France, 1995; 332p.
9. d'Errico, F.; Vanhaeren, M. Les méthodes d'analyse de l'art mobilier paléolithique. Quelques exemples issus de la région Cantabrique. *Anthropol. Préhist.* **1999**, *110*, 31–45.
10. D'Errico, F.; Giacobini, G.; Puech, P.-F. An Experimental Study of the Technology of Bone-Implement Manufacture. *MASCA J.* **1984**, *3*, 71–74.
11. Fritz, C.; Menu, M.; Tosello, G.; Walter, P. La gravure sur os au Magdalénien: Etude microscopique d'une côte de la grotte de la Vache commune d'Alliat, Ariège. *Bull. Société Préhistorique Française* **1993**, *90*, 411–425. [CrossRef]

12. Averbouh, A. Technologie de la Matière Osseuse Travaillée et Implications Palethnologiques [Microform]: L'Exemple Des Chaînes D'Exploitation du Bois de Cervidé Chez Les Magdaleniens Des Pyrenées. Ph.D. Thesis, Université de Paris I, Paris, France, 2000.
13. Rivero Vilá, O. La Noción de Aprendizaje En El Arte Mobiliar Del Magdaleniense Medio Cántabro-Pirenaico: La Contribución Del Análisis Microscópico. *Trab. Prehist.* **2011**, *68*, 275–295. [CrossRef]
14. Bello, S.M.; Soligo, C. A new method for the quantitative analysis of cutmark micromorphology. *J. Archaeol. Sci.* **2008**, *35*, 1542–1552. [CrossRef]
15. Bello, S.M.; Parfitt, S.A.; Stringer, C. Quantitative micromorphological analyses of cut marks produced by ancient and modern handaxes. *J. Archaeol. Sci.* **2009**, *36*, 1869–1880. [CrossRef]
16. Bello, S.M.; De Groote, J.; Delbarre, G. Application of 3-dimensional microscopy and micro-CT scanning to the analysis of Magdalenian portable art on bone and antler. *J. Archaeol. Sci.* **2013**, *40*, 2464–2476. [CrossRef]
17. Boschin, F.; Crezzini, J. Morphometrical Analysis on Cut Marks Using a 3D Digital Microscope. *Int. J. Osteoarchaeol.* **2012**, *22*, 549–562. [CrossRef]
18. Courtenay, L.A.; Yravedra, J.; Huguet, R.; Ollé, A.; Aramendi, J.; Maté-González, M.Á.; González-Aguilera, D. New taphonomic advances in 3D digital microscopy: A morphological characterisation of trampling marks. *Quat. Int.* **2019**, *517*, 55–66. [CrossRef]
19. Courtenay, L.A.; Yravedra, J.; Mate-González, M.Á.; Aramendi, J.; González-Aguilera, D. 3D analysis of cut marks using a new geometric morphometric methodological approach. *Archaeol. Anthropol. Sci.* **2019**, *11*, 651–665. [CrossRef]
20. Güth, A. Using 3D scanning in the investigation of Upper Palaeolithic engravings. *J. Archaeol. Sci.* **2012**, *39*, 3105–3114. [CrossRef]
21. Majkić, A.; d'Errico, F.; Stepanchuk, V. Assessing the significance of Palaeolithic engraved cortexes. A case study from the Mousterian site of Kiik-Koba, Crimea. *PLoS ONE* **2018**, *13*, e0195049. [CrossRef]
22. Maté González, M.A.; Yravedra, J.; González-Aguilera, D.; Palomeque-González, J.F.; Domínguez-Rodrigo, M. Micro-photogrammetric characterization of cut marks on bones. *J. Archaeol. Sci.* **2015**, *62*, 128–142. [CrossRef]
23. Brochard, É.; Doyon, L.; Courtenay, L.; Tosello, G.; d'Errico, F. Carved in stone: Experimental criteria for identifying Paleolithic bas-relief production techniques and sculptors' expertise. *PLoS ONE* **2023**, *21*, e0346099. [CrossRef]
24. Boschin, F.; Moretti, E.; Crezzini, J.; Arrighi, S. Geometric morphometrics reveal relationship between cut-mark morphology and cutting tools. *Acta IMEKO* **2021**, *10*, 109–113. [CrossRef]
25. Moretti, E.; Arrighi, S.; Boschin, F.; Crezzini, J.; Aureli, D.; Ronchitelli, A. Using 3D microscopy to analyze experimental cut marks on animal bones produced with different stone tools. *Ethnobiol. Lett.* **2015**, *6*, 267–275. [CrossRef]
26. Val, A.; Costamagno, S.; Discamps, E.; Chong, S.; Claud, E.; Deschamps, M.; Mourre, V.; Soulier, M.-C.; Thiébaut, C. Testing the influence of stone tool type on microscopic morphology of cutmarks: Experimental approach and application to the archaeological record with a case study from the Middle Palaeolithic site of Noisetier Cave (Fréchet-Aure, Hautes-Pyrénées, France). *J. Archaeol. Sci. Rep.* **2017**, *11*, 17–28. [CrossRef]
27. Courtenay, L.A.; Yravedra, J.; Aramendi, J.; Maté-González, M.Á.; Martín-Perea, D.M.; Uribelarrea, D.; Baquedano, E.; González-Aguilera, D.; Domínguez-Rodrigo, M. Cut marks and raw material exploitation in the lower pleistocene site of Bell's Korongo (BK, Olduvai Gorge, Tanzania): A geometric morphometric analysis. *Quat. Int.* **2019**, *526*, 155–168. [CrossRef]
28. Yravedra, J.; Maté-González, M.Á.; Palomeque-González, J.F.; Aramendi, J.; Estaca-Gómez, V.; San Jauan Blazquez, M.; García-Vargas, E.; Organista, E.; Gónzalez-Aguilera, D.; Arriaza, M.C.; et al. A new approach to raw material use in the exploitation of animal carcasses at BK (Upper Bed II, Olduvai Gorge, Tanzania): A micro-photogrammetric and geometric morphometric analysis of fossil cut marks. *Boreas* **2017**, *46*, 860–873. [CrossRef]
29. Maté González, M.A.; Palomeque-González, J.F.; Yravedra, J.; González-Aguilera, D.; Domínguez-Rodrigo, M. Micro-photogrammetric and morphometric differentiation of cut marks on bones using metal knives, quartzite and flint flakes. *Archaeol. Anthropol. Sci.* **2016**, *4*, 805–816. [CrossRef]
30. Martellotta, E.F.; Vettese, D.; Nora, D.; Reshef, H.; Mistri, R.; Courtenay, L.A.; d'Errico, F.; Brenet, M.; Vosges, J.; Herzlinger, G.; et al. From edge to mark. Investigating the relationship between cut marks and lithic raw materials. *Front. Environ. Archaeol.* **2026**, *5*, 1738188. [CrossRef]
31. Dubinsky, L.; David, M.; Grosman, L. Recognizing technique variation in rock engravings: ArchCUT3-D for micromorphological analysis. *Humanit. Soc. Sci. Commun.* **2023**, *10*, 316. [CrossRef]
32. Płonka, T.; Wiśniewski, A.; Marciszak, A.; Ziółkowski, G.; Lipecki, G.; Diakowski, M.; Serwatka, K. A Middle Palaeolithic incised bear bone from the Dziadowa Skała Cave, Poland: The oldest marked object north of the Carpathian Mountains. *J. Archaeol. Sci.* **2024**, *166*, 105971. [CrossRef]
33. Goder-Goldberger, M.; Marreiros, J.; Paixão, E.; Hovers, E. Incised stone artefacts from the Levantine Middle Palaeolithic and human behavioural complexity. *Archaeol. Anthropol. Sci.* **2025**, *17*, 27. [CrossRef]
34. Beltramone, L.; De Lucia, V.; Ermini, A.; Innocenti, M.; Silvestri, D.; Rindinella, A.; Ronchitelli, A.; Ricci, S.; Boschin, F.; Salvini, R. Applying SLAM-based LiDAR and UAS technologies to evaluate the rock slope stability of the Grotta Paglicci Paleolithic site (Italy). *GeoHaz* **2024**, *5*, 457–484. [CrossRef]

35. Palma di Cesnola, A. Il sito. In *Paglicci. L'Aurignaziano e il Gravettiano Antico*; Palma di Cesnola, A., Ed.; Grenzi: Foggia, Italy, 2004; pp. 13–14.
36. Zorzi, F. Palaeolithic discoveries in the Grotta Paglicci. *Antiquity* **1964**, *38*, 38–44. [CrossRef]
37. Borgia, V.; Boschin, F.; Ronchitelli, A. Bone and antler working at Grotta Paglicci (Rignano Garganico, Foggia, Southern Italy). *Quat. Int.* **2016**, *403*, 23–39. [CrossRef]
38. Boschin, F. Exploitation of carnivores, lagomorphs and rodents at Grotta Paglicci during the Epigravettian: The dawn of a new subsistence strategy? *J. Archaeol. Sci. Rep.* **2019**, *26*, 101871. [CrossRef]
39. Boschin, F.; Bernardini, F.; Pilli, E.; Vai, S.; Zanolli, C.; Tagliacozzo, A.; Fico, R.; Fedi, M.; Corny, J.; Dreossi, D.; et al. The first evidence for Late Pleistocene dogs in Italy. *Sci. Rep.* **2020**, *10*, 13313. [CrossRef]
40. Palma di Cesnola, A. *Le Paléolithique Supérieur en Italie*; Jérôme Millon: Grenoble, France, 2001.
41. Palma di Cesnola, A. La sequenza stratigrafica della grotta. In *Paglicci. L'Aurignaziano e il Gravettiano Antico*; Palma di Cesnola, A., Ed.; Grenzi: Foggia, Italy, 2004; pp. 21–25.
42. Palma di Cesnola, A. L'Aurignacien et le Gravettien ancien de la grotte Paglicci. *L'Anthropol* **2006**, *110*, 355–370.
43. Palma di Cesnola, A. Le industrie di Grotta Paglicci: Strati 9–8. *Rass. Arch.* **2011**, *23*, 11–54.
44. Ricci, S.; Capecchi, G.; Boschin, F.; Arrighi, S.; Ronchitelli, A.; Condemi, S. Toothpick use among Epigravettian humans from Grotta Paglicci. *Int. J. Osteoarchaeol.* **2016**, *26*, 281–289. [CrossRef]
45. Ronchitelli, A.; Mugnaini, S.; Arrighi, S.; Atrei, A.; Capecchi, G.; Giamello, M.; Longo, L.; Marchettini, N.; Viti, C.; Moroni, A. When technology joins symbolic behaviour: The Gravettian burials at Grotta Paglicci. *Quat. Int.* **2015**, *359*, 423–441. [CrossRef]
46. Boscato, P.; Palma di Cesnola, A. Nuovi ritrovamenti di Epigravettiano antico iniziale a Grotta Paglicci (Rignano Garganico, Foggia). In *Studi sul Paleolitico, Mesolitico e Neolitico del Bacino Dell'Adriatico*; Biagi, P., Ed.; Società per la Preistoria e Protostoria della Regione Friuli-Venezia Giulia: Trieste, Italy, 2000; pp. 45–60.
47. Boscato, P.; Palma di Cesnola, A. L'industria e la fauna del livello 1A dell'area esterna di Paglicci (Promontorio del Gargano). In *25° Convegno Sulla Preistoria e Storia Della Daunia*; Gravina, A., Ed.; Archeoclub d'Italia: San Severo, Italy, 2005; pp. 3–15.
48. Boscato, P.; Ronchitelli, A. La serie esterna di Paglicci. Gli scavi del 2004–2005. In *26° Convegno Sulla Preistoria, Protostoria e Storia Della Daunia*; Gravina, A., Ed.; Archeoclub d'Italia: San Severo, Italy, 2006; pp. 3–16.
49. Crezzini, J.; Boscato, P.; Ricci, S.; Ronchitelli, A.; Spagnolo, V.; Boschin, F. A spotted hyaena den in the Middle Palaeolithic of Grotta Paglicci. *Archaeol. Anthropol. Sci.* **2016**, *8*, 227–240. [CrossRef]
50. Arrighi, S.; Borgia, V.; Guasparri, G.; Ricci, S.; Scala, A.; Ronchitelli, A. Grotta Paglicci (Rignano Garganico, Foggia): Analisi sulle materie coloranti. *Preist. Alp.* **2012**, *46*, 91–92.
51. Zorzi, F. Pitture parietali e oggetti d'arte mobiliare del Paleolitico scoperti nella Grotta Paglicci. *Riv. Sci. Preist.* **1963**, *17*, 123–137.
52. Sigari, D. *Palaeolithic Rock Art of the Italian Peninsula*; Archivi; Edizioni del Centro: Capo di Ponte, Italy, 2022; ISBN 978-88-86621-62-5.
53. Mezzena, F.; Palma di Cesnola, A. Nuove manifestazioni d'arte epigravettiana della Grotta Paglicci. *AttiIIPP* **1992**, *28*, 277–292.
54. Palma di Cesnola, A. La posizione cronologica delle principali manifestazioni d'arte di Grotta Paglicci. In *Atti del VI Convegno Sulla Preistoria Della Daunia*; Mundi, B., Gravina, A., Eds.; Archeoclub d'Italia: San Severo, Italy, 1987; pp. 23–25.
55. Palma di Cesnola, A. *Paglicci ed il Paleolitico del Gargano*; Claudio Grenzi Editore: Foggia, Italy, 2003.
56. Mezzena, F. Grotta Paglicci: Scoperta di un nuovo gruppo d'incisioni schematiche del tardo Paleolitico. *Taras* **1983**, *3*, 1–2.
57. Mezzena, F.; Palma di Cesnola, A. Oggetti d'arte mobiliare nella Grotta Paglicci. *Riv. Sci. Preist.* **1972**, *27*, 211–224.
58. Mezzena, F.; Palma di Cesnola, A. L'arte paleolitica nel Gargano. In *Atti del VI Convegno Sulla Preistoria Della Daunia*; Mundi, B., Gravina, A., Eds.; Archeoclub d'Italia: San Severo, Italy, 1987; pp. 17–22.
59. Mezzena, F.; Palma di Cesnola, A. L'arte mobiliare di Grotta Paglicci: Nuove acquisizioni. *Riv. Sci. Preist.* **2004**, *54*, 291–320.
60. Berto, C.; Boscato, P.; Boschin, F.; Luzi, E.; Ronchitelli, A. Paleoenvironmental and paleoclimatic context during the Upper Palaeolithic in the Italian Peninsula: The small mammal record from Grotta Paglicci. *Quat. Sci. Rev.* **2017**, *168*, 30–41. [CrossRef]
61. Rossini, M.; Falcucci, A.; Dominici, C.; Ronchitelli, A.; Tomasso, A.; Boschin, F. Analytical Potential of 2D Shape Analysis to Study Epigravettian Lithic Assemblages. *MetroArchaeo* **2022**, *2022*, 52–56. [CrossRef]
62. Rossini, M.; Falcucci, A.; Dominici, C.; Ronchitelli, A.; Tomasso, A.; Boschin, F. Application of 2D shape analysis to study Epigravettian lithic assemblages: Assessing its analytical potential. *Acta IMEKO* **2023**, *12*, 1–8. [CrossRef]
63. Rossini, M. Hunting Strategies and Behavioural Dynamics of Early Epigravettian Hunters-Gatherers in Southern Italy. Lithic Analysis: Reconstruction of Reduction Sequences Connected to Projectile Weapons at the Cave Sites of Grotta Paglicci and Grotta Della Cala. Ph.D. Thesis, Dipartimento di Scienze Fisiche, Della Terra e dell'Ambiente, Università Degli Studi di Siena, Siena, Italy, 2024.
64. Rossini, M.; Tomasso, A.; Boschin, F.; Martini, I.; Crezzini, J.; Dominici, C.; Moroni, A. Early Epigravettian backed pieces from layer O of Grotta della Cala (Southern Italy). A techno-typological and use-wear integrated approach. *J. Archaeol. Sci. Rep.* **2025**, *62*, 105046. [CrossRef]

65. Boschin, F.; Boscato, P.; Berto, C.; Crezzini, J.; Ronchitelli, A. The palaeoecological meaning of macromammal remains from archaeological sites exemplified by the case study of Grotta Paglicci (Upper Palaeolithic, southern Italy). *Quat. Res.* **2018**, *90*, 470–482. [CrossRef]
66. Abbazzi, L.; Delgado Huertas, A.; Iacumin, P.; Longinelli, A.; Ficcarelli, G.; Masini, F.; Torre, D. Mammal changes and isotopic biogeochemistry: An interdisciplinary approach to climatic-environmental reconstructions at the last Pleniglacial/Late-Glacial transition in the Paglicci Cave section (Gargano, Apulia, SE Italy). *Quaternario* **1996**, *9*, 573–580.
67. Delgado Huertas, A.; Iacumin, P.; Longinelli, A. A stable isotope study of fossil mammal remains from Paglicci Cave. *Chem. Geol.* **1997**, *141*, 211–223. [CrossRef]
68. Iacumin, P.; Bocherens, H.; Delgado Huertas, A.; Mariotti, A.; Longinelli, A. Stable isotope study of fossil mammal remains from Paglicci Cave. *Earth Planet. Sci. Lett.* **1997**, *148*, 349–357. [CrossRef]
69. Satta, S.; Renault-Miskovsky, J. Le paléoenvironnement des Pouilles. *Bull. Assoc. Fr. Étude Quat.* **1985**, *22*, 219–227.
70. d'Errico, F. Nouveaux indices et nouvelles techniques microscopiques pour la lecture de l'art gravé mobilier. *Comptes Rendus l'Acad. Sci. Paris* **1987**, *304*, 761–764.
71. d'Errico, F. Microscopic and statistical criteria for the identification of prehistoric systems of notation. *Rock Art Res.* **1991**, *8*, 83–93.
72. Maté-González, M.-Á.; Aramendi, J.; Yravedra, J.; Blasco, R.; Rosell, J.; González-Aguileira, D.; Domínguez-Rodrigo, M. Assessment of statistical agreement of three techniques for the study of cut marks: 3D digital microscope, laser scanning confocal microscopy and micro-photogrammetry. *J. Microsc.* **2017**, *267*, 356–370. [CrossRef] [PubMed]
73. Maté-González, M.-Á.; Courtenay, L.; Aramendi, J.; Yravedra, J.; Mora, R.; González-Aguileira, D.; Domínguez-Rodrigo, M. Application of geometric morphometrics to the analysis of cut mark morphology on different bones of differently sized animals. Does size really matter? *Quat. Int.* **2019**, *527*, 33–44. [CrossRef]
74. Duches, R.; Nannini, N.; Romandini, M.; Boschin, F.; Crezzini, J.; Peresani, M. Identification of Late Epigravettian hunting injuries. *J. Archaeol. Sci.* **2016**, *66*, 88–102. [CrossRef]
75. Hammer, Ø.; Harper, D.A.T.; Ryan, P.D. PAST: Paleontological statistics software package for education and data analysis. *Palaeontol. Electron.* **2001**, *4*, 9.
76. Rohlf, F.J. *tpsUtil*, Version 1.58; State University of New York, Stony Brook: New York, NY, USA, 2013.
77. Rohlf, F.J. *tpsDig*, Version 2.17; State University of New York, Stony Brook: New York, NY, USA, 2013.
78. R Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2021. Available online: https://www.R-project.org/ (accessed on 1 May 2026).
79. Grosman, L.; Muller, A.; Dag, I.; Goldgeier, H.; Harush, O.; Herzlinger, G.; Nebenhaus, K.; Valetta, F.; Yashuv, T.; Dick, N. Artifact3-D: New software for accurate, objective and efficient 3D analysis and documentation of archaeological artifacts. *PLoS ONE* **2022**, *17*, e0268401. [CrossRef]
80. Courtenay, L.A.; Maté-González, M.-Á.; Aramendi, J.; Yravedra, J.; González-Aguileira, D.; Domínguez-Rodrigo, M. Testing accuracy in 2D and 3D geometric morphometric methods for cut mark identification and classification. *PeerJ* **2018**, *6*, e5133. [CrossRef] [PubMed]
81. Conard, N.J. Palaeolithic ivory sculptures from southwestern Germany and the origins of figurative art. *Nature* **2003**, *426*, 830–832. [CrossRef] [PubMed]
82. Clottes, J. *La Grotte Chauvet: L'art des Origins*; Le Seuil: Paris, France, 2001.
83. Pigeaud, R.; Hinguant, S.; Paitier, H.; Pommier, V.; Bonic, P. La grotte Margot (Thorigné-en-Charnie). *Bull. Soc. Préhist. Ariège-Pyrénées* **2012**, *67*, 81–101.
84. Nicolau-Guillaumet, P. Avifaune et art pale' olithique. Essai pour une bibliographie exhaustive. *Alauda* **2008**, *76*, 287–298.
85. Sigari, D.; Mazzini, I.; Conti, J.; Forti, L.; Lembo, G.; Mecozzi, B.; Muttillo, B.; Sardella, R. Birds and Bovids: New Parietal Engravings at the Romanelli Cave, Apulia. *Antiquity* **2021**, *95*, 1387–1404. [CrossRef]
86. Crémades, M. Le comportement des animaux à travers l'art paléolithique. *Cah. Vallée Couze* **1996**, *7*, 1–19.
87. Bueno Ramírez, P.; De Balbín Behrmann, R.; Alcolea González, J.J. Style v dans le bassin du Douro. *L'Anthropol* **2007**, *111*, 549–589. [CrossRef]
88. García-Diez, M.; Cacho Quesada, C. Beyond Leroi-Gourhan's Style IV: Portable Art at La Peña de Estebanvela Rock-Shelter (Segovia, Spain). *J. Anthropol. Archaeol.* **2015**, *3*, 23–36. [CrossRef]
89. Santos, A.T.; Aubry, T.; Barbosa, A.F.; García-Díez, M.; Sampaio, J.D. O final do ciclo gráfico paleolítico do Vale do Côa: A arte móvel do Fariseu (Muxagata, Vila Nova Foz Côa). *Portugalia* **2018**, *39*, 5–96. [CrossRef]
90. Domingo, I.; Roman, D. Beyond the Palaeolithic: Figurative Final Palaeolithic Art in Mediterranean Iberia. *Quat. Int.* **2020**, *564*, 100–112. [CrossRef]
91. Ibero, Á.; Ochoa, B.; García-Díez, M.; López-Calle, P. El final del ciclo gráfico de las sociedades cazadoras? Recolectoras: Arte mueble finipaleolítico de la Cueva de Arenaza (San Pedro de Galdames, Bizkaia). *Cuad. Prehist. Arqueol.* **2023**, *49*, 11–28. [CrossRef]

92. Sigari, D. The Figurative Motifs in the Portable Art of Grotta Romanelli (Southern Italy) within the Late Pleistocene Art Tradition of Southwestern Europe. *J. Arch. Sci. Rep.* **2026**, *71*, 105630. [CrossRef]
93. Abramova, Z.A.; Page, C.; Chard, C.S. Paleolithic art in U.S.S.R. *Arct. Anthropol.* **1967**, *4*, 1–179.
94. Abramova, Z.A. *L'art Paléolithique d'Europe Orientale et Sibérie*; Éditions Jérôme Millon: Grenoble, France, 1995.
95. Capitan, L.; Breuil, H.; Bourrinet; Peyrony, D. Observation sur un bâton de commandement orné de figurations animales et de personnages semi-humains. *Rev. Mens. Anthr. Paris* **1909**, *19*, 64–76.
96. Piette, E. *L'Art Pendant l'Âge du Renne*; Masson: Paris, France, 1907.
97. d'Errico, F.; Laroulandie, V. Art mobilier: Authentification et analyse technologiques des représentations aviaires des galets de la Croze. In *Catalogue D'exposition, Pré Proto Gallo Méro, Histoire de l'Ain en Archéo, Musée de Brou*; Musée de Brou: Bourg-en-Bresse, France, 1998; pp. 24–26.
98. Bosinski, G. Tierdarstellungen von Gönnersdorf. Nachträge zu Mammut und Pferd sowie die übringen Tierdarstellungen. In *Der Magdalenien Fundplatz Gönnersdorf, Band 9/Monographien des Römisch-Germanischen Zentralmuseums, Band 72*; Verlag es RGZM: Mainz, Germany, 2008.
99. Graziosi, P. *L'arte Preistorica in Italia*; Sansoni: Firenze, Italy, 1973.
100. Gala, M.; Tagliacozzo, A. Aspetti ecologici ed economici dell'avifauna del Tardoglaciale italiano. In *Atti del 6° Convegno Nazionale di Archeozoologia*; San Romano in Garfagnana: Lucca, Italy, 2009.
101. Crémades, M.; Pellicer, M.; Sanchidrián Torti, J.L. Nouvelles figurations d'oiseaux de l'art mobilier paléolithique franco-espagnol. *Paléo* **1997**, *9*, 371–387. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.