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Revision of Neanderthal Activity Zones at Kůlna Cave: Use-wear Analysis of the Micoquian Lithic Industry

Alexandra Dermeková
dermekova.alexandra@gmail.com

Masaryk University
João Marreiros
Monrepos. Archaeological Research Centre and Museum for Human Behavioural Evolution – LEIZA
Petr Neruda
Anthropos Institute, Moravian Museum

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Abstract

Investigating the spatial organisation of Neanderthal sites offers critical insights into their behavioural patterns, adaptive strategies, and site use. Studying how different lithic tools are organised in space and linked to specific functions is therefore essential. Kůlna Cave provides evidence of multiple occupation areas characterised by distinct activity patterns, making it a particularly suitable neanderthal site for investigating spatial organisation and testing related hypotheses. Previous interpretations, based primarily on techno-typological analyses, proposed that the cave surface was divided into clearly defined zones for activities such as tool production, carcass processing, or serving as a “central place” for interactions. However, the actual function of tools, essential for verifying such models, remained undetermined.

In our study, we applied use-wear analysis to the lithic artefacts, dated to approximately 50,000 BP (Layer 7a) to assess their function and evaluate previously proposed spatial zones.

Microscopic examination of artefacts excavated by between 1955–1977, focused on identifying worked materials and performed tasks, aiming to clarify the use of artefacts from different cave areas and refine interpretations of site use. The results revealed a variety of functional types and materials, correlating with distinct spatial zones. While the analysis confirmed the organised spatial structuring, it also led to a revised interpretation of functional areas, showing a more nuanced division of tasks across the cave.

This research demonstrates that use-wear analysis is essential for evaluating spatial organisation in archaeological contexts, and it provides robust proxy data that significantly enhances interpretations of Middle Palaeolithic site use and Neanderthal behavioural complexity.

1. Introduction

The spatial organisation of activities within Middle Palaeolithic sites offers key insights into Neanderthal lifeways and adaptive strategies (Deschamps et al. 2022; Berruti et al. 2024). Understanding the function and structure of space is central to reconstructing broader patterns of behaviour. One of the most valuable tools for investigating such questions is use-wear analysis of lithic artefacts, as it is a well-established method that has been widely applied to study past technology, behaviour, spatial use, and mobility (e.g., Marreiros et al. 2014; Marreiros et al. 2015).

Across Central Europe, Middle Palaeolithic research has mainly focused on typological and technological aspects, with functional analyses still underrepresented for many regions. In Czech Republic, one of the key areas for understanding Middle Palaeolithic occupation in Central Europe, research has extensively examined typology, technology, and raw material economy (e.g. Fridrich 1982; Valoch 1961; 1988; 2002; Valoch et al. 1993, 2011; Svoboda 1991; Neruda 2011; 2017; 2021; Romagnoli et al. 2022). However, despite these advances, comprehensive use-wear studies remain scarce, and their integration with spatial data remains virtually absent. To date, only three use-wear analyses have been conducted, namely on assemblages from Kůlna Cave, Moravský Krumlov IV and Vedrovice V (Krásna 2009; Šajnerová Dušková 2009; Neruda et al. 2010) (Fig. 1). Examinations were based on a very limited sample in terms of both the number of artefacts and the diversity of technological types. Furthermore, the published studies provide insufficient supporting evidence to allow for comparison or verification of their results. This gap limits our understanding of the eventual variability and organisation of tool use and functionality at Middle Palaeolithic sites in the region of the Czech Republic, highlighting the need for a more systematic investigation of these assemblages.

For the purposes of this study, use-wear analysis was conducted on lithic assemblages from specific sectors of Layer 7a at Kůlna Cave. As a prime example, this site represents the most complex stratified Middle Palaeolithic locality in Moravia with comprehensive archaeological excavations. Additionally, previous analyses of its assemblages have enabled researchers to identify distinct activity zones within Layer 7a (Neruda 2011, 2017, 2021), which form the direct focus of the present analyses. This implies that data concerning the specific location of the artefacts were collected, and there are also reliable absolute data provided for the studied archaeological layer (Valoch, 1988; Rink et al. 1996; Patou-Mathis et al. 2000; Michel et al. 2006; Nejman et al. 2011; Neruda/Nerudová 2014).

The main objective was to closely identify possible activities carried out by Neanderthal groups at the already identified zones of occupation, while simultaneously evaluating those zones and testing whether previous interpretations, based on technological and typological analyses of the assemblage, align with the results of use-wear analysis. Previous interpretations indicate the presence of distinct zones within Layer 7a, each associated with specific functions. For instance, sector G1 has been identified as a workshop based on the presence of bone retouchers and the absence of finished tools. Sector E, characterised by a generally high concentration of artefacts, its location within the cave, and the presence of hearths, has been interpreted as a central place for Neanderthal interactions. In contrast, the function of sector G3 remains undefined in earlier studies, as only a high concentration of retouchers was noted in this area (Neruda 2017). Consequently, this provided an ideal opportunity to examine whether the presumed typological functions of lithic tools align with their actual use at this specific site.

The question of whether the activity zones in Kůlna Cave during the formation of Layer 7a (approximately 50,000 years before the present) were created by a single group of Neanderthals repeatedly, or resulted from multiple palimpsests of occupation, remains under debate (Neruda 2017). However, the results of this study could lead to a better understanding of the settlement character of Layer 7a at this particular site. It is acknowledged, that the data will remain limited, primarily due to ambiguous spatial information and the state of preservation of the lithic artefacts (Neruda 2011).

2. Material and methods

2.1 The archaeological site of Kůlna Cave

Kůlna Cave represents a multicultural settlement site in the Czech Republic. It is located in the northern part of the Moravian Karst region, at an altitude of 464 meters above sea level. The cave is composed of Devonian limestone. To the south of the cave is the Pustý žleb valley, while to the west and east are the Drahany uplands. The Kůlna Cave is a tunnel cave, comprising a northern entrance of smaller dimensions and a portal entrance oriented to the south-west. The cave is 91 metres long, with a maximum width of 25 metres and a height of 8 metres. The initial comprehensive systematic excavations of Kůlna Cave were conducted between 1961 and 1976 under the direction of Karel Valoch. The total area of the cave that was explored was 900 m² (Valoch et al. 2011). The methodology employed for the sediment excavation was a trench system. The artefacts were recorded in the field notebooks, along with their stratigraphic details and location. In terms of spatial information, a grid network was employed to define the area, while depth was determined using intervals - representing one artificial excavation level within a layer (Neruda 2017). Based on the collected material, he also divided the sedimentary record into chronostratigraphic units (Valoch 1988a; Valoch 2002). In general, the stratigraphy described by K. Valoch was found to be highly complex, comprising several layers. The Middle Palaeolithic was described from Layer 14 to Layer 6a (the end of MIS6 to MIS3), within which three distinct Middle Palaeolithic technocomplexes were identified (Fig. 2). The described technocomplexes were identified as Mousterian with Levallois method (Layer 14), Taubachian (Layers 13a-10) and Micoquian (layers 9b, 8a, 7a-7d, 6a) (Valoch 1988; 2002; Neruda 2017).

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2.2 Layer 7a and excavation sectors

During the formation of Layer 7a, represented by Layer 7a1 in the inner part of the cave (for more details see Neruda 2017), the cave was occupied to the largest extend and also the most complex settlement structures were documented. This layer contains artefacts concentrated in different sectors of the cave. These sectors include B, D1, D2, F, E, G1-G3, H1 and H3 (Fig. 3). According to the most recent absolute dating results (acquired in 2014), the layer was formed around 50 ka cal BP (Neruda/Nerudová 2014). The layer undergoing analysis was excavated during two excavation projects, in years 1961–1976 and 1995–1997 by Karel Valoch (Valoch 1988b, 2002a). The distribution of finds, such as bones with anthropic impacts, varies significantly across different sectors, with notable concentrations in Sectors D1, E, G1, and G2, correlating with the lithic industry. However, some areas, like D2 and F, contain only lithic artefacts and animal remains without anthropic impacts. Overlaying density maps of finds from around 50 ka BP reveals several distinct accumulations (Neruda 2017).

Despite the extensive use of the cave, retouchers made of organic materials are primarily concentrated in a small area in the cave's right-centre, Sectors G1 and G2. Unlike Layer 7c, these tools do not coincide with the highest concentrations of side scrapers and bifacial tools. Lithic artefacts are dispersed throughout the cave, with lower densities observed in the northern sectors (H1, H2, and H3), possibly due to the slope's inclination limiting human activity there (see Neruda 2013). For instance, a niche in Sector G2 - contains charcoals suggesting an elongated hearth, indicating it may have been the warmest part of the cave. Nearby, evidence of stone tool production and organic material processing is observed, particularly in Sector G1, where retouchers of hard animal tissues are present. However, bifacial tools and side scrapers are less frequent here.

Sector E, near the left wall (from the southern entrance) and illuminated by natural light, contains a significant accumulation of lithic artefacts, including side scrapers, bifacial tools - and cores, as well as a small hearth. Neanderthal remains and bones with anthropic modifications were also found here, suggestive of a central area for Neanderthal activities. In contrast, the southern sectors - D1, F, and the southern edge of E - show high concentrations of lithic artefacts but lack organic remains, indicating different functional uses, possibly for lithic raw material processing. Sector D1 may have had a specific role, evidenced by the discovery of a Neanderthal parietal bone (Jelínek 1980; Valoch 1988a, 1988b; Jelínek 2012), suggesting a deliberately cleaned area with stones and bones piled nearby. The composition of finds here is similar to Sector E, except for the absence of organic retouchers. The right side of the cave entrance also has a distinct character, with few lithics but some mammoth remains. Evidence suggests that large flakes were produced here, likely for butchering animals, which were then transported to the central cave for consumption (Neruda 2017).

2.3 Lithic Assemblage and Raw Material Overview

The lithic industry from Layer 7a of the Kůlna Cave represents one of the most significant Micoquian assemblages in Moravia and Central Europe (Neruda 2011).

During the formation of Layer 7a, Neanderthal groups´ use of raw materials at Kůlna Cave reflects a significant shift in economic and logistical behaviour (Neruda 2011, 2016; Romagnoli et al. 2022). It is well documented in the lithic assemblage of Layer 7a from Kůlna Cave, that despite the site's function remaining similar to that observed during the formation of Layer 11, there is a noticeable difference in raw material composition. During the Micoquian period, the Neanderthal group began to place a greater emphasis on the quality of raw materials. One of the raw materials of best quality, Cretaceous Chert, is present in Micoquian Layers – 7c to 6a - at a rate of over 63%. This demonstrates the existence of a specialised supply of raw materials, the sources of which are located 15 km from the site. In case of Layer 7a especially, there is evidence of a logistic supply of raw materials, as certain raw materials were imported by specialized expeditions (Neruda 2011, 2016). The second main difference that manifested during the Micoquian period is a notable reduction in raw material import from greater distances. The most distant materials were chert from Krumlovský les region and various types of quartz from Drahanská vrchovina (Fig. 2). Based on these observations, it can be postulated that the Micoquian economic strategy was oriented towards the direct procurement of necessary raw materials, facilitated by short-distance expeditions undertaken by a few individuals (Neruda 2011, 2016). A similar scenario is observed on

other Moravian sites of the same chronology. For example, assemblages from Šipka or Čertova díra illustrate similar orientation of local Neanderthal groups towards regional raw material sources (Neruda 2011).

This preference for high-quality raw materials such as Cretaceous chert is reflected in the tool assemblage of Layer 7a, where a majority of the artefacts were manufactured on fine-grained, locally sourced stone suited for bifacial shaping and curated tool forms. The spatial distribution is demonstrated on Fig. 3.

The lithic industry from Layer 7a of Kůlna Cave comprises over 2600 artefacts with documented context, as shown in the Table 1. Typologically, the assemblage is dominated by flakes and fragments, followed by cores. The discoidal method is the most commonly employed flaking technique, though the presence of prism-like cores indicates some technological variability. Extensive flake debris and features associated with tool manufacture suggest that tool production occurred on-site. The assemblage includes a diverse range of tool types: scrapers (simple, complex, convex, ventral, etc.), denticulates, notches, bifacial tools (handaxes, knives, scrapers), and combination tools (Neruda 2011).

Table 1
Comparison of main lithic categories and raw materials of Layer 7a (modified after Neruda 2

	Raw material										
Type of artefact	**Limestone**	**Quartz**	**Greywacke**	**Orthoquarzite**	**Chert of "Němčice"**	**Spongolite**	**Chert**	**Chert of Býčí skála**	**Chert of Olomoučany**	**Chert of Stránská skála**	**Chert of Krumlovs les**
Tests	1	3	7		1	2	1				
Unmodified blanks		52	5	12	11	600	13		3		7
Blank fragments		52	3	14	11	426	9	2	7		1
Waste	2	86	7	9	17	341	13		4		4
Tools		17	6	12	21	316	38	1	5	1	1
Modified blanks	1	10	2	7	5	204	9	1			1
Cores		12		4	4	142	7		2		2
Ground tools	1	6	47	2		2					
Total	5	238	77	60	70	2033	90	4	21	1	16
%	0,19	9,03	2,92	2,28	2,66	77,12	3,41	0,15	0,8	0,04	0,61

2.4 Materials and selection of archaeological sample

The first step involved sampling the lithic assemblage from Layer 7a. The sampled sectors were D1, D2, E, G1–G3, H1, and H3. Sectors B and C were excluded from analysis due to the extensive post-depositional surface damage evident even at the macroscopic level during the initial assessment, rendering them unsuitable for microscopic examination.

Given the high number of artefacts in Layer 7a, the sampling strategy aimed to include approximately 20%–50% of the total number of pre-determined technological types from each sector (Table 2). The sampled types comprised unretouched flakes, scrapers, notches, denticulates, bifacial tools, and combination tools. The latter category refers to artefacts intentionally designed to serve multiple functions, typically incorporating different working edges or tool forms on a single piece (Neruda 2011). Raw material sampled for the purposes of this study was silicite, more specifically, in terms of the Kůlna Cave lithic assemblage, Cretaceous chert, Olomoučany chert, unspecified chert and unspecified silicite. The selection of raw material was primarily based on the predominance of various types of silicite at the site.

Table 2
General composition of sampled assemblage by tool type and sector

	D1		D2		E		G1-G3		H1;H3		Total	
Type	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Scrapers	6	17%	12	21%	22	22%	30	43%	6	24%	76	27%
Bifacials	2	6%	3	5%	9	9%	7	10%	1	4%	22	8%
Unretouched flakes	18	51%	24	42%	47	48%	23	33%	11	44%	123	43%
Denticulates	4	11%	5	9%	4	4%	2	3%	3	12%	18	6%
Notches	3	9%	9	16%	10	10%	3	4%	3	12%	28	10%
Combination tools	2	6%	4	7%	6	6%	5	7%	1	4%	18	6%
Total	**35**	**100%**	**57**	**100%**	**98**	**100%**	**70**	**100%**	**25**	**100%**	**285**	**100%**

The sampling process was conducted using a binocular microscope, with the primary selection criterion being minimal post-depositional surface alteration. The final number of artefacts selected from each sector was as follows: D1–35, D2–57, E – 98, G1–30, G2–34, G3–6, H1–19, and H3–6. It represents 285 artefacts in total.

2.5 Cleaning protocol

All artefacts included in the analysis were initially cleaned with brushes and water immediately after excavation. However, due to the presence of residual sediment visibly adhering to their surfaces, ultrasonic cleaning was also required prior to analysis. For the purposes of use-wear analysis, the artefacts were cleaned in an ultrasonic bath (BANDELIN Sonorex Digitec DT 255 H) to minimise the risk of surface damage. Each artefact was placed separately into a clean, sealable plastic bag filled with a solution of distilled water and non-ionic detergent. The ultrasonic bath was preheated to 40°C, and the cleaning cycle lasted 15 minutes. Following this, the artefacts were rinsed with distilled water and left to air dry on a clean, absorbent surface.

In addition to this initial cleaning, the artefacts were also cleaned with acetone during the use-wear analysis for microscopic observation. This step was necessary to remove greasy residues, primarily resulting from handling.

2.6 Use-wear analysis

A qualitative approach was selected as the most appropriate methodology, given that this study represents the first assessment of the assemblage. The initial analysis focuses primarily on the state of tool preservation, the presence or absence of use-wear traces, and, where such traces are identified, a more detailed characterization of the observed wear types.

The use-wear analysis was conducted using both the low- and high-power approaches. To assess the microwear traces the upright light microscope for transmitted light Zeiss AxioScope.A1, equipped with an XY stage, a C-DIC filter and four EC Epiplan objectives (5×/0.13, 10×/0.25, 20×/0.40 and 50×/0.75) was used. For the purpose of assessing the macroscopic damage and documentation of working edges, a 3D digital microscope Zeiss Smartzoom 5, equipped with PlanApo D 1.6x/0.1 FWD 36mm objective, was used.

Reference collections at the Laboratory for Traceology and Controlled Experiments and specific studies were referred to for a more accurate recognition of micro-wear attributes useful for inferring processed materials.

3. Results

The use-wear analysis allowed the identification of use-wear traces on 21% of the sample, which means 61 artefacts with positive use-wear traces and 112 documented traces altogether. The most diagnostic variables for this analysis were microtopography, texture, and density. The identified worked materials include wood (hardwood, softwood or plants and undetermined wood), bone, hide, soft material, medium-hard material, and unidentifiable materials (Table 3). Other recorded variables were contour, distribution, and orientation of polish, which were later used to assess possible performed activities.

Table 3
Worked materials and tool types organised by percentage

Stĺpec1	Hard wood	Hard wood/ Bone	Wood	Soft wood/ Plants	Hide	Bone	Wood +hide	Soft material	Medium hard material	Un-identifiable	Total
Scrapers	5		11		3		5			2	**26**
Combination tools			3				2			5	**10**
Notches			2	2	5			2	2		**11**
Denticulates	10		2					2			**5**
Bifacial tools	8		3		2			1		3	**10**
Unretouched flakes	5	2	7	8	2	3	5	5		2	**36**
Total	**13**	**2**	**28**	**10**	**11**	**3**	**10**	**10**	**2**	**11**	**100**

Table 4
Worked materials and tool types organised by total number

Stĺpec1	Hard Wood	Hard wood/ bone	Wood	Soft wood/ plants	Hide	Bone	Wood + hide	Soft material	Medium hard material	Un-identifiable	Total
Scrapers	3		7		2		3			1	**16**
Combination tools			2				1			3	**6**
Notches			1	1	3			1	1	-	**7**
Denticulates	1		1					1		-	**3**
Bifacials											
Knifes			2		1			1		1	**5**
Handaxe										1	**1**
Bifacial scraper	1										**1**
Unretouched flakes	3	1	4	5	1	2	2	3		1	**22**
Total	**8**	**1**	**17**	**6**	**7**	**2**	**6**	**6**	**1**	**7**	**61**

In sector D1 (Table 5, 6), six artefacts with identifiable use-wear traces were recorded. The majority of these traces are associated with woodworking, either in a general sense or linked explicitly to hardwood processing. The tool types bearing woodworking traces (Fig. 4) include two flakes and one scraper (Table 4), with use-wear oriented in parallel or oblique directions. Hide working was also documented in this sector, occurring on flakes and a bifacial knife. In these cases, the traces were predominantly perpendicular or parallel to the working edge. Notably, one unretouched flake displayed use-wear attributable to both hide and wood, indicating multiple functional uses for a single tool.

In sector D2, seven artefacts with identifiable use-wear traces were documented, reflecting a pattern similar to that observed in sector D1. The traces are associated exclusively with woodworking and hide processing. Woodworking traces (Fig. 5) were identified on a scraper, a combination tool, a denticulate, and a bifacial knife, with directions recorded as parallel, oblique, and perpendicular. Hide-working traces (Fig. 6) were observed on a scraper, a combination tool, and notches, oriented predominantly obliquely and perpendicularly. Importantly, both the scraper and the combination tool bear traces attributable to wood and hide, indicating their multifunctional use.

Sector E exhibited the highest number of artefacts with identifiable use-wear traces, with 18 pieces exhibiting diagnostic modifications. Despite this higher frequency, the variability of worked materials remains comparable to that observed in the previously described sectors. In addition to wood and hide, traces associated with the processing of soft wood or plants were documented with notable frequency. Woodworking traces were recorded on scrapers and a bifacial knife, while traces linked to soft wood or plant working were predominantly present on unretouched flakes (Fig. 7), generally oriented in a parallel direction. Hide-working traces were identified on a wide range of tool types, including scrapers, a bifacial knife, a denticulate, notches, and flakes. These traces typically exhibit oblique and perpendicular orientations, with occasional parallel directions.

In sector G1, eleven artefacts displayed identifiable use-wear traces. These were attributed to activities involving hardwood, general wood, hide, and, in one case, bone (Fig. 9). Traces interpreted as the result of hardwood working were documented on a scraper and an unretouched flake, with orientations predominantly perpendicular or parallel in relation to the tool edge. Scrapers also exhibited traces consistent with both hide processing and general woodworking. The latter were additionally observed on flakes, most frequently oriented in parallel, although single instances of perpendicular and oblique directions were also recorded. Notably, one unretouched flake, which exhibited traces of perpendicular orientation attributable to bone working, marked the

only occurrence of this activity within the sector. Within the category of unretouched flakes, one specimen also displayed traces resulting from the working of soft wood or plants.

In sector G2, nine artefacts from the analysed sample exhibited use-wear traces. The worked materials identified include hide, wood (Fig. 10, 11), hardwood (Fig. 12), and, in one instance, traces attributable to either hardwood or bone. The range of tool types bearing use-wear in this sector is relatively limited, comprising only scrapers and flakes. On one scraper, both hide-working and woodworking traces were present, indicating its multifunctional use.

In sector G3, four artefacts exhibited use-wear traces. These were attributed to activities involving wood, hardwood, and possibly hide. Corresponding to the limited range of worked materials, the tool types with positive use-wear traces are restricted to scrapers and unretouched flakes. In one case, a scraper showed traces of both woodworking and hide-working, suggesting multifunctional use.

Table 5
Worked materials and sectors organised by percentage

Stĺpec1	**Hard wood**	**Hard wood/ bone**	**Wood**	**Soft wood/ plants**	**Hide**	**Bone**	**Wood +hide**	**Soft material**	**Medium hard material**	**Un-identifiable**	**Total**
D1			3	2	2		2	3			**10**
D2			3		2		3	2		2	**11**
E			7	7	5			4		5	**30**
G1-G3	10		13	2	2	3	5		2	3	**40**
H1,H3	3	2	2		7					2	**10**
Total	**13**	**2**	**28**	**10**	**11**	**3**	**10**	**10**	**2**	**11**	**100**

In sector H, six artefacts exhibited diagnostic use-wear traces. The tool types represented include a handaxe, flakes, a denticulate, a notch, and a scraper. Identified worked materials comprise hide, bone or hardwood, hardwood, and wood. Traces associated with animal-derived materials (hide and bone) were observed on unretouched flakes, whereas wood-working traces were identified on retouched tools, specifically the denticulate, notch, and scraper.

Table 6
Worked materials and sectors organised by total number

Stĺpec1	**Hard wood**	**Hard wood/ bone**	**Wood**	**Soft wood/ plants**	**Hide**	**Bone**	**Wood + hide**	**Soft material**	**Medium hard material**	**Not identifiable**	**Total**
D1			2	1	1		1	1		0	**6**
D2			2		1		2	1		1	**7**
E			4	4	3			4		3	**18**
G1-G3	6		8	1	1	2	3		1	2	**24**
H1,H3	2	1	1		1					1	**6**
Total	**8**	**1**	**17**	**6**	**7**	**2**	**6**	**6**	**1**	**7**	**61**

Table 7
Descriptive correlation between the most represented polish attributes organized by working material

		wood	**hard wood**	**soft material**	**hide**	**soft wood/ plants**	**bone**	**bone/ hard wood**	**medium hard material**
microtopography	*domed*	x		x	x	x			
	flat		x				x	x	x
texture	*fluid*	x			x	x			
	hard	x	x	x		x	x	x	x
	soft								
density	*dense*	x		x	x	x			
	semi-open/ connected	x							
	diffuse								
	compact		x				x	x	x
contour	*sharp*	x	x	x		x	x	x	x
	diffuse			x	x				

The descriptive correlation presented in Table 7 highlights the characteristic combinations of polish attributes associated with each worked material. For example, surfaces interpreted as the result of wood working consistently exhibited a domed microtopography, sharp contour, and fluid or hard texture. Comparable patterns were observed across the other material categories, each showing its own recurring combination of attributes.

4. Discussion

4.1 Worked material, stone-tool type and tool multifunctionality

One of the key questions in our research was to assess whether the functional assumptions based on typology of different tool types in the Micoquian layer 7a of Kůlna Cave are coherent with the results of use-wear analysis, and, whether tools were used multifunctionally or as specialised tools for a single activity.

When examining the data, it appears that flakes were used across the widest range of activities and materials. They seem to have been used for scraping and sawing various types of wood, as well as processing hide and plants. There is also evidence suggesting their involvement in bone processing. This pattern is consistent with findings from middle palaeolithic sites in Italy and Spain, where the use of unretouched flakes for a broad array of activities has been observed. Although unretouched flakes are often classified as waste in technological analyses and have frequently been excluded from use-wear studies, these examples (Grimaldi & Lemorini 1993; Lemorini et al. 2003; Berruti et al. 2020; Martín-Viveros et al. 2020) suggest they may have played a more significant role than traditionally acknowledged.

Denticulates, by contrast, seem to be associated with a more limited range of materials - hardwood, wood, and hide – and, based on available data, were most likely used exclusively for actions such as sawing or cutting. While a similar pattern was anticipated for notches, in two instances, traces suggested their use in hide scraping. According to our findings, notches were most likely not associated with hardwood processing but were used for cutting softwood or plants instead.

Scrapers were linked to a relatively narrow spectrum of materials namely wood, hardwood, and hide. The associated activities - sawing, scraping, and cutting - are in line with their conventionally understood roles in hideworking and woodworking (Bisson 2001).

Among combination tools, the most frequently identified use-wear traces were connected to wood sawing, followed by cutting and scraping hide.

Bifacial artefacts, often interpreted as multifunctional tools suitable for diverse tasks and materials (Soresi 2005; Brenet et al. 2017), seem to have been used in this assemblage in a manner similar to scrapers. Their functions included scraping, sawing, and cutting wood, hardwood, and hide. However, it is noteworthy that no evidence of bone processing was identified within the bifacial tool category, despite this being a commonly assumed use. While this absence may be meaningful, it could also be influenced by sample size, preservation conditions, or analytical limitations.

Regarding the multifunctionality of the examined tools, the identification of worked materials confirmed that certain tools were used on two different raw materials, specifically, hide and wood (Fig. 13). Notably, this was the only combination of working materials observed. Such tools were identified in six cases, spanning typological categories including scrapers, combination tools, and unretouched flakes. Another way to assess multifunctionality was to identify the types of movements employed by each tool. Based on this criterion, 10 artefacts exhibited use-wear traces indicative of multiple activities. In addition to scrapers, combination tools, and unretouched flakes, one bifacial knife also bore traces indicating both scraping and sawing wood. Furthermore, two additional combination tools displayed traces of cutting/sawing and scraping on a single tool, although the exact worked material could not be determined. Beyond cases where multifunctionality was inferred solely from different worked materials, the remaining examples - showed combinations of activities such as cutting and scraping hide and sawing and scraping wood or hardwood. This leads to another noteworthy finding - the presence of use-wear traces associated with materials of different hardness on the same tool, such as soft materials like hide and harder materials like hardwood. This pattern of multifunctionality was not confined to a single sector but was observed throughout the entire Layer 7a. The low degree of functional specialization and the frequent multifunctional use of tools are common characteristics in Neanderthal behaviour, although most prevalently in the case of mobile toolkits, as frequently observed among Iberian Neanderthals (Navazo Ruíz et al. 2020; Picin et al. 2020b).

4.2 Site function interpretations

The main objective of this study was to explore the presumed functional division of the space of the cave defined by P. Neruda (2017). Based on the results of use-wear analysis, there appears to be a noticeable distinction between the left and right sides of the cave in terms of the types of worked materials and activities performed. These differences are reflected in both the variability and frequency of identified activities. On the left side of the cave (Sectors D1, D2, and E), the range of activities seems more limited when compared to the right side (Sectors G1–G3 and H). Specifically, up to four distinct activities were identified in the left sectors, whereas in some sectors on the right, as many as seven different activities were recorded.

There also appear to be differences in the nature of activities across the two areas (Fig. 14, 15). In Sectors D1, D2, and E, the identified activities were limited to woodworking—primarily involving medium-hard wood—and hide-working. In contrast, Sectors G1 and G2 revealed a broader spectrum of both activities and materials. Woodworking in these areas included materials of varying hardness - medium-hard, hard, and soft wood, as well as plants - with hard wood being particularly common. Evidence of processing animal tissues was also more diverse in these sectors, with traces related to both hide and bone. Notably, traces of bone processing were observed only on the right side of the cave, whereas hide-working traces were present on both sides.

The artefact composition of Sector D1 consists primarily of bones with anthropic impacts and lithic industry. Based on previous interpretations, it was speculated that this sector may had a specific function as well. This hypothesis was mainly based on the discovery of a Neanderthal parietal bone within a seemingly deliberately cleaned accumulation of limestone blocks filling a shallow depression in Sector D1 (Neruda 2017). However, new data from our study

demonstrate that this sector was used for the processing of organic materials, primarily wood and hide. This suggests that, while Sector D1 may have had a special function within the cave, it was still used for daily activities such as processing organic materials.

Sector D2 is notable for its absence of bones with anthropic impacts. However, there was a significantly higher concentration of lithic artefacts, particularly cores, bifaces, and side scrapers, compared to Sector D1. Based on this, the assumed function of the sector was the processing of lithic raw materials (Neruda 2017). As with sector D1, new data reveal the processing of wood and hide, including cutting and scraping hide, and scraping and sawing wood. While this does not exclude the use of this sector for raw material processing, it expands its role to organic material processing as well.

Sector E represents the largest settled area in the cave and contains the highest concentration of artefacts. Its location within the cave allows for ample natural light, thanks to the southern entrance. This sector is also unique in that it is one of the two locations in the cave where a hearth was found. Artefact-wise, Sector E has a high concentration of lithic tools, as well as the largest deposition of bones with anthropic impacts, unlike the previous sectors. Two Neanderthal remains were also found here. The composition of finds and the presence of a hearth led to the interpretation of Sector E as a central site for Neanderthal interaction (Neruda 2017). Surprisingly, despite the significant differences in artefact composition between Sector E and Sectors D1 and D2, the use-wear analysis showed, that the types of worked materials were quite similar. Notably, no evidence of bone processing was identified, despite the high concentration of bones with anthropic impacts. The activities identified were sawing and scraping wood, cutting soft wood or plants, and cutting and scraping hide.

In sector G1, a high concentration of retouchers made of hard animal tissue was found. Based on this, and the absence of a proportional concentration of bifacial tools and side scrapers, this sector was interpreted as a workshop, with the assumption that tool production occurred here while tools were used in other parts of the cave, possibly sector E (Neruda 2017). However, new data reveal that the sector was used for a broader range of materials, including bone, wood, hard wood, plants, and hide, with activities ranging from butchering and scraping to cutting and sawing. This challenges the previous interpretation of the sector as solely a workshop, suggesting that its function was more varied. While tool production could have still been part of performed activities in this sector, it was not merely a workshop where tools were used elsewhere.

Sector G2 is often perceived as a niche area, as it is the warmest part of the cave due to the presence of a hearth and its surrounding cave wall. Based on the lithic artefacts and bones with anthropic impact, it was initially interpreted as a place for stone tool production and organic material processing (Neruda 2017). Results from use-wear analysis confirm the latter but provide more specificity regarding the types of organic materials processed. In this sector, the worked materials included bone, wood, hardwood, hide, and softwood or plants, making it the second most diverse sector in terms of the variety of materials and activities.

Sector G3 lacked a proper interpretation in previous studies, although it was noted for a high concentration of bone retouchers (Neruda 2017). Based on new data, it appears that this sector was primarily used for the processing (both scraping and sawing) of hard wood and wood, with some evidence of hide cutting. Given its proximity to Sector G2, where charcoal, indicating the presence of a hearth was discovered, it is possible that wood was also stored and prepared for use as fuel.

In Sector H, it was expected that human activity would be limited, primarily due to the documented decrease in the accumulation of lithic artefacts in Sectors H1, H2, and H3, as well as the inclination of the slope in this part of the cave (Neruda 2017). However, while the variety of identified activities is not as high as in the G sectors, several distinct activities were still discovered, including sawing wood and hardwood, bone processing, and cutting hide. The function of this sector appears to be similar to that of sectors D1 and D2 from a use-wear perspective, although the presence of bone as a worked material in sector H is unique within this occupation.

Use-wear analysis has revealed a broader spectrum of activities across all studied sectors, which allows to refine earlier interpretations of spatial organisation within the cave. One of the most notable differences from the previous interpretation (Neruda 2017) is the apparent shift in the core zone of Neanderthal activity, from Sector E to Sector G. Given the environmental conditions in Sector G, particularly with respect to temperature and wind flow, it may have offered more favourable living conditions.

While interpretations of activities within individual sectors have evolved, the overall pattern now appears considerably more diverse than previously understood. Despite this, evidence still supports the notion of a functional division of space within the cave, as distinctions in activity types between the eastern and western parts remain observable. This is broadly consistent with current research suggesting that Neanderthals structured their cave settlements into distinct functional zones (Conard et al. 1998; Bonjean & Otte 2004; Oron & Goren-Inbar 2014; Sánchez-Romero et al. 2020; Sánchez-Romero et al. 2025).

Our findings align with the widely acknowledged view that use-wear studies are essential for refining interpretations of archaeological material. Numerous studies have shown that typological categories—such as scrapers, bifacial tools, or notches—are insufficient on their own for reliably inferring how tools were used. These formal classifications do not capture the variability in actual tool use and often overlook the functional significance of unretouched flakes. Existing work also demonstrates that typology alone cannot reveal the specific materials worked or the motions involved, underscoring the value of use-wear studies in developing more accurate functional interpretations (Knutsson et al. 2015; Fuentes et al. 2019; Marreiros et al. 2020).

Although bone retouchers were identified in several sectors, no corresponding microscopic traces were observed on artefacts such as scrapers or bifacial tools that would typically indicate contact with these implements. This contrasts with earlier studies demonstrating that bone retouchers often leave distinctive use-wear traces as a result of their interaction with such tools (Mozota 2013; Costamagno et al. 2018; Hutson et al. 2018). However, this discrepancy may stem from various factors. The reason why no traces resulting from bone retouchers were observed in the assemblage is most likely related to the specific character of the retouching process itself: Firstly, the point of contact between the retoucher and the worked artefact is typically removed during the retouching itself, and therefore is no longer available for further examination. Secondly, during retouching, the contact between the

retoucher and the artefact is considerably shorter than during regular bone working, which may prevent the formation of any visible traces in the first place. Other reasons for this include sampling strategies, preservation conditions, or surface alterations.

It is important to stress that these interpretations should not be taken as definitive. Post-depositional processes, such as sedimentation, possible artefact displacement e.g. slope, and other taphonomic factors, may have influenced the current spatial distribution. Furthermore, the risk of misinterpreting use-wear traces should also be considered. As such, while the current findings provide valuable insights, they must be approached with appropriate caution.

4.3 Limitations

Several limitations arose during the analysis, affecting the identification and interpretation of use-wear traces, which, in turn, may have influenced the interpretation of functional zones. A primary limitation of this study lies in the taphonomic alteration of artefact surfaces, largely due to post-depositional processes. Extensive surface polishing was observed on the majority of artefacts, often obscuring potential use-wear traces beyond recognition. Additionally, widespread macroscopic damage – mainly in a form of surface polish - complicated interpretation, as it could not be conclusively attributed to either use or post-depositional disturbance, and was therefore excluded from further functional analysis.

Post-excavation conservation procedures introduced further challenges. In numerous cases, the nail polish used to secure inked inventory numbers was applied directly adjacent to working edges. Despite repeated cleaning in ultrasonic baths and acetone, microscopic residues of this substance remained, potentially affecting the visibility of micro use-wear traces. Similarly, graphite pencil residues, resulting from artefact illustration, were frequently present on tool edges which limited the analysis of retouched zones.

Another limitation pertains particularly to retouched tools, where intensive reutilization and resharpening of the working edge through retouching likely removed earlier use-wear traces. As a consequence, certain original activities may not be identifiable through use-wear analysis, despite high possibilities of having been previously performed with the tool.

5. Conclusion

The main findings concerning the spatial organisation show, that the left side of the cave (Sectors D1, D2, E) has significantly less variability in terms of performed activities. Activities included mainly hide and wood processing and in general, this area shows lower intensity of use, possibly due to its position within the cave (more draft and harsher weather conditions). The right side of the cave (Sectors G1-G3, H) however, shows much higher variability in performed activities, including those not identified in previous sectors, such as processing wood of different hardness, plants and bone. This area also shows a slightly higher intensity of use. The reason for this may be the natural shelter in the form of a wall and hearth.

Multifunctional use of tools was confirmed on unretouched flakes, scrapers, combination tools and bifacial knife. The most common combination of movements represents sawing/cutting, and are employed for hide and wood. Based only on average number of use-wear traces, denticulates seem to be used the most intensely, with their use identified namely for sawing wood and cutting hide, which makes them the least versatile tool type in the assemblage. Conversely, flakes were the most versatile tool type, as they were used for the widest variety of activities.

Data from certain sectors - D1, D2, G2 - provided a more detailed view of their function, while at the same time did not exclude previous interpretation. Significant changes in functional interpretation are however confirmed for Sector G1, which is no longer perceived as a sole place for tool production but rather as a multifunctional part of the cave. New data also allowed for interpretation of Sectors G3 and H, which were not previously described in detail. Sector E, was previously interpreted as a central part for Neanderthal interactions, however, the new data suggest that it was used mainly for wood and hide processing.

The results of this study provided new insight into the spatial organisation of Kůlna Cave and highlighted the importance of use-wear analysis in reconstructing functional zones. By integrating new data with previous research, the interpretation of several sectors has been refined, offering a more detailed understanding of Neanderthal activities during the late Middle Palaeolithic in Kůlna Cave.

This study could also provide broader insights into Middle Palaeolithic technology, typology, and Neanderthal behaviour. The use-wear analysis in this study challenges traditional assumptions about artefact function, highlighting the potential for multifunctionality and adaptive technological choices. These findings contribute to the ongoing discussion about technological variability in Neanderthal societies, showing that artefact function cannot always be inferred solely from the typology. As a case study, this research could offer a framework for re-examining other assemblages and sites, demonstrating how functional analysis can refine our understanding of how settlement spaces were used.

Declarations

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Author Contribution

Conceptualization: A.D., J.M., P. N.; Investigation, Writing original draft: A.D.; Writing—review and editing: A.D., J.M., P.N.; Figures: A.D., P.N.; Supervision: J.M, P.N.

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Data Availability

All data supporting the findings of this study are available within the paper.

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Figures

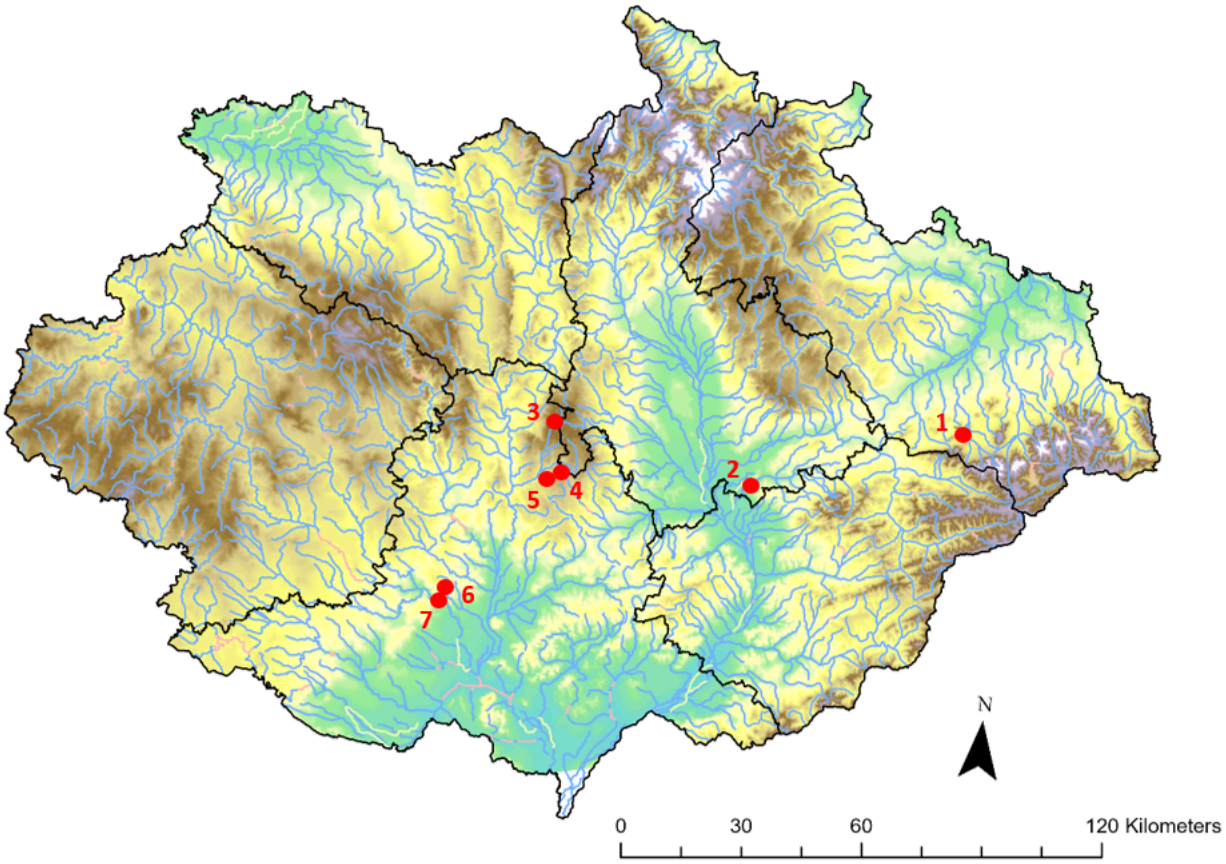


Figure 1

Map of stratified Middle Palaeolithic sites in Moravia. 1 – Šipka cave, 2 – Předmostí II, 3 – Kůlna Cave, 4 – Švedův stůl, 5 – Malomeřice, 6 – Vedrovice Ia, 7 – Moravský Krumlov IV. Graphics: A. Dermeková, after Neruda 2016

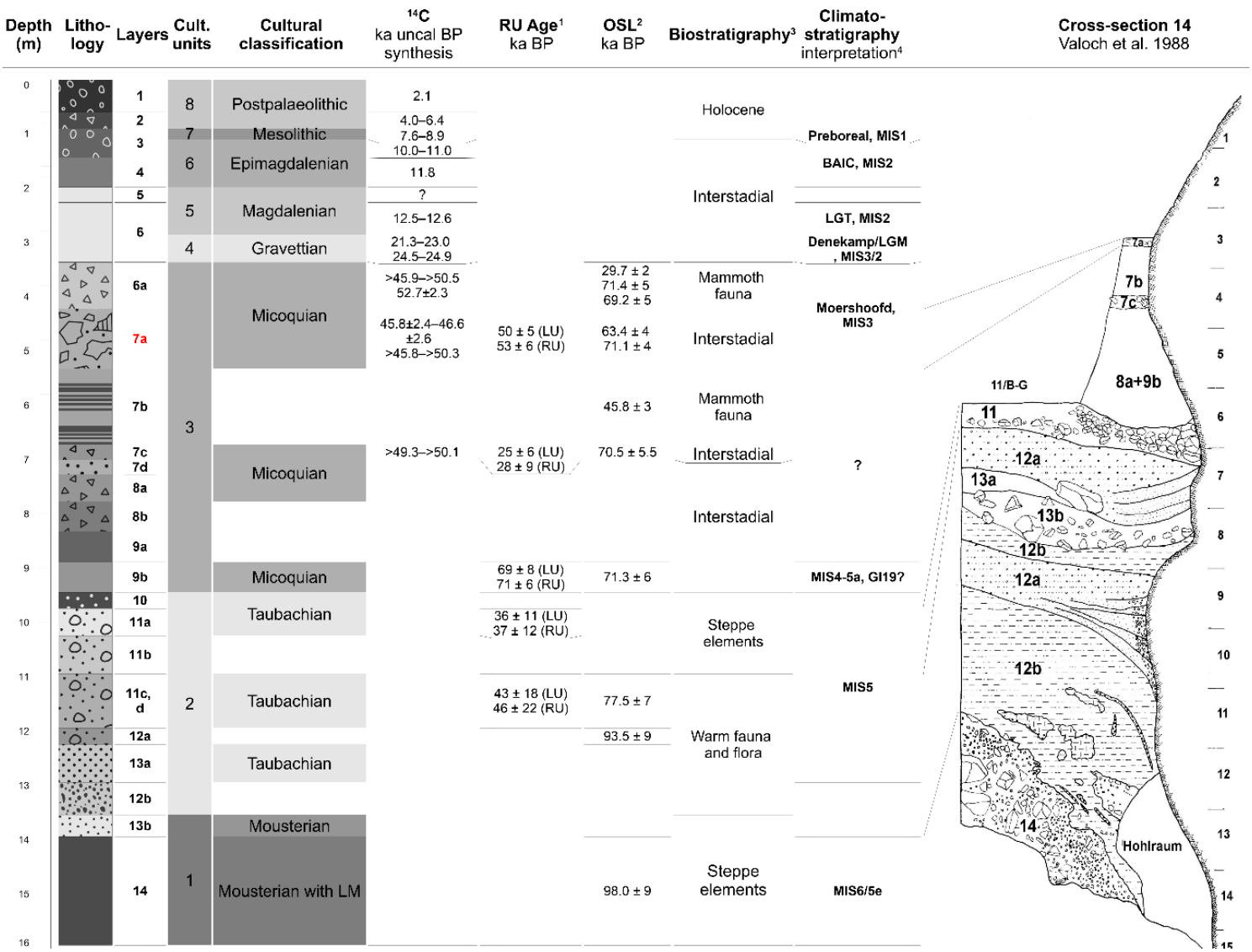


Figure 2

Chronostratigraphic model of sediments in Kůlna Cave. 1 - RINK W. J., SCHWARCZ H. P., VALOCH K., SEITL L., STRINGER C. B., 1996: ESR Dating of Micoquian Industry and Neanderthal Remains at Kůlna Cave, Czech Republic. Journal of Archaeological Science 23, 6: 889-901.

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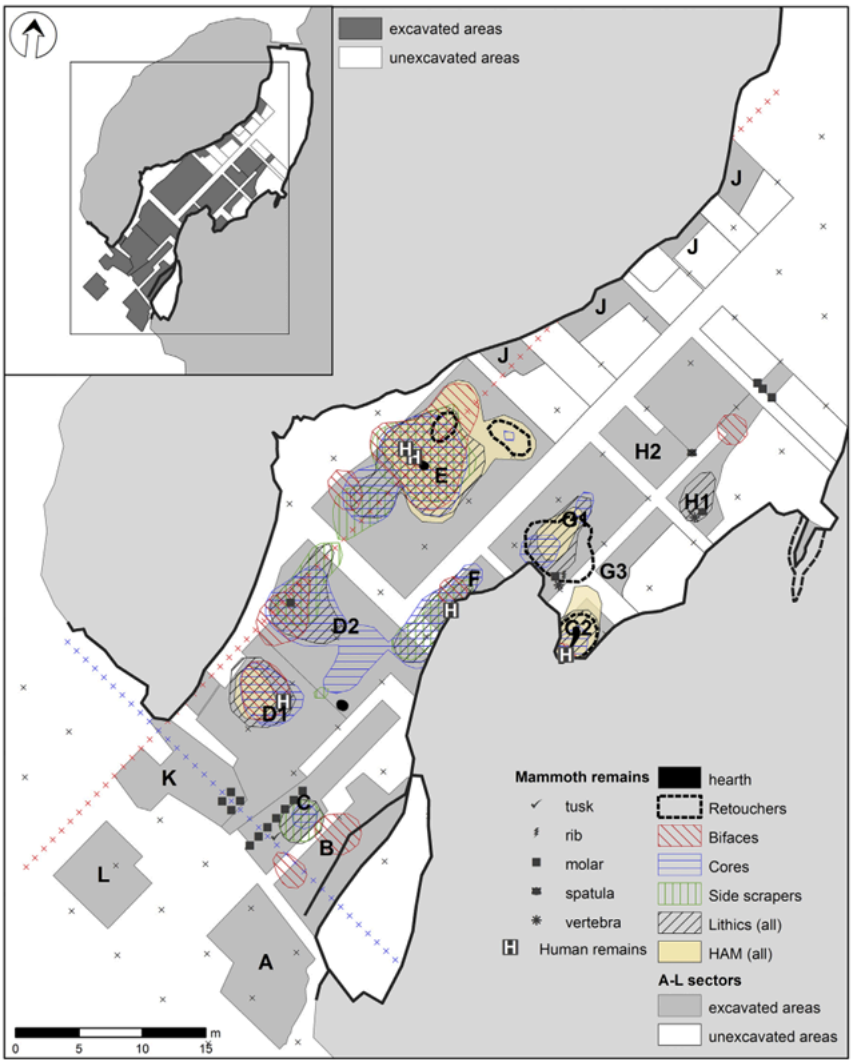


Figure 3

Plan of the Layer 7a with excavated areas and sectors (Neruda 2017)

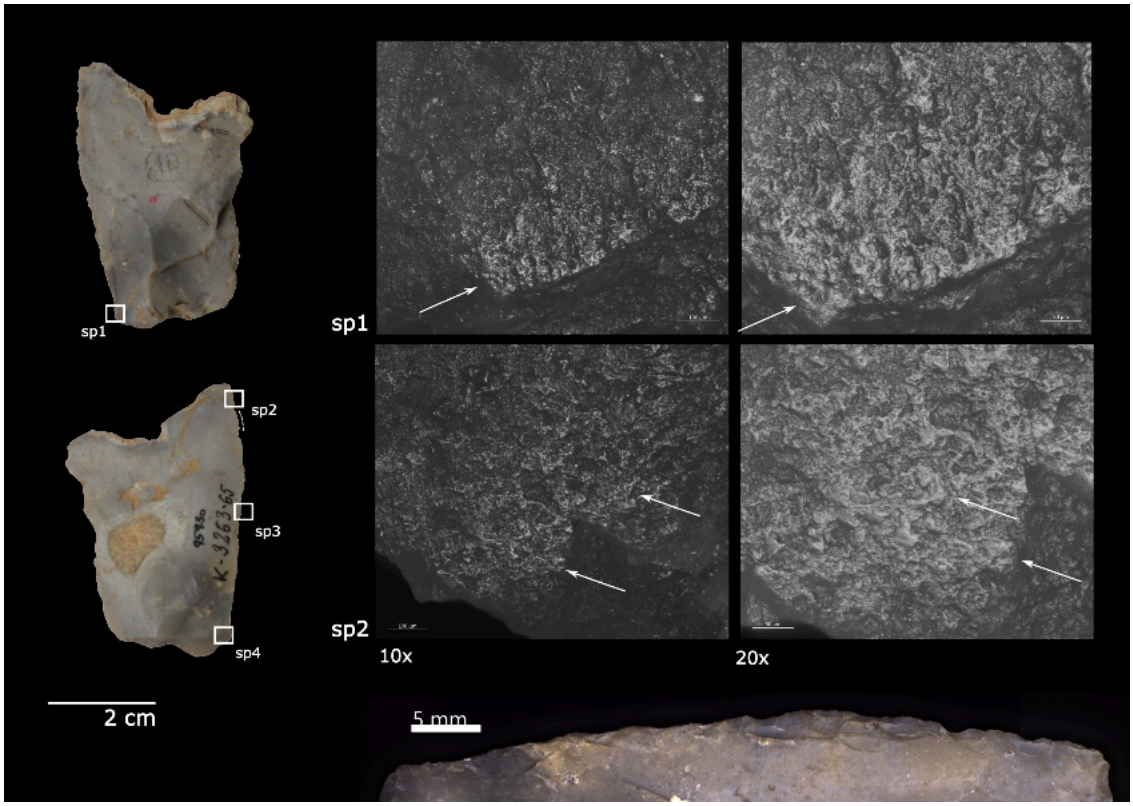


Figure 4

Scraper exhibiting use-wear traces associated with woodworking

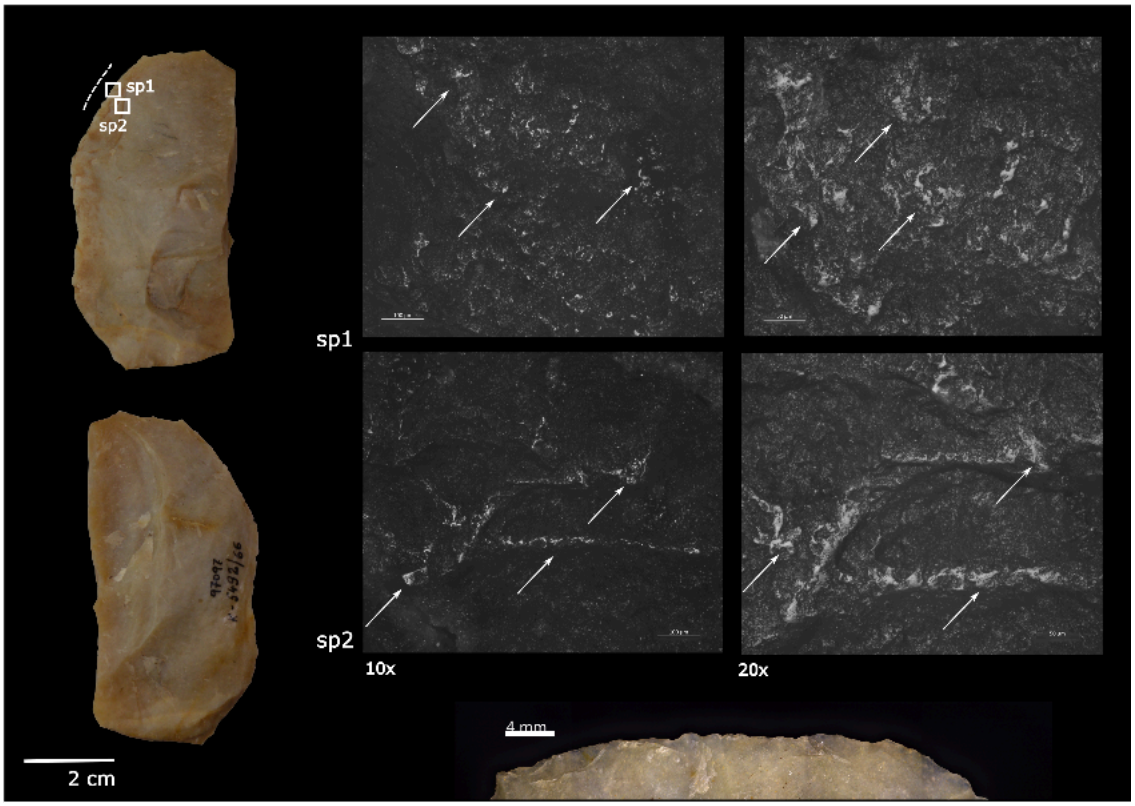


Figure 5

Unretouched flake exhibiting traces associated with working hard wood

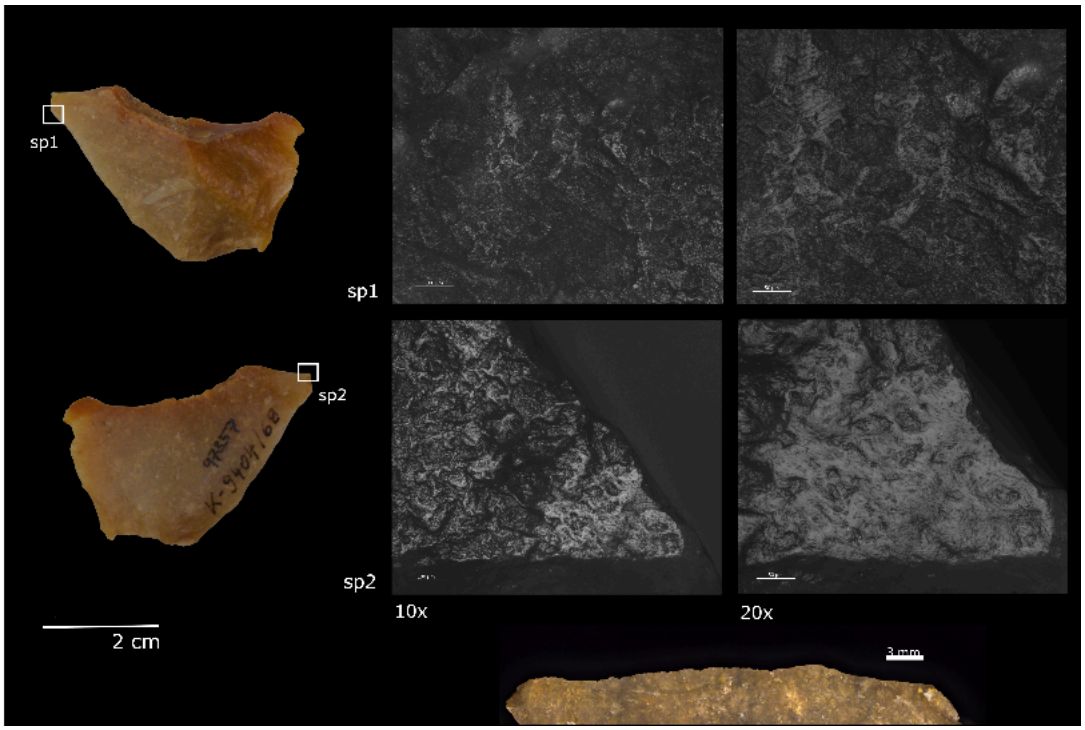


Figure 6

Unretouched flake exhibiting traces associated with hide-working

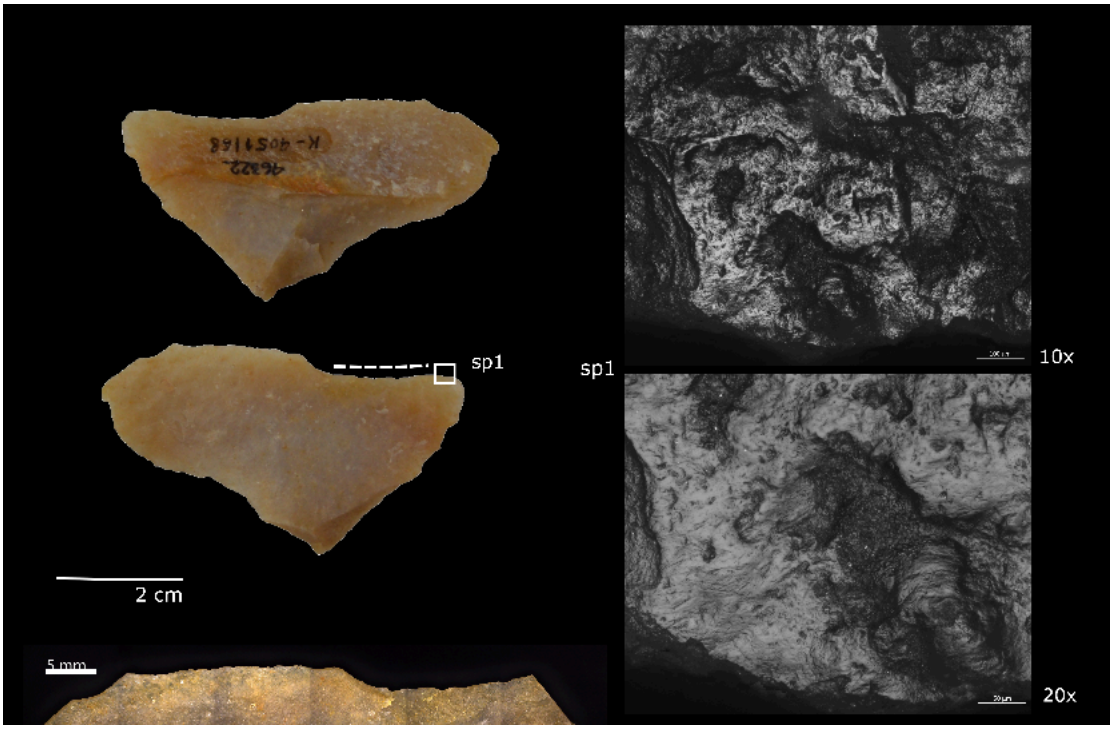


Figure 7

Unretouched flake exhibiting traces associated with working soft wood/plants

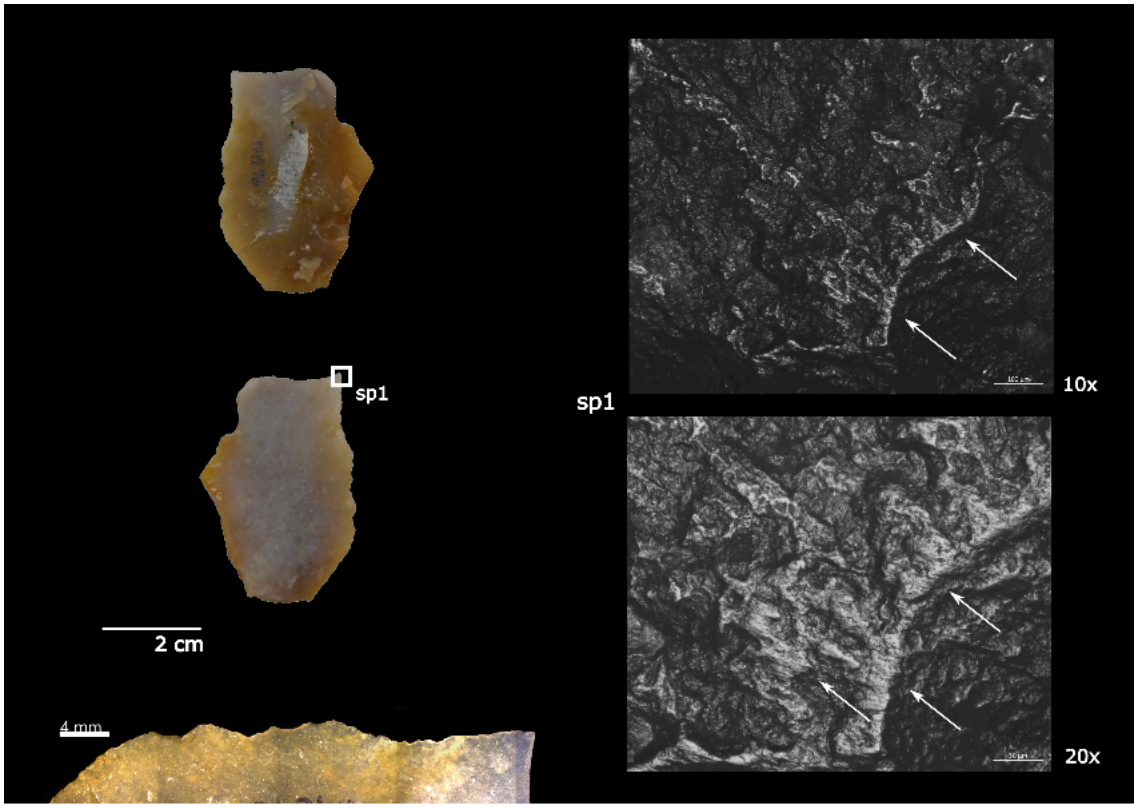


Figure 8

Unretouched flake exhibiting traces associated with wood-working

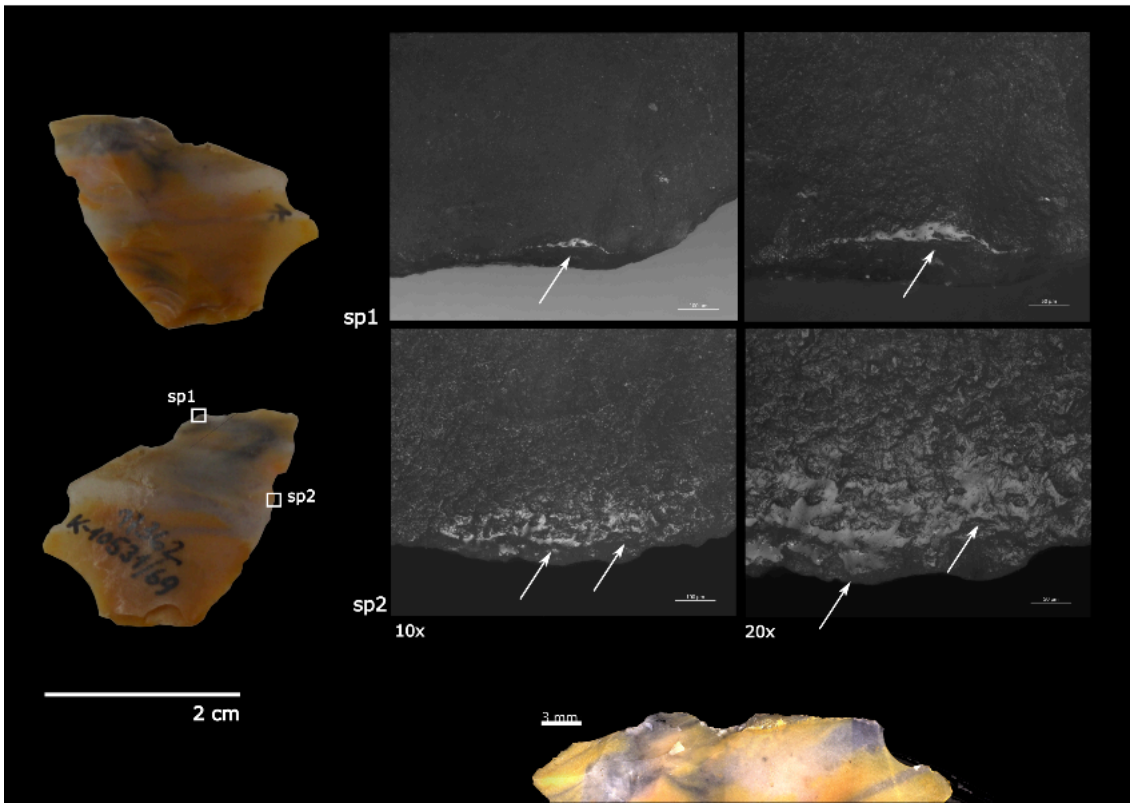


Figure 9

Unretouched flake exhibiting traces associated with bone-working

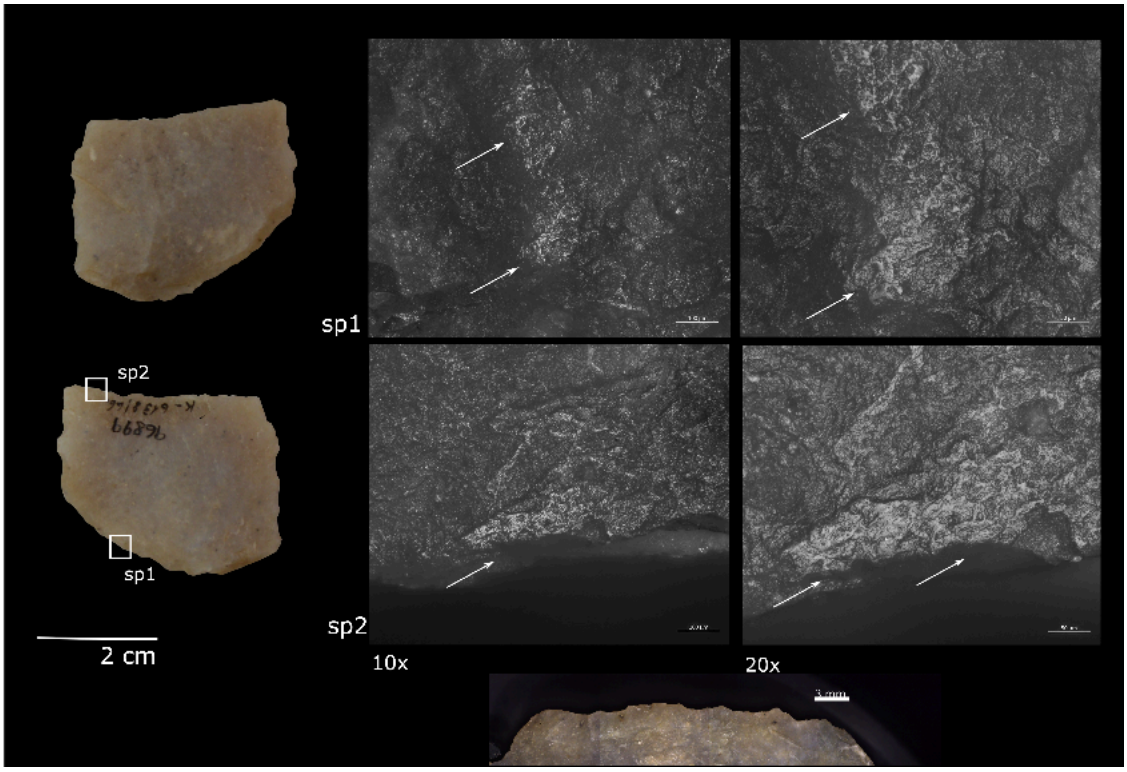


Figure 10

Unretouched flake exhibiting traces associated with wood-working

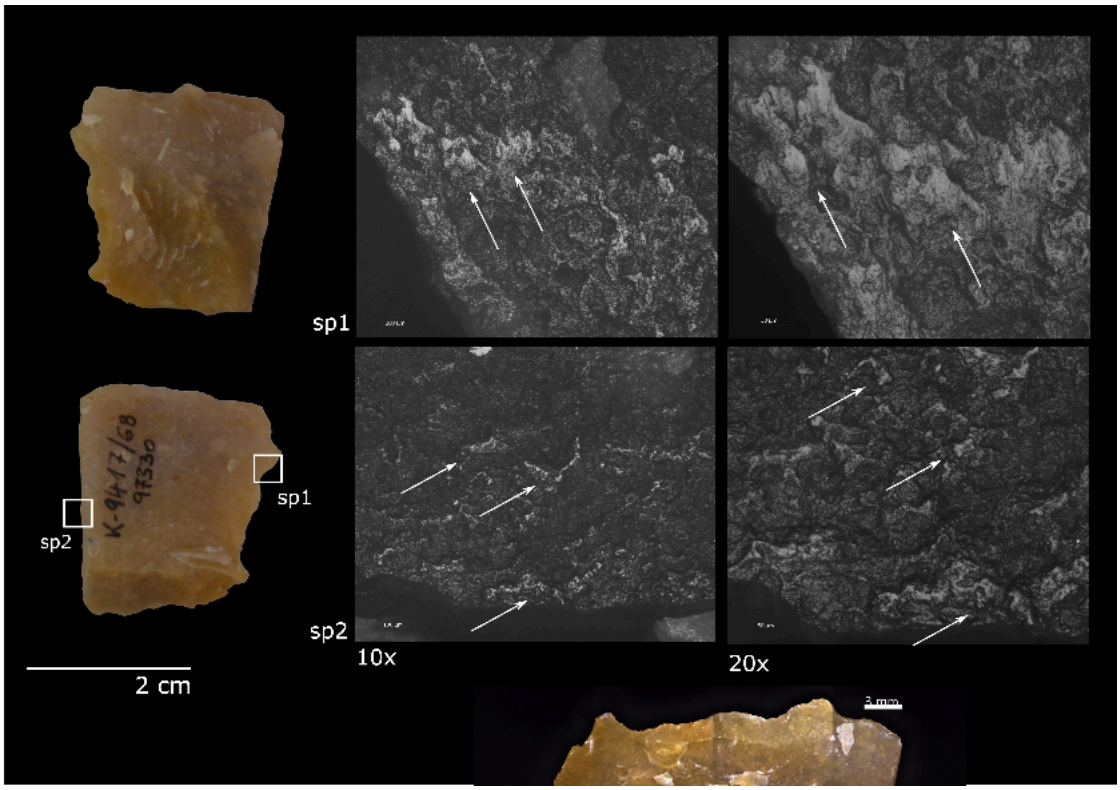


Figure 11

Notch exhibiting traces associated with wood-working

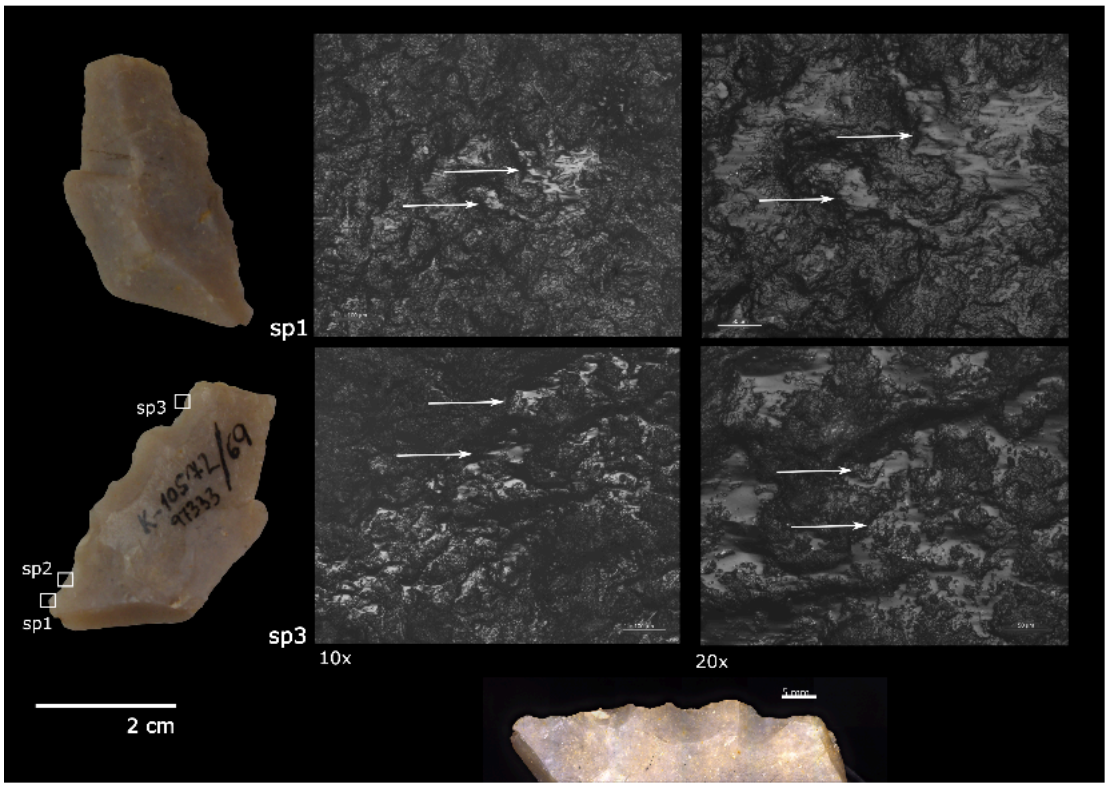


Figure 12

Denticulate exhibiting traces associated with hard wood working

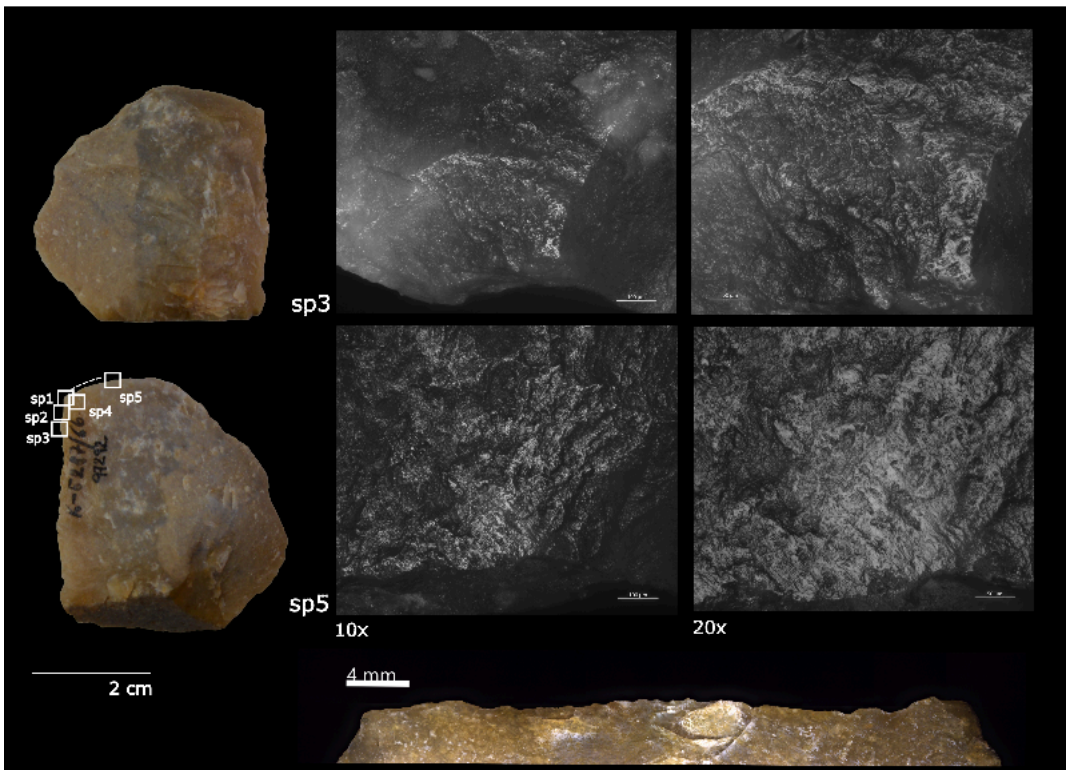


Figure 13

Unretouched flake exhibiting traces associated with hide working and wood working

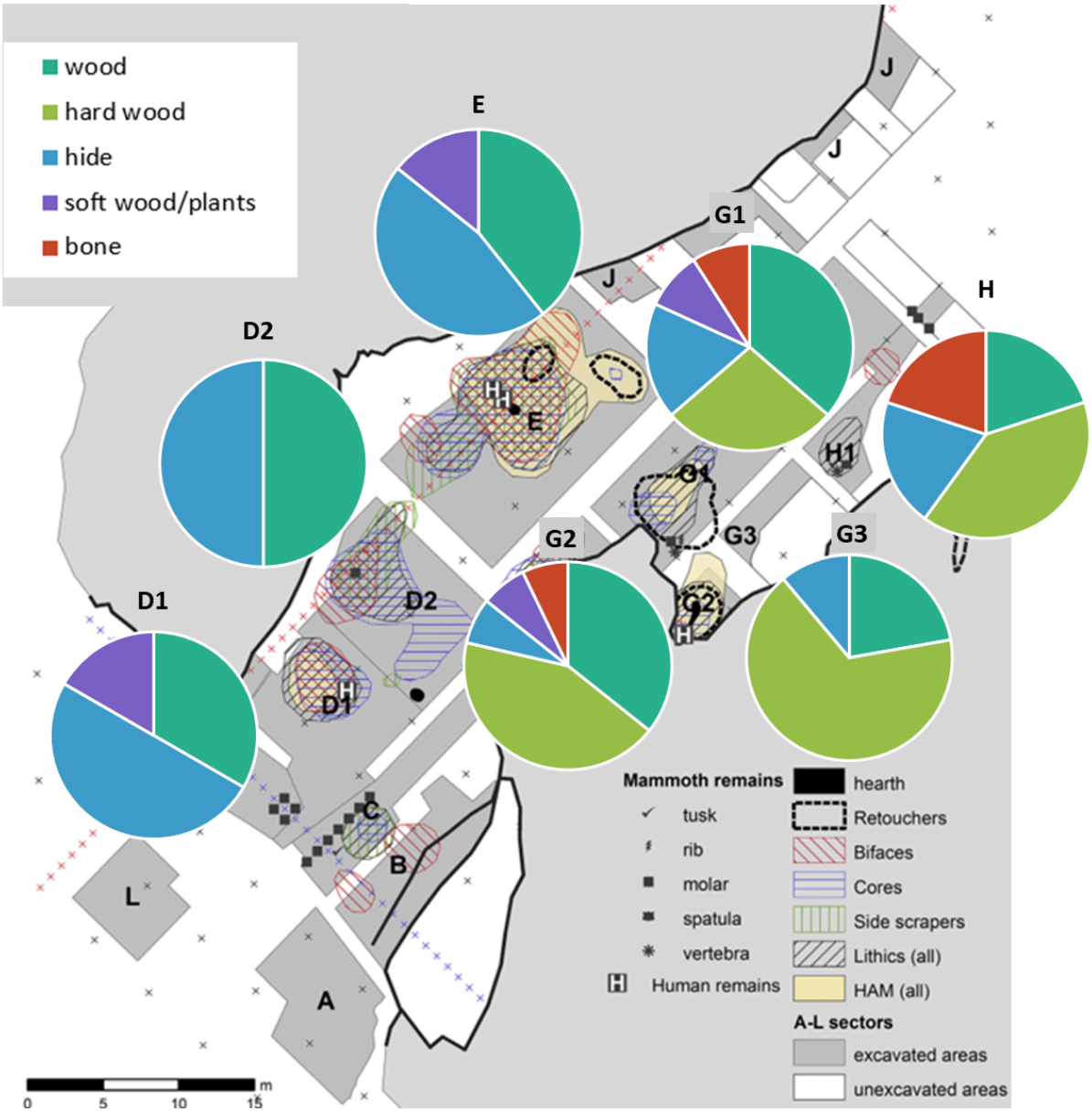


Figure 14

Plan of Layer 7a of Kůlna Cave with identified working materials in individual sectors visualized in pie charts. Adapted from: Neruda 2017

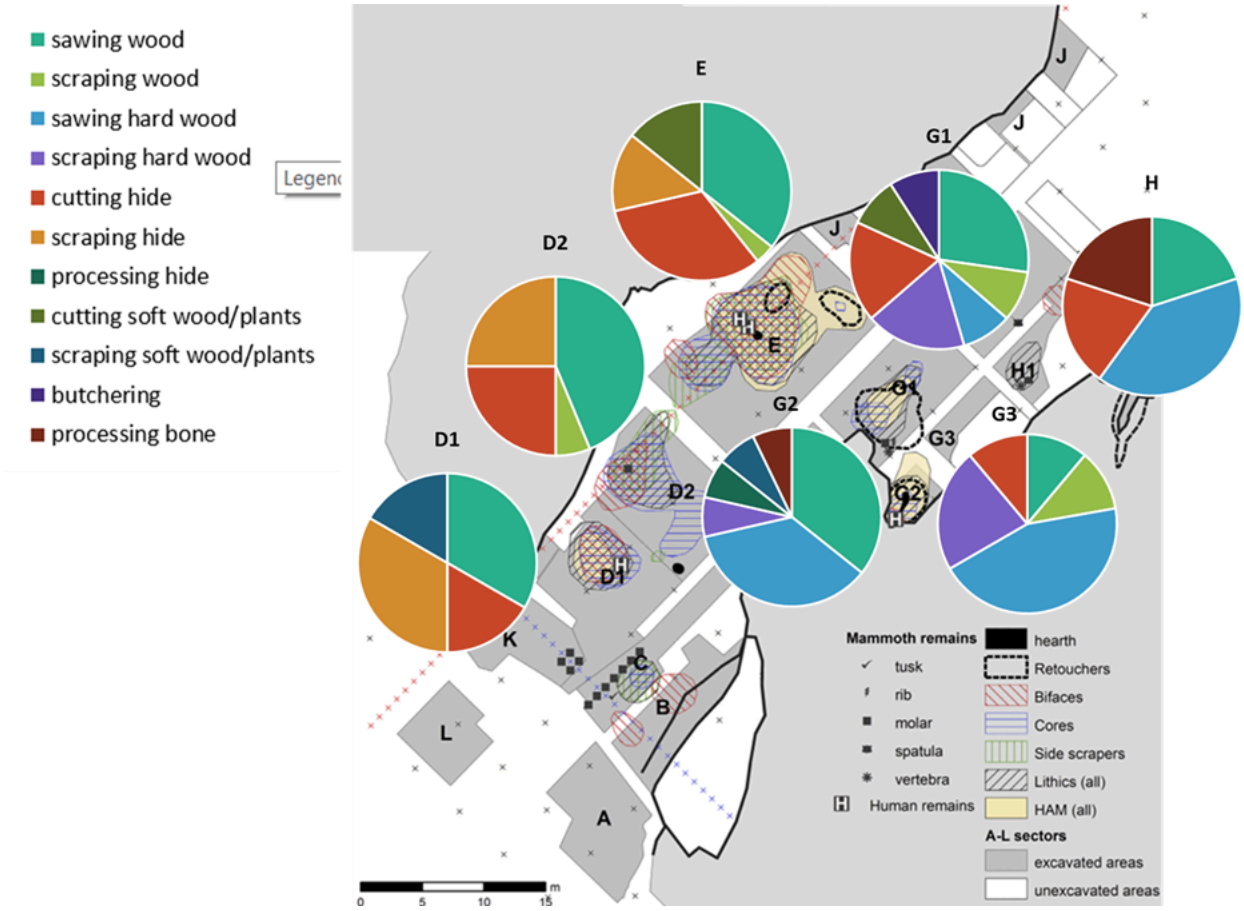


Figure 15

Plan of Layer 7a of Kůlna Cave with identified activities in individual sectors visualized in pie charts. Adapted from: Neruda 2017