

# Late Upper Palaeolithic ornaments from Vlakno cave, Croatia

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**ABSTRACT** - *This paper presents the richest prehistoric assemblage of ornaments in the Eastern Adriatic discovered to date, found in the Late Upper Palaeolithic layers of Vlakno cave, Croatia. The abundance and multiform of bead types indicate that the site was likely used as a workshop for ornaments, i.e. that production was performed on site. Technological and use-wear analysis of each taxon used for beads allowed us to elaborate on its mode of production, use, and overall position of the Vlakno cave site and its role in the regional context during the Late Pleistocene.*

**KEY WORDS** - *ornaments; use-wear analysis; Late Upper Palaeolithic; Eastern Adriatic; Vlakno cave*

## Poznomlajšepaleolitski nakit v jami Vlakno, Hrvaška

**IZVLEČEK** - *V članku predstavljamo najbogatejšo doslej odkrito prazgodovinsko zbirko nakita na vzhodnem Jadranu, ki je bila najdena v poznomlajšepaleolitskih plasteh v jami Vlakno na Hrvaškem. Številčnost in raznolikost jagod nakazujeta, da je bilo najdišče verjetno uporabljano kot delavnica za nakit in da je proizvodnja potekala na kraju samem. Tehnološka analiza in analiza obrabe vsakega taksona, ki je bil uporabljen za izdelavo jagod, nam omogočata določiti način izdelave in uporabe ter mesto in vlogo jamskega najdišča Vlakno v regionalnem kontekstu v poznem pleistocenu.*

**KLJUČNE BESEDE** - *ornamenti; analiza sledov uporabe; pozni mlajši paleolitik; vzhodni Jadran; jama Vlakno*

## Introduction

During the Upper Palaeolithic period, craft specialization reflects the increasing complexity of human culture and behaviour. The development of sophisticated tools, artistic expression, and symbolic artefacts suggests that our ancestors possessed advanced cognitive abilities, social structures, and cultural practices. These crafts served practical purposes but also were crucial in expressing identity, spirituality, and social cohesion within Upper Palaeolithic societies. One of the recognized prehistoric crafts is the production of ornaments

(Rigaud et al. 2019). Personal ornaments have been, and continue to be, elements that embody and signify social and individual identity. Since the Upper Palaeolithic, our ancestors have crafted beads and pendants from various materials (e.g., Vanhaeren, d'Ericco 2006; Bar-Yosef 2015; Radović et al. 2015; Sehasseh et al. 2021). However, the only ones preserved are those made of inorganic and animal hard tissues like stone, clay, bone, ivory, teeth, and mollusc shells. In contrast, organic materials such as wood, leather, and

feathers that were likely used for ornamentation have decomposed and disappeared (Hurcombe 2014). Since Randall White (1992) highlighted the social and symbolic roots of ornaments' origin, prehistoric body adornment has been studied widely. However, there is still much to understand and learn about the symbolic behaviour of our ancestors. What were the modes of acquiring raw materials for ornamentation or the modalities of bead production, use, and finally discard? Obtaining information on these specific issues is not an easy task because of the archaeological contexts of their discovery. Prehistoric beads are rarely found *in situ* as a part of the preserved ornamental composition, *i.e.* as a part of burials (*e.g.*, Orschiedt 2016; Gravel-Miguel et al. 2022). Mostly, they are discovered scattered throughout the deposits or during the subsequent sieving of the sediment. Despite the challenging circumstances of their found state, detailed analysis of these mainly small-sized artefacts can provide important information about our ancestors' lifestyles and symbolic behaviour. In that sense, the Vlakno cave stands out as an important site for activities related to prehistoric ornaments in the wider Adriatic region during the Late Peniglacial and beginning of the Holocene. Integrated analysis of the most numerous col-

lection of *Columbella rustica* shells from Vlakno cave gave us solid arguments for how this prehistoric site was used as a specialized workshop for ornaments, especially during the Holocene (Cvitkušić et al. 2024). To strengthen the hypothesis of the site's role as a workshop for ornaments and to extend it to the Upper Palaeolithic period, here we present a detailed analysis of the ornaments discovered in the Epigravettian layers of Vlakno cave, which is to date the richest discovered assemblage of ornaments in the Eastern Adriatic. Moreover, a thorough analysis of each taxon used for beads during the Pleistocene in Vlakno cave allowed us to elaborate on its mode of production and use in the regional context spanning a period of almost 10 000 years.

### Site background

The Vlakno cave is situated on the island of Dugi Otok on the Eastern Adriatic coast of present-day Croatia (Fig. 1). The cave is positioned on the eastern slopes of the central part of the island, 150m away from today's seashore (Fig. 2.a). A wide opening oriented towards south/south-east and the small inner cave space of about 40m<sup>2</sup> made it ideal for small groups of foragers during the Upper Palaeolithic and the Early Mesolithic (Vujević, Parica 2011; Vujević, Bodružić 2014; 2021; Vukosavljević et al. 2014; Vujević 2016; 2021; Cvitkušić et al. 2018). The potential of the cave for such use is additionally emphasized by a spring in the immediate vicinity, next to today's beach (Brusić 2004:198; Vujević 2018:41; 2021:35).

Research in the cave started with a small test trench (2m<sup>2</sup>) in 2004 (Brusić 2004). Research was continued in 2007 (Brusić 2007:400–401), and systematic excavations began in 2011. They covered an area of 12m<sup>2</sup> east of the test trench.<sup>1</sup> The five-meter-deep test trench revealed numerous cultural layers which can be monitored with relative continuity to 19550–19400 cal BP (Beta-302247:

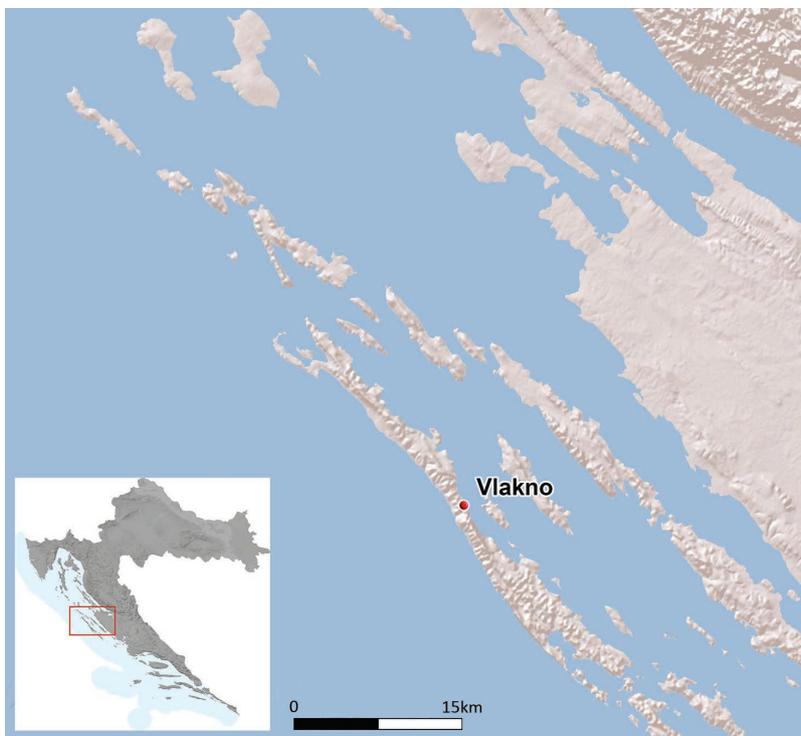


Fig. 1. Position of Vlakno cave on Dugi otok, Croatia.

<sup>1</sup> The research was carried out as part of two scientific research projects of the Croatian Science Foundation: Epigravettian communities of Northern Dalmatia (IP-2019-04-6115) and Transition and tradition in the Vlakno cave: Model of the transition from the Palaeolithic to the Mesolithic in the area of Northern Dalmatia (UIP-2014-09-1545).

16 330±70 BP). However, the bedrock has not been reached, so this depth regarding the archaeological stratigraphy is probably not final. Ongoing systematic excavations reached a 4 m depth from the surface (Fig. 2.b).

The stratigraphy reflects the potential of the site. The preliminary results of the geoarchaeological analysis show strong anthropogenic processes in almost all layers (Boschian pers. comm.). The stratigraphic sequence is intersected at a depth of approximately 2m by a 10–15cm thick layer of tephra (Neapolitan Yellow Tuff) from the eruption on the Phlegraean fields near Naples that happened 14.9±0.4 ka cal BP (Deino et al. 2004; Vujević 2021). The thick cultural layer and stratigraphy without visible hiatus (beside tephra) places Vlakno cave among the few sites in the wider Adriatic region that makes it possible to explore the last

phases of the Pleistocene after the Last Glacial Maximum (LGM) and adaptation of communities to the new climatic period of the Holocene (Vujević, Parica 2011; Vujević, Bodružić 2014; Vukosavljević et al. 2014; Vujević 2016; 2018; 2021; Cvitkušić et al. 2018).

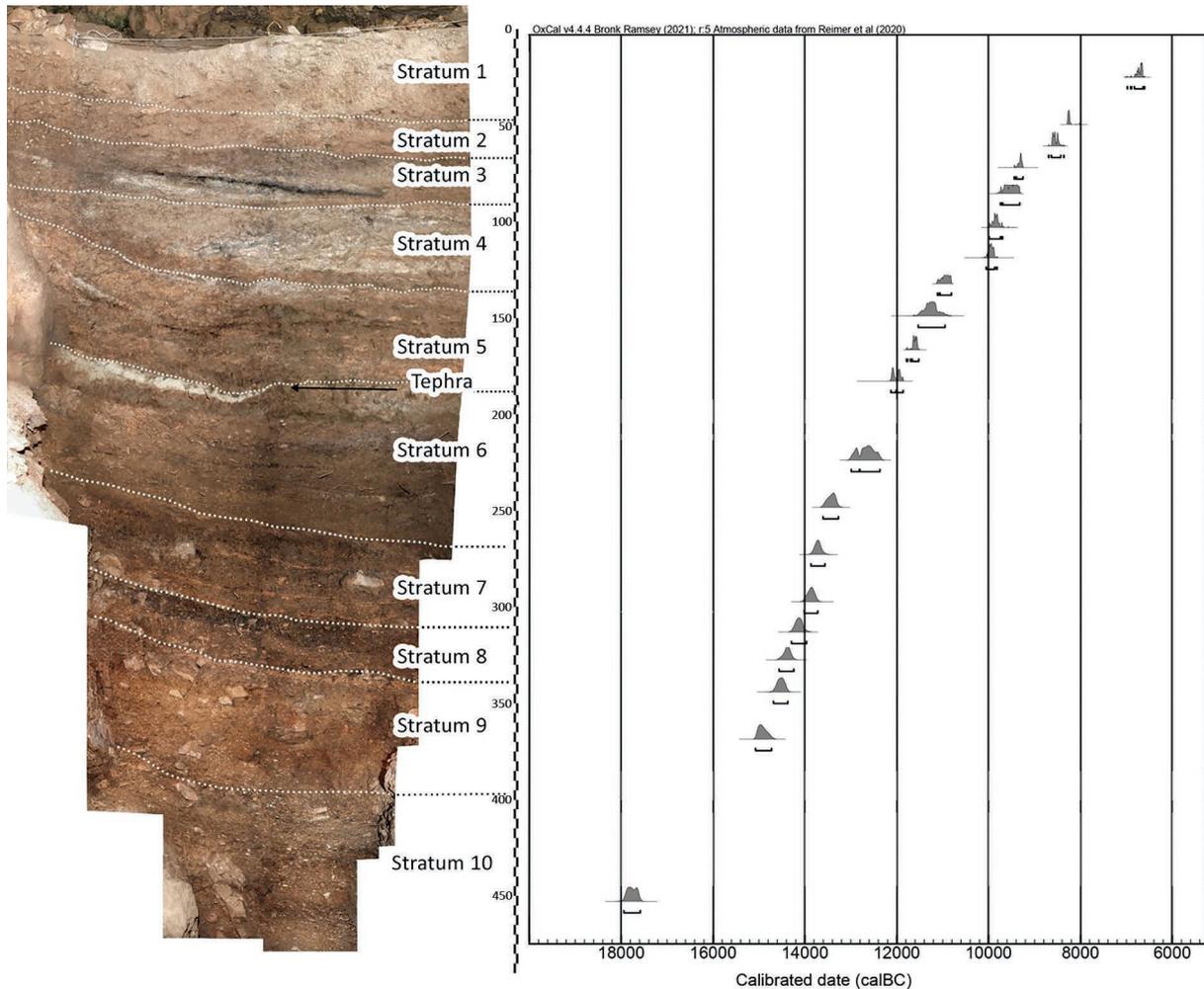
To date the stratigraphy of the Vlakno cave is divided into ten strata, five of which form the upper part of the stratigraphic sequence, the one above the tephra, while the other strata are in layers below it (Figure 3). Stratum 1 represents the surface layer. It is characterized by dominant Mesolithic finds mixed with a smaller amount of cultural material from other periods, from the Neolithic to the Modern Age. Strata 2 and 3 are associated with the very beginning of the Holocene. Chronologically, the Holocene occupation started ca. 11 300 cal BP (Beta327417 9860±40 BP, (94.2%) 9370–9260 cal BC; 11 320–11 210 cal BP) and lasted until c. 10 000 cal BP (Beta677951 9300±30 BP, (95.4%) 8179–7773 cal BC; 10 128–9722 cal BP; Vujević, Cvitkušić 2024).

Stratum 4 ends the Pleistocene, while Stratum 5 represents the first phase of the cave settlement after the eruption in the Phlegraean fields. The tephra layer served as a stratigraphic boundary between Stratum 5 and Stratum 6 (Vujević, Parica 2011.26; Vujević, Bodružić 2021). Strata 6–10 below the tephra layer represent various Late Upper Palaeolithic (LUP) phases. The dates cover the chronological period from about 15 000 to 19 500 cal BP. Stratum 10 includes the lowest layers from the test trench, although since these layers have not yet been reached through systematic excavations, the phasing could be somewhat different in the future.

In cultural terms, Strata 2 and 3 belong to the Early Mesolithic period. Although it corresponds temporally to the *Sauveterian* (see Visentin 2017), the characteristics of the lithic assemblage show little similarity with it, showing one more time that the use of the term Mesolithic in the Northern Adriatic context is primarily a chronological determinant (Miracle et al. 2000; Vukosavljević et al. 2014). Basically, almost the entire stratigraphic sequence of Vlakno cave is so far characterized by the



**Fig. 2.** A The position of Vlakno cave on the eastern slopes of the central part of the Dugi otok; B Inner place during systematic excavations.



**Fig. 3.** The stratigraphic sequence of Vlakno cave (D. Vujević).

Epigravettian cultural assemblage. Some differences can be noticed in the lithic assemblage of Stratum 2, but they relate to the frequency of different tool types without the emergence of new ones. There is a decrease in the number of endscrapers and backed tools, as well as in bladelets and blades usage for tool production (Vujević, Bodružić 2021). Faunal records show similar patterns, although with more pronounced changes during the transitional and especially Holocene period in which big game hunting (mostly red deer) continued to be practised but groups also made use of other available mammalian species, in particular small game and small to medium-sized carnivores such as foxes. Holocene groups also adapted and diversified their diets by including land snails, marine molluscs and fish (Radović et al. 2021). Lithic analyses by Vukosavljević (2012.127) and Dario Vujević and Mario Bodružić (2021) have shown that the occupation at Vlakno in all phases had a strong residential character. However, the question is whether it has always been the primary reason for choosing Vlakno. Nikola Vuko-

savljević (2012.128) has questioned the residential character of the site during the formation of Stratum 2 due to the presence of a Mesolithic burial in the small cave area. Other categories of finds, especially ornaments, could also indicate different functions of the place, at least in certain periods. A rich assemblage of personal ornaments in the form of beads and pendants is represented throughout the sequences. Besides ornaments made from modified shells and animal teeth, in Late Upper Palaeolithic deposits artefacts decorated with geometric incisions have also been discovered, such as an anthropomorphic bone pendant, two deer canines, an animal bone rib, and two fragments of chert nodules. As this paper focuses on the ornaments, such decorated artefacts will not be presented here.

### Material and methods

Throughout the Late Upper Palaeolithic deposits, 897 pieces of ornamental assemblage were discovered, of

which 413 are beads, 36 are unmodified specimens (Fig. 3; Tab. 1, see below), together with 448 fragments and debris. The ornamental assemblage is classified according to taxonomic and ecological/environmental attributes (see Methods), as follows: Class 1 – marine gastropods, bivalves, and scaphopods; Class 2 – freshwater gastropods; and Class 3 – terrestrial mammals. Table 1 presents the distribution of beads and unmodified specimens for each taxon throughout LUP layers. In particular, Class 1 is represented by gastropods *Columbella rustica*, *Tritia neritea*, *Luria lurida* and *Tritia nitida*; bivalves *Glycymeris* sp. and *Acanthocardia tuberculata*; scaphopods *Antalis* sp. In Class 2 are *Theodoxus danubialis* and *Lithoglyphus naticoides*, while in Class 3 are *Cervus elaphus* teeth. Out of 448 fragments and debris in the assemblage, 29 fragments belong to the *Glycymeris* shells and 419 to the posterior ends of *Antalis* sp., determined as production waste.

Taxonomical determination of marine species is done by the Atlas of the Mediterranean Seashells (Giannuzzi-Savelli et al. 2001; 2002; 2003), while the nomenclature follows the World Register of Marine Species (<https://www.marinespecies.org/index.php> – accessed on February 2019 and April 2020). The poor state of preservation and surface exfoliation made it impossible to taxonomically determine two marine species belonging to the *Glycymerididae* and *Dentaliidae* families. According to the literature, several similar scaphopod species were present along the Mediterranean shores during the Pleistocene (Poppe, Goto 1991). Formerly in the generic genus *Dentalium*, species from the Mediterranean are now attributed to the genus *Antalis* (H. Adams, A. Adams 1854). Vlakno specimens are likely a mix of more than one species e.g., *Antalis vulgaris*, *Antalis dentalis*, and *Antalis inaequicostata* that we group under the taxon *Antalis* sp. Regarding the *Glycymerididae* family, there are three determined species in the Adriatic Sea: *Glycymeris bimaculata* (Poli 1795), *Glycymeris glycymeris* (Linnaeus 1758) and *Glycymeris nummaria* (Lamarck 1758) (Legač, Hrs-Brenko 1999; Crnčević 2014). In earlier studies, *Glycymeris pilosa* (Linnaeus 1767) and *G. glycymeris* were mistakenly identified as *G. glycymeris* (e.g., Poppe, Goto 1991; Legač, Hrs-Brenko 1999; Peharda et al. 2010). Recently *G. pilosa* and *G. glycymeris* have been identified as two different species (Purroy et al. 2016). While *G. glycymeris* is well documented in the North Atlantic, its presence is poorly documented in the Mediterranean, compared to *G. pilosa* and *G. bimaculata*, which are well docu-

mented in the Adriatic Sea (Purroy et al. 2016; Legač, Hrs-Brenko 1999). Overall, the complex determination of bivalves is the reason for different data on the distribution of species of this genus (Legač, Hrs-Brenko 1999). Concerning the Vlakno case, characterized by poor preservation and surface exfoliation on a significant share of *Glycymeris* specimens, we have decided to group them under the taxon *Glycymeris* sp. *Tritia neritea* (Linnaeus 1758) is a species of marine gastropods that belongs to the *Nassariidae* family and is widespread in shallow waters of the Mediterranean, sandy shores of the Atlantic coast (e.g., in Portugal, Spain and France) as well as in coastal lagoons, salt-marshes and close to river mouths (Southward et al. 1997). Its distribution is also well recorded in the Adriatic region. All the marine species used for bead production in Vlakno cave can be found in the Adriatic Sea.

The taxonomy of freshwater gastropods is determined according to the literature (Mastitsky, Samilenko 2006; Komšo, Vukosavljević 2011; Cristiani 2012). *Theodoxus danubialis* is a common species of river snail present in the area of the Danube River, which can also be found in rivers and lakes from northern Italy to Slovakia, Ukraine, and Croatia (Hartzhauser et al. 2007). *Lithoglyphus naticoides* are present in the shallow waters of rivers and lakes in central and eastern Europe (Hartzhauser et al. 2007) as well as in the Balkans, in the rivers of the Black Sea drainage basin (Radoman 1983). Both species can be considered autochthonous.

Siniša Radović (Department of Palaeontology and Quaternary Geology, Croatian Academy of Sciences and Arts) determined the attribution of mammal teeth, while the sex determination of red deer canines was carried out according to the criteria in Francesco d'Er-rico and Marian Vanhaeren (2002).

The complete ornamental assemblage has undergone technological, use-wear, and residue analysis to reconstruct its production and use modalities. Our methodology integrates metric, technological, use-wear, and residue studies supported by taphonomical examination. Taxonomic identification was carried out on all specimens, including fragments. Morphometric measurements were taken to determine variability and frequencies. After visual inspection, the specimens were sorted according to their integrity into three groups: Group 1 – whole specimens with perforation; Group 2 – whole specimens without perforation; and Group

3 – broken specimens, fragments, and debris. Group 1 includes whole, undamaged perforated specimens and specimens with missing small parts, e.g., the apices of the gastropods, small parts of the roots, or crowns of the teeth.

Metrical variables are recorded with a digital calliper in two general categories: (1) the dimensions of maximum length and width (in mm) for all specimens (Groups 1, 2 and 3), and (2) the dimensions of maximum length and width (in mm) of hole for all perforated specimens (Group 1). For *Antalis* sp., additional dimensions were taken, in particular, the radius of the anterior and posterior extremities. Specimens with a radius of dorsal aperture ranging from 0.64 to 1.98mm are selected as waste, and those with an aperture equal or larger to 1.99mm as beads (Lindberg 2013; Arrighi et al. 2020). Concerning the length, *Antalis* beads are divided into three categories: Category 1 – beads smaller than 10.00mm; Category 2 – beads between 10.01 and 19.99mm; and Category 3 – beads longer than 20.00mm.

The taphonomic study was carried out on marine and freshwater shells' beads with a focus on pre-depositional alterations (predator drilling, bioerosion), anthropogenic modifications (perforations, ochre residues, thermal alterations), and post-depositional alterations (fragmentations, decalcifications) (Driscoll, Weltin 1973; Claassen 1998; Crothers 2004; d'Errico et al. 2005).

All specimens were analysed by low and high magnification using a Zeiss Axio Zoom V16 stereo microscope with progressive magnifications ranging between  $\times 10$  and  $\times 112$  and equipped with a Zeiss AxioCam 305/506 colour camera in the DANTE – Diet and Ancient Technology Laboratory, Sapienza University of Rome, Italy. The use-wear and technological analysis of beads aimed to identify functional modifications such as the rounding of the perforation, faceting of the profile, changes of colour, striations, and residues to discern patterns of acquisition, manufacturing, wear, use, and deposition/discard. The type and distribution of use-wear traces and residues on well-preserved perforated shells related to the perforation hole, the lip, and dorsal and ventral surfaces have been recorded. Use-wear traces and residues related to the root, crown, and perforation were recorded for teeth pendants. Interpretative criteria for the technological and functional study are established by previously conducted studies on the production and use of prehistoric orna-

ments (Tabarin 1993; Vanhaeren, d'Errico 2001; 2003; 2005; d'Errico, Vanhaeren 2002; Bonnardin 2007; 2009).

## Results

The LUP ornamental assemblage from Vlakno cave is rich and diverse (Fig. 4). Analysis showed that beads (N=413) were produced from ten different raw materials (Tab. 1 and Fig. 4), i.e. *Columbella rustica* (N=23), *Tritia neritea* (N=132), *Luria lurida* (N=1), *Tritia nitida* (N=7), *Glycymeris* sp. (N=29), *Acanthocardia tuberculata* (N=1), *Dentalium* sp. (N=183), *Theodoxus danubialis* (N=6), *Lythoglyphus naticoides* (N=2), and *Cervus elaphus* teeth (N=29). Throughout the LUP layers, 36 unmodified specimens of marine shells (N=18) and red deer canines (N=18) were discovered. Most of the LUP ornamental assemblage is well preserved.

### Marine molluscs

Of the marine species, *Columbella rustica* shells are the best preserved (Fig. 4.a). Most of the *C. rustica* shells are complete, while ~20% of specimens are missing lip or apex parts. Pitting and root damage are observed on two specimens. Almost 20% of perforated *C. rustica* shells are black, characterized by the even dark colour of the surface and core, likely resulting from controlled exposition to the fire (Perlès, Vanhaeren 2010). The natural pattern of the shell's surface is lost in most LUP *C. rustica* due to the various chemical and mineralogical changes that occur during the long-term residence in the sediment (Claassen 1998). The use-wear is detected on ~60% of the LUP *C. rustica* beads. The perforations are mostly round in shape. The integrated analysis determined that *C. rustica* beads from Vlakno cave were produced with a simple technique involving direct percussion with pebbles (Cvitkušić et al. 2024). Spots of red residues have been identified inside one LUP specimen.

Of the 134 *Tritia neritea* shells, 93 are whole and perforated, 25 are missing half of the perforation and outer lip area, and 14 are fragmented (Fig. 4.b). Almost 80% of the *T. neritea* shells are poorly preserved, with significant post-depositional alterations, such as exfoliated surfaces and concretions from the sediment. Analysis of less than 20% of well-preserved *T. neritea* beads showed they were used (Fig. 6.d,e). In a few specimens, the suspension mode is indicated by rounding in the lip area (Fig. 6.d,e). The perforations on *T. neritea* beads are oval in shape. A small share (~14%) of



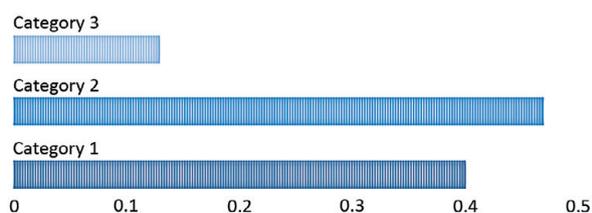
**Fig. 4.** Selection of LUP ornaments from Vlakno cave. A *Columbella rustica*; B *Tritia neritea*; C *Antalis* sp.; D *Lithoglyphus naticoides*; E *Tritia nitida*; F *Cervus elaphus* teeth; G *Luria lurida*; H *Acanthocardia tuberculata*; I *Glycymeris* sp.

the *T. neritea* beads are black, with an even colour and high surface polish, likely indicating deliberate burning (Perlès, Vanhaeren 2010; Perlès 2018). Ochre residues in the form of small stains and spots are detected on a dozen *T. neritea* located along the perforation hole, in the lip area, and on the two specimens all over the upper surface of the shell.

Significant surface exfoliation prevented the exact species determination of *Antalis* shells, as well as their processing and use modes (Fig. 4.c). Out of the total number of *Antalis* specimens (N=602), only 30% are beads, while the rest are waste with a dorsal aperture too narrow to be strung (Arrighi et al. 2020). *Antalis* sp. is the most represented taxa in the Vlakno LUP ornaments, but compared to the others its accumulation is mainly restricted to a single stratum with 95% of finds discovered in Stratum 6.1., i.e. layer 98 (Tab. 2, see below). The length of *Antalis* beads ranges from 1.93 to 30.09mm, with a mean of 12.31mm. The length

distribution shows that most of the beads fall into two categories: smaller than 10.00mm or between 10.01 and 19.99mm, respectively (Graph 1). Beads longer than 20.00mm are the least represented. *Antalis* shells were likely collected from thanatocoenoses as a significant share of specimens have surface abrasions, typical small holes drilled by predators, and sponge marks (Arrighi et al. 2020; Bar-Yosef Mayer 2008). Use-wear analysis of a small share of well-preserved beads (~20%) showed that most beads have polished extremities, most often with rounded rims and grooves, indicating that the beads were suspended and used (Fig. 5.h,i). Most used beads have ochre spots dispersed along the body's surface (Fig. 5.i). Identifying the production techniques for *Antalis* shell in Vlakno will remain a matter for future research.

Most *Tritia nitida* discovered in the layers above the tephra are poorly preserved with heavy surface exfoliation (Fig. 4.e). Of seven perforated *T. nitida* beads,



**Graph 1. Length frequencies of *Antalis* sp. beads: Category 1 >10.00mm; Category 2 10.01 – 19.99mm; Category 3 <20.00mm.**

use-wear with developed rounding along the perforation hole is observed on one specimen, but it cannot be distinguished if it is from the use or taphonomy.

*Glycymeris* sp. shells are present throughout the LUP deposits and are characterized by various states of integrity and size range, and notably there are 29 perforated whole valves, three unmodified whole valves, and fragments (N=38) (Fig. 4.i). Modified *Glycymeris* valves are perforated in the umbo area on the beak. Developed use-wear traces of the hole rim and polished hinge teeth with ochre residues are observed on a few large and better-preserved specimens, suggesting that these were likely suspended as ornaments (Fig. 5.f,g). Moreover, we have detected rounding of the edges, striation and ochre residues on a few randomly analysed fragments, which directed us to a more detailed study of the use of *Glycymeris* sp. in Vlakno cave in the future. In Stratum 9, a small perforated *Glycymeris* shell was discovered together with a perforated *Luria lurida* gastropod. Microscopic analyses of *Luria lurida* showed horizontal incisions and striation in the perforation area, indicating that the hole was made by horizontal sawing movements using a sharp tool (Fig. 4.G). One fragment conditionally attributed to *Luria lurida* from Stratum 6 was perforated using the same technique, with ochre residues all over the inner part and less on the external surface (Fig. 4.g).

One perforated and one whole unmodified valve of *Acanthocardia tuberculata* was discovered in the LUP layers above the tephra. A polished beak and elongated irregular perforation with rounded edges at the top of the umbo area with clear use-wear traces indicate extended use of perforated *A. tuberculata* specimen (Fig. 4.h).

#### **Freshwater molluscs**

Eight perforated freshwater gastropods were discovered in LUP deposits: six *Theodoxus danubialis* and two *Lithoglyphus naticoides* (Fig. 4.d). Poor preservation and surface alteration affected the observation

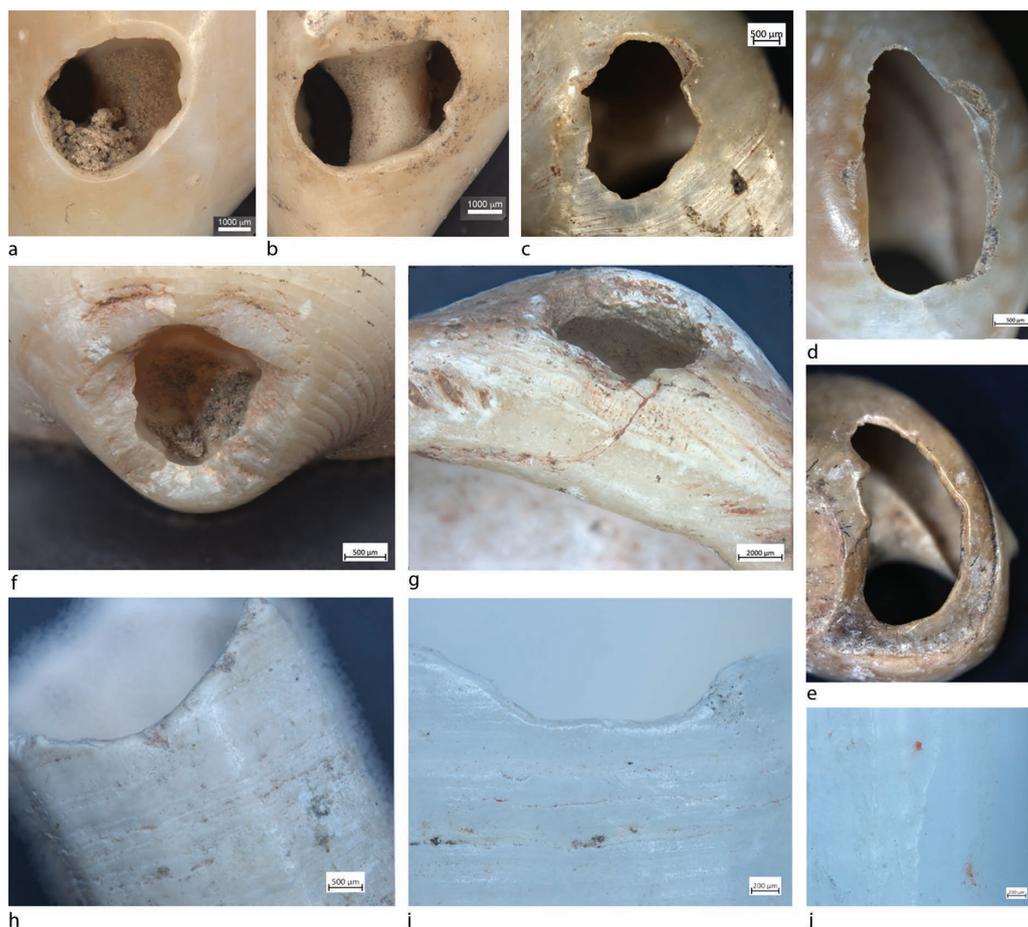
of possible use-wear traces on most specimens, while clear use is detected on one *Theodoxus danubialis* and one *Lithoglyphus naticoides* (Fig. 5.c). Perforations on all freshwater gastropods are oval. One *Theodoxus danubialis* is black, likely due to intentional heating.

#### **Mammal teeth**

Taxonomical analysis showed that all 47 mammal teeth from LUP deposits belong to *Cervus elaphus* (Figs. 4.f and 6). Specifically, there are 29 modified teeth: 26 whole perforated canines, two whole perforated incisors, and one canine with traces related to the initial stage of production (Fig. 6). There are 18 whole canines without traces of modification. Half of the unmodified teeth have flint traces in the ventral/labial bottom of the crown area, which results from the extraction activity, indicating the collection mode. Small parts of the root or crown are missing on almost half of the teeth. Female and male canines are almost equally represented. Use-wear analysis showed that all perforated teeth are used. Technological analysis of the perforation mode revealed two main production techniques. The first and most frequent one is characterized by bilaterally thinning, followed by scraping and grooving of the root surface (Fig. 6.c-k,n-p). The second, less represented technique is characterized by bilateral drilling of roots (Fig. 6.l,m). A significant share of teeth pendants have rounding on the lateral sides of the roots, indicating the suspension mode. One canine demonstrates unfinished perforation with the initial stage of the most represented production technique in Vlakno – bilateral grooving and thinning of the root (Fig. 6.q). The fracture encompassing the scraped surface of the root area indicates that this specimen may have been discarded during processing, as the tooth would break in the case of ongoing production activity. Few perforated teeth have lateral fractures in the perforation area or the broken tip of the hole in the root area. The asymmetric profile of the perforation holes, accompanied by a specific arrangement of inside striations, demonstrates that perforations were made manually. Moreover, anthropic production is supported by two canines with incised decorative notches on the lobe surface (Fig. 6a,b).

#### **Discussion and conclusion**

Our study emphasizes the significance of the Vlakno cave as a vital LUP site for understanding the production and use of ornaments in the Adriatic region. Additionally, it complements previous research on Holocene ornaments (Cvitkusić et al. 2024) extending the

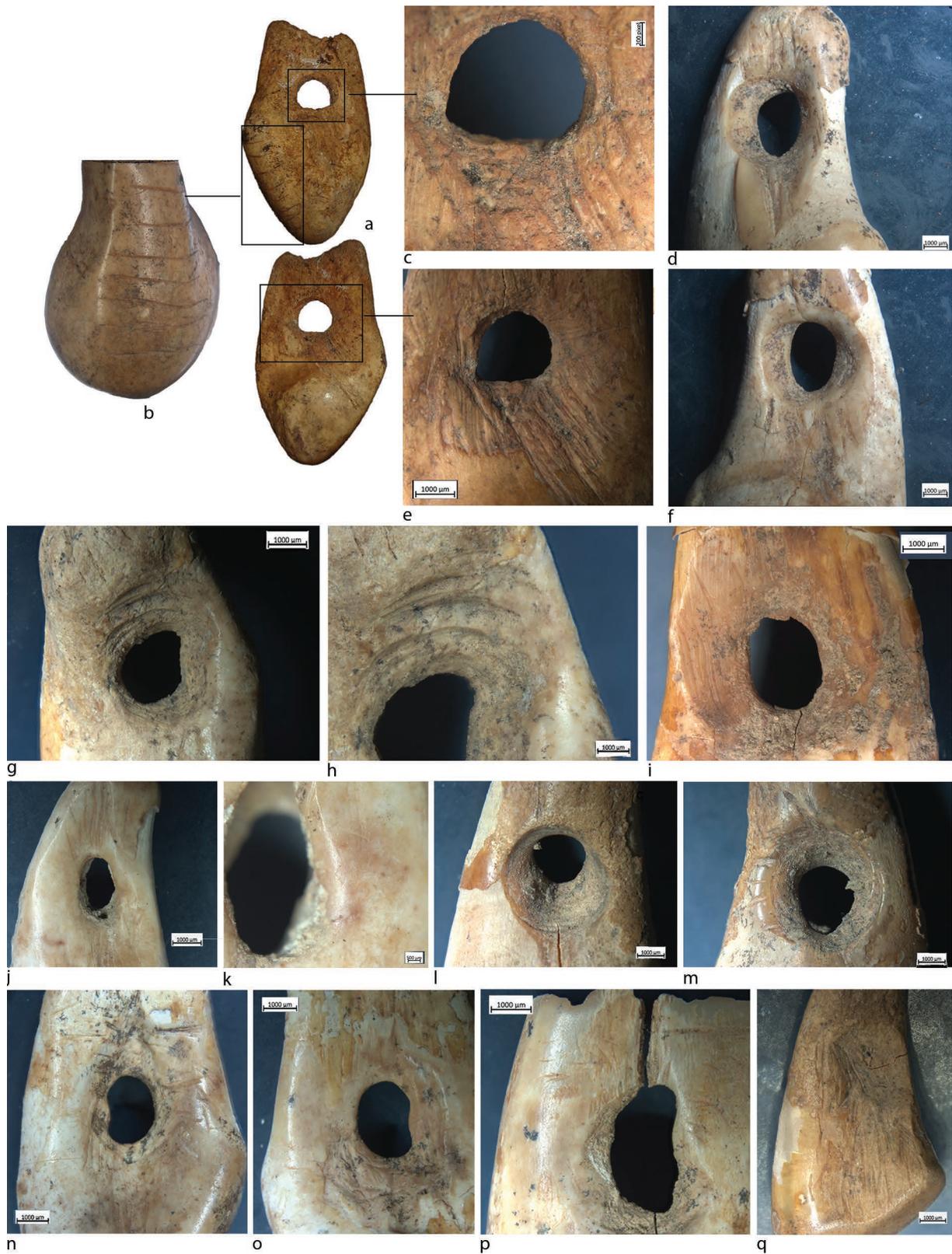


**Fig. 5.** Selection of use-wear and ocher traces on LUP shell ornaments from Vlakno cave presented by sample numbers: a *Columbella rustica* VL/O/78.4; b *Columbella rustica* VL/O/56.6; c *Lithoglyphus naticoides* VL/O/58.34; d *Tritia neritea* VL/O/58.22; e *Tritia neritea* VL/O/67.6; f *Glycymeris* sp. VL/O/58.18; g *Glycymeris* sp. VL/O/89.1; h *Antalis* sp. VL/O/101.9; i *Antalis* sp. VL/O/98.40; j *Antalis* sp. VL/O/97.99.

role of Vlakno cave as a production site for ornaments in the broader regional context to the Late Upper Palaeolithic.

From the LGM to the early Holocene, dramatic climate change profoundly affected the geography of this area, and the transformation of the Adriatic Plain into the Adriatic Sea, as we know it today, fundamentally altered the lifestyle of prehistoric people (Sikora et al. 2014; Peresani et al. 2021). Numerous prehistoric sites with rich archaeological assemblages, including ornaments, faunal remains, and stone and bone artefacts, have been revealed on the present-day margins of the prehistoric Adriatic Plain, such as Šandalja II (Karavanić 1999), Kopačina (Vukosavljević, Perhoč 2017), Vela Spila (Čečuk, Radić 2002; Cristiani et al. 2014), Badanj (Borić et al. 2023). However, these sites provide partial insight into the subsistence strategies and lifeways of people inhabiting the submerged Adriatic area during the Upper Palaeolithic (Rossi Radić et al. 2020). In this context, the Vlakno cave, serving as

both an inland and later island site, gives us vital information about the adaptations of prehistoric people who repeatedly occupied it for more than 10 000 years. During LUP, a significant number of discovered sites with ornaments in the Eastern Adriatic (Cvitkušić 2017; Borić et al. 2023; Vukosavljević 2023; Cristiani et al. 2014) suggest their important role in the lives of prehistoric peoples of this region. In Eastern Adriatic LUP contexts, beads are primarily discovered in small amounts, likely lost while being used (Cvitkušić, Komšo 2015; Cvitkušić 2017). Vlakno cave is an exception, boasting the most extensive and varied ornaments yet discovered in the Eastern Adriatic region, strongly implying *in situ* production. The nearest site to Vlakno cave with a rich LUP ornamental assemblage is Badanj cave, situated in present day Bosnia and Herzegovina (~330km away from Vlakno cave) (Borić et al. 2023). Compared to Vlakno, there are no traces of *in situ* production in Badanj, although we cannot completely exclude this activity because of the old excavation methods. Heterogeneous materials for ornaments in the



**Fig. 6.** Selection of LUP deer canines from Vlakno cave presented by sample numbers: a VL/O/60.23; b detail of VL/O/60.23 with decorative notches; c, e details of production traces with grooving and scraping of VL/O/60.23 in hole area; d, f VL/O/16.1; g VL/O/11.1; h detail of drilling in hole area together with use-wear of VL/O/11.1; i detail of scraping and grooving of surface of VL/O/60a.8; j, k VL/O/101.2 detail of production and use-wear; l VL/O/3.1 drilling mode of production; m detail of decorative notches of hole of VL/O/3.1; n, o VL/O/102.1; p VL/O/6.3; q VL/O/66.30 initial production stage with scraping and grooving traces.

LUP layers of Vlakno cave are locally outsourced. The selection of specific raw materials for ornamental purposes in Vlakno Cave, along with the used beads and ochre residues, reflects their symbolic role.

Our detailed analysis of each taxon from the Vlakno cave allowed us to elaborate on *in situ* production and discuss specific ornaments in the wider regional context (Fig. 7). During LUP, the beads made of marine species are the most represented in Vlakno cave, mainly corresponding to regional trends (Tab. 2, see below). Regarding marine species, the most numerous are scaphopods, *i.e.* *Antalis* sp., but compared to the second most frequent type, gastropods *Tritia neritea*, their appearance is limited almost exclusively to Stratum 6. *Antalis* sp. is almost equally represented by beads and posterior pieces, *i.e.* production waste. In archaeological contexts, a narrow posterior end (<1mm) is rare, and the reason is likely the impossibility of suspending such beads (Arrighi et al. 2020). In Vlakno cave, 41% of *Antalis* posterior ends, *i.e.* production waste, suggest *in situ* production. Like the *C. rustica* (Cvitkušić et al. 2024), *Antalis* shells indicate that raw material was brought to the site for *in situ* production. *Antalis* beads are discovered in the LUP horizons of Badanj cave (Borić et al. 2023) and, in the broader region, in Franchthi cave (Perlès 2018; 2019). Besides *Antalis* sp., the *in situ* production during the LUP in Vlakno cave is supported by red deer teeth (*Cervus elaphus*). Half of the sample exhibits use-wear traces, while the other half consists of whole, unmodified teeth with flint extraction marks. Additionally, one canine shows the initial production stage, *i.e.* traces of grooving. A preliminary analysis of the LUP faunal assemblage of Vlakno cave shows red deer is the prevailing species, while lithic artefacts indicate that hunting was the dominant economic activity (Cvitkušić et al. 2018). Significant symbolic finds are two decorated deer canines with transversal incisions over lobe surfaces. An analogous example of decorated notches on the red deer canine is known from Badanj cave and Riparo Tagliente (Leonardi 1983; Borić, Cristiani 2023). This ornament type is relatively common during LUP in the Adriatic basin. Vlakno and Badanj are the sites with large numbers of finds

of red deer teeth, while a smaller quantity was retrieved at Biarzo (Bertolini et al. 2016), Šandalja II, Romualdova cave (Cvitkušić 2017), and Vela spila (Cristiani et al. 2014).

*T. neritea* beads, the second most numerous LUP bead type in Vlakno, are almost uniformly represented throughout the layers. Due to its naturally thin and fragile shell, it can be easily perforated but also damaged, which could be a possible cause of a significant share of broken and unpreserved specimens in the sample. A similar distribution of *T. neritea* in the ornamental assemblage is recorded in Badanj cave, while in Franchthi cave and Riparo Tagliente, *T. neritea* is the dominant taxa during LUP (Fontana et al. 2009; Perlès 2019; Borić et al. 2023). The presence of *T. neritea* beads in the hinterland site of Zala cave likely suggests the existence of contacts and exchanging routes in the Eastern Adriatic region during LUP (Cvitkušić 2015). Moreover, a regional exchange system in this area during the Holocene is suggested by Darko Komšo et al. (2019) based on the distribution of beads made from marine and freshwater shells, a hypothesis supported by Vukosavljević and Ivor Karavanić (2015), who provide evidence of similar patterns in



**Fig. 7.** Map with the sites in the broader Late Upper Palaeolithic context discussed in the text: 1 Romualdova cave; 2 Šandalja II; 3 Ljubičeva cave; 4 Pupičina cave; 5 Zala cave; 6 Vlakno cave; 7 Vela spila; 8 Badanj; 9 Crvena stijena; 10 Franchthi cave; 11 Grotta Palicci; 12 Riparo Tagliente; 13 Riparo Biarzo.

lithic raw material distribution. Marine bivalves, predominantly *Glycymeris* sp. shells, are exclusively found in the LUP deposits of Vlakno cave. Its use is ambiguous due to the detected use-wear traces and ochre residues on a few perforated specimens and fragments, suggesting that *Glycymeris* shells in the Vlakno cave may have had a functional purpose. In the broader LUP regional context, the same situation is recorded in Franchthi cave (Perlès 2019). The most extensive number of *Glycymeris* sp. is discovered in Badanj (Borić et al. 2023), and to a small extent in Vela Spila (Cristiani et al. 2014), Šandalja II (Cvitkušić 2017), Crvena stijena (Borić, Cristiani 2019), and Riparo Tagliente (Fontana et al. 2009). In the regional LUP context, besides Vlakno, only one unmodified specimen of *Acanthocardia tuberculata* is discovered in Šandalja II (Cvitkušić 2015). Regarding *Luria lurida*, its presence is recorded in the Gravettian burial of Grotta Palicci in Puglia, situated across the Vlakno cave, slightly to the south (Ronchitelli et al. 2015).

Freshwater gastropods are sporadically represented in the Vlakno ornamental assemblage. Out of two species, *Theodoxus danubialis* is more numerous compared to *Lithoglyphus naticoides*. In the regional context, both species' use as an ornament is recorded in the Riparo Biarzo (Cristiani 2012), Badanj (Borić et al. 2023) and Vlakno cave. In general, in the spatiotemporal and chrono-cultural distribution, *L. naticoides* is more frequent in archaeological records of hunter-gatherers (Boroneanţ 1999; Eriksen 2002; Niţu et al. 2019). Freshwater sources likely had a significant role in hunter-gatherer lifeways. The importance of fishing is suggested by the results of stable isotope analyses showing high protein intake from freshwater fish in the Adriatic during Epigravettian (Vukosavljević 2023), which finds of harpoons and freshwater gastropods from Badanj and Vlakno caves can additionally support. More-

over, the presence of marine gastropods *T. neritea* in the hinterland site of Zala cave points to the existence of long-distance contacts from hinterland sites to those closer to the Late Glacial shore.

The variety of carefully chosen LUP ornament types in Vlakno cave in general corresponds to the broader regional trends spanning present-day Italy and Slovenia, the Adriatic littoral zone and its hinterland of the Dinaric Alps including present-day Croatia, Bosnia and Herzegovina and Montenegro (Cristiani et al. 2014; Cvitkušić 2015; 2017; Cvitkušić, Komšo 2015; Borić, Cristiani 2016; Borić et al. 2023; Vukosavljević 2023). Considering this observation alongside the well-documented LUP sites with ornaments in the northeastern Mediterranean, the Vlakno cave stands out as a prominent place for activities related to ornament production in this vast region. The Danube Gorges Epipalaeolithic sites and various contemporaneous Late Epigravettian sites in Italy share common features such as specific lithic artefacts, geometric motifs, and particular bead types (Mussi 2002; Borić, Cristiani 2016), such as the sites of Grotta Paglicci (Mezzena, Palma di Cesnola 1967), Riparo Tagliente (Fontana et al. 2009), Riparo Biarzo (Cristiani 2012), S. Maria di Agnano (Giacobini 2006), Grotta di Fumane (Fiocchi 1997), Grotta dei Fanciulli (Vanhaeren, d'Errico 2003), Ovčja jama (Osole 1962/63), Vela spila (Cristiani et al. 2014), Vrbička cave (Borić, Cristiani 2016), Crvena Stijena (Mihailović et al. 2017), Badanj (Borić et al. 2023), Franchthi cave (Perlès 2018), Cuina Turcului (Cârciumaru, Niţu 2018) and Climente II (Mărgărit 2008). Vlakno cave, with its *in situ* activities, rich symbolic assemblage, and central geographical location in the aforementioned area, perfectly fits in this broader LUP context, complementing our knowledge of how symbolic behaviour influenced movements of Late Upper Palaeolithic hunter-gatherers.

#### Acknowledgements

The research at Vlakno cave (D.V.) and the analysis of the material (B.C.) was conducted through the Croatian Science Foundation projects IP-2019-04-6115 "Epigravettian communities of Northern Dalmatia" and UIP-2014-09-1545 "Transition and tradition in Vlakno cave: Model of the transition from the Palaeolithic to the Mesolithic in the Northern Dalmatia region".

This research was also supported by the European Research Council under the European Union's Horizon 2020 Research and Innovation Programme (grant agreement no. 639286 HIDDEN FOODS to EC; <http://www.hidden-foods.eu>) (E.C.) and by Postdoctoral SAPIExcellence Fellowship (no. 616\_22\_SAPIEX ReDress) at Sapienza University of Rome, Rome, Italy (B.C.).

We thank the anonymous reviewers for their insightful comments, which have greatly contributed to the improvement of this paper.

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Tab. 1. Ornaments assemblage from the Late Upper Paleolithic layers of Vlakno cave. \*Numbers indicated in the parenthesis indicate unmodified specimens.

Period	Stratum	Division of Stratum / Layers	Marine gastropods, bivalve and scaphopods				Freshwater gastropods		Mammal teeth						
			<i>Columbella rustica</i>	<i>Tritia neritea</i>	<i>Tritia nitida</i>	<i>Luria lurida</i>	<i>Glycymeris sp.</i>	<i>Acanthocardia tuberculata</i>		<i>Antalis sp.</i>	<i>Theodoxus danubialis</i>	<i>Lythoglyphus naticoides</i>	<i>Cervus elaphus</i>		
L a t e U p p e r	4	4.1.	1	9 (1)	1 (1)		1								
		4.2.	2	12	2		(1)						2		
		4.3.	2	6			1			1					
		4.4.	4 (1)	15	1 (4)				1	1			1		
		5.1.	9	20	2 (6)		12			1			1		
		5.2.		3			2 (1)				1		1 (1)		
		5.3.					1						(1)		
5.4.	1	6					(1)								
5.5.	3							4							
5.6.	1	5						1				(1)			
5.7.	2					4 (1)									
TEPHRA ~ 14.9±0.4 ka cal BP															
P a l e o l i t h i c	6	6.1.		38			2					1		6 (2)	
		6.2.		1	1		2							2 (1)	
		6.3.	1	2			1						1	3 (2)	
		6.4.		2 (1)									1	3 (1)	
		6.5.													
		6.6.		1			1								3 (6)
		6.7.		1			1								1
8	7	7.1.												3 (2)	
		7.2.													
		7.3.		1											
		7.4.												1	
7.5.		6										1	(1)		
8.1.		1													
8.2.															
8.3.															
8.4.													2		
9							1								

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Tab. 2. The ornamental assemblage from the IUP contexts in the Eastern Adriatic region.

Period	General classification	Species	EASTERN ADRIATIC REGION															
			Šandalja II	Pupčina cave	Ljubičeva cave	Romualdova cave	Vlakno	Vela spila	Zala	Crvena Stijena	Badanj							
P L a t e o  U I p t e h r i c	Terrestrial mammal	<i>Bos/bison</i> tooth	1															
		<i>Lynx lynx</i> tooth	1															
		<i>Cervus elaphus</i> tooth	5			1		29 (18)	7								30	
		<i>Alces alces</i> tooth		1														
		Unidentified sp. bone	2															
	Marine gastropods, bivalves and scaphopoda	<i>Tritia neritea</i>			1		132 (2)	2	14								269	
		<i>Columbella rustica</i>		1			23 (1)	2									38	
		<i>Dentalium/Antalis</i> sp.					183										371	
		<i>Tritia nitida</i>					7 (11)											
		<i>Nassarius (Tritia) gibbosulus</i>						7									22	
		<i>Acanthocardia tuberculata</i>	(1)				1(1)											
		<i>Luria lurida</i>					1											
		<i>Glycymeris</i> sp.		1	(1)		29 (3)	5							3		53	
		<i>Teodoxus danubialis</i>					6											1
		<i>Lithoglyphus naticoides</i>					2											8
			<b>TOTAL</b>		<b>10 (1)</b>	<b>2 (1)</b>	<b>1</b>	<b>414 (36)</b>	<b>23</b>	<b>14</b>	<b>3</b>	<b>792</b>						