



Through Time: Reconstructing Palaeolithic Occupations Through Use-Wear Analysis in the Middle Palaeolithic Site of Ciota Ciara (Borgosesia, Italy)

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Abstract

Lithic use-wear analysis, through defining site function and allowing reconstructing of patterns of human occupation, can contribute to our understanding of archaeological palimpsests. The Ciota Ciara cave represents an excellent case study for this methodology. Multidisciplinary research so far conducted on the materials recovered from the atrial sector of the cave distinguishes three archaeological units from a Middle Palaeolithic occupation of the site: stratigraphic units (SUs) 13, 14, and 15. Each unit is interpreted as referring to a period of numerous, superimposed episodes of human occupation, the characteristics of which we try to reconstruct and present in this work through use-wear studies. The functional analysis of lithic industries from the upper units (13 and 14) has already been published previously; here, we report corresponding new data from the lowest level, SU 15. By comparing the use-wear results from the three units and integrating the findings with data from the geoarchaeological, palaeontological, zooarchaeological, and technological studies, we attempt to reconstruct the different phases of human occupation represented in the site through time, contributing to current interpretations regarding settlement dynamics and human behaviour in the Middle Palaeolithic of north-western Italy.

Keywords Ciota Ciara cave · Use-wear analysis · Middle Palaeolithic · Piedmont · Settlement

Introduction

The use of objects to extract resources or to create shelters is not an exclusively human trait; a bird can use different materials to build a nest (Campbell & Lack, 1985), a

chimpanzee can use a twig to capture termites, a sea otter can use stones as anvils to break the shell of molluscs (Hall & Schalle, 1964). Nonetheless, humans are unique in the extent to which they rely on technology, and *Homo* is characterised as a genus of obligated tool users (Kuhn, 1992). The surviving evidence of tools related to the Palaeolithic refers almost exclusively to knapped stone artefacts. Investigating how hominins have produced, designed, and used these tools in the past is crucial to our understanding of the evolution of human behaviour (Ambrose, 2001). During the last 70 years, archaeological research has featured different aspects of the study of lithic artefacts, such as morphology and classification (typological approach) (e.g. Bordes, 1961; Broglio & Kozłowski, 1984; Fernández Eraso & García Rojas, 2013; Laplace, 1964), methods and techniques of production (technological approach) (e.g. Boëda, 1993; Boëda et al., 1990; Chazan, 1997; Geneste, 1991; Moncel et al., 2020; Pelegrin et al., 1988; Peresani, 2003; Rey-Rodríguez et al., 2016; Tixier, 1978), procurement of raw materials (Andrefsky Jr., 1994; Aubry et al., 2012; Bailey et al., 2011;

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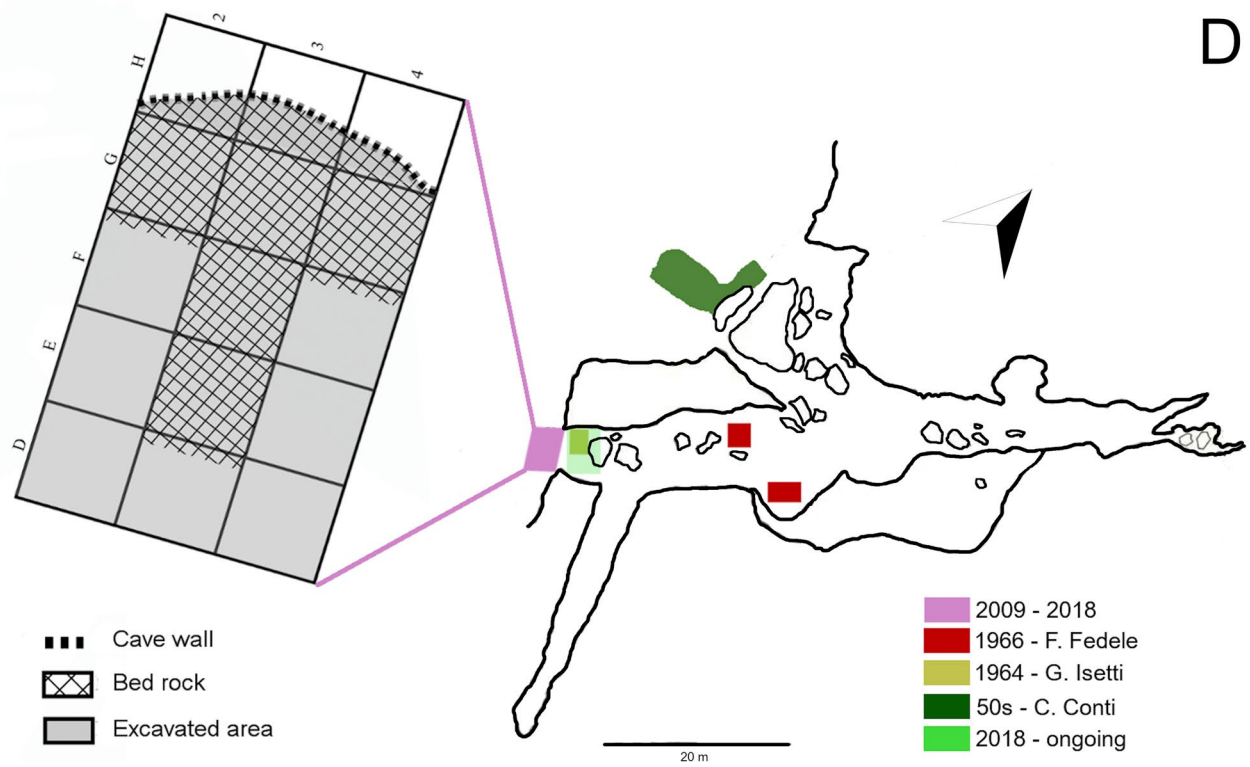
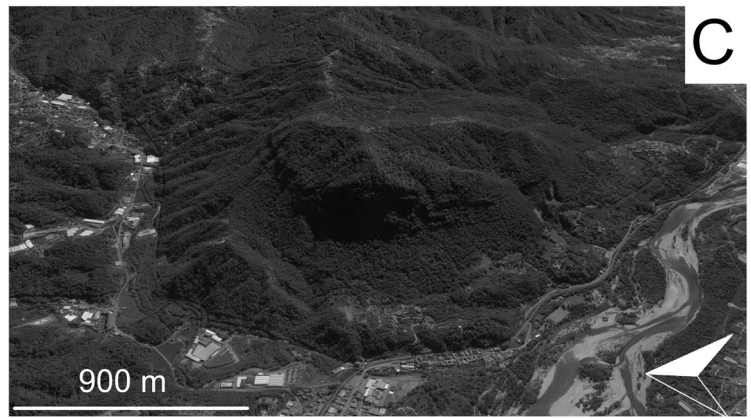
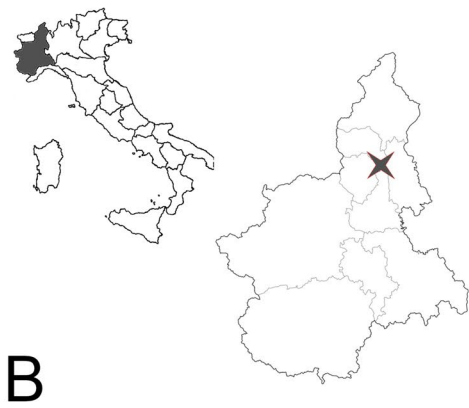


Fig. 1 **A** Southwest entrance of the Ciota Ciara cave. **B** Location of Piedmont and Monte Fenera. **C** View of the west side of the mountain. **D** Planimetry of the cave showing the areas investigated during the 1950–1960s, detail of the excavated area in the atrial sector of the cave (Berruti et al., 2023)

Beller, 2023; Borrazzo & Etchichury, 2010; Doronicheva et al., 2016; Féblot-Augustins, 1997; Fernandes et al., 2008; Gurova et al., 2016; Mayor et al., 2022; Olivares et al., 2009; Pop et al., 2022; Tarrío et al., 2015; Vallejo Rodríguez et al., 2017; Wilson et al., 2018), and tool use and function (Cahen et al., 1979; Carbonell et al., 1999; Faulks et al., 2011; Iwase, 2016; Keeley, 1980; Martín-Viveros & Ollé, 2020; Odell, 1988; Ollé et al., 2017; Pedernana & Ollé, 2019; Rots, 2008; Semenov, 1964; Tringham et al., 1974; Vergès & Ollé, 2011).

The functional analysis of prehistoric tools based on use-wear traces emerged in the early 1900s with the pioneering works of Spurrell (1892) and Curwen (1930) but started to thrive only in 1957 with the work of Semenov and its diffusion after translation from Russian in 1964 (Semenov, 1964). In his work, he defined the fundamentals of the discipline: the use of microscopes to observe and interpret traces found on the surface of ancient tools by comparing them with traces produced experimentally (Semenov, 1964). Subsequently, aspects concerning the formation of traces depending on the type of raw material, tool morphology, hardness of contact material, and gesture applied during tool use were discussed (Odell, 1981; Semenov, 1964; Tringham et al., 1974). Throughout the years, the discipline has gone through many adaptations and developments according to changes in the methodological and theoretical frameworks (Calandra et al., 2019; Kimball et al., 1995; Tringham et al., 1974; Van Gijn, 2014), with recent discussions also concerning terminology (Marreiros et al., 2020). Many researchers underline that the discipline requires new quantitative techniques, while others focus on improving the accuracy of the method through developing more detailed experiments, employing more controlled protocols, or incorporating blind tests (e.g. Berruti & Cura, 2016; Cahen et al., 1979; Church & Ellis, 1996; Grace et al., 2010; Kohler & Parker, 1986; Lemorini et al., 2014; Marreiros et al., 2015; Ollé et al., 2017; Xhaufclair et al., 2017).

To date, studies concerning the application of use-wear analysis can be divided into different groups. The first includes studies that aim to expand the discipline with the adoption of new technologies or implementing the methodology on different types of raw material (e.g. Beyries et al., 1988; Borel et al., 2014; Calandra et al., 2019; d'Errico & Backwell, 2009; Faulks et al., 2011; Groman-Yaroslavski et al., 2022; Ollé & Vergès, 2014; Pedernana, 2019; Pedernana et al., 2020; Pedernana & Ollé, 2016; Stemp, 2014; Stemp et al., 2019). The second focuses on relating tool

function to specific typological or technological elements in a lithic assemblage (e.g. Berruti, 2017; Berruti et al., 2020; Lasuén & Delagnes, 2014; Lemorini et al., 2003, 2016; Lombard, 2005; Mazza et al., 2006; Moncel et al., 2009; Zupancich et al., 2016). The last category concerns lithic analyses that aim to reconstruct the economy and behaviour of the prehistoric groups that frequented an archaeological site (e.g. Arrighi et al., 2009; Berruti, Arnaud, et al., 2016; Berruti & Cura, 2016; Hardy, 2004; Keeley & Toth, 1981; Lemorini et al., 2014; Martínez & Rando, 2001; Peretto et al., 1998; Sahnouni et al., 2013; Shen & Chen, 2000).

The present work belongs to this last category. It concerns use-wear studies conducted on the lithic industries recovered from the archaeological excavations (2009–2019) in the atrial sector of the Middle Palaeolithic site of Ciota Ciara (Borgosesia, Northern Italy) (Angelucci et al., 2019; Arzarello et al., 2012; Berruti et al., 2023; Berto et al., 2016; Daffara, Berruti, & Arzarello, 2021; Vietti, 2016). The functional analysis of the lithic assemblage from the upper levels (stratigraphic units 13 and 14) has already been published in previous works (Berruti, 2017; Berruti et al., 2023; Berruti & Arzarello, 2012; Daffara et al., 2014; Daffara, Berruti, & Arzarello, 2021), while the study of the lower level corresponding to the oldest occupation (SU 15) is presented here for the first time. We begin with analysing use-wear results for the lithic industries from SU 15 and comparing them with use-wear data from the other stratigraphic units. We then consolidate these findings with those from associated palaeontological, geoarchaeological, zooarchaeological, and technological studies to comprehensively describe what each stratigraphic unit represents. We also refer to the literature for the formulation of interpretations (Bargalló et al., 2020; Berruti et al., 2023; Binford, 1978, 1980; Chacón et al., 2012; Delagnes & Rendu, 2011; Eixea, Chacón, et al., 2020; Fisher & Strickland, 1989; Grove, 2009; Ibáñez Estévez & González Urquijo, 1996; Lourdeau, 2011; Machado et al., 2013, 2017; Moncel et al., 2021; Picin & Cascalheira, 2020; Rendu, 2010; Spagnolo et al., 2020; Vallverdú et al., 2005; Vaquero et al., 2012b; Yellen, 1977). The primary objective is to observe how, by comparing the results of the functional analysis from different stratigraphic units in an archaeological site, in this case the Ciota Ciara cave, it is possible to reconstruct the dynamics of site frequentation and its transformation over time.

The Site

The cave of Ciota Ciara is located at an altitude of 665 m. a.s.l on the west slope of the Monte Fenera (Borgosesia, VC) (Fig. 1). It is an active karstic cave with a total extension of 80 m and a positive elevation gain of 15 m from the southwest entrance. Following the length of the cave to the north

appears a short branch that leads to the secondary entrance facing west. The area where the two branches cross is a wide space, enlarged during the years by the dissolution of large boulders and cave wall collapse (Testa, 2005). The construction of a fence gate partitioned the main entrance zone into two sectors: for ease of reference, the excavation area located outside the gate is called the atrial sector, and that inside the gate towards the twilight zone is called the internal sector.

The first excavation at the Ciota Ciara was reported with the mention of a non-systematic test pit in the 1930s (Conti, 1931). In 1953, the local speleological association conducted the earliest proper survey of the cave. The first systematic archaeological exploration was reported in 1964 (Fedele, 1966; Fedele et al., 1966; Strobino, 1981, 1992), followed by a few sporadic excavations up to the 1970s (Fedele, 1988) in the different areas of the cave. In the early 1990s, two teeth, later attributed to *H. neanderthalensis* (Villa & Giacobini, 1993, 2005), were retrieved from reworked sediments transported out of the cave through water action. An extensive archaeological campaign ensued to clarify these findings, focusing on the upper deposits in the area of the southwest cave entrance (Busa et al., 2005). Since 2009, archaeological investigations have resumed under the direction of the University of Ferrara. Excavations were focused on the atrial sector, where a 2-m-thick sequence was unearthed (Angelucci et al., 2019), yielding archaeological materials which have become the basis of research that continue to bring to light prehistoric conditions and many aspects of the behaviour of the ancient inhabitants of the cave (Angelucci et al., 2019; Arzarello et al., 2012; Berruti et al., 2023; Berto et al., 2016; Buccheri et al., 2016; Cavicchi, 2018; Daffara et al., 2014, 2019; Daffara, Berruti, & Arzarello, 2021). In 2018, a new excavation area was opened in the internal sector. Investigations have since then been redirected to this area, for which the analyses of different materials are ongoing.

The Ciota Ciara is not the only archaeological site on the Monte Fenere. In the area, there are other sites attributed to different chronologies from the Palaeolithic (Belvedere shelter and Ciutarun cave located in the immediate vicinity of the Ciota Ciara) up to the Roman period (Brecciaroli Taborelli, 1994; Conti, 1931; Fedele, 1966, 1985; Strobino, 1981; Viola & Besse, 2019). Lithic assemblages uncovered in Piedmont and assigned to the Middle Palaeolithic were also designated to the “Alpine Mousterian” (Battaglia, 1953; Lo Porto, 1957), a tradition characterised by lithic production systems less developed than those seen in other contemporary European sites. Recent research from the Ciota Ciara and nearby localities has shifted this view by demonstrating instead well-adapted technological behaviours and lithic exploitation strategies suited to raw material constraints (Berruti, Rosina, & Raposo, 2016; Daffara et al., 2022; Daffara, Berruti, & Arzarello, 2021; Daffara, Giraudi, et al., 2021; Rubat Borel et al., 2013), thereby

evenly integrating the Fenere sites into the Italian and European Middle Palaeolithic.

Stratigraphy and Chronology

Excavations at the cave atrium revealed five stratigraphic units (SUs 103, 13, 14, 15, and 16), all of which exhibit slightly irregular stratigraphic boundaries and dip outwards with a low angle (Fig. 2).

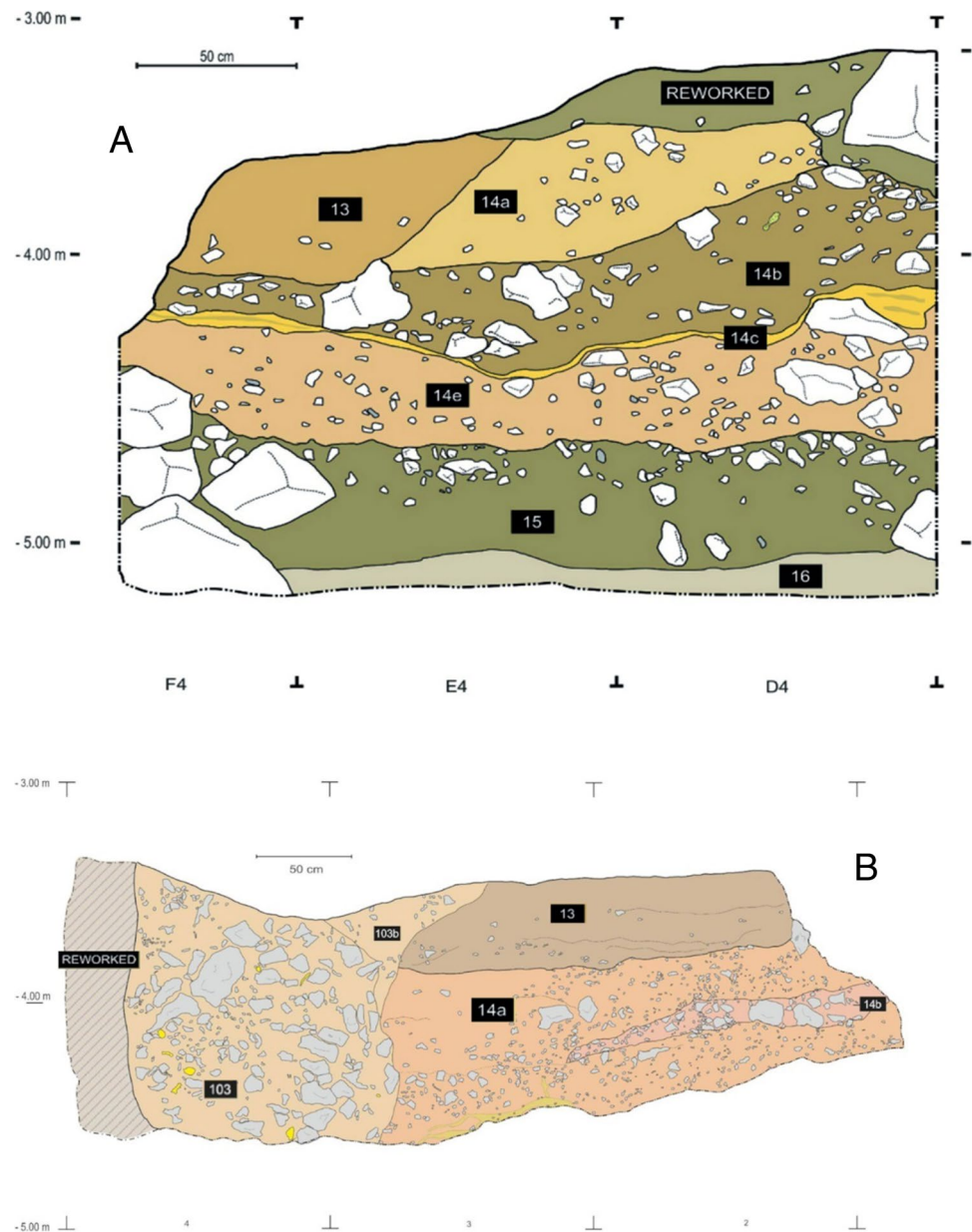
Unit 13 is composed of brown silty-clayey sediment with few dolostone fragments and exhibits brownish-black staining due to secondary Fe–Mn oxide accumulation. This unit shows slight traces of ancient pedogenesis, which has probably masked former internal flat lamination, anyhow still locally recognisable. Thin intercalations of well-sorted sand occur within units 13 and 14, separated by a poorly distinct, gradual, apparently horizontal limit. Unit 14 consists of well-recognisable subunits formed by poorly sorted and chaotically arranged, fine, sandy-silt to silty-loam sediment, and common fragments of local dolostone and scarce sandstone fragments. The unit dips south-west and exhibits lateral variations in the shape, size, and arrangement of the coarse dolostone fragments. Traces of biological activity are scarce. The lower boundary to SU 15 is poorly distinguishable, marked by an increase in coarse components and sand fraction. Coarse components include dolostone fragments from the cave roof and walls, the average size of which decreases from top to bottom. The bottom unit, SU 16, lies directly on the cave bedrock and does not contain material of archaeological interest. Unit 103, which is difficult to interpret, is found only in the western portion of the excavation area and appears to cut across units 13 and 14. It is a clast-supported breccia with fine material that fills all voids; given its peculiar nature, it is considered to be the result of ancient reworking and is not the subject of this study.

Geoarchaeological data show that the infilling of the southwest entrance of the cave was mainly built up by debris-flow and runoff events coming from the cave’s inner passages and that the lower part of the examined succession (units 14 and 15) suffered significant frost action soon after its accumulation (Angelucci et al., 2019; Zambaldi et al., 2016). Preliminary numerical dating of SU14 indicates that the human occupation of this sector of Ciota Ciara may date from the latter half of the Middle Pleistocene (Vietti, 2016).

The Lithic Assemblage of the Atrial Sector

The technological data about the lithic assemblage of Ciota Ciara testify to a rather complex technological behaviour involving extensive knowledge of the regionally available natural resources and of the mechanical properties of the various raw materials. This behaviour did not change significantly in the different phases of human occupation

Fig. 2 Stratigraphy of the Ciota Ciara cave, atrial sector. **A** North section (from Angelucci et al., 2019) where SU 16 corresponds to a sterile level lying upon the bed rock. **B** West section (from Zambaldi, 2015)



at the site: the same reduction sequences with the same characteristics and with the preferential use of pebbles and slabs as cores, as well as a very limited débitage on flake is evident in the different archaeological levels (Daffara, Berruti, & Arzarello, 2021). The availability and quality of the rocks present in the environment are the main factors influencing the tool-making strategies and the evolution of the reduction sequences (Andrefsky Jr., 1994).

The lithic industry of the atrial sector counts 7106 artefacts (excluding, small size fragments and *debris*). In all the archaeological levels, the predominant raw material is vein quartz, representing 70.6% of the lithic assemblage, followed by spongolite (21.1%), and then other local and

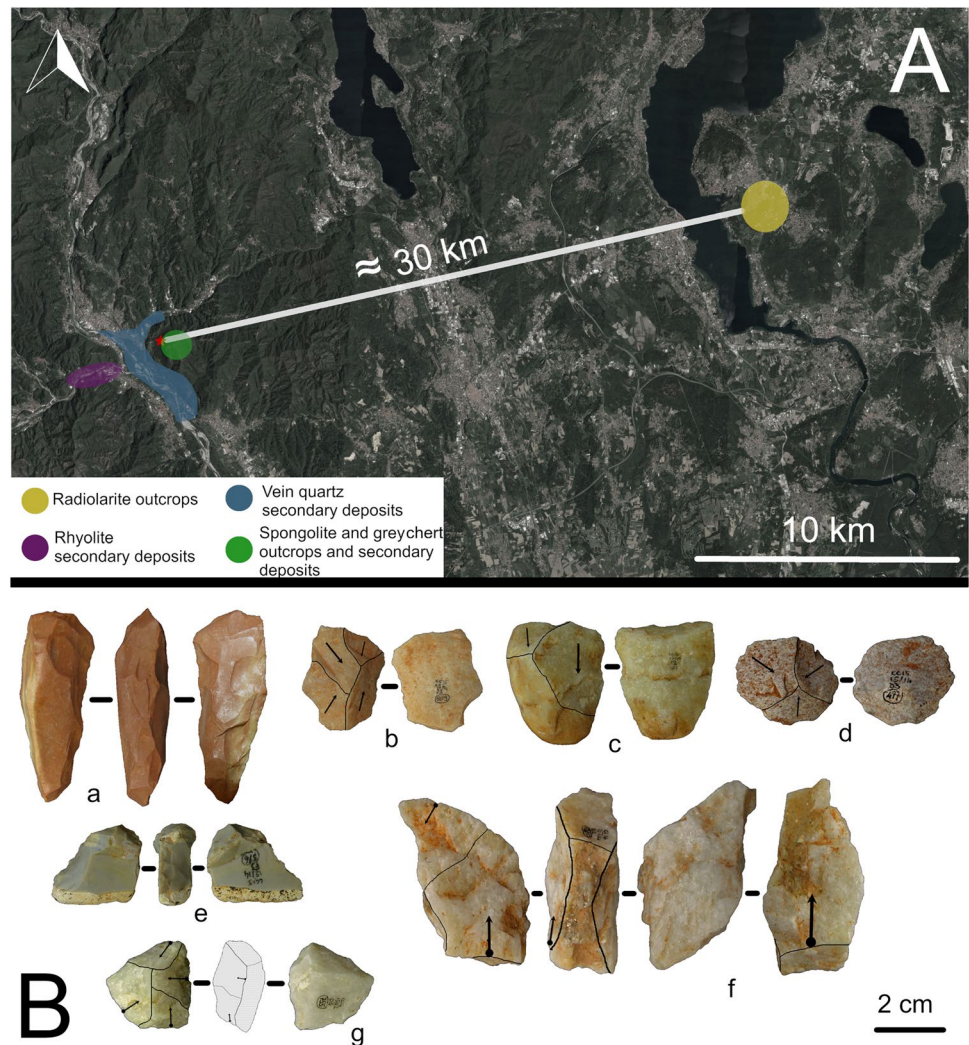
allochthonous raw materials (grey chert—4.9%, radiolarite—1.4%, and rhyolite—1.0%) (Table 1).

Other local rocks, like mylonite, are sporadically attested (Berruto, 2016; Daffara et al., 2019). The vein quartz was collected in secondary deposits at the base of Monte Fenera, while spongolite and grey chert outcrops were identified a few hundred metres from the site. The rhyolite was collected in a secondary position at about 2 km as the crow flies from the Ciota Ciara cave, while the radiolarite arrives from a distance of approximately 25–30 km to the east (Berruto, 2011; Daffara et al., 2019) (Fig. 3).

The important presence of vein quartz and spongolite cores and debris indicates that for the most represented

Table 1 Ciota Ciara cave, atrial sector. Lithic raw materials present in each archaeological layer

	Quartz	Spongolite	Grey chert	Rhyolite	Radiolarite	Others	Total
<i>SU 103</i>	227 53%	141 32.9%	57 13.3%	1 0.2%		2 0.4%	428
<i>SU 13</i>	768 86.2%	59 6.6%	52 5.8%	1 0.1%	8 0.9%	3 0.3%	891
<i>SU 14</i>	3119 78%	508 12.7%	210 5.3%	50 1.3%	67 1.7%	45 1.1%	3999
<i>SU 15</i>	905 50.6%	793 44.4%	28 1.6%	21 1.2%	22 1.2%	19 1.1%	1788
<i>Total</i>	5019 70.6%	1501 21.1%	347 4.9%	73 1%	97 1.4%	69 1%	7106

Fig. 3 Ciota Ciara cave. **A** Supply areas of lithic raw materials (Berruti et al., 2023; Daffara et al., 2019). **B** Lithic artefacts from SU 15. (a) Limace on a radiolarite flake. (b) Vein quartz recurrent centripetal Levallois flake. (c) Opportunistic vein quartz flake; (d) Spongolite recurrent centripetal Levallois flake. (e) Double scraper on a patinated spongolite flake. (f) Opportunistic vein quartz core. (g) Unifacial discoid core on a vein quartz pebble. The red dot indicates the location of the Ciota Ciara cave

raw materials, the knapping activities took place in the site while the other local rocks were probably knapped out of the site or in an area not documented yet (Arzarello et al., 2012; Daffara et al., 2014; Daffara, Berruti, & Arzarello, 2021) (Table 2). Rhyolite and radiolarite are present in the lithic assemblage mainly as finished tools whose edges have been intensively rejuvenated and as flakes issued

from tool re-shaping (Berruti et al., 2023; Daffara, Berruti, & Arzarello, 2021). The opportunistic reduction strategies (Carpentieri & Arzarello, 2022; Inizan et al., 1995) are predominant in the whole lithic industry. For vein quartz and spongolite, the reduction sequences are generally short, with the frequent use of natural and neocortical surfaces as striking platforms. The cores were discarded

Table 2 Ciota Ciara cave. General composition of the lithic assemblage of the atrial sector (Berruti et al., 2023). The black line separates local raw materials (above) from allochthonous ones (below)

Raw material		SU 103	SU 13	SU 14	SU 15	Total
<i>Quartz</i>	Cores	7 – 1.6%	31 – 3.5%	111 – 2.8%	20 – 1.1%	169 – 2.4%
	Flakes	136 – 31.8%	444 – 49.8%	2150 – 53.8%	611 – 34.2%	3341 – 47%
	Retouched tools	5 – 1.2%	16 – 1.8%	50 – 1.3%	9 – 0.5%	80 – 1.1%
	Debris	78 – 18.2%	276 – 31.0%	807 – 20.2%	265 – 14.8%	1426 – 20.1%
	Unworked blanks	1 – 0.2%	1 – 0.1%	1 – 0.03%	-	3 – 0.04%
<i>Spongolite</i>	Cores	5 – 1.2%	1 – 0.1%	17 – 0.4%	31 – 1.7%	54 – 0.8%
	Flakes	68 – 15.9%	33 – 3.7%	280 – 7.0%	429 – 24%	810 – 11.4%
	Retouched tools	1 – 0.2%	2 – 0.2%	9 – 0.2%	9 – 0.5%	21 – 0.3%
	Debris	58 – 13.6%	22 – 2.5%	191 – 4.8%	299 – 16.7%	570 – 8%
	Unworked blanks	9 – 2.1%	-	11 – 0.3%	25 – 1.4%	45 – 0.6%
<i>Grey chert</i>	Cores	1 – 0.2%	-	3 – 0.1%	-	4 – 0.1%
	Flakes	31 – 7.2%	30 – 3.4%	139 – 3.5%	20 – 1.1%	220 – 3.1%
	Retouched tools	3 – 0.7%	1 – 0.1%	5 – 0.1%	3 – 0.2%	12 – 0.2%
	Debris	21 – 4.9%	21 – 2.4%	63 – 1.6%	4 – 0.2%	109 – 1.5%
	Unworked blanks	1 – 0.2%	-	-	1 – 0.1%	2 – 0.03%
<i>Others</i>	Cores	-	1 – 0.1%	-	1 – 0.1%	2 – 0.03%
	Flakes	2 – 0.5%	1 – 0.1%	30 – 0.8%	10 – 0.6%	43 – 0.6%
	Retouched tools	-	-	1 – 0.03%	-	1 – 0.01%
	Debris	-	1 – 0.1%	9 – 0.2%	6 – 0.3%	16 – 0.2%
	Unworked blanks	-	-	5 – 0.1%	2 – 0.1%	7 – 0.1%
<i>Rhyolite</i>	Cores	-	-	1 – 0.03%	2 – 0.1%	3 – 0.04%
	Flakes	1 – 0.2%	1 – 0.1%	37 – 0.9%	12 – 0.7%	51 – 0.7%
	Retouched tools	-	-	6 – 0.2%	1 – 0.1%	7 – 0.1%
	Debris	-	-	6 – 0.2%	6 – 0.3%	12 – 0.2%
	Unworked blanks	-	-	-	-	-
<i>Radiolarite</i>	Cores	-	-	-	-	-
	Flakes	-	4 – 0.4%	50 – 1.3%	12 – 0.7%	66 – 0.9%
	Retouched tools	-	2 – 0.2%	3 – 0.1%	5 – 0.3%	10 – 0.1%
	Debris	-	3 – 0.3%	14 – 0.4%	5 – 0.3%	22 – 0.3%
	Unworked blanks	-	-	-	-	-
<i>Total</i>		428	891	3999	1788	7106

when the natural convexities suitable for knapping were exhausted, and in most cases, just two adjacent, orthogonal, or opposed striking platforms were exploited. Multi-directional reduction strategies are rare (Daffara, Berruti, & Arzarello, 2021). The Levallois (preferential and recurrent centripetal) and discoid methods (Boëda, 1993, 1994, 1995; Boëda et al., 1990; Boëda & Pelegrin, 1980; Pearsani, 2003) are well attested all along the archaeological sequence and for all the raw materials (vein quartz, spongolite, grey chert, radiolarite, and rhyolite). Vein quartz and spongolite reduction sequences have specific features interpreted as adaptations to the mechanical characteristics of these raw materials: shortness of the production phases with cores abandoned after only one phase of exploitation; frequent use of natural striking platforms; phases of core shaping that are absent or very hurried; and Levallois and discoid cores chosen among blanks with suitable natural convexities (Daffara, Berruti, & Arzarello, 2021; de

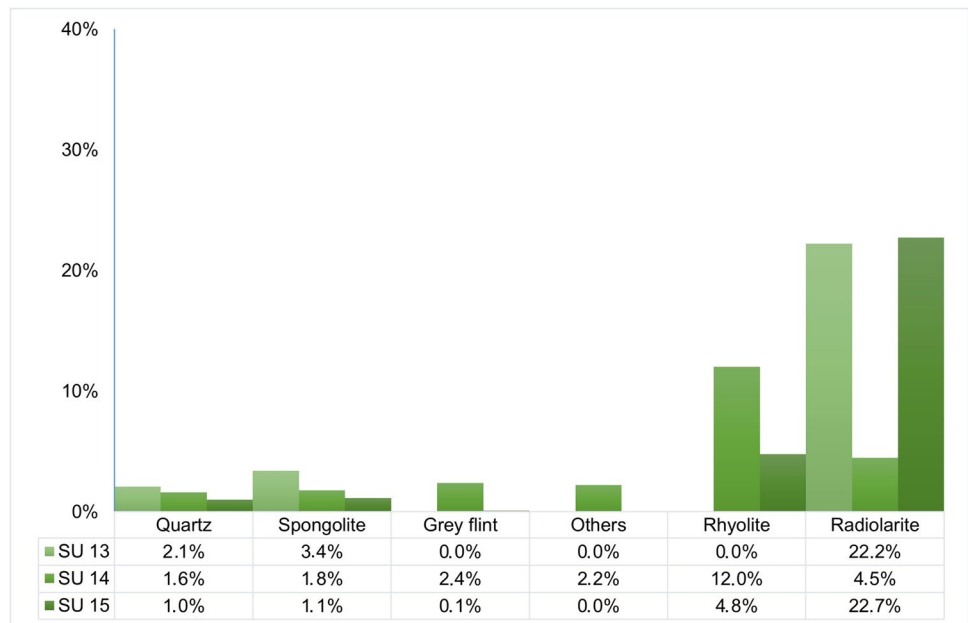
Lombera-Hermida & Rodríguez-Rellán, 2016; Driscoll, 2011; Mourre, 1996; Tallavaara et al., 2010).

The presence of retouched tools is low in all the archaeological levels (Table 2) but is high compared with the absolute number of artefacts concerning the finds made with allochthonous raw materials (Fig. 4). Retouched tools at the Ciota Ciara consist mainly of side-scrapers and denticulated flakes (Berruti et al., 2023; Daffara, Berruti, & Arzarello, 2021).

Faunal Remains, Palaeoenvironment, and Zooarchaeology

The large mammal assemblage recovered from the atrial sector is mainly composed of carnivores (Berto et al., 2016; Cavicchi, 2018): *Ursus spelaeus*, *Ursus arctos*, *Canis lupus*, *Vulpes vulpes*, *Meles meles*, *Martes martes*, *Lynx lynx*, *Panthera spelaea*, and *Panthera pardus*. Ungulates are also

Fig. 4 Graph showing the proportion of retouched tools for each raw material and archaeological level in the atrial sector of the Ciota Ciara cave. Percentages are calculated independently for each raw material and do not refer to the total lithics of each SU. Refer to Table 2 for the percentage of retouched tools out of the total lithic assemblage of each SU



present, although less represented. The main ungulate taxa identified are *Rupicapra rupicapra*, *Cervus elaphus*, cf. *Dama*, *Bos primigenius*, *Bos* sp., *Bos* vel. *Bison*, *Sus scrofa*, *Stephanorhinus* sp., *Marmota marmota*, *Stephanorhinus hemitoechus*, cf. *Macaca*, *Capra ibex*, *Capreoleus capreoleus*, *Castor fiber*, and *Elephantidae*. As in many caves in the Alpine arc, the remains that dominate the faunal assemblage are attributed to *Ursus spelaeus*. The biodiversity in the site varies greatly depending on the stratigraphic unit: it increases from SU 15 to SU 14, in which taxa not attested in other units are reported, such as cf. *Macaca*, *Castor fiber*, *Felis* sp., *Lynx* sp., *Panthera pardus*, cf. *Gulo gulo*, *Martes* sp., *Sus scrofa*, *Capreolus capreolus*, *Bos primigenius*, and *Capra ibex*. In SU 13, a drop in the number of taxa was observed as the felids disappeared along with the rhinoceros, some ungulates (*Capreolus capreolus* and *Capra* sp.), the marmot, and the beaver (Cavicchi, 2018).

The small mammal assemblage of units 13 and 14 is dominated by *Clethrionomys glareolus*, *Microtus arvalis*, and *Microtus (Terricola)* gr. *multiplex-subterraneus* (the most represented), *Arvicola* cf. (Berto et al., 2016). The preliminary study of SU 15 presents a slightly different assemblage, characterised by the presence of *Microtus (Terricola)* gr. *mosbachensis*, *Allocrietus bursae*, and *Crocidura leucodon* (Angelucci et al., 2016). The presence of *A.* cf. *mosbachensis*, if confirmed, might indicate that this unit accumulated during the Middle Pleistocene (Kotsakis et al., 2003; Masini & Sala, 2007; Masini & Sala, 2011; Sala & Masini, 2007).

The small mammal assemblage, and to a certain extent, the large mammals allowed for a reconstruction of the climatic and environmental characteristics during their deposition. During the deposition of the remains of SU 14, the

climate was colder than the present, with a mixed-type environment surrounding the cave, characterised by an alternation of forests, large clearings, and grasslands; the latter probably following the increase in altitude on the exposed slopes (Berto et al., 2016; Cavicchi, 2018). The fauna of SU 13, on the other hand, revealed a milder and more temperate climate, with conditions more similar to the current ones, accompanied by a forest environment with few open areas. The preliminary analysis of the assemblage represented in SU 15 indicates a greater antiquity than the other units, together with a colder climatic context (Cavicchi, 2018).

Taking into consideration the large mammal remains, a climatic oscillation can be noted, from a relatively cold phase, thanks to the presence of *Marmota marmota* in the SU 15–14, to a more temperate phase in SU 13, where this species is entirely absent. The presence of remains attributable to the genus *Stephanorhinus* in units 14 and 15, together with the record of cf. *S. hemitoechus* (a species usually related to the presence of open environments and cold, arid climates) confirms that the lower units of the sequence may have accumulated in a colder-arid period (Masini & Sala, 2007; Pandolfi & Tagliacozzo, 2015). Unit 13 also contains two remains attributed to the genus *Hystrix*, which might be related to a more temperate climate (Cavicchi, 2018; Van Weers, 2006; Van Weers & Montoya, 1996; Viseras et al., 2006).

A complete zooarchaeological study is available only for the remains from the SU 14. The analysis of 1144 faunal remains indicates nine types of taphonomic alterations: root activity (63%), cracking (50%), carnivore intervention (55%), deposition of manganese oxide (99%), concretions (22%), trampling marks (30%), water abrasion (28%), and

cut marks (3%) (Buccheri et al., 2016). Half of the remains with cut marks are undeterminable, but the other half is attributable to large or medium-sized ungulates. Twelve cut marks have been identified on determinable bones of two species: one on a *Canis lupus* bone and eleven on *U. spelaeus* remains. The study of these remains identified four activities attested at the site: flesh removal, evisceration, fur removal, and disarticulation (Buccheri et al., 2016).

Materials and Methods

Materials and Selection of the Archaeological Sample

The lithic assemblage of SU 15 consists of 1788 elements (coming from 8 square metres), including cores, flakes, and debris on the various types of raw material. For this work, only flakes on quartz and chert bigger than 2 cm were considered, narrowing the sample to 1081. With the naked eye and a stereomicroscope, we identified the artefacts suitable for use-wear analysis according to two criteria: the presence of at least one functional edge (i.e., edge with an angle between 80 and 60° regardless of its length) (Terradillos-Bernal & Rodriguez-Alvarez, 2017) and surface preservation (i.e., the absence of marked post depositional alterations and post depositional surface modifications) (Sala, 1986). Finally, 85 pieces were selected for microscopic analysis: 49 in quartz and 36 in chert. The selected artefacts were washed with warm water and soap and soaked in an ultrasonic tank containing demineralised water and alcohol to remove all surface dirt. They were then open-air-dried to avoid any damage that might be caused by heat or other drying methods.

Use-Wear Analysis

The use-wear analysis was conducted using both the low- and high-power approaches. Several researchers have found this integrated methodology more effective and productive (e.g. Beyries, 1993; Cruz et al., 2016; Lemorini et al., 2014; Ziggioni, 2011), and different scholars have successfully applied it to lithic artefacts realised on different raw materials, such as flint, chert, obsidian, quartz, and quartzite (Berruti, Arnaud, et al., 2016; Berruti & Cura, 2016; Igreja, 2009; Knutsson et al., 2015). Specific studies were referred to for a more accurate recognition of micro-wear attributes useful for inferring materials processed with vein quartz tools (Igreja, 2009; Knutsson & Lindé, 1990; Lemorini et al., 2014; Márquez et al., 2016). The following microscopes were used: stereomicroscope Seben Incognita III with magnification from 20× to 80×; stereomicroscope Leica Ez4 HD with magnification from 8× to 35×;

metallographic microscope Optika B 600 Met with 10× oculars, five objectives PLAN IOS MET (5-10-20-50-100×), polarising filters, and bright and dark field, equipped with a digital camera Optika B5; and metallographic microscope AmScope ME300T-M (40×-640×) equipped with AmScope MD600 camera. To reduce the intensity of the fastidious glare typical of quartz-rich rocks like quartz and quartzite, the metallographic microscope was equipped with a differential interference contrast microscopy (Berruti, 2017; Clemente-Conte & Gibaja Bao, 2009; Igreja, 2009; Knutsson et al., 2015).

The Experimental Collection

To create a reference collection that is relevant to the site and objectives of the study, a specific experimental protocol was designed considering factors consistent with those of the archaeological assemblage of Ciota Ciara based on previous technological, supply areas, functional, and zooarchaeological analyses (Arzarello et al., 2012; Berruti & Arzarello, 2012; Buccheri et al., 2016; Daffara, Berruti, & Arzarello, 2021) as well as comparable Middle Palaeolithic contexts (e.g. Berruti et al., 2020; Hardy, 2004; Picin & Carbonell, 2016; Spagnolo et al., 2019). The raw materials (quartz and chert) were collected from the same supply areas determined for those found in the archaeological context (Daffara et al., 2019) and knapped to produce unretouched flakes through the opportunistic method. Before use, each flake and its designated functional edge were observed and photographed, first under the stereomicroscope (Leica EZ4 HD, magnifications 8×–36×) and then under the metallographic microscope with reflected light (Optika 4083 equipped with camera B3, magnifications 40×–200×). After use in activities in which one of several materials (deer antler, dry wood, fresh wood, meat, fresh hide, fresh bone, and marsh reeds) was worked employing either longitudinal or transversal actions for a fixed duration of 10 min (Table 3), the flake tool edges were observed again under the microscopes, in a manner

Table 3 Experimental collection divided per raw material, material worked, and actions performed (* mixed action)

Material	Chert		Quartz	
	Transversal	Longitudinal	Transversal	Longitudinal
Bone	S05	S11	Q05	Q11
Meat	S02	S09	Q02	Q09
Fresh hide	S03	S10	Q03	Q10
Antler	S04	S08	Q04	Q08
Fresh wood	S05	S12	Q05	Q12
Dry wood	S06	S13	Q06	Q13
Marsh reeds	S07	S14	Q07	Q14
Butchering*	S15	S15	Q15	Q15

that eventually allowed for the comparison of the areas of interest before and after the formation of use-related traces.

Results

Experimental Results

The characteristics of use traces identified on the chert reference collection were found to be comparable with those previously described in the literature (e.g. Dayet et al., 2019; Hayden, 1979; Lemorini, 2000; Longo, 1994; Odell, 1988; Odell & Odell-Vereecken, 1980; Semenov, 1964; Tringham et al., 1974; Ziggotti, 2011): edge removals, edge rounding, striations, polish, and bright spots that varied in size, morphology, localisation, distribution, and organisation depending on the action applied and the hardness of the material in contact. The digital illustrations of the flake margins before and after tool use significantly aided in identifying, in further detail, the macroscopic changes in the edge morphology and formation of traces (Fig. 5). The analysis of the quartz tools, moreover, revealed how the formation and observation of traces under the microscope are significantly affected by the mineralogical characteristics of the raw material. Because of its granulometry, during the stress caused by contact with the worked material, the wearing of the margin does not take place gradually and consistently as it does on chert edges but follows to a great extent the natural detachment of the polyhedral crystals that make up the quartz artefact. Findings were consistent with those of previous experiments and studies in which rounding, micro-removals, striations, fractures, micro-pits, polish, and plastic deformation of quartz crystals were observed as use-related traces, with properties that varied based on the type of contact material (Berruti, 2017; Igreja, 2009; Knutsson et al., 2015; Knutsson & Lindé, 1990) (Table 4). Moreover, it was found that the equipment of a differential interference contrast (DIC) capability effectively addressed the difficulty encountered in visualising the traces due to the glare that was produced by the highly reflective quartz surface under the metallographic microscope, producing an image projection with a definition high enough for the identification of use-wear traces.

Use-Wear Analysis of Archaeological Finds

The analysis of the selected artefacts from SU 15 identified 24 flakes (13 on quartz, 11 on chert) with traces of use consistent with activities related to butchering and treating hunted animal resources (Table 5). For chert, five artefacts were identified to have been used to perform longitudinal actions, three for transversal actions, and three from both, associated with cutting, scraping, or a combination of these

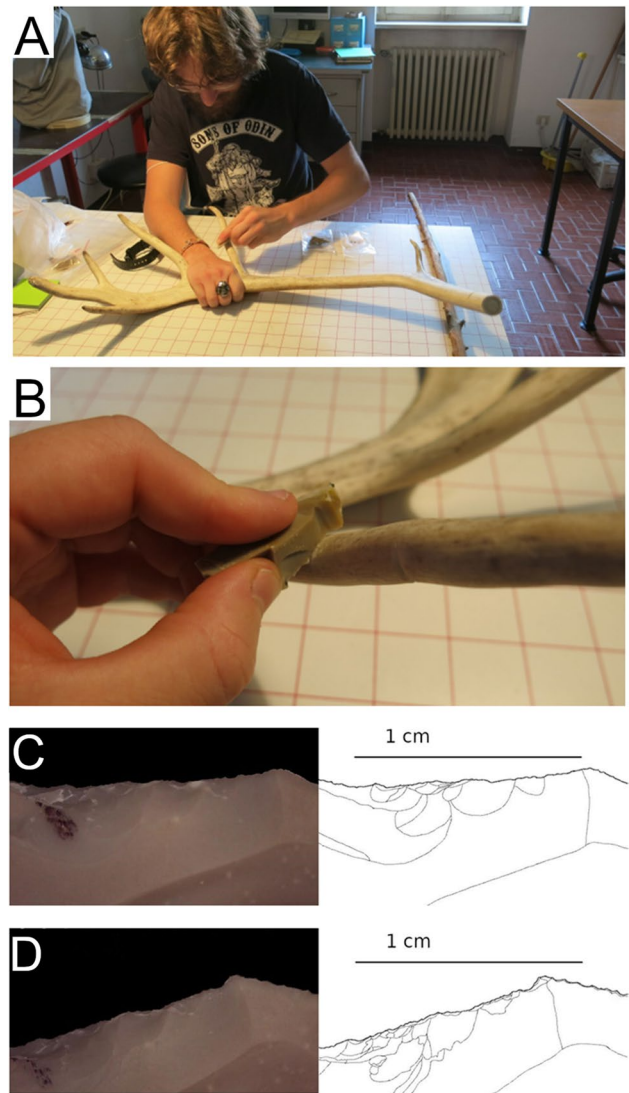


Fig. 5 Experiments. **A** S08 use on deer antler. **B** S08 on deer antler, detail; S05 flakes. stereo-microscope photos and related drawings, before (**C**) and after (**D**) cross-sectional use on deer antler (8×)

movements (Fig. 6). Of those on quartz, six were observed to have traces derived from longitudinal actions, six from transversal actions, and one from both, carried out on hard and soft materials in butchering activities with contact on both bone and meat mass (Figs. 7, 8, 9, and 10). Most of the traces are therefore attributable to exploitation centred on treating animal carcasses, mainly processing meat and skin, followed by working bone and antler.

The identification and interpretation of use-wear traces on quartz artefacts are based on the experimental activity and the works of Berruti (2017), Igreja (2009), Knutsson and Lindé (1990), Knutsson et al. (2015), Lemorini et al. (2014), and Márquez et al. (2016). The traces interpreted as results of butchering activity are characterised by striae, micro holes, and micro scars in association with

Table 4 Wear features on the experimental vein quartz tools. The relative abundance of each feature is expressed on a four-step scale

Wear on the surfaces of the crystals	Worked Material							
	Meat	Fresh bone	Dry bone	Fresh wood	Dry wood	Fresh skin	Dry skin	Butchering
Polish with rough appearance	■					■	■	■
Polish with dommed topography		■	■	■	■			■
Widespread rounding	■					■	■	■
Plastic deformation			■			■	■	■
Edge rim worn down		■	■					■
Edge rounding	■		■	■	■	■	■	■
Fracture of the edge		■	■	■	■		■	■
Impact pits				■	■			
Micro holes		■	■	■	■			■
Micro scars		■		■	■			■
Striae		■	■	■	■		■	■
Cracks		■	■			■	■	■
Grooves							■	

Table 5 Use-wear traces on SU 15 artefacts, grouped by action, method of *débitage*, and worked material

	Discoid			Levallois						Opportunistic						Total	%										
	Chert			Quartz			Chert			Quartz			Chert					Quartz									
	T	L	M	T	L	M	T	L	M	T	L	M	T	L	M			T	L	M							
Butchery									1										1	1	1	1	5	21%			
Fresh skin																							1	3	13%		
Soft animal tissue																							1	1	7	29%	
Bone																							1	2	4	17%	
Wood																									0	-	
Non-woody plant																									0	-	
Dry skin																									0	-	
Soft																								1	4%		
Medium soft																								1	4%		
Medium hard																								1	1	2	8%
Hard																								1	4%		
<i>Total</i>	0	1	1	0	2	0	1	1	1	0	0	0	2	3	1	6	4	1	24	100%							
<i>Total per raw material</i>	2			2			3			0			6			11											

T transversal action, L longitudinal action, M mixed action

edge rounding and polish with a rough appearance. The identification and interpretation of use-wear traces on chert artefacts are based on the experimental activity and the descriptions presented by Anderson-Gerfaud (1990), Beyries (1987), Claud (2012), Hardy (2004), Lazuén and González-Urquijo (2015), Lemorini et al. (2003, 2006, 2016), Palmqvist et al. (2005), and Zupancich et al. (2016). The traces interpreted as results of butchering activity are characterised by polish with a closed texture linked to the edge morphology, by rounding (meat processing) and, in some cases, by the presence of flat and brilliant polish spots (contact with bone).

According to the technological data (Daffara, 2018), most of these artefacts were produced with the opportunistic method, followed by discoid, then Levallois. It is interesting to note that, as also underlined in other studies (Claud, 2012; Hardy, 2004; Lazuén & González-Urquijo, 2015; Lemorini et al., 2003, 2006, 2016; Zupancich et al., 2016), in the considered lithic assemblage, there does not seem to be any clear specific relationship between the method employed to produce the tools and the activity performed with them. Even between Levallois and discoid products, there are no apparent differences in terms of the type of actions and activities carried out (Berruti, 2017).

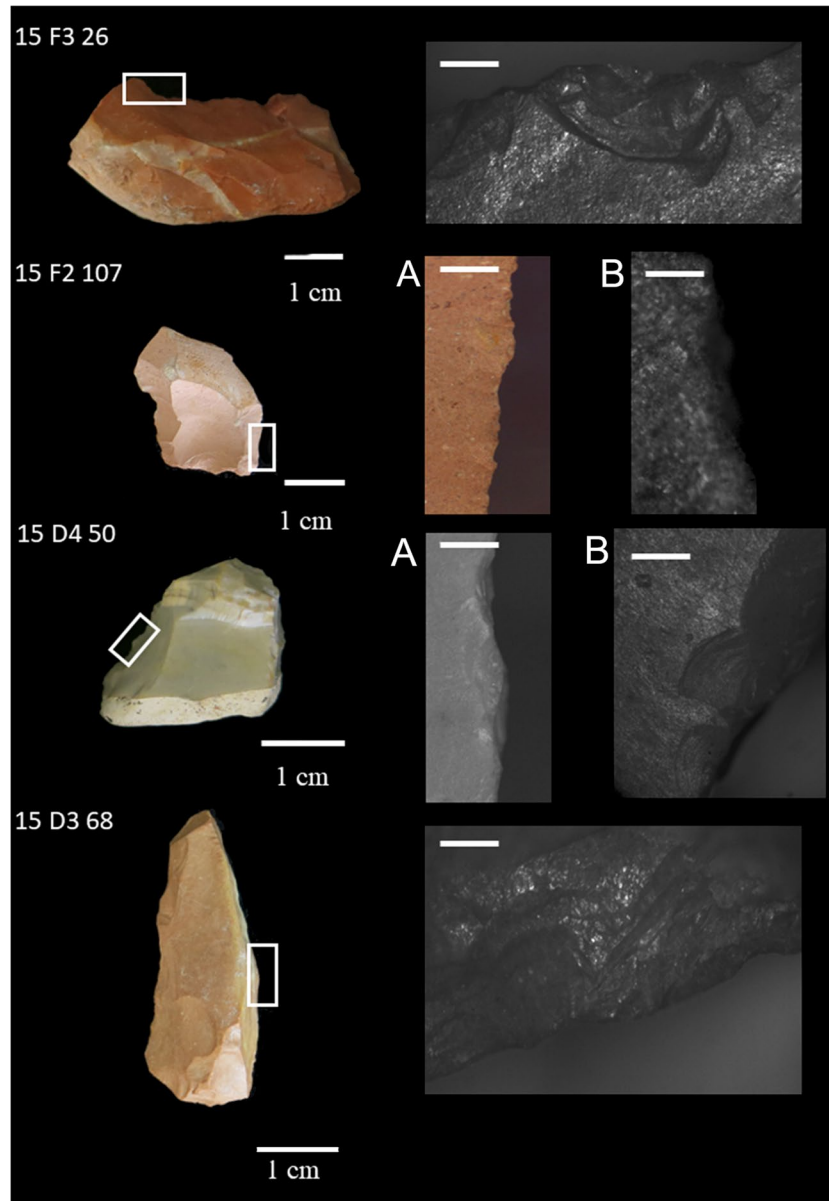
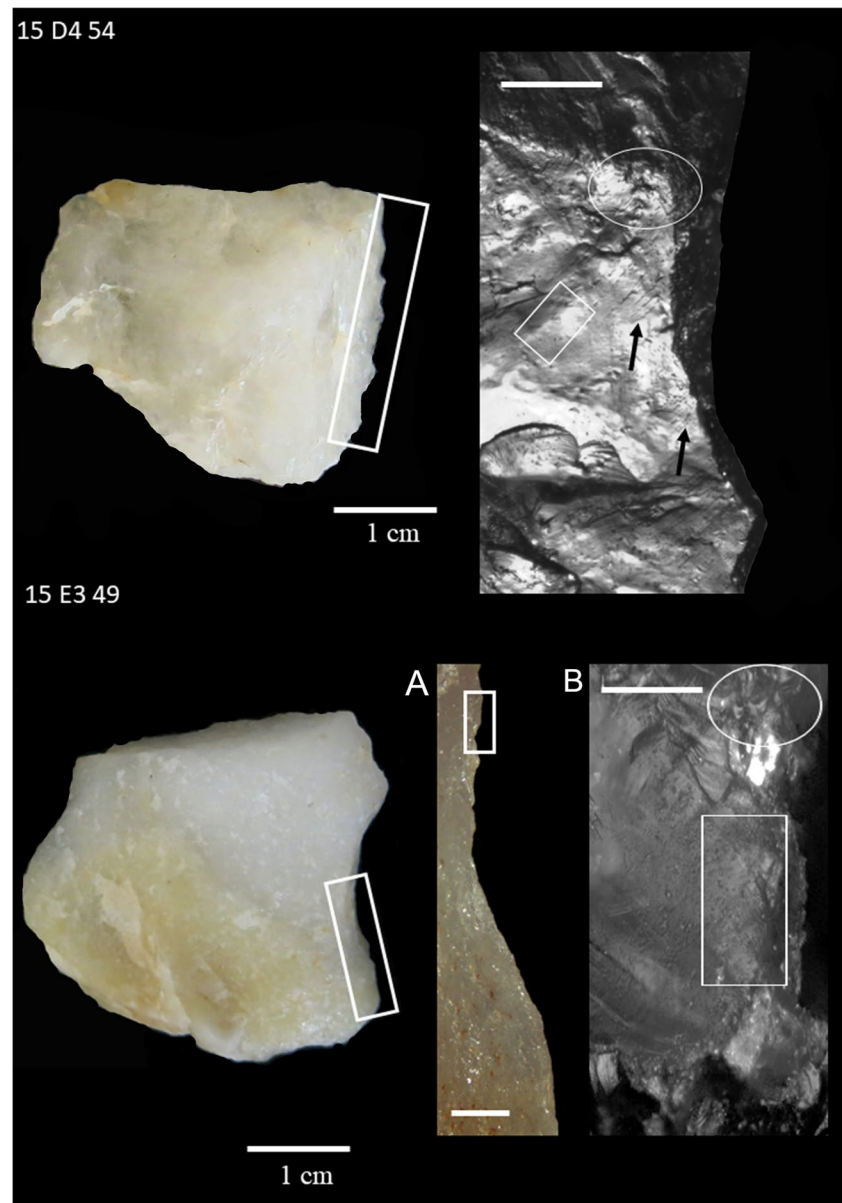


Fig. 6 Use wear traces on chert artefacts. Artefact 15 F3 26 (sidescraper). The traces are located on the active edge of the tool. On the right (scale bar 0.5 μm), two lines of rough polish can be seen in association with two edge removals. The traces identified are very similar to those obtained in the experimental collection (see Supplementary materials Fig. 1) and show clear similarities with previously published studies (e.g. Berruti et al., 2023; Lazuén & Delagnes, 2014; Lemorini et al., 2015) where these kinds of traces have been interpreted as the result of meat working activity. Artefact 15 F2 107 (unretouched flake). A Series of crescent-shaped edge removals (scale bar 1 mm). B Series of small and localised areas of smooth and flat polish (scale bar 0.5 μm). The traces identified are very similar to those obtained in the experimental collection and show clear similarities with previously published studies (e.g. Berruti et al., 2023; Lazuén & Delagnes, 2014; Lemorini et al., 2015) where these kinds of traces have been interpreted as the result of a longitudinal

action on bone. Artefacts 15 D4 50 (sidescraper). A Edge removals (scale bar 0.5 mm). B Two lines of rough polish can be seen in association with the edge removals (scale bar 0.5 μm). These traces are very similar to those observed on the artefacts 15 F3 26 and show clear similarities with previously published studies (e.g. Berruti et al., 2023; Lazuén & Delagnes, 2014; Lemorini et al., 2015) where these kinds of traces have been interpreted as the result of meat working transversal activity. Artefact 15 D3 68 (limace): on the right (scale bar 0.5 μm), two lines of rough polish can be seen in association with two edge removals and with small and localised areas of smooth and flat polish. The traces identified are very similar to those obtained in the experimental collection (see Supplementary materials Fig. 1) and show clear similarities with several previously published studies (e.g. Berruti et al., 2023; Lazuén & Delagnes, 2014; Lemorini et al., 2015) where these traces have been interpreted as the result of longitudinal meat working activity

Fig. 7 Use wear traces on quartz artefacts. Artefact 15 D4 54 (unretouched flake): polish with dommed topography (in the rectangle on the right), edge rim worn down (in the ellipse on the right) and two sets of striae indicated by the arrows; in addition, micro holes and widespread rounding can be observed on the surface of the artefact (scale bar 0.5 μm). The traces identified are very similar to those obtained in the experimental collection (see supplementary materials Fig. 1) and show clear similarities with previously published studies (e.g. de la Peña et al., 2018; Knutsson et al., 2015; Márquez et al., 2016; Taipale, 2012). Looking at Table 4, the presence of all these types of traces (each not highly developed) is to be associated with butchering activity. Artefact 15 E3 49 (unretouched flake). A series of crescent-shaped edge removals (scale bar 1 mm). B Polish with dommed topography (in the rectangle) and edge rim worn down (in the ellipse); in addition, micro holes and widespread rounding can be observed on the surface of the artefact (scale bar 0.5 μm). In this case as well the use wear traces observed can be referred to butchering activities



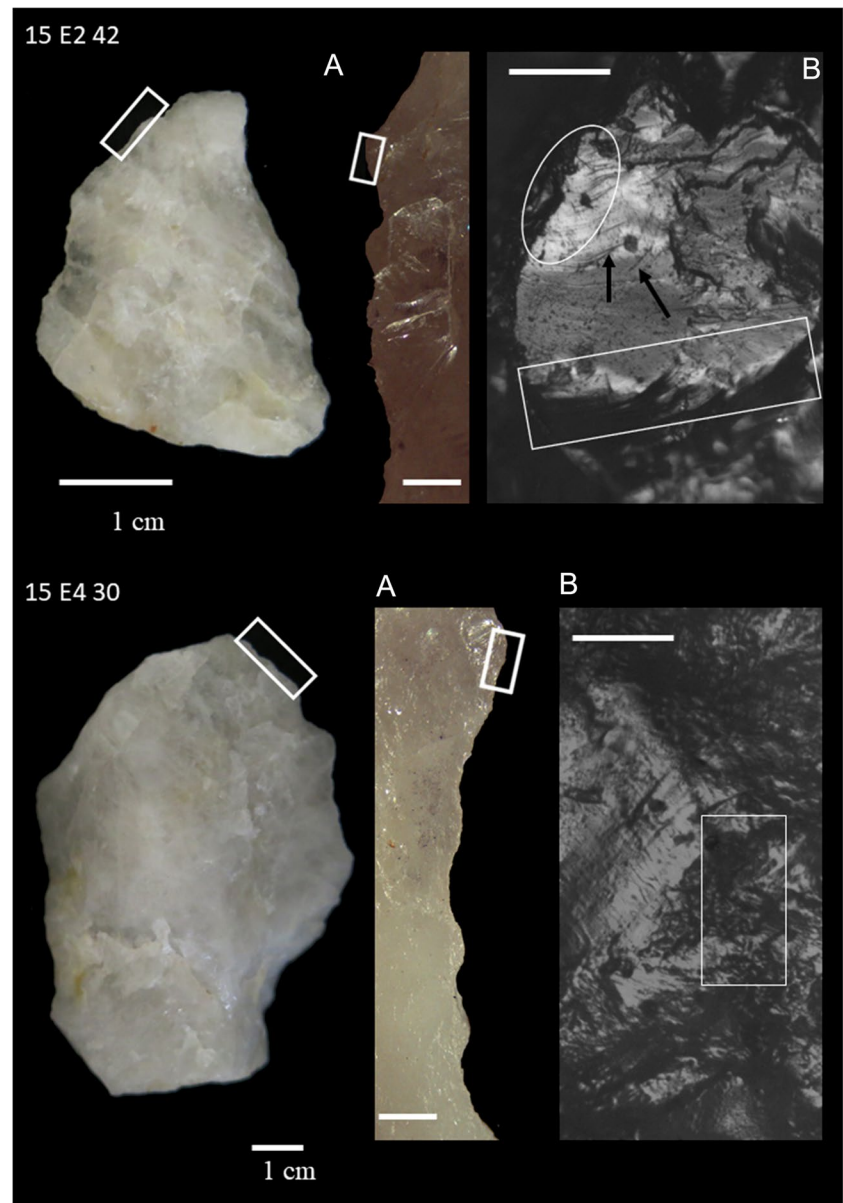
Discussion

The Use-Wear Analysis of the SU 15

Of the sample considered in the study, 30.5% (11) of the chert and 26.5% (13) of the quartz artefacts show use-wear traces, representing 1.34% (out of 883) and 1.43% (out of 640) of the lithic assemblage from SU 15, respectively (Tables 2 and 5). This low turnout may have been a result of the post-depositional processes to which the archaeological assemblage has been subjected, which left alterations on the surface of the lithic industries, rendering it impossible to recognise any potential use-wear (Asryan et al., 2014; Berruti & Arzarello, 2020; Burrioni et al., 2002). In SU 15, post-depositional alterations were, in fact, observed in 70.6%

of the chert and 50.2% of the quartz artefacts (Fig. 11). This phenomenon is related to the depositional context of SU 15, distinguishable from SUs 13 and 14 by the greater presence of dolomite fragments and sandy portion, and from SU 16 by the difference in the size of clast composition, correlates its formation to the karstic activity of the cave (Angelucci et al., 2019). Prolonged contact with a humid environment then favoured the formation of patina and concretion on the surface of the lithic artefacts, obscuring if not covering potential use traces on them. Identified use-wear traces for SU 15 indicate tool use in activities involving the handling of animal resources (20.8% butchering, 12.5% fresh skin working, 29% soft animal tissue processing, 16.7% bone working, and 16.7% other undefined organic materials processing). Local raw materials (quartz and spongolite) make up 95% of the

Fig. 8 Use wear traces on quartz artefacts. Artefact 15 E2 42 (unretouched flakes). A Series of crescent-shaped edge removals (scale bar 1 mm). B Polish with dommed topography and edge rounding (in the rectangle), two edge fractures in the ellipse and micro holes on the surface of the artefact (scale bar 0.5 μm). Looking at Table 4 and to previous published studies (e.g. de la Peña et al., 2018; Knutsson et al., 2015; Márquez et al., 2016; Taipale, 2012), the presence of all these types of traces (each not highly developed) is to be associated with butchering activity. Artefact 15 E4 30 (unretouched flake). A Series of crescent-shaped edge removals (scale bar 1 mm). B Polish with dommed topography and edge fracture (in the rectangle); striae and micro scars on the edge of the artefact (scale bar 0.5 μm). The traces identified are very similar to those obtained in the experimental collection and show clear similarities with previous published studies (e.g. de la Peña et al., 2018; Knutsson et al., 2015; Márquez et al., 2016; Taipale, 2012). Looking at Table 4, the presence of these types of traces is to be associated with longitudinal activity on bone (probably fresh)



identified lithic tools from SU 15; safe to say that most of the tools were produced and discarded at the site.

The Use-Wear Analysis of the SU14

A significant amount of tools with use-wear traces (41% of the sample, i.e., 27 lithics out of 136) was identified from SU 14, offering a highly reliable interpretation of activities carried out as represented in this unit (Berruti, 2017; Berruti et al., 2023; Berruti & Arzarello, 2012; Daffara, Berruti, & Arzarello, 2021). Artefacts with combined traces associated with butchering, working fresh and dry hide, and working bone and soft animal tissues were found (17), meaning that the assemblage attests to different phases of carcass exploitation: skinning,

evisceration, disarticulation, and de-fleshing (Lemorini et al., 2006). The tools that exclusively have traces of soft animal tissue processing (2) were probably used in filleting, while tools that present traces mainly linked to a transversal action applied on the bone (5) were for periosteum removal, necessary during marrow extraction (Grayson, 1984). This data is consistent with the results of the zooarchaeological study for SU 14, highlighting the presence of several bones with clear traces of scraping actions and cutmarks identified to have resulted from the use of lithic artefacts for evisceration, filleting, and skinning activities (Buccheri et al., 2016). Also found in SU 14 are tools with traces linked to processing fresh and dry hide (7) interpreted to have been used in some type of tanning activity, denoting the execution

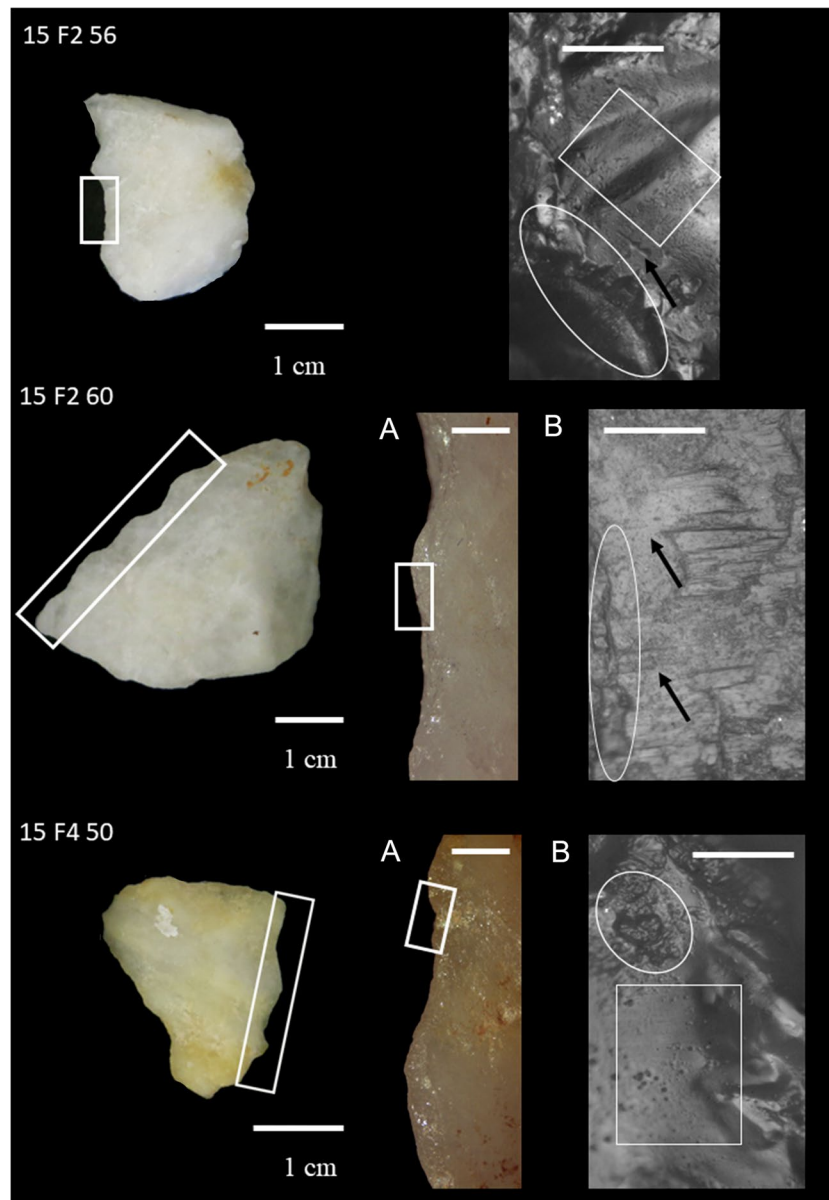


Fig. 9 Use wear traces on quartz artefacts. Artefact 15 F2 56 (unretouched flake): polish with dommed topography, edge rounding and edge fracture (in the ellipse), a widespread rounding in the area delimited by the rectangle (scale bar 0.5 μm). In agreement with both our experimentation and the existing bibliography (e.g. de la Peña et al., 2018; Knutsson et al., 2015; Márquez et al., 2016; Taipale, 2012), the presence of this combination of traces can be referred to longitudinal butchering activities. Artefact 15 F2 60 (double scraper). A Series of crescent-shaped edge removals (scale bar 1 mm). B Edge fracture (in the ellipse) and indicated by the arrows, striae, and micro scars (scale bar 0.5 μm). In agreement with both our

experimentation and the existing bibliography (e.g. de la Peña et al., 2018; Knutsson et al., 2015; Márquez et al., 2016; Taipale, 2012), the presence of this combination of traces can be referred to longitudinal activity on the bone (probably fresh). Artefact 15 F4 50 (denticulate). A Series of crescent-shaped edge removals (scale bar 0.5 mm). B Polish with dommed topography (in the rectangle), edge rim worn down and scars are visible in the ellipse; in addition, micro holes and widespread rounding can be observed on the surface of the artefact (scale bar 0.5 μm). In this case, the set of traces of use observed is most likely to be related to longitudinal butchering activities

of long-lasting operations at the site (Anderson-Gerfaud, 1990; Beyries, 1987; Lemorini et al., 2006; Palmqvist et al., 2005). While relatively less frequent, SU14 also yielded artefacts with traces linked to the processing of woody and non-woody plants (8), an operation related to

manufacturing spears or other utilitarian wood objects (Hardy, 2018; Rots & Hardy, 2015) and, in some cases, processing herbaceous plants. These findings suggest that the Ciota Ciara cave inhabitants may have gathered plant resources in addition to animal carcasses for their

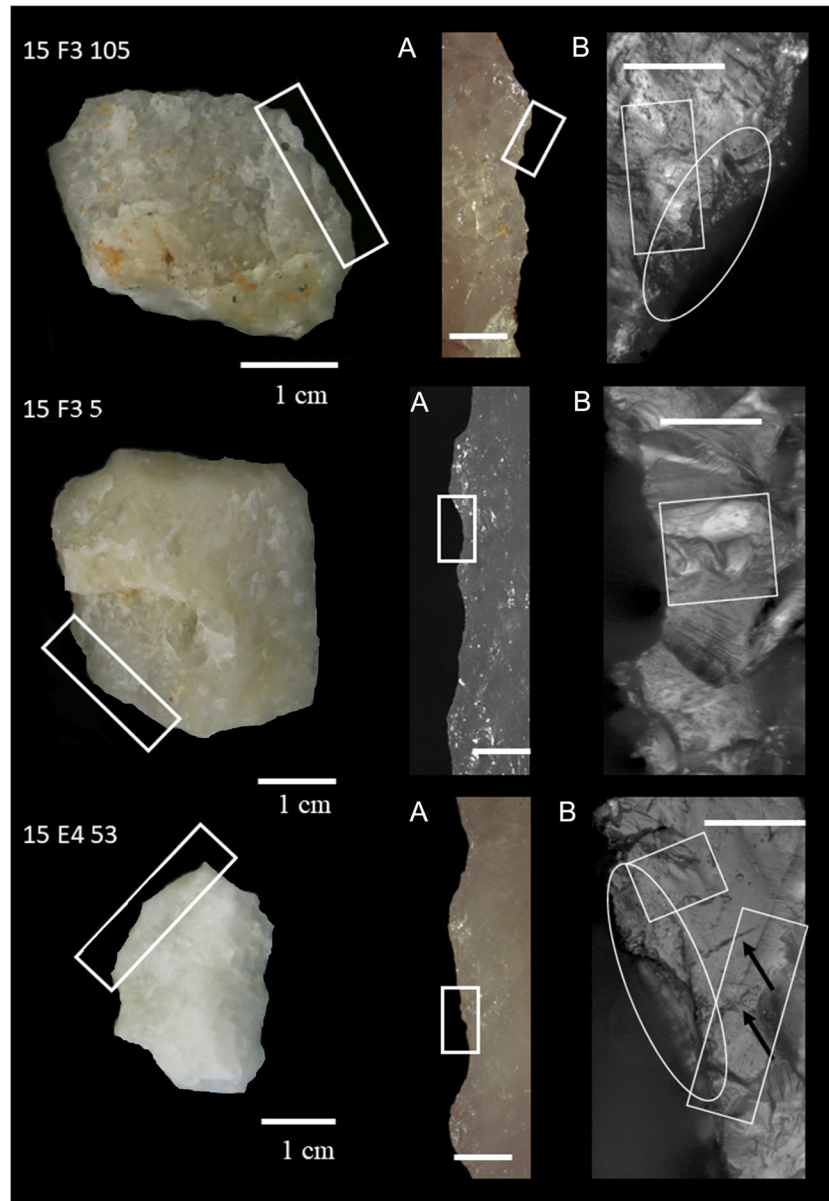


Fig. 10 Use wear traces on quartz artefacts. Artefact 15 F3 105 (unretouched flake). A Series of crescent-shaped edge removals (scale bar 0.5 mm). B Edge rounding and edge fracture (in the ellipse) and a polish with dommed topography in the area delimited by the rectangle; holes and widespread rounding can be observed on the surface of the artefact (scale bar 0.5 μ m). In agreement with both our experimental data and the existing bibliography (e.g. de la Peña et al., 2018; Knutsson et al., 2015; Márquez et al., 2016; Taipale, 2012), the set of traces of use observed is most likely to be related to longitudinal butchering activities. Artefact 15 F3 5 (unretouched flake). A Series of crescent-shaped edge removals (scale bar 0.5 mm). B A polish with dommed topography in the area delimited by the rectangle in association with an edge removal; widespread rounding can

be observed on the surface of the artefact (scale bar 0.5 μ m). This combination of traces allows us to hypothesise a use of this flake for a longitudinal butchering activity. Artefact 15 E4 53 (unretouched flake). A Series of crescent-shaped edge removals (scale bar 1 mm). B Edge fracture and edge rounding (in the ellipse); two rounded areas (in the rectangle), arrows indicate the presence of two deep striae (scale bar 0.5 μ m). The traces identified are very similar to those obtained in the experimental collection and show clear similarities with previously published studies (e.g. de la Peña et al., 2018; Knutsson et al., 2015; Márquez et al., 2016; Taipale, 2012). In this case as well as the use wear traces observed can be referred to butchering activities

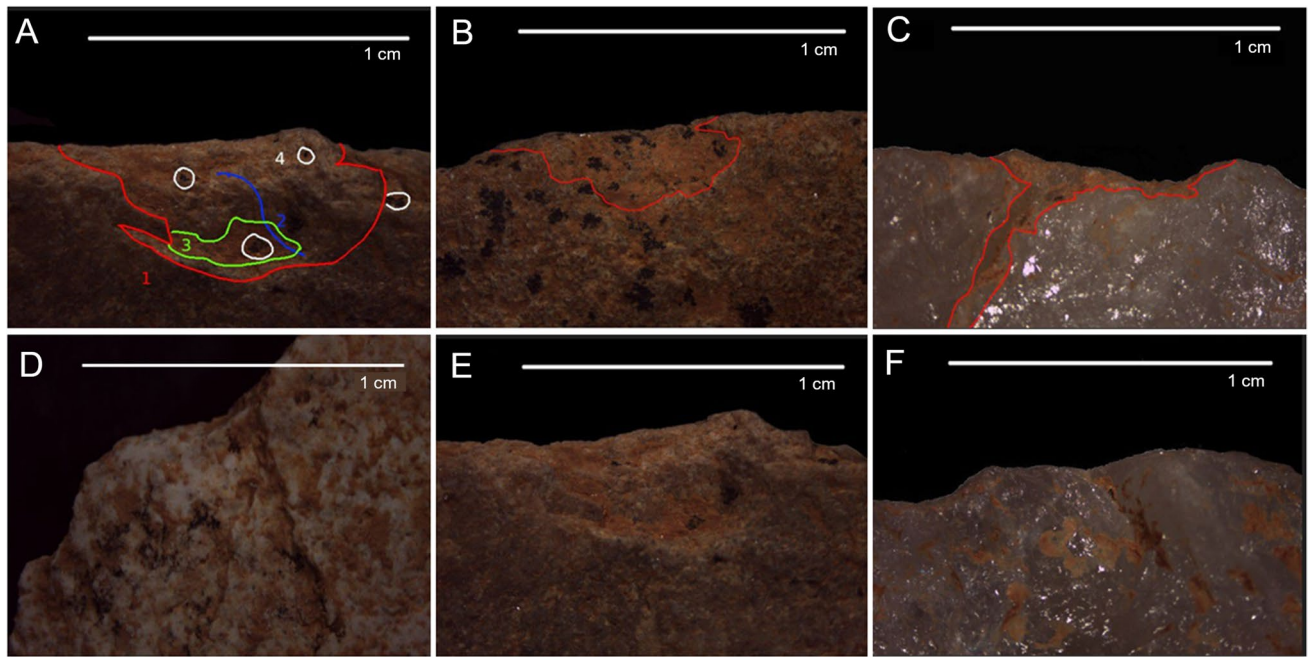


Fig. 11 Edges of chert and quartz flakes with post-depositional traces at 8× magnification. **A** Edge with a sequence of post depositional alterations: detachment of part of the surface (1), followed by rounding (2), deposition of a concretion (3) and deposition of spots of iron

manganese (4). **B** Edge with fracture (red) and rounding. **C** Edge with fracture (red) and rounding. **D, E, F** Edges with rounding. All this post depositional traces are due to the presence of water in the sediment

subsistence or for medicinal purposes (Hardy, 2018). The representation of various well-manifested activities suggests a phase of medium-term occupations at the cave for SU 14 (Stiner, 2013).

The Use-Wear Analysis of the SU13

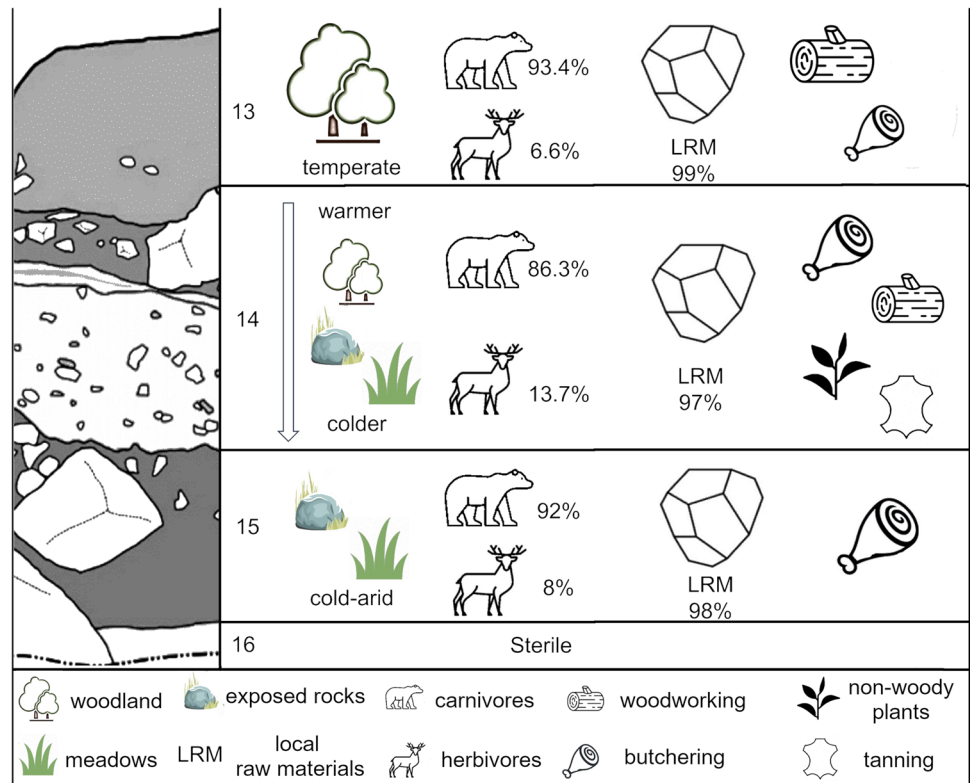
For the lithic industry of SU 13, functional analysis shows the predominance of traces (65% of artefacts with use-wear, i.e., 8 out of 12) linked to woodworking activities. A bi-convex convergent scraper with an impact fracture and two artefacts with traces attributable to meat and bone working attest to a secondary presence of activities linked to hunting or exploitation of animal carcass (Arzarello et al., 2012; Berruti & Arzarello, 2012). The technological characteristics of the lithic industries (Daffara et al., 2014, 2019; Daffara, Berruti, & Arzarello, 2021), together with the important presence of *Ursus spelaeus* fossil remains (Berto et al., 2016; Cavicchi, 2018) frame this phase as characterised by repeated, short-to-medium duration occupations, with the use of the cave as a hunting shelter. The complete operational chains involving the processing of wooden materials are related mainly to the maintenance of hunting tools and only contingently to the primary acquisition of resources (Berruti & Arzarello, 2012; Stiner, 2013).

Through Time

The Middle Palaeolithic occupation of the Ciota Ciara cave is divided into three archaeological levels (SU 13, 14, and 15), each of which, based on geoarchaeological and palaeontological data (Angelucci et al., 2019; Cavicchi, 2018), covers a broad chronological span. Each archaeological level is thus configured as a palimpsest (e.g. Bargalló et al., 2020; Machado et al., 2013; Spagnolo et al., 2020) or the result of the superimposition of several human occupation events. The comparison of the results of the lithic functional analysis and the combination of these findings with data from the technological, palaeontological, geoarchaeological, and zooarchaeological studies (Angelucci et al., 2019; Arzarello et al., 2012; Berruti et al., 2023; Berruti & Arzarello, 2012; Berto et al., 2016; Buccheri et al., 2016; Cavicchi, 2018; Daffara et al., 2014, 2019; Daffara, Berruti, & Arzarello, 2021), provide bases for the formulation of hypotheses on how settlement dynamics at the cave changed through the various phases of human occupation, the characteristics of which we outline below (Fig. 12).

Unit 15 corresponds to a phase of generally cold and arid climate and a relatively low turnout in the faunal presence (Cavicchi, 2018). Frost-related features were clearly identified in the micromorphological analysis of the sediments, thus confirming the paleoenvironmental reconstruction based on palaeontological data (Angelucci

Fig. 12 Schematic representation of the archaeological levels of Ciota Ciara atrial sector indicating aspects of the palaeoenvironment, fauna, lithic raw materials, and main activities carried out at the site as identified by the use-wear analysis



et al., 2019). The lithic industry consists of 1788 finds, of which 1745 (97.7%) derive from the exploitation of local raw material resources, and 43 (2.3%) are made from allochthonous rocks (Table 1). Local rocks are introduced into the site as natural blanks for the production of tools through production sequences characterised by a low technological investment (Daffara, Berruti, & Arzarello, 2021; Vaquero & Romagnoli, 2018). As indicated by the use-wear analysis, lithic tools were mainly used and discarded at the site in the processing of animal resources. Correlating all these data, we assume that during the deposition of SU 15, the cave was repeatedly used as a shelter for short-term occupations dedicated to expeditive butchering activities along foraging routes (Stiner, 2013). Moreover, it is likely during these shifts that tools made of allochthonous raw materials were introduced to the site as part of “personal toolkits” involving versatile tools that could respond to any kind of need along the itinerary covered by the Middle Palaeolithic hunter-gatherers (Kuhn, 1992). In the context of Western Europe, the situation highlighted in level 15 of the Ciota Ciara cave is comparable with that of Fox do Enxarrique (Portugal) (Berruti, Rosina, & Raposo, 2016), Chez Pinaud–Jonzac (France) (Soressi, 2004), Castel di Guido (Boschian & Saccà, 2015), La Polledrara di Cecanibbio (Santucci et al., 2016), Isernia La Pineta (Carpentieri et al., 2023), and Marillac-Les Pradelles (France) (Costamagno et al., 2006), which were interpreted as

butchering sites based on palaeontological, zooarchaeological, techno-typological, and functional data.

Unit 14 was also formed in a generally colder climate, but in its upper part, the micromorphological analysis showed a change towards milder climatic conditions (Angelucci et al., 2019). Palaeontological data indicate a mixed-type palaeoenvironment with forested areas and towards the higher altitudes of Monte Fenera, open areas of grassland, and exposed rocks (Berto et al., 2016; Cavicchi, 2018). Here we observe an increase in the number of herbivorous remains (Berto et al., 2016; Cavicchi, 2018), an increase in the number of imported lithic raw materials (Daffara et al., 2019) along with the general increase of lithic artefacts in the assemblage (Arzarello et al., 2012; Daffara et al., 2014; Daffara, Berruti, & Arzarello, 2021) (Table 2), the presence of a fireplace (Arnaud et al., 2014), and an increased variety of activities practised on the site (butchering, processing of bone to extract marrow, tanning activities, processing of woody and non-woody plants). A high density of archaeological remains, high taxonomic diversity, and the presence of hearths are characteristics generally associated with long-term occupations (Bargalló et al., 2020). However, the lack of other reliable factors, such as a high percentage of cores and a low percentage of retouched tools, limits such interpretation. According to ethnographic studies, hunter-gatherer groups also make hearths in places that are occupied for short stays (Binford,

1978, 1980; Foley & Gamble, 2009; Gaudzinski & Turner, 1996; Rosell et al., 2012; Stiner, 2013; Vaquero & Pastó, 2001). Moreover, it has been pointed out that a large palimpsest presenting a great taxonomic variety and high numbers of lithic artefacts might be a result of several episodes of short/medium-term settlements that overlapped within an extended period rather than a long-term occupation (Bargalló et al., 2020). All the data and considerations, therefore, seem to suggest that the deposition of SU 14 resulted from medium-term occupations characterised by complex sets of activities in the use of the cave as a base camp (Stiner, 2013). Level 14 of Ciota Ciara finds comparisons with the sites of Jarama VI (Spain) (Romero et al., 2019), Les Canalettes (France) (Patou-Mathis, 1993), Coudoulous I (France) (Jaubert et al., 2005), and Abric Romani (Spain) (e.g. Eixea, Romagnoli, et al., 2020; Gómez de Soler et al., 2020; Vaquero et al., 2001, 2015) where zooarchaeological data indicate the practice, within the site, of various activities related to the processing of animal carcasses, and as far as Abric Romani is concerned, good evidence of woodworking.

Paleoenvironmental and geoarchaeological data indicate that SU 13 formed in a more temperate climate than the lower units, characterised by an open woodland environment (Angelucci et al., 2019; Berto et al., 2016; Cavicchi, 2018). The lithic assemblage consists of 891 artefacts; the lowest turnout among all three units, and is composed almost exclusively (98.6%) of locally sourced raw materials (Table 1). The results of the functional analysis demonstrate the practice of butchering activities at the site and, similar to level 15, the absence of long-term processes such as tanning. The critical point to SU 13 is that here we find consistent evidence of woodworking, probably linked to the production and/or maintenance of hunting tools (e.g. Conard et al., 2020) or digging tools (e.g. Aranguren et al., 2018), although the presence of fractures interpreted as the result of impacts on the bi-convex convergent scraper strongly suggests that the production of hunting tools took place in the site. In our opinion, a plausible hypothesis is that SU 13 represents a period of repeated occupations of short duration in which the cave served as a hunting camp. Toolkits and a high percentage of retouched tools are typical to short-term occupations (Bargalló et al., 2020), but the specialised site use could explain the absence of these factors. The fair quantity of charcoal revealed in the geoarchaeological analysis (Angelucci et al., 2019) can also be interpreted as probable unstructured hearths used for short periods, later obliterated by the recurrence of human occupations and post-depositional processes at the site. Similar characteristics and interpretations are known for the Middle Palaeolithic sites of Lagoa do Bando (Portugal) (Berruti & Cura, 2016), Sassefelsgrotte (Germany) (Rots, 2009), and San Quirce (Spain) (Terradillos-Bernal et al., 2017).

We propose here a reconstruction of the various phases of occupation of the cave, highlighting those similarities and differences in the practiced economy that can be seen through the technological and functional study of the lithic industries. In this way, it is possible to reconstruct macroscopically the occupation patterns of the cave over time. To obtain detailed reconstructions of the single phases of occupation of the site, we refer to future studies that can incorporate the data presented here with spatial analyses. In fact, there are numerous works in the literature that, through spatial analyses come to accurately identify the functional areas into which a prehistoric camp was structured, such as resting areas (e.g. Spagnolo et al., 2019, 2020; Hernandez et al., 2014; Mellars, 1996; Rigaud & Geneste, 1996) and knapping areas or areas dedicated to the processing animal resources (e.g. Jones, 2008; Spagnolo et al., 2019, 2020). Such detail of analysis is beyond the scope of this paper but will be the focus of future research.

Conclusion

The Ciota Ciara cave continues to be one of the reference archaeological contexts for the Middle Palaeolithic in north-western Italy. The results of the multidisciplinary studies conducted on the site make it possible to delineate with ever greater clarity the characteristics of the population in a geographical area still very little known from this point of view. The present work confirms how functional analysis, integrated with paleoenvironmental, palaeontological, technological, and geoarchaeological data, is a fundamental tool for defining site function and changes in the modalities of site frequentation. The results of the use-wear analysis completed for the atrial sector of Ciota Ciara highlight that from the bottom to the top of the stratigraphic sequence, the cave defines an initial phase in which it was used only as a butchering site (SU 15), followed by a phase of more intensive occupations (SU 14), and finally, a phase of short-term occupations linked to hunting activities (SU 13). These variations could be caused by adjustments or changes in territorial pattern systems, in the use of settlement space, in the acquisition and management of food resources, or variations in demographic densities of human groups (Eixea, Chacón, et al., 2020; Linscott et al., 2023). Moreover, paleoenvironmental factors and changes in the cycles of human or carnivore presence in terms of protection and accessibility were likely to have had an impact on the modalities of how Neanderthals used different locations (Eixea, Chacón, et al., 2020).

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Declarations

Ethical Approval Not applicable

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