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ORIGINAL PAPER

# Use-wear analysis applied in a dissected palimpsest at the Middle Palaeolithic site of El Salt (eastern Iberia): working with lithic tools in a narrow timescale

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## Abstract

Use-wear analyses are very useful to increase knowledge about the economic and subsistence dynamics carried out by Neanderthals. In general terms, functional results traditionally came from the analysis of tools belonging to stratigraphic units whose timescale refers to geological time. This is due to the fact that many Neanderthal sites are palimpsests of reiterated occupations over time, which must be dissected to approach us to human timescale. In the stratigraphic unit xa of El Salt (Alcoi, eastern Iberia), high temporal resolution archaeostratigraphic studies have been carried out. Diachronic material assemblages have been identified, allowing us to analyse more precisely the variability of Neanderthal behaviour over time. Amongst these assemblages, three have been selected (i.e. 5.3.1, 5.3.2 and 5.3.3) in order to analyse the lithic material functionality. The results obtained bring out the performance of different tasks within each analytical framework: woodworking in 5.3.1, woodworking and animal processing in 5.3.2, and butchering activity in 5.3.3. These results reflect the existence of a series of diachronic tasks carried out in overlapping activity areas. In this way, this work evidences flint use variability in a specific area of the site across time that could have been recognised only by means of high temporal resolution analytical frameworks.

**Keywords** Middle Palaeolithic · Use-wear analysis · Palimpsest dissection · Interoccupational variability · El Salt

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## Introduction

An increasing number of functional lithic studies since the 1960s has contributed to overcome speculation on use based on artefact typology and improve our understanding of some of the activities carried out by Neanderthal hunter-gatherers (e.g. Beyries 1987; Anderson-Gerfaud 1990; Lemorini 1996, 2000; Jardón & Bosquet 1999; Claud 2008; Clemente et al. 2014; Lazuén & González 2014; Venditti et al. 2019a). The bulk of data has been obtained from the analysis of tools belonging to stratigraphic units (SUs) (e.g. Beyries 1987; Jardón 2000; Lemorini 2000; Rodríguez et al. 2002; Martínez 2005; Rots 2011, 2016; Hortelano 2016; Lemorini et al. 2016; Márquez et al. 2017), which usually are a palimpsest of reiterated occupations whose timescale spans millennia or unknown amounts of time. Therefore, the use of the SU as an analytical frame provides general results that drive us away from human temporality and hamper the analysis of the variability of human behaviour throughout time. Narrowing down the information on stone tool use to timescales at which we can explore behavioural variability and change remains a challenge.

In the last decades, there has been an increasing concern for problems derived from the palimpsest condition of archaeological sites (e.g. Harding 2005; Bailey 2007; Holdaway & Wandsnider 2008; Lucas 2010; Henry 2012). In this framework, the SU xa from the site of El Salt (Alcoi, eastern Iberia) has been the focus of several studies aimed at approaching human single occupation episodes through multiproxy analyses (cf. Marrero et al. 2011; Machado et al. 2011, 2017; Mallol et al. 2013; Machado and Pérez 2015; Vidal et al. 2018; Leierer et al. 2019; Mayor et al. 2020; Pérez et al. 2020). Earlier studies carried out at SU xa showed archaeostratigraphically well-delimited material beds, leading to the definition of analytical frames called archaeostratigraphic units (AUs) (cf. Machado et al. 2011, 2017; Machado and Pérez 2015). Despite displaying a higher temporal resolution, these units constituted a micropalimpsest that was dissected in later studies (cf. Mayor et al. 2020), resulting in new analytical frames (i.e. 5.3.1, 5.3.2 and 5.3.3) that are even more accurate from a temporal perspective and closer to human single occupation episodes.

These studies have allowed the formulation of two main hypotheses related to SU xa:

The activities were carried out generally around hearths, as indicated by material scatters that fit the hearth-related assemblage model (cf. Vaquero & Pastó 2001).

The Neanderthals here did not occupy the place for long periods of time.

In this frame, it is of great interest to analyse the lithic artefacts from discrete and short-spanned activity events from a functional perspective. In this sense, the utilisation of high temporal resolution analytical frameworks is a differentiating factor of this research regarding other use-wear studies. If we take as examples other Neanderthal sites located within the Mediterranean Iberian coast whose lithic material has been subjected to functional analyses, such as Cova Negra (cf. Moriel 1985), Abric Romaní (cf. Martínez 2005; Martín-Viveros et al. 2020), Abric del Pastor (cf. Galván et al. 2008), La Quebrada (cf. Eixea et al. 2015), Cova del Bolomor (cf. Hortelano 2016), and even El Salt (cf. Rodríguez et al. 2002), we can observe that the SU is employed as an analytical framework, and that the results derived from this tend to homogenise the human behaviours.

Thus, the goal of this research is to explore the potential of lithic functional studies in small timescale analytical frameworks as proxies to identify the tasks performed in a specific space of the site. The study consists in carrying out use-wear analysis on the lithic assemblages from AUs 5.3.1, 5.3.2 and 5.3.3, which are three successive analytical frames that are part of diachronic, discrete, brief human occupations (cf. Mayor et al. 2020). Comparing these analytical frames across time could provide insight into Neanderthal behavioural variability.

### The archaeological site of El Salt

The archaeological site of El Salt is an open-air rockshelter at 680 m above sea level located in Alcoi and featuring a 38-m-high travertine wall at the foot of the excavated area (Fig. 1). It has a 6.3-m-thick stratified deposit divided into 13 stratigraphic units (cf. Fumanal 1994), dating mainly from the Upper Pleistocene. Uranium–thorium (U-Th), thermoluminescence (TL) and optically stimulated luminescence (OSL) dating techniques carried out on the site indicated a broad temporal range between 81.5 ± 2.7 ky BP for SU xiii and 44.7 ± 3.2 ky BP for SU v. The first evidence of human occupation is found in stratigraphic unit xii, datable to 60.7 ± 8.9 ky BP (cf. Galván et al. 2014a, b).

Archaeological research at El Salt has been ongoing since 1986 and is geared at approaching human behavioural evolution in the Alcoian valleys from a multidisciplinary perspective. To this date, the resulting data have provided a diversity of geoarchaeological, palaeoanthropological, palaeoenvironmental, palaeodietary and palaeoeconomic information (cf. Fumanal 1994; Rodríguez et al. 2002; Galván et al. 2006; Dorta et al. 2010; Machado et al. 2011; Sistiaga et al. 2011, 2014; Mallol et al. 2012, 2013; Machado and Pérez 2015; Herrejón et al. 2016; Vidal 2016, 2017; Machado et al. 2017; Fagoaga et al. 2018, 2019; Vidal et al. 2018; Leierer et al. 2019; Pérez et al. 2020); Fagoaga 2020; Mayor et al. 2020; Rampelli et al. 2021; Marín et al. 2021).

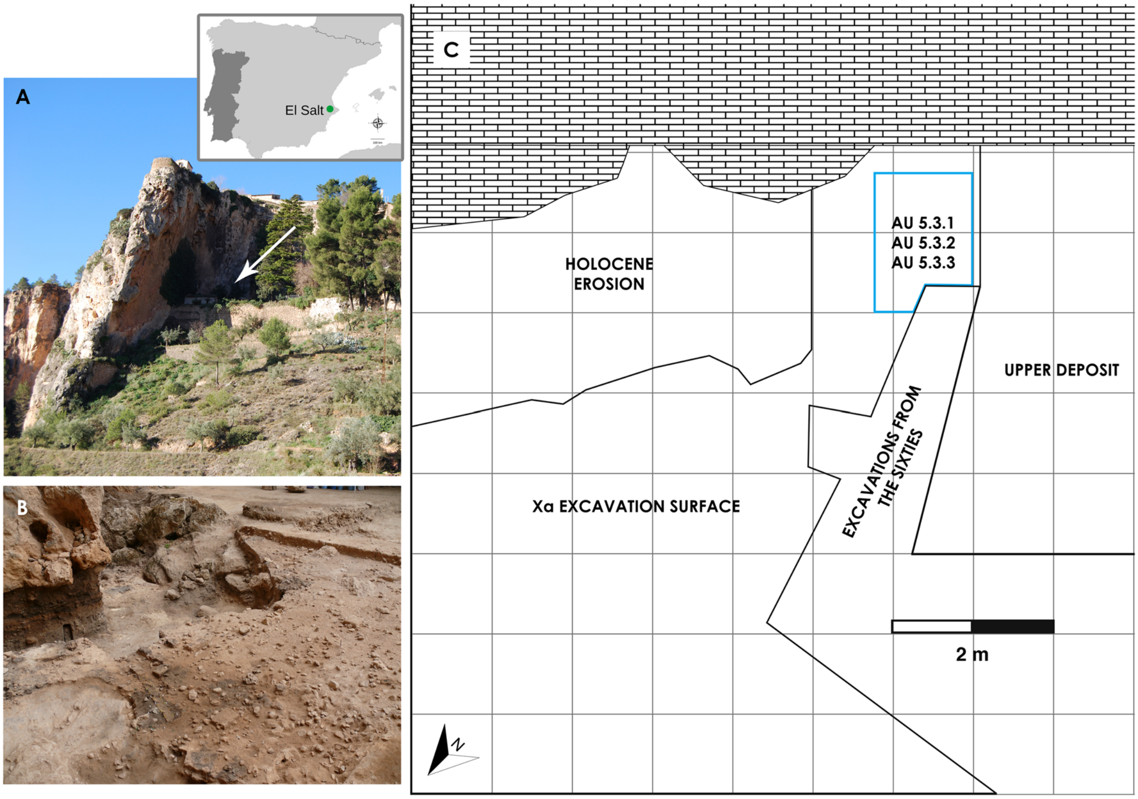


**Fig. 1** **A** Location of El Salt. **B** Unit xa excavation surface. **C** Plan illustrating the horizontal position of the AUs

In recent years, research at El Salt has focused on SU xa, dated to 52.3 ± 4.6 ky BP (cf. Galván et al. 2014a, b). This unit is characterised by a rich and diverse archaeological record that includes lithic artefacts, faunal remains and well-preserved combustion structures. The SU xa lithic record comprises cores and both retouched and unretouched flakes manufactured using mainly the Levallois method (cf. Machado 2016; Mayor et al. 2020) on different available flint types: Serreta, Mariola, Beniaia and Font Roja (cf. Molina 2016; Machado 2016).

The SU xa faunal record suggests the exploitation of medium-sized mammals, mainly wild goat (i.e. *Capra pyrenaica*), deer (i.e. *Cervus elaphus*) and horse (i.e. *Equus ferus* and *Equus hydruntinus*). Archaeozoological data indicate hunting and subsistence activities (*cf.* Pérez 2019). Geoarchaeological data indicates that the SU xa hearths were simple, flat and short-lived (*cf.* Mallol et al. 2013) and anthracological data point to pine (i.e. *Pinus nigra*) as the prevalent fuel choice (*cf.* Vidal 2017; Vidal et al. 2017).

## Materials and methods

The materials selected for this study are integrated in AU 5.3, located near the travertine wall and whose archaeological record covers an area of approximately 2m$^2$ from the 36m$^2$ of the excavation surface (*cf.* Machado et al. 2017).

This AU was in turn dissected into 3 new AUs conceived as higher resolution analytical frames: 5.3.1, 5.3.2 and 5.3.3 (Table 1) from specific diachrony indicators relating to the three-dimensional position of raw material units, in addition to their relationship with the stratigraphic location of

**Table 1** Raw material units (RMU), associated hearths and technological ascription of the 5.3.1, 5.3.2 and 5.3.3 lithic assemblages (*cf.* Mayor et al. 2020)

| AUs | Involved hearths | *N* of RMUs | Involved RMUs | *N* of raw material types | Tech. ascription |
|---|---|---|---|---|---|
| 5.3.1 | H31 | 4 | 5.3_5, 13, 14, 16 | 3 | RCL with non-L |
| 5.3.2 | H29 | 5 | 5.3_3, 4, 9, 15, 19 | 3 | RCL |
| 5.3.3 | H32 | 13 | 5.3_1, 2, 6–8, 10–12, 17, 18, 20–22 | 5 | RCL with non-L |

hearths (*cf*. Mayor et al. 2020). These three new archaeostratigraphic units represent contexts that are singular, overlapped between them. Each of these AUs represents potential hearth-related assemblages that are closer to the human timescale and could also signify self-contained activity areas. For this reason, they are optimal frameworks to perform use-wear characterisation aiming to recognise diachronic Neanderthal behaviours.

In total, the three frames comprise 56 objects. Most of them are ascribed to the Levallois method. They are mainly flakes (43: 77%), 15 of which show recurrent centripetal Levallois production features. The remaining are 2 cores and fragments that have not been technologically ascribed. There is only one support that has been retouched as a transversal scraper. The predominant flint type is Serreta (i.e. 46.4%), followed by Mariola (i.e. 30.6%), Beniaia (i.e. 12.5%), Font Roja (i.e. 3.5%) and an undetermined type (i.e. 7%) (*cf*. Mayor et al. 2020). Regarding their dimensions, the lithic objects have been assigned to three different size classes: small (i.e. < 2 cm on its axis), medium (i.e. 2–3 cm) and large (i.e. > 3 cm).

Taking previous research as a reference (*cf*. Mayor et al. 2020), the technological ascription, raw material and measurements of the supports integrating each analytical frame are explained next:

Archaeostratigraphic unit 5.3.1

It includes 9 flakes and a fragment made of Serreta (i.e. 40%), Mariola (i.e. 40%) and Beniaia (i.e. 20%) flint types (Table 2).

Archaeostratigraphic unit 5.3.2

It involves 15 products, mainly flakes, but also a core and a fragment made of Serreta (i.e. 66.67%), Mariola (i.e. 13.33%) and Beniaia (i.e. 20%) flint types (Table 3).

Archaeostratigraphic unit 5.3.3

It includes 31 elements: 21 flakes, a transversal scraper, a core and 8 fragments made on Serreta (i.e. 38.7%), Mariola (i.e. 35.4%), Font Roja (i.e. 6.4%), Beniaia (i.e. 6.4%) and an undetermined flint type (i.e. 12.9%) (Table 4).

## Functional analysis

Use-wear analysis has been carried out on 41 of the 56 objects (i.e. 73.2%). The remaining 15 objects have not been analysed due to either the presence of visible physical and chemical alteration or the absence of edges or regular, potentially usable platforms.

Use-wear analysis has been performed from two perspectives: functional and morphopotential. Regarding the functional perspective, we have analysed tool-use, kind of worked materials and kinds of performed actions. Analysis of potentially prehensile areas has also been carried out to detect possible signs of hafting. Functional inference was based on experimental data (see the "Experimental programme" section for further details) obtained from working different materials using the most relevant predominant flint type (i.e. Serreta). These data were compared and contrasted with other studies (*e.g*. Tringham et al. 1974; Hayden 1979; Keeley 1980; Anderson-Gerfaud 1981, 1990; Vaughan 1985; González & Ibáñez 1994; Gutiérrez 1996; Jardón 2000; Lemorini 2000; Rots 2011).

Regarding the morphopotential approach, we documented edge angles, measured in degrees, and morphologies (i.e. concave, straight, convex) to explore the relationship between shape and function (*e.g*. Venditti et al. 2019b).

## Experimental programme

An experimental programme to ensure the reliability of traceological data was carried out using the Serreta flint type. The flakes were comparable in size to the

**Table 2** Lithic assemblage belonging to the AU 5.3.1. Technological ascriptions, products, flint types and size classes are indicated

| AU | ID | Tech. ascription | Product | Flint type | Size (mm) |
|---|---|---|---|---|---|
| 5.3.1 | ×6/31 | Unipolar non-Levallois | Flake | Serreta | 27×24×12 |
| | ×6.7/24 | Unipolar non-Levallois | Flake | Serreta | 41×6×5 |
| | ×5.6/278 | RCL | Flake | Beniaia | 35×31×8 |
| | ×5.6/279 | RCL | Flake | Beniaia | 15×19×2 |
| | ×5/1310 | RCL | Flake | Mariola | 22×21×5 |
| | ×5/1312 | RCL | Flake | Mariola | 21×17×3 |
| | ×5/1028 | Undiagnosed | Cortical flake | Mariola | 19×22×6 |
| | ×5/1313 | Undiagnosed | Cortical flake | Mariola | 27×25×9 |
| | ×4/810 | Undiagnosed | Cortical flake | Serreta | 30×18×6 |
| | ×5/14 | Undiagnosed | Cortical fragment | Serreta | 16×16×8 |

*RCL* means recurrent centripetal Levallois

**Table 3** Lithic assemblage belonging to the AU 5.3.2. Technological ascriptions, products, flint types, and size classes are indicated

| AU | ID | Tech. ascription | Product | Flint type | Size (mm) |
|---|---|---|---|---|---|
| 5.3.2 | ×4/758 | RCL | Flake | Mariola | 34×17×4 |
| | ×5/1322 | RCL | Flake | Mariola | 24×15×4 |
| | ×6/22 | RCL | Flake | Serreta | 16×16×2 |
| | ×5/1545 | RCL | Flake | Serreta | 17×21×4 |
| | ×5/1062 | RCL | Flake | Serreta | 30×20×2 |
| | ×4/781 | RCL | Flake | Serreta | 23×12×6 |
| | ×4/803 | RCL | Flake | Serreta | 26×9×2 |
| | ×5/12 | Undiagnosed | *Débordant* flake | Beniaia | 32×22×6 |
| | ×4/775 | RCL | Flake | Beniaia | 30×14×2 |
| | ×4/801 | RCL | Flake | Beniaia | 19×30×2 |
| | ×4/826 | RCL | Cortical flake | Serreta | 30×21×9 |
| | ×4/787 | RCL | Flake | Serreta | 37×25×10 |
| | ×4/782 | RCL | Flake | Serreta | 19×21×7 |
| | ×4/789 | Recurrent centripetal | Core | Serreta | 28×19×8 |
| | ×5/990 | Undiagnosed | Cortical fragment | Serreta | 24×14×9 |

*RCL* means recurrent centripetal Levallois

archaeological ones and they were produced replicating the hierarchised centripetal sequences observed in the archaeological record. We conducted mechanical (i.e. repeating a movement mechanically) and replicating (i.e. reproducing and completing an activity) experiments on animal (i.e. *Capreolus capreolus*) and woody matter (i.e. *Pinus nigra* and *Pinus halepensis*), as their remains are abundant at the site. We used the tools for variable amounts of time, from 20 min to over 2 h, depending on the action and the availability of the material to be worked upon (see supplementary information for further details).

Apart from this experimentation, we have conducted an experimental programme on splintered pieces (*cf.* Jardón et al. 2018), and on thermoaltered woodworking (*cf.* Bencomo & Jardón 2022).

### Tool cleaning and microscopy

We washed the archaeological and experimental artefacts with lukewarm water and mild soap (Hygenia, Magnum Blue), and then with acetone in an ultrasonic bath (Metason 120, Struers) for a variable time (i.e. from 10 min to 1 h). For more persistent sediment adherences and concretions, we used acetic acid (5%). Acetone was also used to remove surface grease from recent handling.

Microscopic observation was carried out using a Leica Microsystems® M165C stereomicroscope at 3.65–60 magnifications, and two metallographic microscopes: Leica Microsystems® DM6000M and Zeiss Axio Scope A1, both at 50–500 magnifications.

## Results

Our results indicate that around half of the examined artefacts (i.e. 48.78%) show evidence of use (Table 5). Tables 6, 7 and 8 show a summary of the functional data obtained by each AU.

Our data suggest that the tools were used for processing wood and animal tissue (i.e. butchery activity and skin).

The diagnostic features are:

- Regarding wood (fig. S1-S3), there is a slight development of edge rounding. The edges exhibit scars with an aligned organisation, but in some cases, it is superimposed. In general, they have a semicircular morphology and a feather, transverse or step termination. In terms of size, they are small or medium. The polish is bright, with a rough texture, which sometimes tends to be smooth directly on the edge, and the topography is domed, especially on the higher parts of the surface. None of the tools exhibits striations.
- Regarding the work performed on animal tissues (fig. S4-S6), we can distinguish between work on skin and processing of animal carcasses. The former shows scars with a small and medium size, with an aligned organisation (sometimes superimposed), semicircular morphology (sometimes irregular) and a feather or step termination and a well-developed rounding of the edge. The polish is dull with a rough texture and a domed topography in the higher and lower parts of the surface. For the animal carcasses, the tools present small and medium scars with an aligned organisation, a semicir-

**Table 4** Lithic assemblage belonging to the AU 5.3.3. Technological ascriptions, products, flint types and size classes are indicated

| AU | ID | Tech. ascription | Product | Flint type | Size (mm) |
|---|---|---|---|---|---|
| 5.3.3 | ×6/28 | Kombewa | Flake | Serreta | 21×6×4 |
| | ×6/8 | Undiagnosed | Flake | Serreta | 29×22×10 |
| | ×6.7/30 | RCL | Flake | Serreta | 34×17×5 |
| | ×5/1320 | Undiagnosed | Fragment | Serreta | 15×14×4 |
| | ×5/1309 | Kombewa | Transversal scraper | Serreta | 19×33×5 |
| | ×6/15 | Kombewa | Flake | Serreta | 17×15×3 |
| | ×5/1008 | Undiagnosed | Flake | Font Roja | 13×18×2 |
| | ×6.7/12 | Unipolar non-Levallois | Flake | Font Roja | 34×18×7 |
| | ×5/1316 | Discoidal | Fragment | Mariola | 18×17×3 |
| | ×5/1315 | Discoidal | Flake | Mariola | 27×26×11 |
| | ×5/1311 | Discoidal | Cortical flake | Mariola | 34×36×12 |
| | ×5/1553 | Non-Levallois | Flake | Undet | 27×43×8 |
| | ×5/1550 | Non-Levallois | Flake | Undet | 20×8×6 |
| | ×5/1019 | RCL | Flake | Mariola | 35×50×10 |
| | ×5/1025 | RCL | Flake | Mariola | 15×14×3 |
| | ×6/7 | RCL | Flake | Serreta | 15×22×3 |
| | ×5.6/208 | RCL | Flake | Serreta | 13×15×6 |
| | ×5/1024 | RCL | Flake | Serreta | 15×20×3 |
| | ×5/13 | RCL | Flake | Serreta | 15×22×6 |
| | ×5/352 | Undiagnosed | Fragment | Beniaia | 13×28×7 |
| | ×5/1502 | Undiagnosed | Fragment | Beniaia | 26×43×10 |
| | ×6/24 | Undiagnosed | Fragment | Mariola | 18×12×4 |
| | ×5/1547 | Undiagnosed | Flake | Mariola | 6×15×8 |
| | ×4/811 | Undiagnosed | Flake | Mariola | 31×18×4 |
| | ×5/976 | Undiagnosed | Flake | Mariola | 20×15×5 |
| | ×4/764 | Undiagnosed | Flake | Mariola | 34×24×6 |
| | ×4/780 | Undiagnosed | Core | Mariola | 30×37×27 |
| | ×4/607 | Undiagnosed | Fragment | Serreta | 43×22×13 |
| | ×4/614 | Undiagnosed | Flake | Serreta | 21×14×6 |
| | ×6.7/176 | Undiagnosed | Fragment | Undet | 24×16×8 |
| | ×6.7/176 | Undiagnosed | Fragment | Undet | 18×16×4 |

*RCL* means recurrent centripetal Levallois

**Table 5** List of tools exhibiting microscopic use-wear

| AUs | Total number of tools | Tools views under the microscope | Tools exhibiting use wear |
|---|---|---|---|
| 5.3.1 | 10 | 9 | 3 |
| 5.3.2 | 15 | 13 | 8 |
| 5.3.3 | 31 | 19 | 9 |

cular morphology and a feather or transverse termination. The polish is fluid (follows the relief without affecting it), the topography is domed and the contour tends to be fuzzy. In some cases, there are large scars with step termination associated with well-developed polished in the highest parts of the topography which means that there was contact with hard material (e.g. cartilage, bone).

**Table 6** Use-wear data in AU 5.3.1

| Tool ID | Tool morphology | Edge morphology | Edge angle | Worked material | Action |
|---|---|---|---|---|---|
| x6/31 | Pentagonal | Straight | 60° | Wood | Scraping |
| | | Straight | 45° | Wood | Scraping |
| x6.7/24 | Rectangular | Convex | 45° | Wood | Scraping |
| x5.6/278 | Heptagonal | Convex | 30° | Wood | Undiagnosed |

**Table 7** Use-wear data in AU 5.3.2

| Tool ID | Tool morphology | Edge morphology | Edge angle | Worked material | Action |
|---|---|---|---|---|---|
| ×4/826 | Quadrangular | Concave | 55° | Meat and skin | Cutting |
| ×4/781 | Rectangular | Straight | 20° | Wood | Cutting |
| ×5/1322 | Rectangular | Convex | 35° | Dry skin | Cutting |
| ×5/1545 | Rectangular | Straight | 30° | Wood | Cutting |
| ×4/758 | Rectangular | Convex | 35° | Wood | Scraping |
| ×5/1062 | Rectangular | Concave | 30° | Wood | Cutting |
| ×4/775 | Irregular | Convex | 30° | Skin, meat in contact with hard material (cartilage, bone…) | Cutting |
| ×4/787 | Irregular | Concave-convex | 40° | Dry skin | Cutting |

**Table 8** Use-wear data in AU 5.3.3

| Tool ID | Tool morphology | Edge morphology | Edge angle | Worked material | Action |
|---|---|---|---|---|---|
| x5/1315 | Triangular | Straight | 40° | Dry skin | Cutting |
| x6/28 | Rectangular | Straight | 40° | Dry skin | Scraping |
| x5/1502 | Rectangular | Straight | 55° | Meat and hard material (bone, cartilage) | Cutting |
| x6.7/30 | Irregular | Straight | 55° | Meat, skin and hard material (bone, cartilage) | Cutting |
| x5/1311 | Quadrangular | Straight | 50° | Hard material (bone?) | Percussion |
| x5/1309 | Triangular | Straight | 35° | Meat and skin | Cutting |
| | | Straight | 70° | Dry skin | Cutting |
| x6/15 | Pentagonal | Convex | 45° | Meat and skin | Cutting |
| x5/1024 | Rectangular | Straight | 35° | Dry skin | Scraping |
| x5/13 | Rectangular | Convex | 35° | Meat and skin | Cutting |

Regarding the actions that can be deduced from our analysis, they are cutting (longitudinal movement) and scraping (transversal movement). The distribution of the polish, scars and striations on both sides of a piece suggests a longitudinal action, while the distribution of the polish and striations on one side, and the scars on the other, allows us to speak of a transversal action. On the other hand, the orientation of the traces of use, especially the striations (parallel or perpendicular to the edge) and the scars (perpendicular or oblique) also indicates the type of motion.

As for the morphopotential data, they revealed the following pattern: large and medium-sized flakes with straight or convex edges, with angles mainly between 30 and 45°, were used for woodworking, and large or medium-sized flakes with straight edges and angles between 35 and 55° were used for animal tissue processing.

This is a detailed account of the functional results from each analytical frame:

Archaeostratigraphic unit 5.3.1

Four edges in three lithic tools (i.e. 33.33%) revealed use-wear traces of woodworking mainly in scraping actions (Table 6, Figs. 2, and 3).

Archaeostratigraphic unit 5.3.2

Eight lithic tools (i.e. 61.5%) revealed use-wear traces of woodworking mainly in cutting actions, and animal tissue, both butchery and skin, in cutting actions (Table 7, Figs. 4, 5, 6, and 7).

Archaeostratigraphic unit 5.3.3

Ten edges in nine lithic tools (i.e. 47.3%) revealed use-wear traces of animal tissue, related to butchery activities as well as skin processing, with cutting and scraping actions (Table 8, Figs. 8, and 9).

## Discussion

Our use-wear analysis has provided information about the kind of activities that were carried out in the frame of three spatially delimited, superimposed high temporal resolution AUs (Fig. 1). According to the functional analysis, we can infer that the tools were employed in a variety of activities

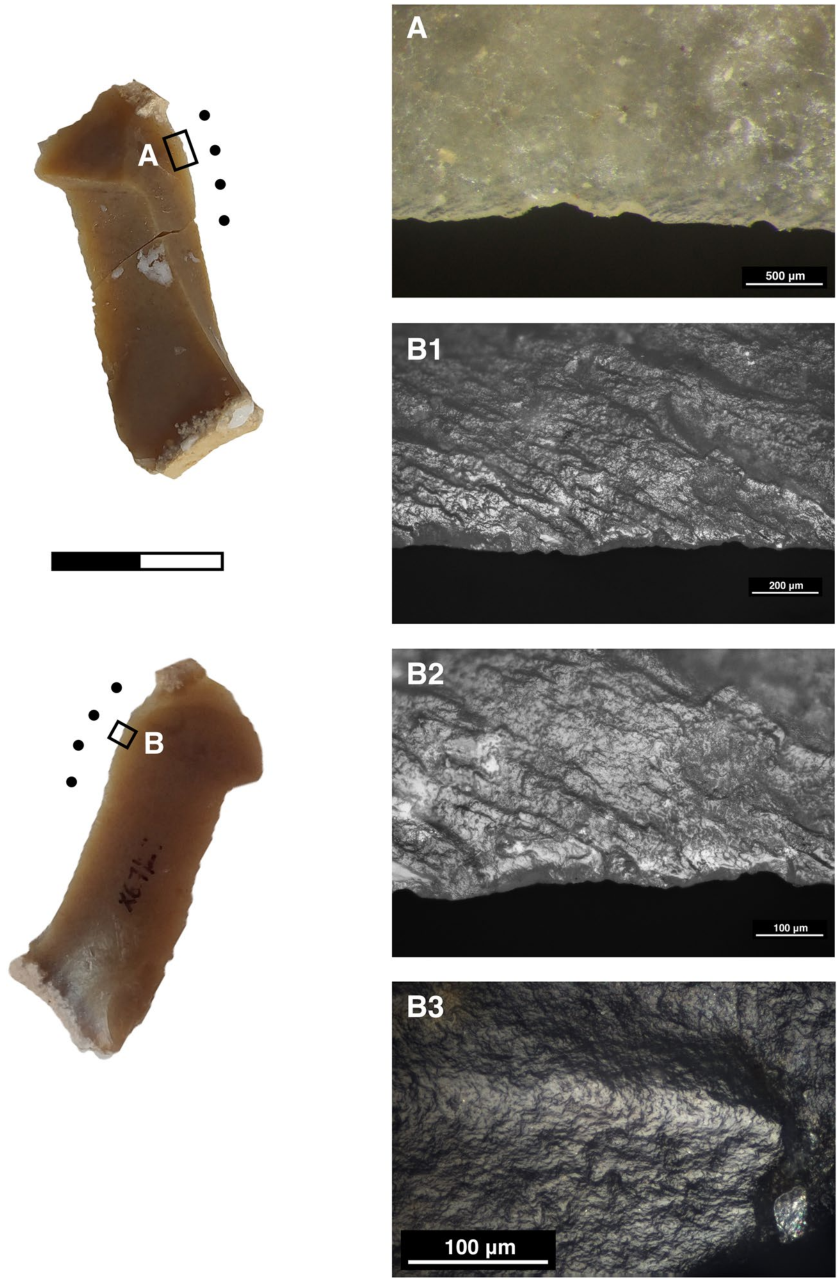


**Fig. 2** Tool x6.7/24 with woodworking traces in a scraping action. **A** Small and medium-sized scars on the dorsal surface with an aligned organisation, a semicircular morphology, feather termination and perpendicular orientation at 50×. **B** Well-developed and bright polish on the ventral surface, especially on the higher parts, with a rough texture, which tends to be smooth directly on the edge, a domed topography and a development of edge rounding at 100, 200 and 500×. The black dots represent the area with use-wear traces and the black square represents the area depicted. The same markers are valid for the rest of the figures

across time: AU 5.3.1 shows evidence of woodworking, 5.3.2 displays traces of work on animal tissue and wood, and 5.3.3 exhibits evidence of animal tissue processing.

The preservation state of the analysed tools is acceptable, as well as the rate of tools showing evidence of use (i.e. 5.3.1: 30%; 5.3.2: 53%; 5.3.3: 29%). However, some elements did not present suitable features to be functionally analysed, since they either have a scarce morphopotentiality, or display physicochemical alterations, with variable numbers between each AU. These alterations are mainly due to fire action.

The fact that almost all the elements with use-wear traces are unretouched flakes highlights the multifunctional characteristics of this kind of product. In the AU 5.3.2, in which tools were used for woodworking and butchering, it is observed a preference for the utilisation of recurrent centripetal Levallois modalities. This remarks the suitability of this knapping strategy to make products with multiple potentially active edges.

Another significant aspect is the fact that two tools with use-wear traces (i.e. x6/15 and x5/1024) are small-sized flakes. Our data join a growing number of Neanderthal contexts with small-sized used tools (*e.g.* Lazuén & González 2014; Lazuén & Delagnes 2014; Hortelano 2016; Borel et al. 2017).

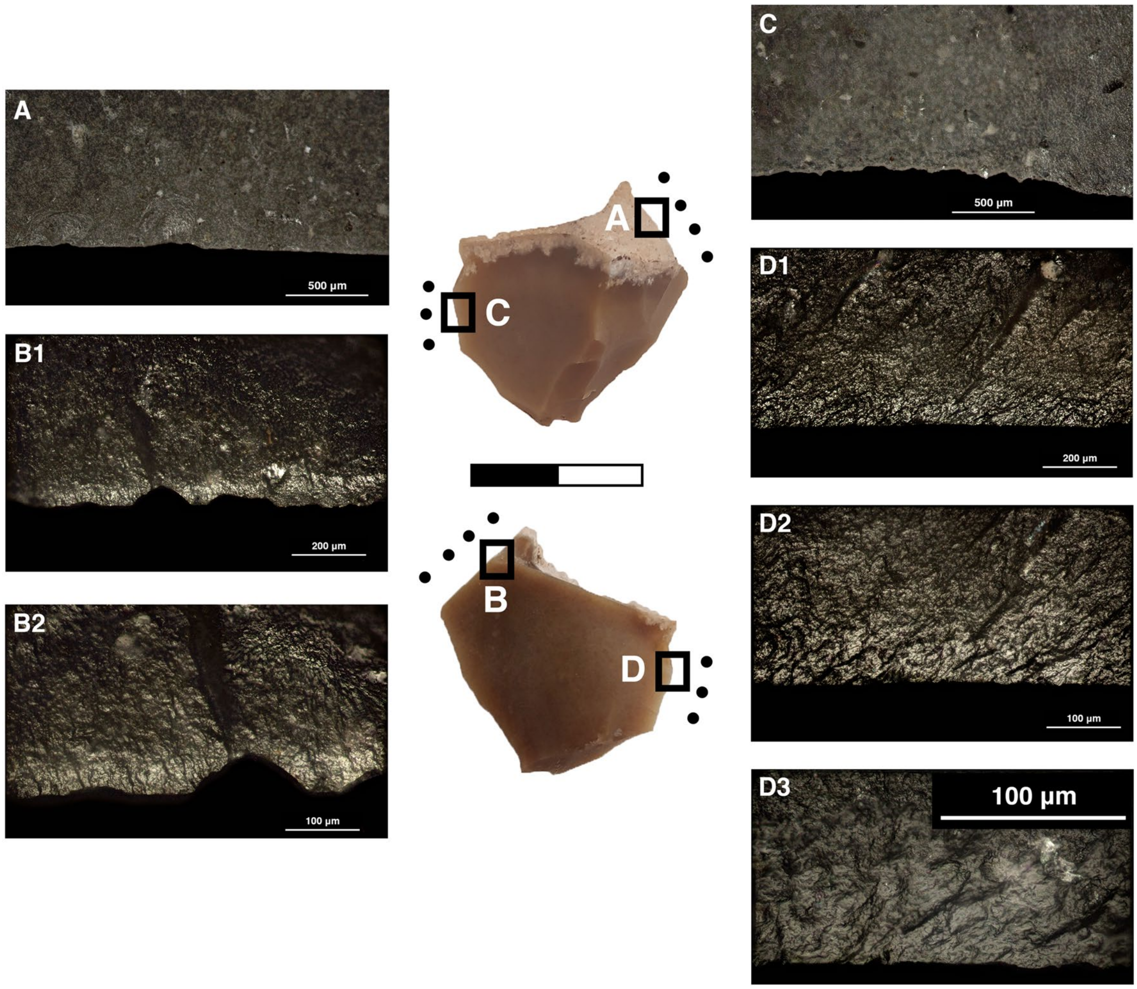


**Fig. 3** Tool x6/31 with woodworking traces in a scraping action. (**A**) Small and medium-sized scars on the dorsal surface with an aligned organisation, in some cases superimposed, a semicircular morphology, feather termination and perpendicular orientation at 50×. (**B**) Bright polish on the ventral surface with a rough texture and a domed topography at 100, 200×. (**C**) Small scars on the dorsal surface with an aligned organisation, a semicircular morphology, feather or transverse termination and perpendicular orientation at 50×. (**D**) Bright polish on the ventral surface with a rough texture and a domed topography, especially on the higher parts of the surface at 100, 200 and 500×

Through comparison with experimental tools (*vid*. Supplementary information), we can observe a low development of use-wear traces, from which we deduce that the tools were used during a short lapse of time or for low-intensity purposes, or both. The absence of superposition of possible use-wear traces showing work on different materials brings to the same conclusion. There are only two cases in which more than one edge has been used (Fig. 3). In the same way, the predominant use of unretouched edges, alongside the presence of a single retouched tool with use-wear traces, leads us to deduce that the tools were exclusively used for the above-mentioned activities with no need of resharpening. The absence of clear use-wear traces on thermally altered elements is in the same vein. If polishes were well developed, they could be identified in spite of thermal alteration (*cf*. Clemente 1997), but this is not our case. Taking all this into consideration, we may conclude that the tasks performed in these activity areas were neither intense nor long-spanned.

As for the prehensile parts of the tools, there is no evidence of them having undergone hafting processes, even if we can not rule out the possibility that no use-wear has been recorded, or traces of another kind of manipulation. Still, it is significant that the totality of the tools, including small-sized ones, can be held by hand. Hafting in Neanderthal contexts has been previously documented (*e.g*. Beyries 1987; Mazza et al. 2006; Rots 2011, 2013, 2014, 2016; Rots et al. 2015; Degano et al. 2019; Niekus et al. 2019). According to Rots (2014, 2016), hafted tools may show an explicit need responding to the recurrency for which a

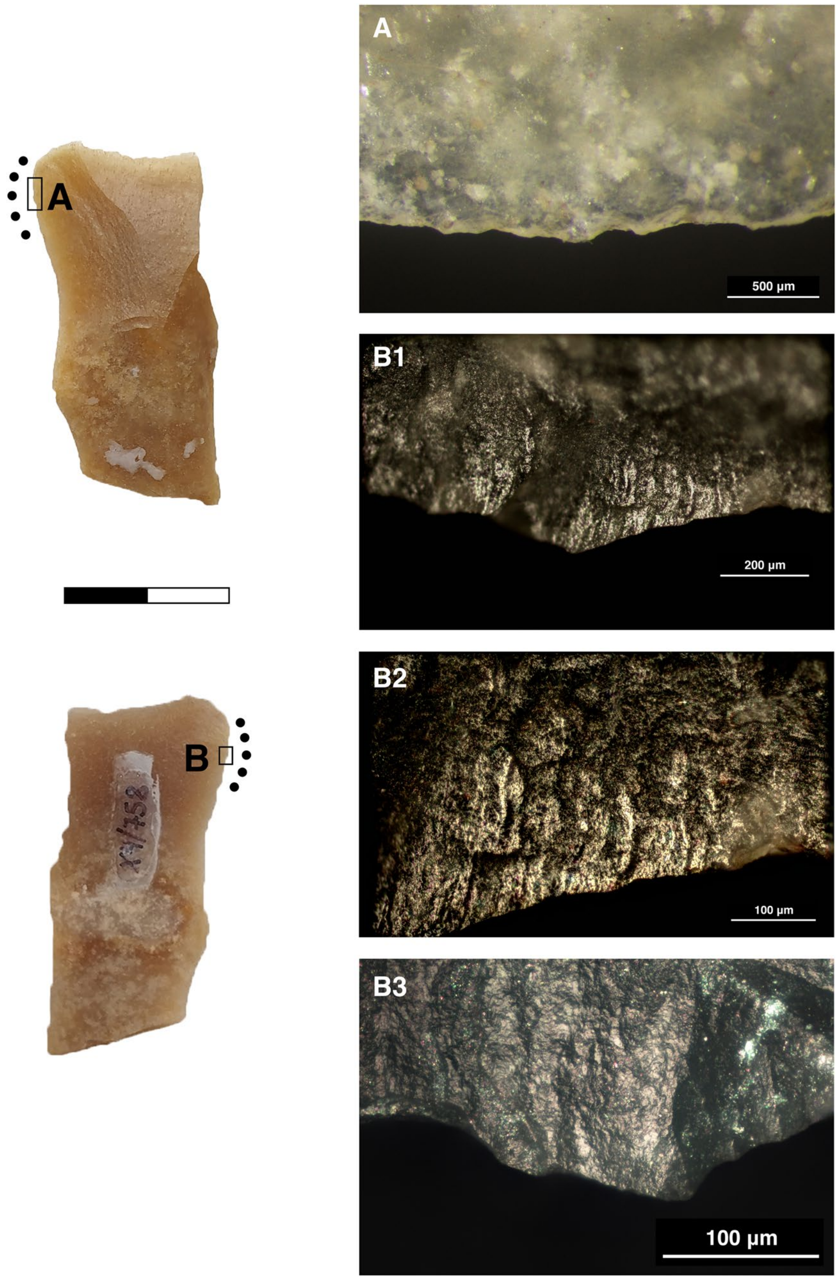


**Fig. 4** Tool x4/758 with woodworking traces in a scraping action. **A** Small and medium-sized scars on the dorsal surface with an aligned organisation, a semicircular morphology, feather termination and perpendicular orientation at 50×. **B** Bright polish on the ventral surface with a rough texture and a domed topography especially on the higher parts of the surface at 100, 200 and 500×

task was performed. The absence of hafting observed in our analysis supports our hypothesis of the low-intensity and short-spanned use of the tools.

## Characterising activity areas through functional analysis

Thanks to the functional results obtained through the analysis of the three AUs, we have been able to examine the tasks carried out in each case. As for woodworking, two processes were identified in the AUs 5.3.1 and 5.3.2: cutting and scraping. This enables us to deduce that both frames are related to the processing of woody material. These actions can be associated with different kinds of activities, such as fuel processing, for which there is much evidence in El Salt (*cf.* Vidal ), or even the production of tools. In regards to this, there is a great number of functional studies applied to Neanderthal material collections that evidence woodworking (*e.g.* Beyries 1987; Lemorini 1996, 2000; Jardón & Bosquet 1999; Claud 2008; Clemente et al. 2014; Lazuén & González 2014; Hortelano 2016). In addition, some woody remains in Schöningen (Germany) (*cf.* Thieme 1997), Aranbaltza III (Spain) (*cf.* Ríos et al. 2018) or Poggetti Vecchi (Italy) (*cf.* Aranguren et al. 2018) show work traces or even vegetal fibres, as in the case of the remains found in Abri du Maras (France) (*cf.* Hardy et al. 2013, 2020). In the case

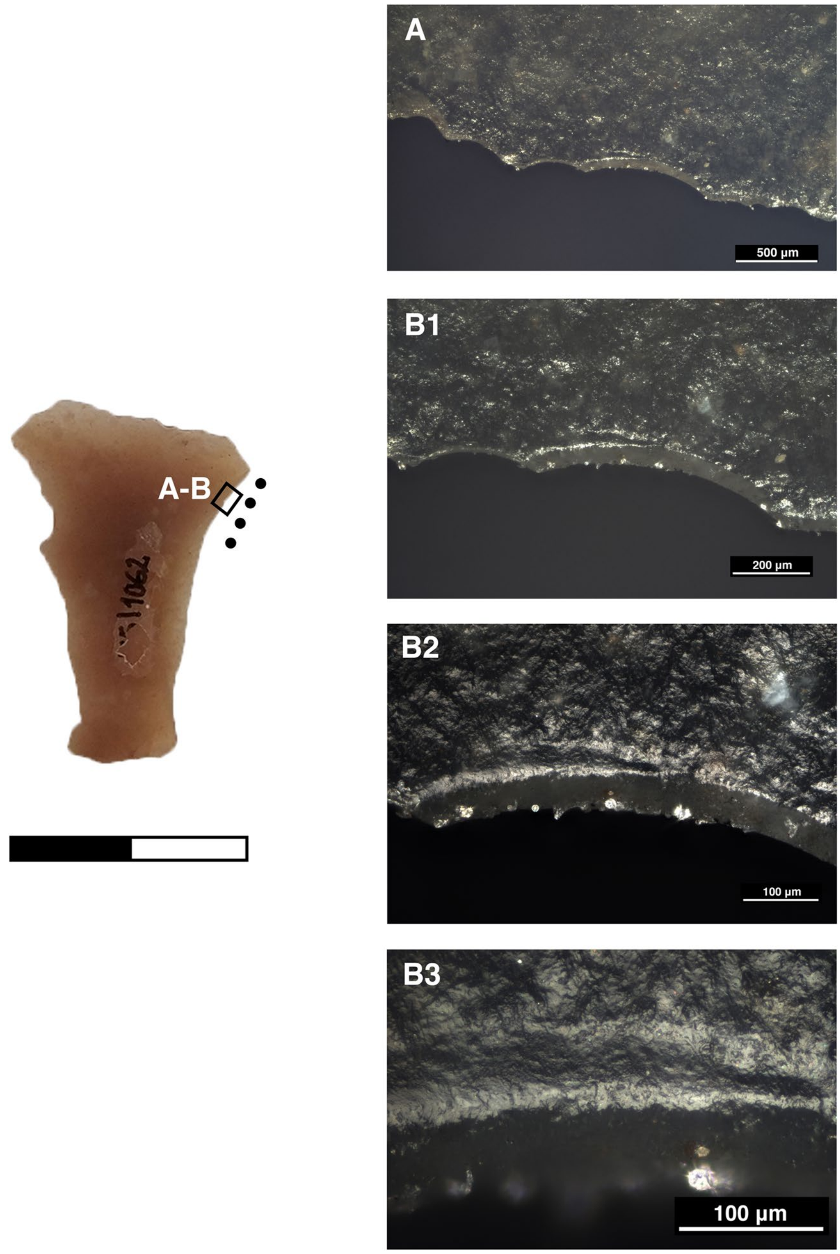


**Fig. 5** Tool x5/1062 with woodworking traces in a cutting action. (**A**) Small and medium-sized scars on the ventral surface with an aligned organisation, a semicircular morphology, transverse termination and oblique orientation at 50×. (**B**) Well-developed polish on the ventral surface with a rough texture, which tends to be smooth, a domed topography, which tends to be flat directly on the edge, and a development of edge rounding at 100, 200 and 500×

of El Salt, the presence of minor woody taxa being suitable for toolmaking has made possible to suggest their use to that end (*cf*. Vidal et al. 2018).

We can also observe different use-wear traces regarding the processing of animal tissues. Prior to the AU 5.3 dissection (*cf*. Mayor et al. 2020), the archaeozoological investigations also had certified butchering activities in the faunal assemblage (*cf*. Pérez 2019; Pérez et al. 2020): four specimens ascribed to the *Caprinae* subfamily, four to the *Equidae* family and two to the *Cervidae* family show evidence of activities like skinning, periosteum removal and quartering of preys. These cut marks are very superficial, concurring with the slightly developed use-wear traces on lithic tools. This allows us to propose the association between the faunal record with cut marks and the lithic record with butchering traces. Taking into account that our functional results ascribe the butchering activity to two of the three events of AU 5.3 (i.e. 5.3.2 and 5.3.3), we suggest the link between the archaeozoological record and these frameworks.

## Use-wear analysis applied in high temporal resolution frames

In the Mediterranean Iberian Neanderthal sites, we can observe that woodworking and prey processing were frequent

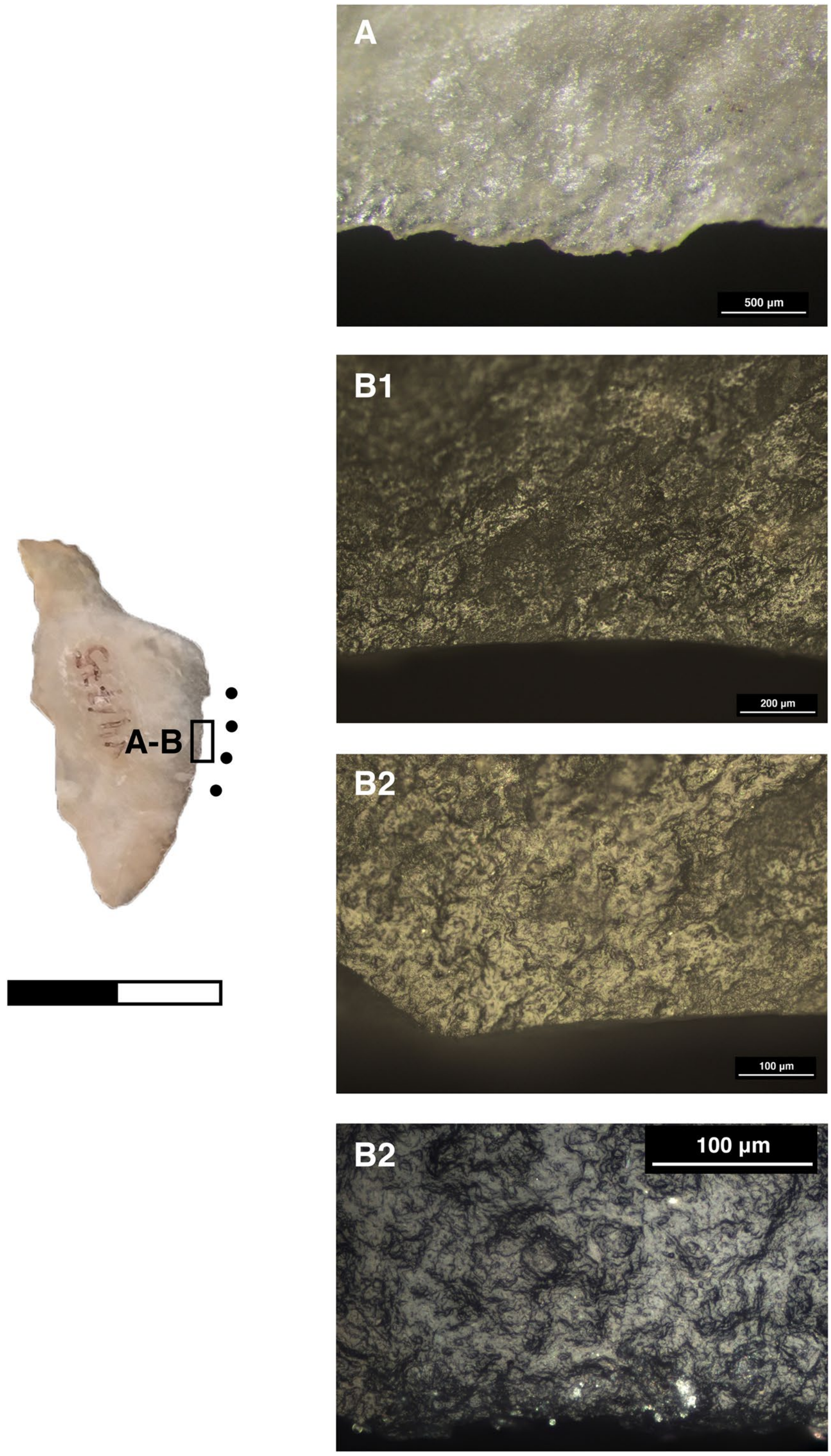


**Fig. 6** Tool × 4/775 with butchering activity traces in a cutting action. (**A**) Small and medium-sized scars on the dorsal surface with an aligned organisation, a semicircular morphology, transverse termination and an oblique orientation at 50 ×. (**B**) Dull polish on the dorsal surface with a fluid texture, a domed topography and a fuzzy contour at 100, 200 and 500 ×

during the Middle Palaeolithic (*cf*. Moriel 1985; Rodríguez et al. 2002; Martínez 2005; Galván et al. 2008; Eixea et al. 2015; Hortelano 2016; Martín-Viveros et al. 2020).

Nevertheless, these studies utilised coarse-time and thus less suitable analytical frameworks to understand human behavioural variability across time.

To date, we only relied on two research works that analysed the function of the lithic tools forming part of a high temporal resolution assemblage. The number of lithic remains comprised in our AUs is along the same lines as that from the Grotta dei Santi 150A unit (n116; *cf*. Spagnolo et al. 2020), or that from the Abric del Pastor AU ɪvfH17

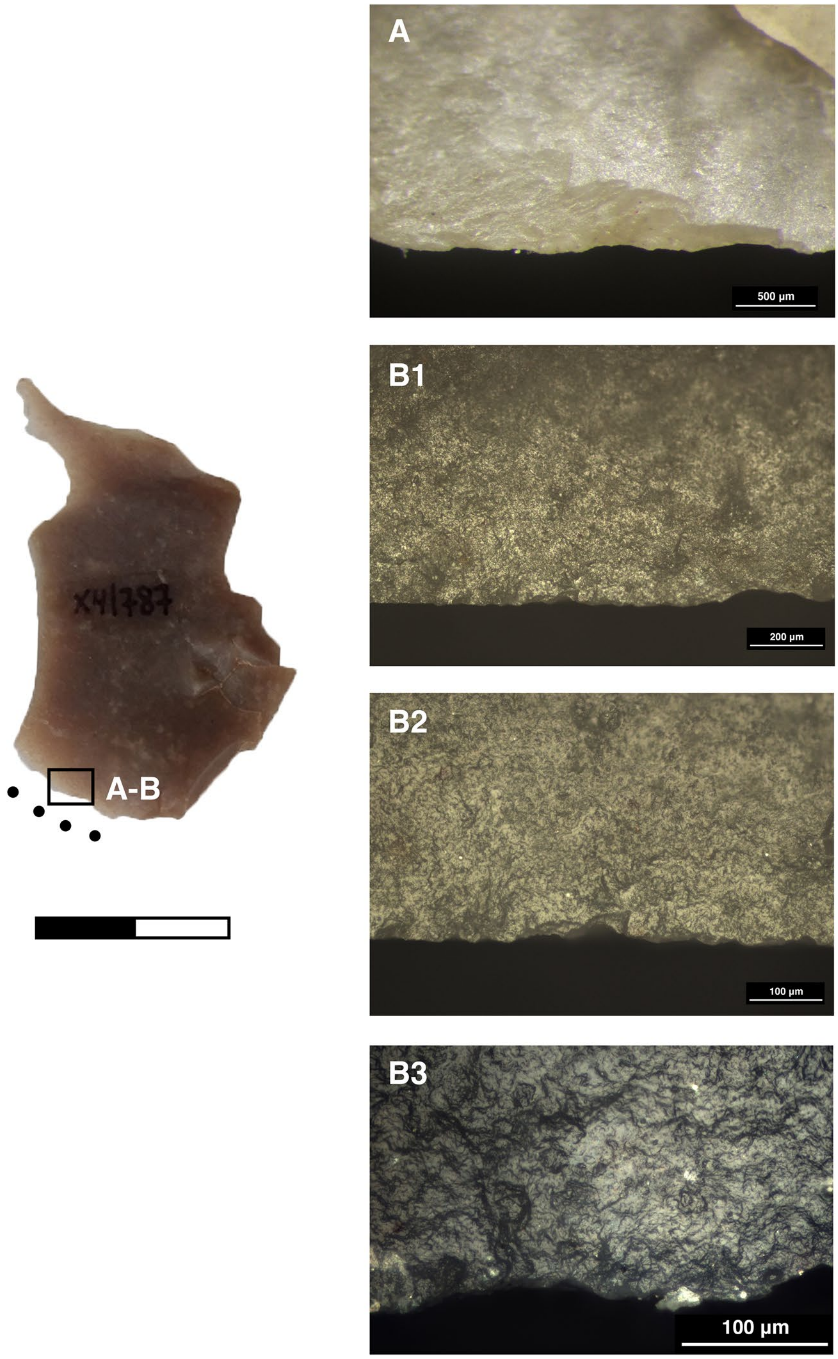


**Fig. 7** Tool x4/787 with dry skin traces in a cutting action. (**A**) Small and medium-sized scars on the ventral surface with an aligned or superimposed organisation, a semicircular or irregular morphology, a feather and step termination and an oblique orientation at 50×. (**B**) Dull polish on the ventral surface, with a rough texture and a domed topography in the higher and lower parts of the surface, and a development of edge rounding at 100, 200 and 500×

(n11; *cf*. Sossa-Ríos et al. 2022). In all cases, the assemblages are very close to human temporality and the number of remains, even if it could seem scarce, could be explained by the activities performed by the Neanderthal groups.

Furthermore, the results of these studies reflect the exclusive performance of butchering activity, which is analogous to that described for the El Salt AU 5.3.3. This brings out the singular character of tasks carried out not only in determinate activity areas, like this case and that of Spagnolo et al. (2020), but also in frames representing human single occupations (*cf*. Sossa-Ríos et al. 2022).

In our case, not one but three successive high-resolution AUs have allowed us to read different functional dynamics. These reflect variations of the activities developed in a determinate space of the site across a narrow timescale. It could be indicating diachronic changes in the spatial management, as a proper way to explore human behavioural variability.

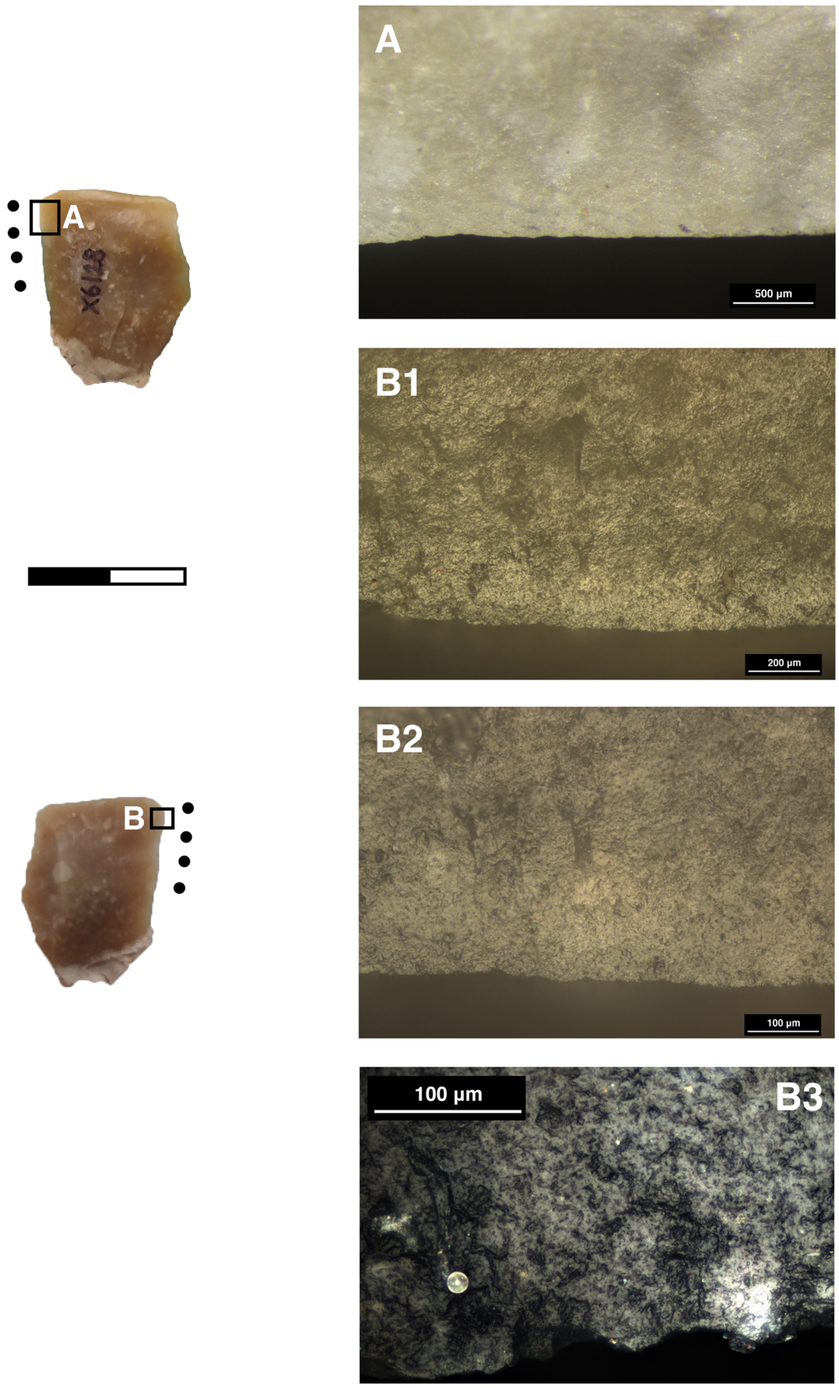


**Fig. 8** Tool x6/28 with dry skin traces in a scraping action. (**A**) Small scars on the ventral surface with an aligned organisation, a semicircular morphology, a feather termination and perpendicular orientation at 50×. (**B**) Dull polish on the dorsal surface, with a rough texture and a domed topography, in the higher and lower parts of the surface, and a development of edge rounding at 100, 200 and 500×

## Conclusions

The use-wear analysis applied to the lithic record from three diachronic AUs has allowed us to recognise particular activities performed in different moments: woodworking in 5.3.1, butchering and woodworking in 5.3.2 and butchering in 5.3.3. These results highlight two relevant issues for analysing the Neanderthal behaviour and its variability:

1. The functional analysis offers determinate temporal markers that can be associated with short-spanned events: the low development of use-wear traces, as well as the absence of superposition of use-wear traces,

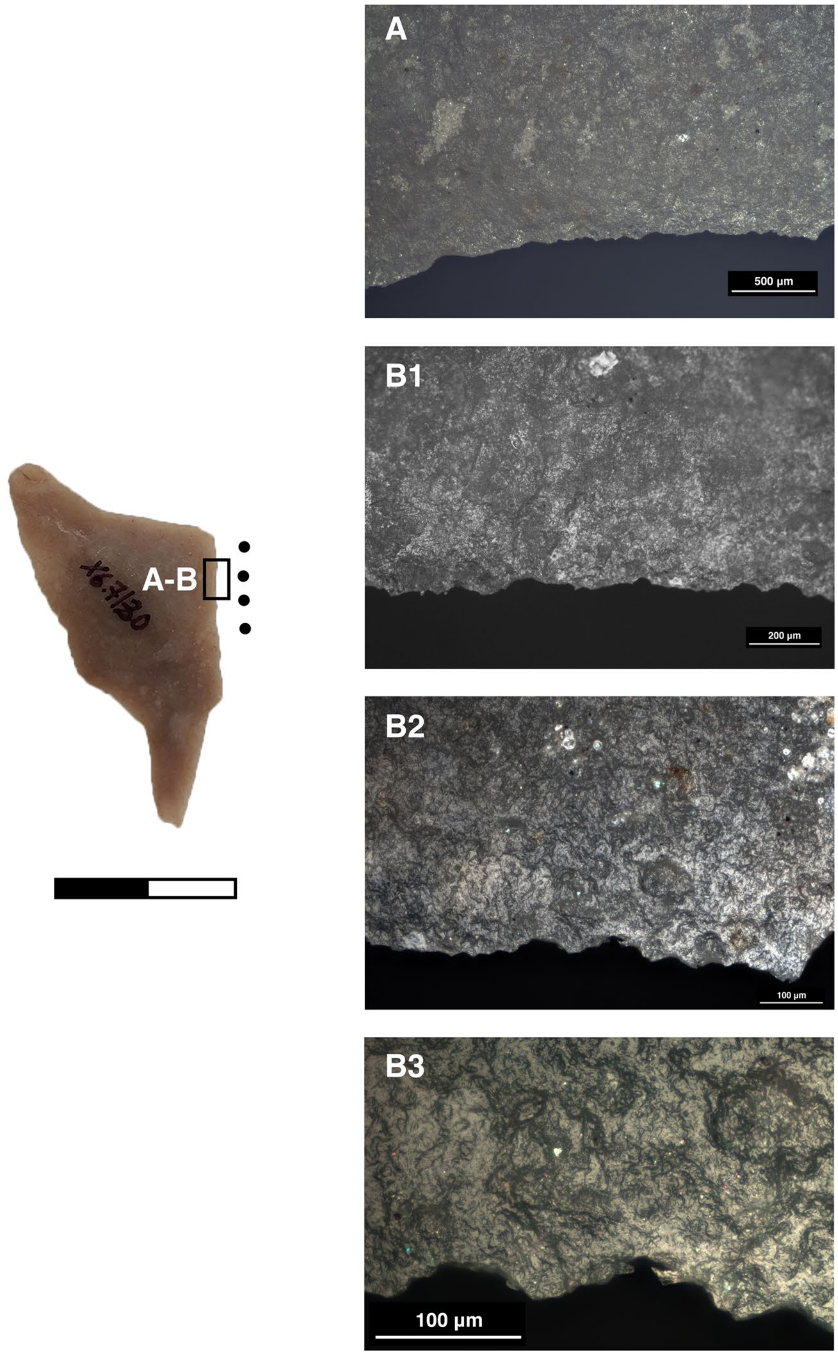


**Fig. 9** Tool x6.7/30 with butchering activity traces in a cutting action. (**A**) Small and medium-sized scars on the ventral surface with an aligned organisation, a semicircular morphology, a feather or transverse termination and oblique orientation at 50×. (**B**) Dull polish on the ventral surface, with a fluid texture and a domed topography, a fuzzy contour and associated with well-developed spots of polish at 100, 200 and 500×

resharpening or hafting marks. These indicators are common in the three AUs and show a pattern held across time, regardless of the activities represented within each.

2. By means of the high-resolution contexts studied here, we leave behind a scenario derived from functional studies focusing on the SU as a framework, in which Neanderthals performed simultaneously the same tasks (i.e. woodworking, butchering and skinning). With this work, we evidence a different scenario, in which we observe a dynamic and changeable behaviour: events revealing a lesser variety of activities (i.e. 5.3.1, 5.3.3) in contrast to another one in which the tasks are more diverse (i.e. 5.3.2).

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## Declarations

**Conflict of interest** The authors declare no competing interests.



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