Journal of Paleolithic Archaeology (2024) 7:9
https://doi.org/10.1007/s41982-024-00173-3

RESEARCH

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

Gabriele L.F. Berruti[1,2] · Diego E. Angelucci[3] · Julie Arnaud[1,2] · Claudio Berto[2,4] · Sandro Caracausi[1,2] · Roberto Cavicchi[1] · Sara Daffara[1,2] · Riccardo Galla[1] · Trishia Gayle Palconit[1] · Maurizio Zambaldi[2,3,5] · Marta Arzarello[1,2]

Accepted: 1 March 2024

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 & Kozlowski, 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;

✉ Gabriele L.F. Berruti
brrgrl@unife.it

1 Sezione di Scienze Preistoriche ed Antropologiche, Dipartimento di Studi Umanistici, Università degli Studi di Ferrara, Corso Ercole I d'Este, 32 Ferrara, Italy

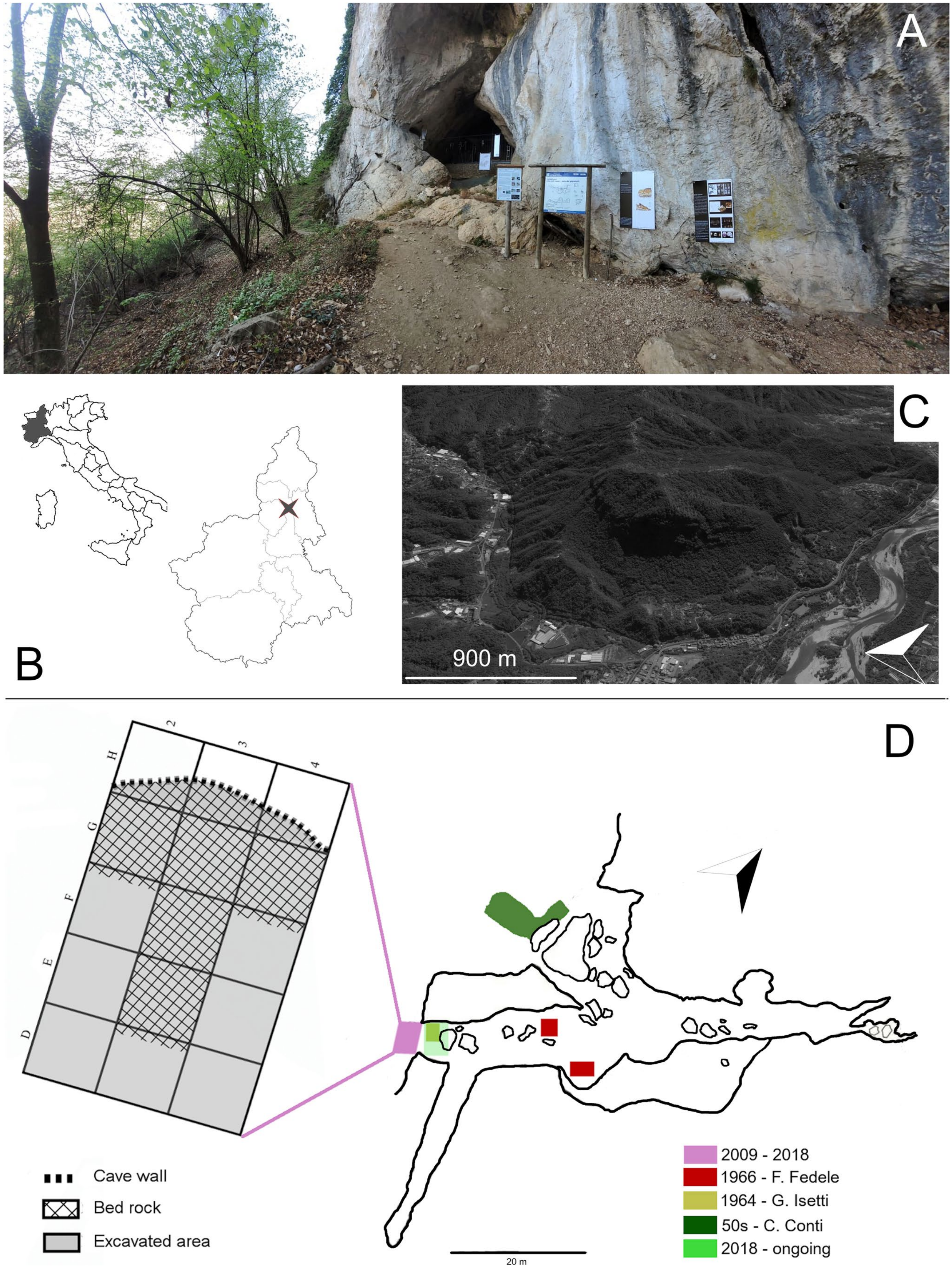
2 Associazione culturale 3P – Progetto Preistoria Piemonte, Via Lunga 38, San Mauro T.se, Italy

3 Dipartimento di Lettere e Filosofia, Università di Trento, Via Tommaso Gar, 14 Trento, Italy

4 Faculty of Archaeology, University of Warsaw, Krakowskie Przedmieście 26, /28 Warsaw, Poland

5 Centro de Arcquelogia da Universidade de Lisboa (UNIARQ)-Faculdade de Letras de Lisboa, Universidade de Lisboa Alameda da Universidade, 1600-214 Lisboa, Portugal

Published online: 06 April 2024


A
B
C
900 m
D
2
3
4
H
G
F
E
D
Cave wall
Bed rock
Excavated area
2009 - 2018
1966 - F. Fedele
1964 - G. Isetti
50s - C. Conti
2018 - ongoing
20 m

◂**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; Tarriño 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; Pedergnana & 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; Xhauflair 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; Pedergnana, 2019; Pedergnana et al., 2020; Pedergnana & 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; Lazuén & 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 & Strickand, 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 Fenera. 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 Fenera 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 course 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

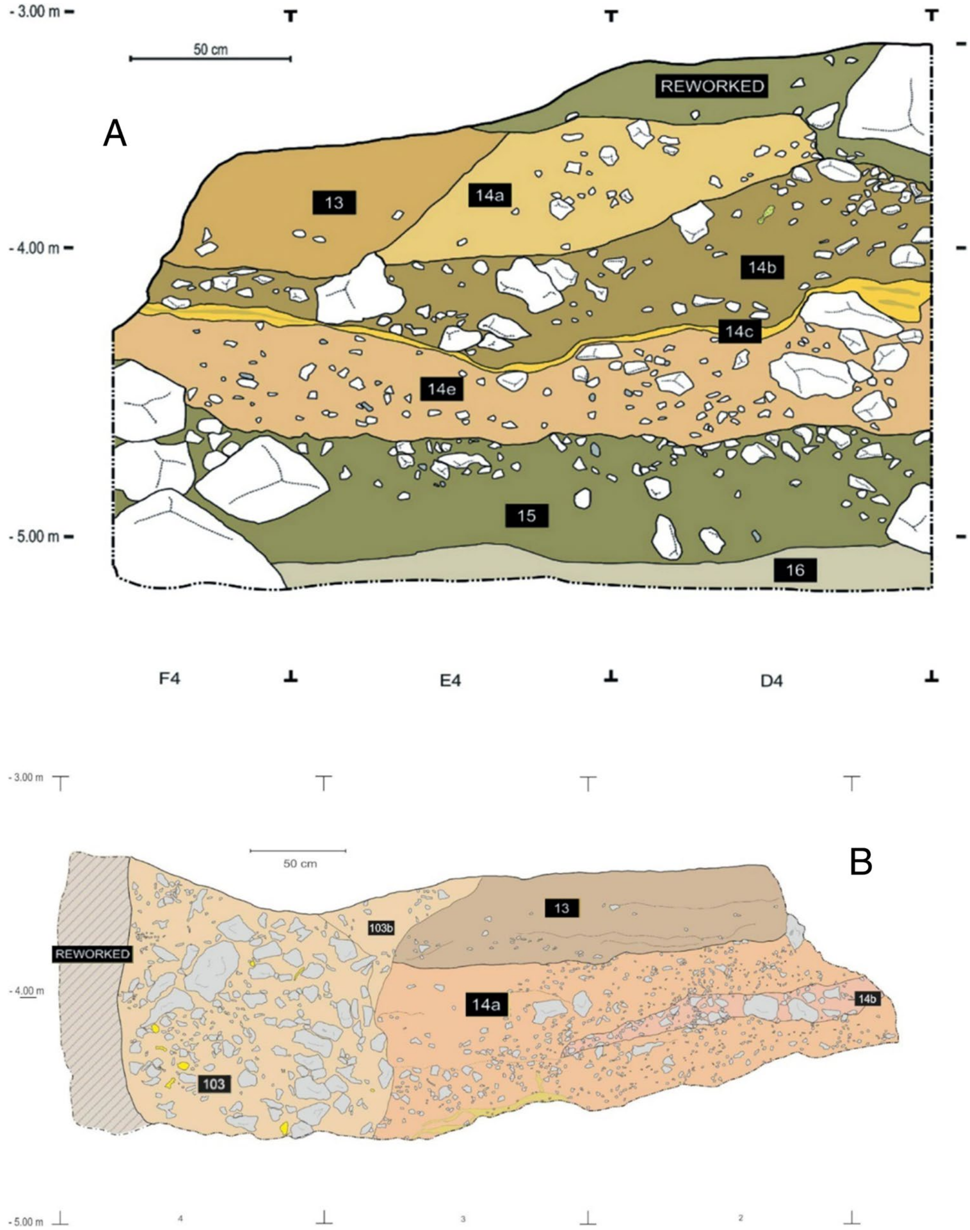


Fig. 2 Stratigraphy of the Ciota Ciara cave, atrial sector. **A** North section (from Angelucci et al., 2019) where SU 16 corresponds to a sterile level lying upon the bed rock. **B** West section (from Zambaldi, 2015)

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

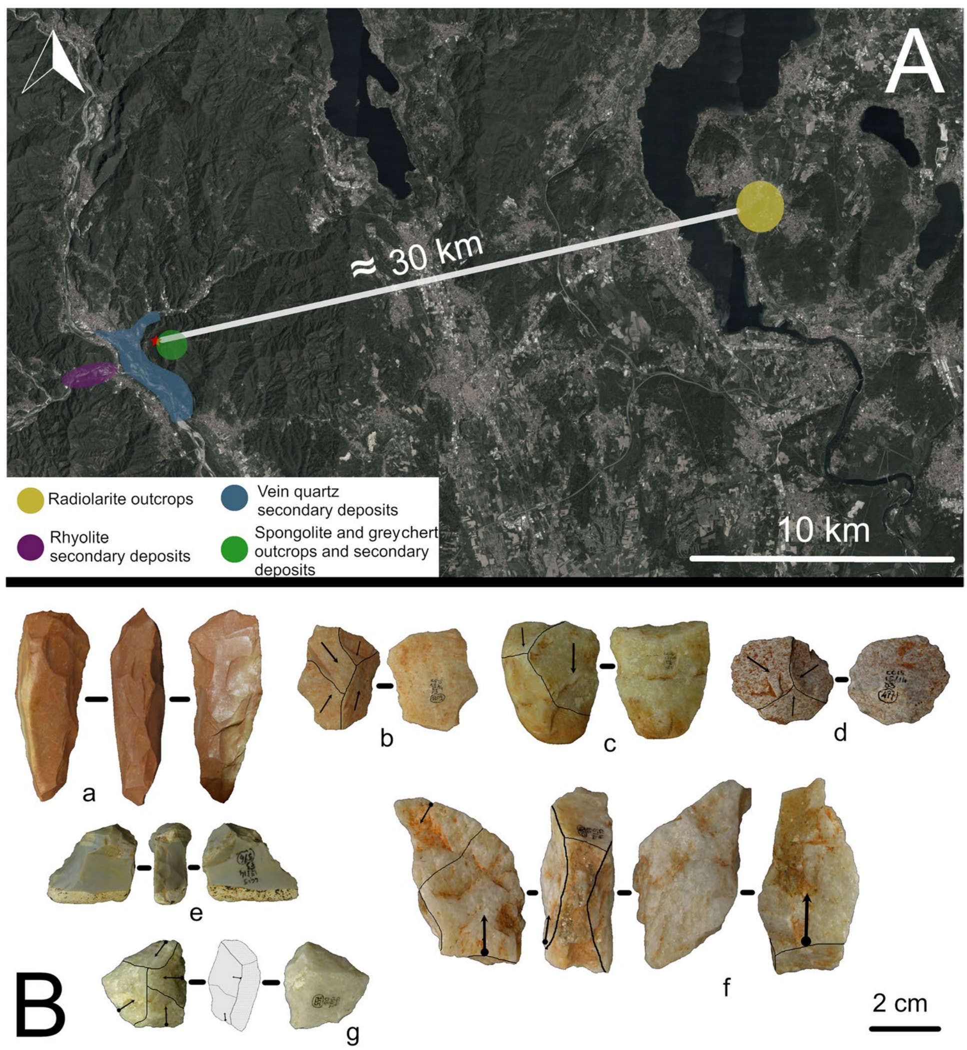


Fig. 3 Ciota Ciara cave. **A** Supply areas of lithic raw materials (Berruti et al., 2023; Daffara et al., 2019). **B** Lithic artefacts from SU 15. (a) Limace on a radiolarite flake. (b) Vein quartz recurrent centripetal Levallois flake. (c) Opportunistic vein quartz flake; (d) Spongolite recurrent 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)

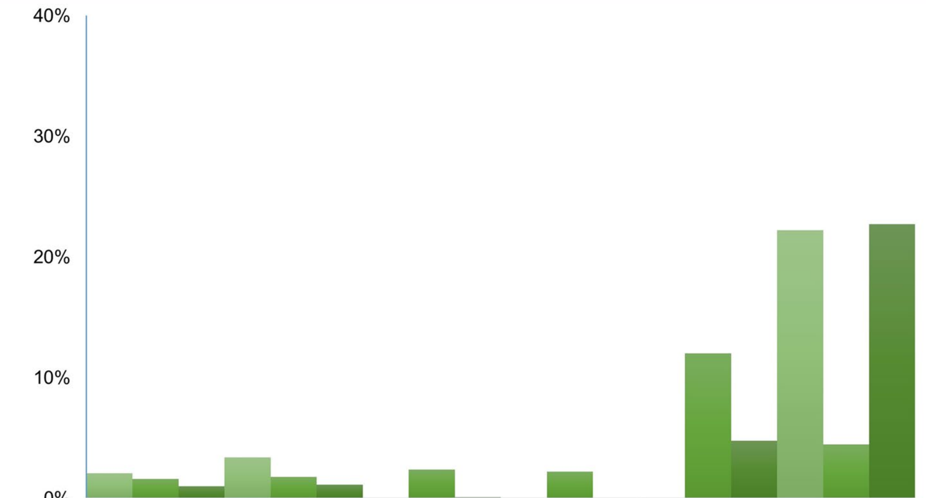
Raw material		SU 103	SU 13	SU 14	SU 15	Total
Quartz	Cores	7 – 1.6%	31 – 3.5%	111 – 2.8%	20 – 1.1%	169 – 2.4%
	Flakes	136 – 31.8%	444 – 49.8%	2150 – 53.8%	611 – 34.2%	3341 – 47%
	Retouched tools	5 – 1.2%	16 – 1.8%	50 – 1.3%	9 – 0.5%	80 – 1.1%
	Debris	78 – 18.2%	276 – 31.0%	807 – 20.2%	265 – 14.8%	1426 – 20.1%
	Unworked blanks	1 – 0.2%	1 – 0.1%	1 – 0.03%	-	3 – 0.04%
Spongolite	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%
Grey chert	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%
Others	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%
Rhyolite	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	-	-	-	-	
Radiolarite	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	-	-	-	-	-
Total		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. Multidirectional 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; Peresani, 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



	Quartz	Spongolite	Grey flint	Others	Rhyolite	Radiolarite
SU 13	2.1%	3.4%	0.0%	0.0%	0.0%	22.2%
SU 14	1.6%	1.8%	2.4%	2.2%	12.0%	4.5%
SU 15	1.0%	1.1%	0.1%	0.0%	4.8%	22.7%

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*, *Stephanorinus* 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*, *Allocricetus 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 SU15 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; Ziggiotti, 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; Ziggiotti, 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.

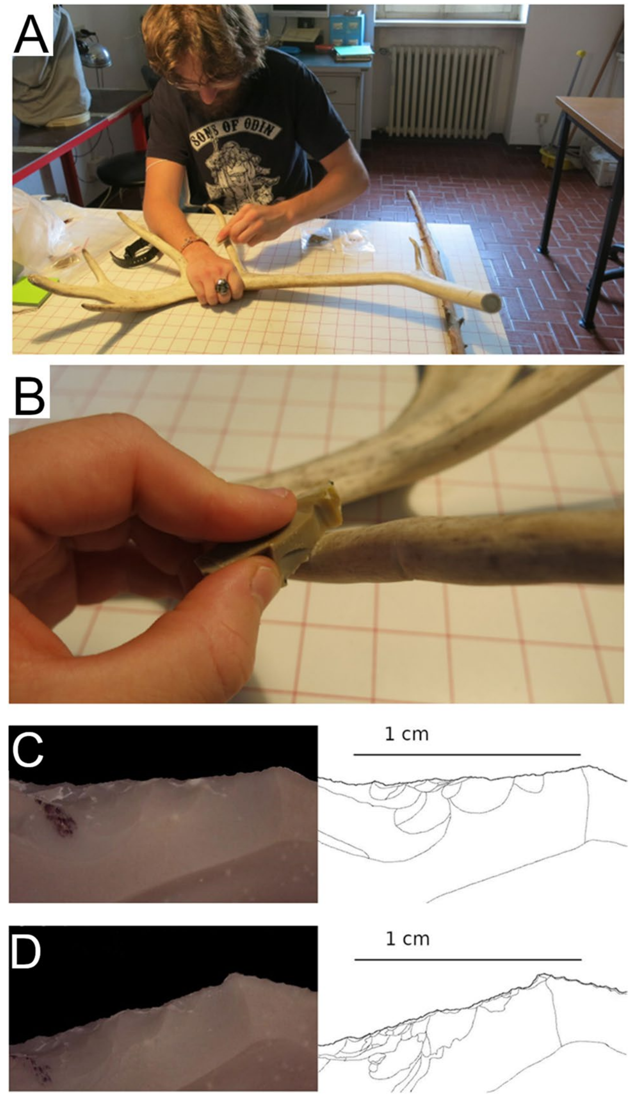


Fig. 5 Experiments. **A** S08 use on deer antler. **B** S08 on deer antler, detail; S05 flakes. stereo-microscope photos and related drawings, before (**C**) and after (**D**) cross-sectional use on deer antler (8×)

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 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 rought apparence	▮					▮	▮▮▮	▮
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		▮	▮▮	▮▮▮▮	▮▮▮▮		▮	▮
Craks		▮	▮▮▮			▮	▮▮	▮
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						1			1			3	13%
Soft animal tissue			1		1			1						2			2		7	29%
Bone													1			2	1		4	17%
Wood																			0	-
Non-woody plant																			0	-
Dry skin																			0	-
Soft		1																	1	4%
Medium soft					1														1	4%
Medium hard																1	1		2	8%
Hard																1			1	4%
Total	0	1	1	0	2	0	1	1	1	0	0	0	2	3	1	6	4	1	24	100%
Total per raw material	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).

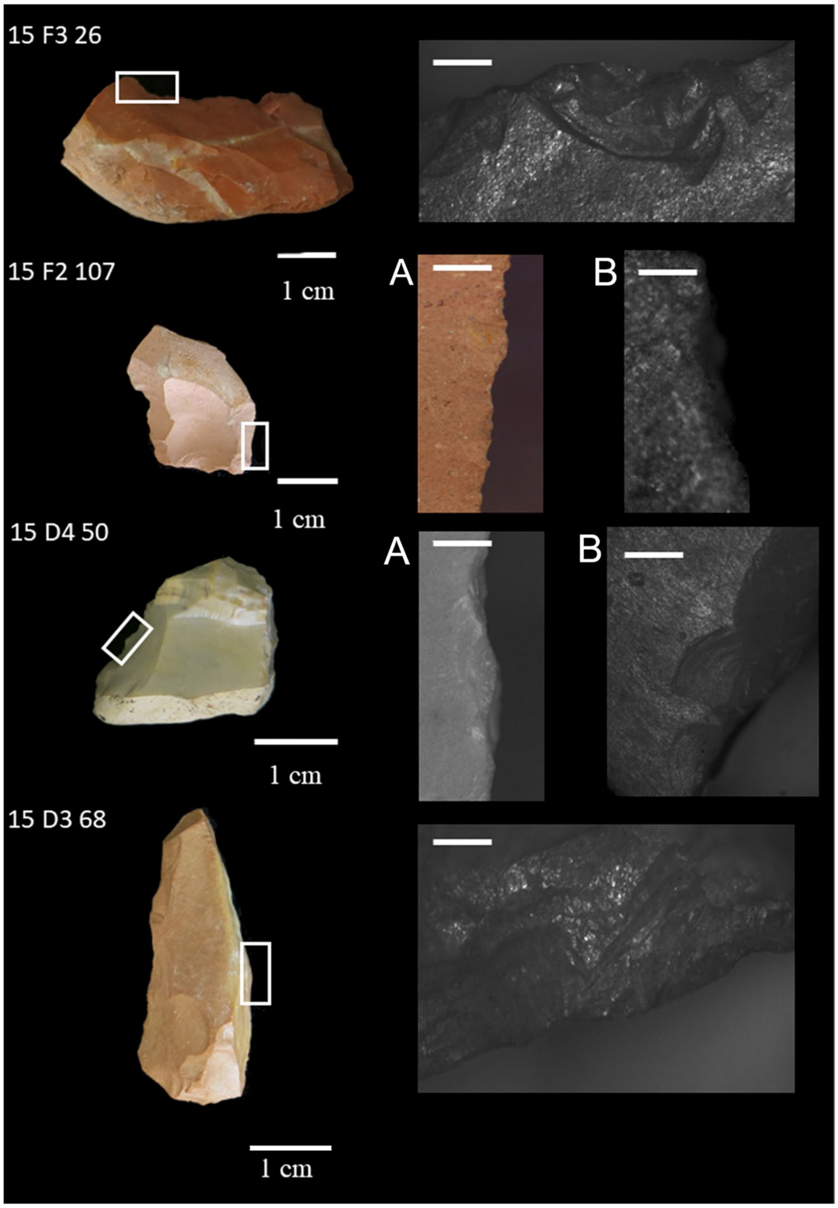


Fig. 6 Use wear traces on chert artefacts. Artefact 15 F3 26 (sidescraper). The traces are located on the active edge of the tool. On the right (scale bar 0.5 µm), two lines of rough polish can be seen in association with two edge removals. The traces identified are very similar to those obtained in 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 0.5µm), 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

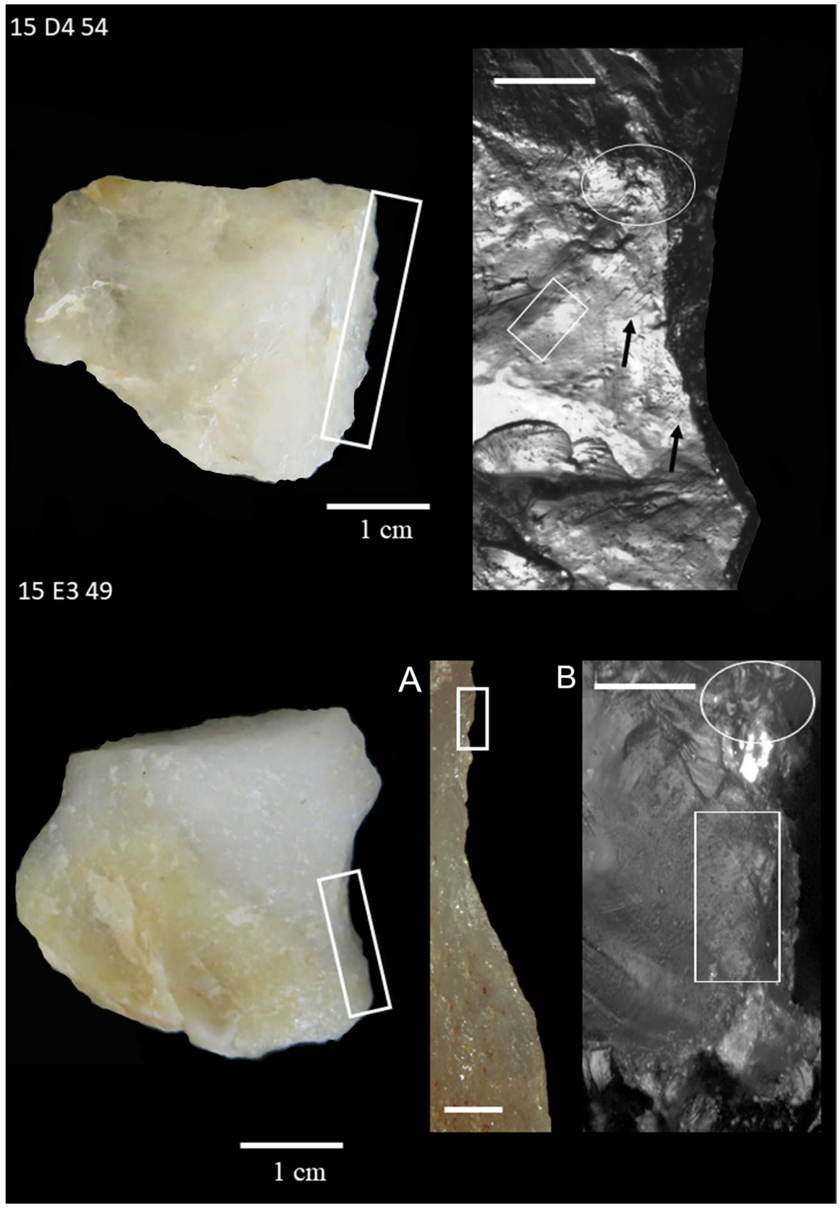


Fig. 7 Use wear traces on quartz artefacts. Artefact 15 D4 54 (unretouched flake): polish with dommed topography (in the rectangle on the right), edge rim worn down (in the ellipse on the right) and two sets of striae indicated by the arrows; in addition, micro holes and widespread rounding can be observed 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; Burroni 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

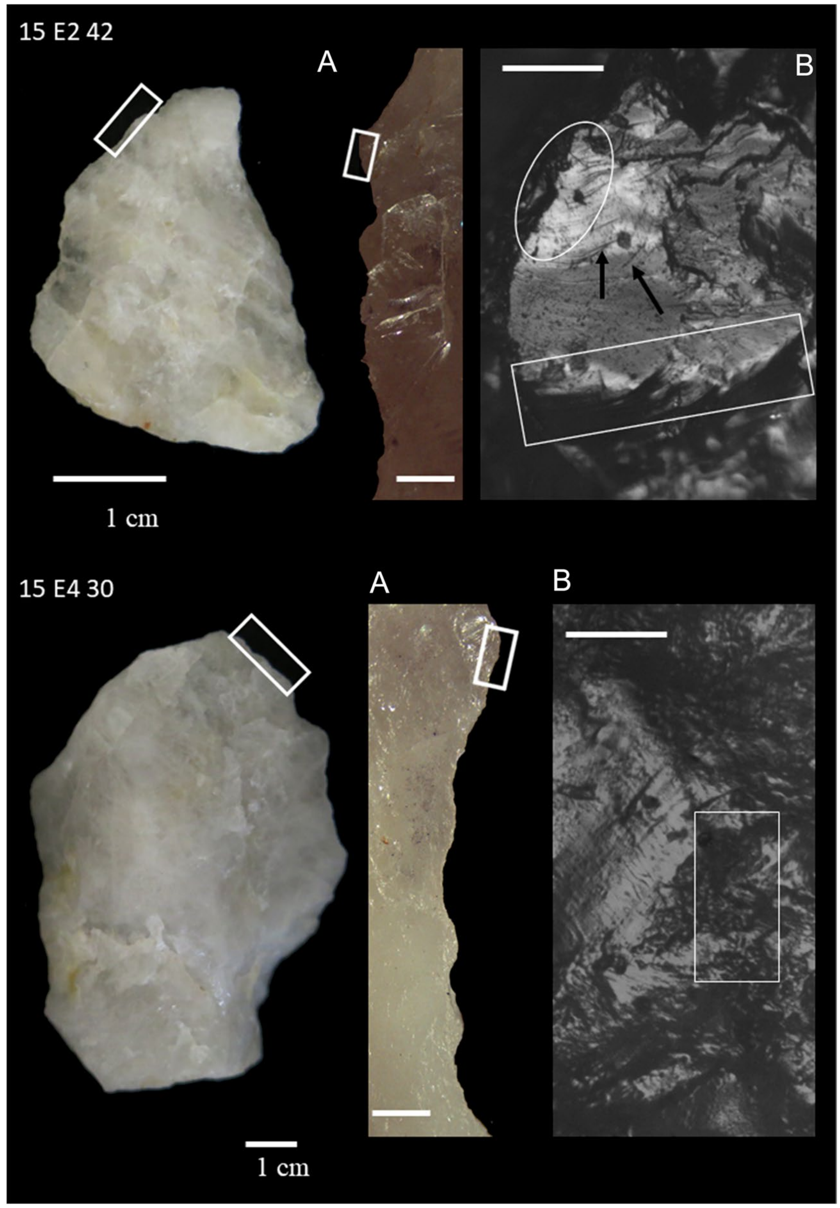


Fig. 8 Use wear traces on quartz artefacts. Artefact 15 E2 42 (unretouched flakes). A Series of crescent-shaped edge removals (scale bar 1 mm). B Polish with dommed topography and edge rounding (in the rectangle), two edge fractures in the ellipse and micro holes on the surface of the artefact (scale 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

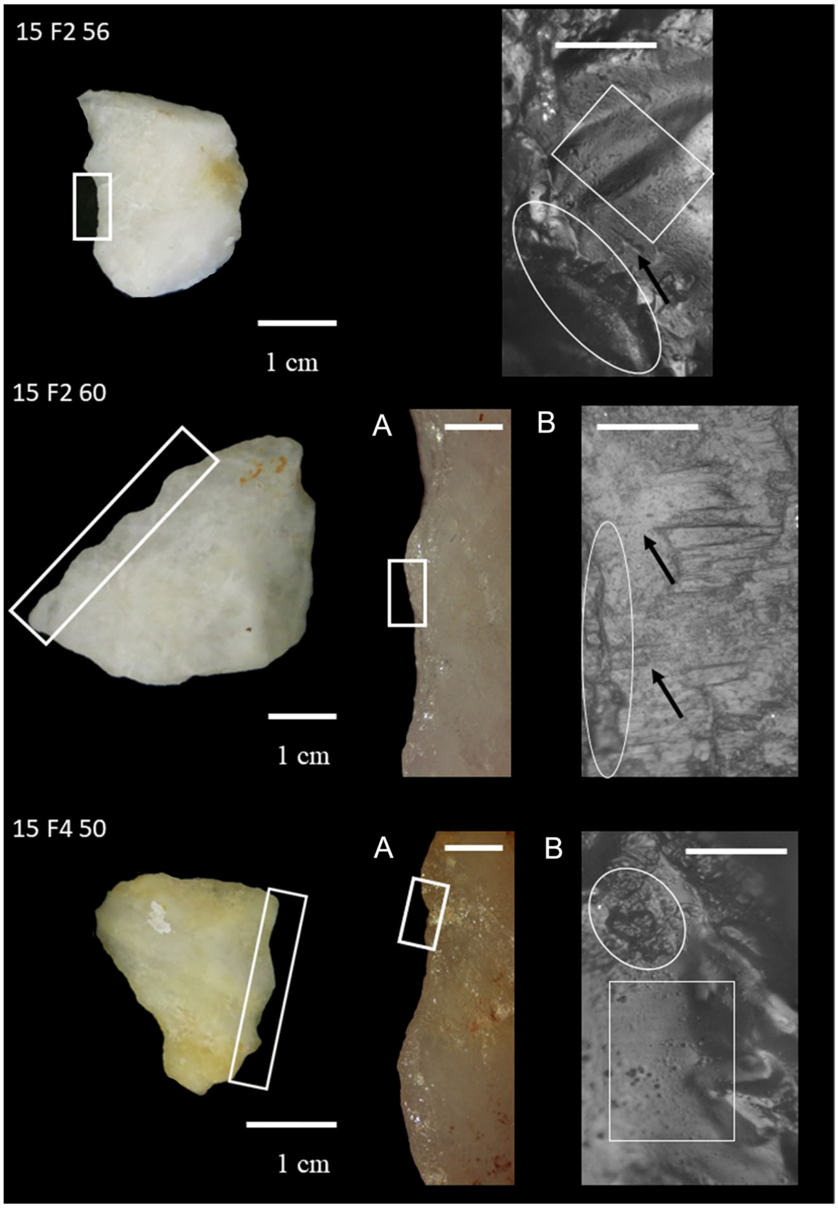


Fig. 9 Use wear traces on quartz artefacts. Artefact 15 F2 56 (unretouched flake): polish with dommed topography, edge rounding and edge fracture (in the ellipse), a widespread rounding in the area delimitated by the rectangle (scale bar 0.5 µm). In agreement with both our experimentation and the existing 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

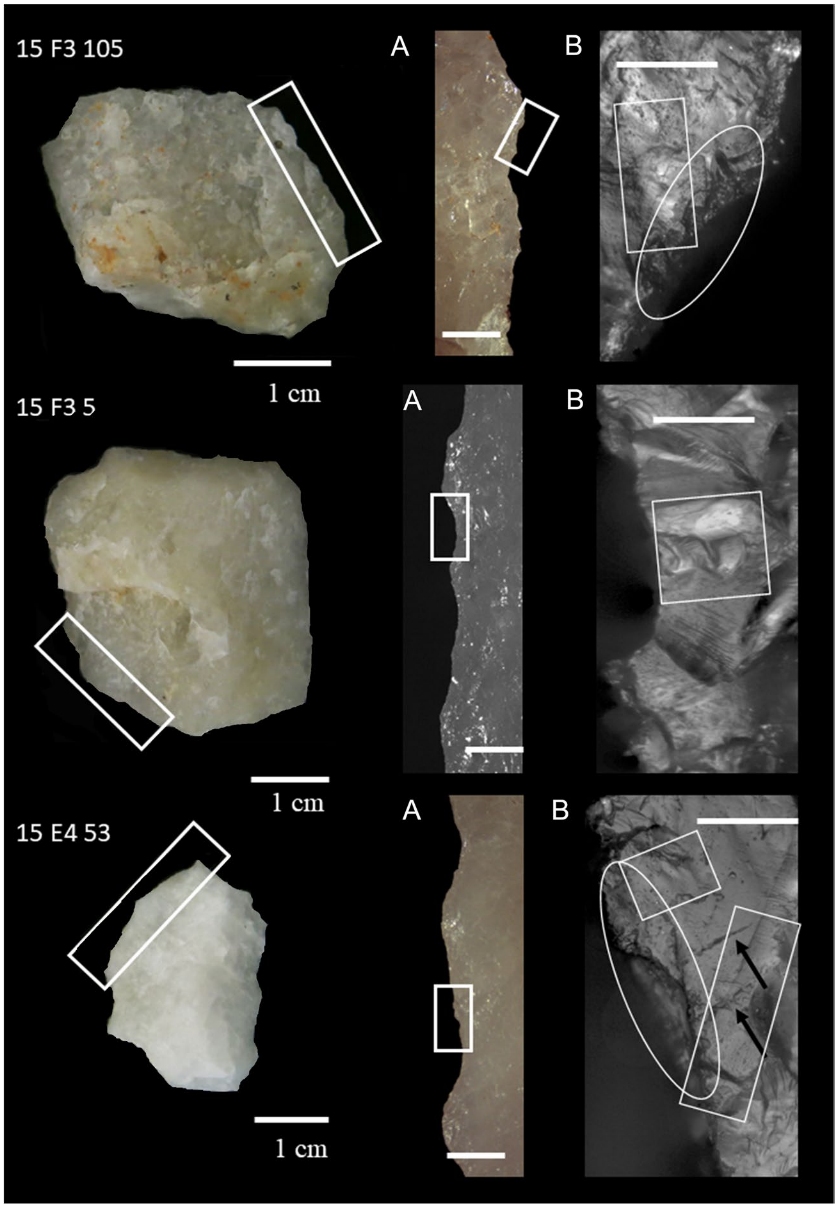


Fig. 10 Use wear traces on quartz artefacts. Artefact 15 F3 105 (unretouched flake). A Series of crescent-shaped edge removals (scale bar 0.5 mm). B Edge rounding and edge fracture (in the ellipse) and a polish with dommed topography in the area delimitated by the rectangle; holes and widespread rounding can be observed on the surface of the artefact (scale bar 0.5 µm). 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 delimitated by the rectangle in association with an edge removal; widespread rounding can be observed on the surface of the artefact (scale bar 0.5 µm). 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 µm). 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

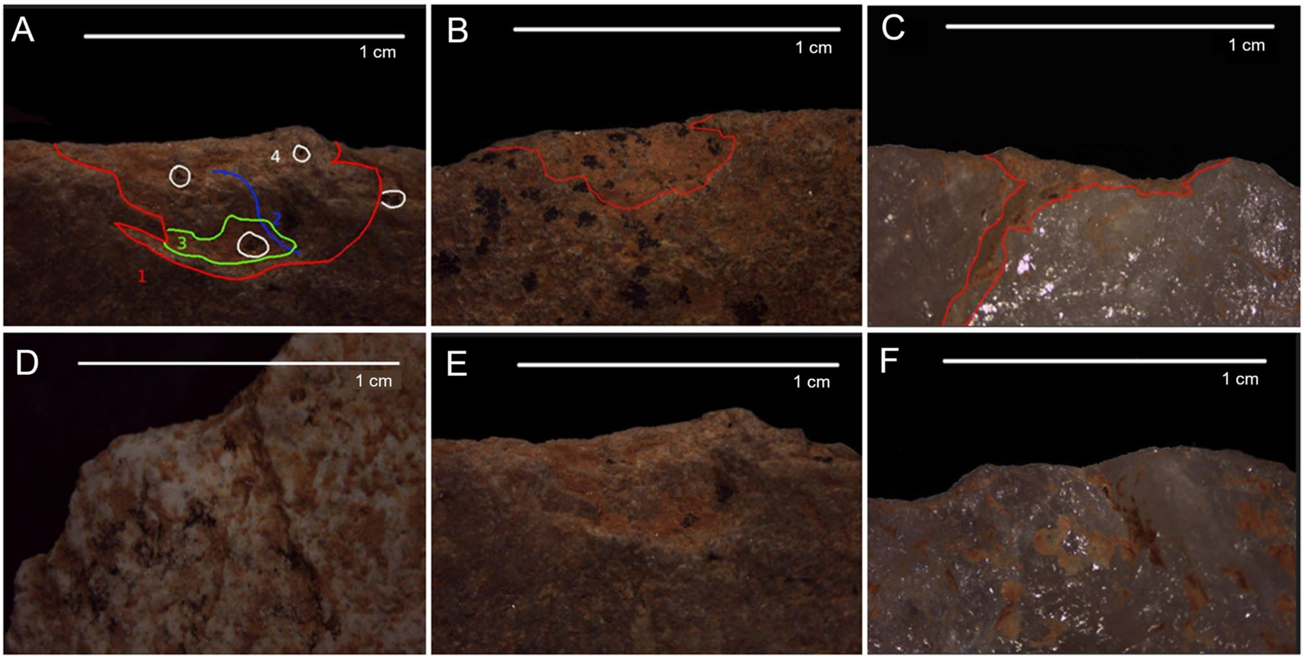


Fig. 11 Edges of chert and quartz flakes with post-depositional traces at 8× magnification. **A** Edge with a sequence of post depositional alterations: detachment of part of the surface (1), followed by rounding (2), deposition of a concretion (3) and deposition of spots of iron-manganese (4). **B** 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

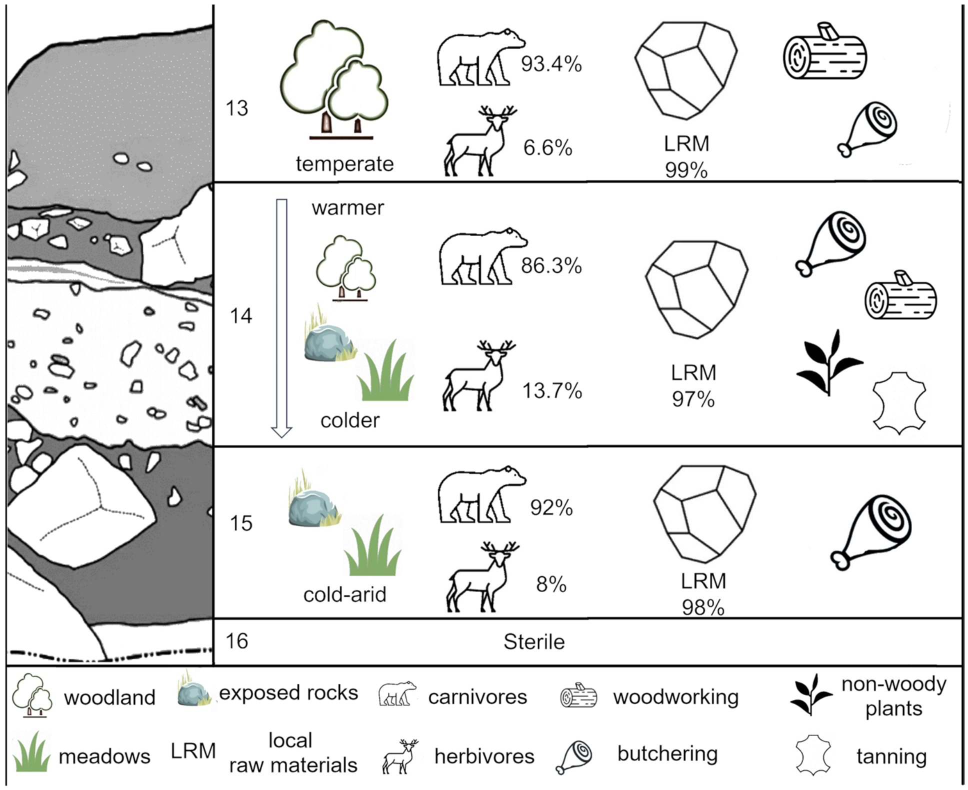


Fig. 12 Schematic representation of the archaeological levels of Ciota Ciara atrial sector indicating aspects of the palaeoenvironment, fauna, lithic raw materials, and main activities carried out at the site as identified by the use-wear analysis

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 Romanì (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), Sasselfelsgrotte (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 northwestern 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).

Acknowledgements The authors would like to dedicate the present work to the loving memory of Teresio Baroli and Franco Gaudio. The research work at the Ciota Ciara cave is possible, thanks to the Borgosesia municipality, the members of the former G.A.S.B. (Gruppo

Archeologico Speleologico di Borgosesia) and all the students and researchers that participate in the archaeological investigations. We would also like to thank the two reviewers for their constructive comments and suggestions, thanks to which the work has been improved.

Author Contribution G.L.F. B., S.D., T.G.P. and R.G. wrote the main manuscript text, original draft; G.L.F. B., S.D., T.G.P. and R.G. prepared Figures 1, 3, 4, 5, 6, 7, 8, 9 and 10; D.A. and M.Z prepared figures 2 and reviewed the geoarchaeological data; C.B. and R.C. reviewed the palaeontological data; G.L.F. B. and S.D. conceptualization of the paper; G.L.F.B and R.G. methodology and formal analysis; G.L.F. B., S.D., T.G.P., M.Z., S.C., J.A. and R.G. data collections; M.A. supervised the work, All authors reviewed the manuscript.

Funding Open access funding provided by Università degli Studi di Ferrara within the CRUI-CARE Agreement.

Data Availability The author confirms that all data generated or analysed during this study are included in this published article.

Declarations

Ethical Approval Not applicable

Conflict of Interest The authors declare no competing interests.

References

Ambrose, S. H. (2001). Paleolithic technology and human evolution. *Science, 291*(5509), 1748–1753. https://doi.org/10.1126/science.1059487

Anderson-Gerfaud, P. (1990). Aspects of behavior in the Middle Paleolithic: Functional analysis of stone tools from Southwest France. In P. Mellars (Ed.), *The Emergence of Modern Humans: An Archaeological Perspective* (pp. 389–418). Edinburgh University Press.

Andrefsky, W., Jr. (1994). Raw-material availability and the organization of technology. *American Antiquity, 59*(1), 21–34.

Angelucci, D. E., Arnaud, J., Arzarello, M., Berruti, G. L. F., Berté, D., Berto, C., Calandra, R., Caracausi, S., Boggio, C., Daffara, S., Luzi, E., Montanari-Canini, G., & Zambaldi, M. (2016). Borgosesia, Monte Fenera. Nuovi dati sull'occupazione della Ciota Ciara. *Quaderni Della Soprintendenza Archeologica Del Piemonte, 31*, 323–326.

Angelucci, D. E., Zambaldi, M., Tessari, U., Vaccaro, C., Arnaud, J., Berruti, G. L. F., Daffara, S., & Arzarello, M. (2019). New insights on the Monte Fenera Palaeolithic, Italy: Geoarchaeology of the Ciota Ciara cave. *Geoarchaeology, 34*(4), 413–429. https://doi.org/10.1002/gea.21708

Aranguren, B., Revedin, A., Amico, N., Cavulli, F., Giachi, G., Grimaldi, S., Macchioni, N., & Santaniello, F. (2018). Wooden tools and fire technology in the early Neanderthal site of Poggetti Vecchi (Italy). *PNAS, 115*(*9*), 2054–2059. https://doi.org/10.1073/pnas.1716068115

Arnaud, J., Arzarello, M., Berruti, G. L. F., Berruto, G., Berté, D., Berto, C., Buccheri, F., Iliana, A., Daffara, S., Luzi, E., Garcia, L., Manuel, J., Peretto, C., Bertè, D., Berto, C., Buccheri, F., Casini, A. I., Daffara, S., Luzi, E., et al. (2014). Borgosesia, Monte Fenera. Grotta della Ciota Ciara. Nuovi dati sull'occupazione musteriana. *Quaderni Della Soprintendenza Archeologica Del Piemonte, 29*, 204–206.

Arrighi, S., Freguglia, M., Ranaldo, F., & Ronchitelli, A. (2009). Production and use in the lithic industry of the Mousterian in Santa Croce (Bisceglie, Italy). *Human Evolution, 24*(2), 91–106.

Arzarello, M., Daffara, S., Berruti, G. L. F., Berruto, G., Bertè, D., Berto, C., Gambari, F. M., & Peretto, C. (2012). The Mousterian settlement in the Ciota Ciara cave: The oldest evidence of *Homo neanderthalensis* in Piedmont (Northern Italy). *Journal of Biological Research, LXXXV*(1), 71–75. https://doi.org/10.4081/jbr.2012.4068

Asryan, L., Ollé, A., & Moloney, N. (2014). Reality and confusion in the recognition of post-depositional alterations and use-wear: An experimental approach on basalt tools. *Journal of Lithic Studies, 1*(1), 9–32. https://doi.org/10.2218/jls.v1i1.815

Aubry, T., Luís, L., Mangado Llach, J., & Matias, H. (2012). We will be known by the tracks we leave behind: Exotic lithic raw materials, mobility and social networking among the Côa Valley foragers (Portugal). *Journal of Anthropological Archaeology, 31*(4), 528–550. https://doi.org/10.1016/j.jaa.2012.05.003

Bailey, G. N., Reynolds, S. C., & King, G. C. P. (2011). Landscapes of human evolution: Models and methods of tectonic geomorphology and the reconstruction of hominin landscapes. *Journal of Human Evolution, 60*, 257–280.

Bargalló, A., Gabucio, M. J., de Soler, B. G., Chacón, M. G., & Vaquero, M. (2020). Rebuilding the daily scenario of Neanderthal settlement. *Journal of Archaeological Science: Reports, 29*, 102139. https://doi.org/10.1016/j.jasrep.2019.102139

Battaglia, R. (1953). Le ossa lavorate della caverna Pocala nella Venezia Giulia e il problema del "Musteriano alpino". *Bullettino Di Paletnologia Italiana, 63*(VI), 5–15.

Beller, J. A. (2023). Raw material characterization and lithic provenance from Shishan Marsh 1, a Middle Pleistocene site in the central Azraq Basin, Jordan. *Journal of Archaeological Science: Reports, 47*(January), 103800. https://doi.org/10.1016/j.jasrep.2022.103800

Berruti, G. L. F. (2017). *Use-wear analysis of discoid-conception lithic industries*. Universidade de Trás-os-Montes e Alto Douro.

Berruti, G. L. F., Arnaud, J., Arzarello, M., Belo, J., Berruto, G., Caracausi, S., Daffara, S., Ferreira, C., Reis, C. H., Rosina, P., & Rubat Borel, F. (2016). Geo-archaeological survey in the Baragge Biellesi area. New data on the Middle Paaleolithic in Piedmont. In F. Negrino, F. Fontana, A. Moroni, & J. R. Salvatore (Eds.), *Il Paleolitico e il Mesolitico in Italia: Nuove ricerche e prospettive di studio The Palaeolithic and Mesolithic in Italy: new research and perspectives* (pp. 93–94). Istituto Italiano di Preistoria e Protostoria (IIPP).

Berruti, G. L. F., & Arzarello, M. (2012). L'analisi tracceologica per la ricostuzione delle attività nella preistoria: l'esempio della Grotta della Ciota Ciara (Borgosesia, VC). In M. Balzani (Eds.), *TEKNEHUB PER I BENI CULTURALI Un laboratorio della rete alta tecnologia Emilia Romagna a servizio delle Imprese Annali Dell'Università Di Ferrara, Mus.Sci. Nat.*, *8(1)*, 117–124.

Berruti, G. L. F., & Arzarello, M. (2020). Talking stones: Taphonomy of the lithic assemblage of Pirro Nord 13 (Apricena, FG, Italy). A new approach to the study of the post depositional alterations on lithics tools. *Journal of Archaeological Science: Reports*, *31*, 102282. https://doi.org/10.1016/j.jasrep.2020.102282

Berruti, G. L. F., Bianchi, E., Daffara, S., Gomes, M., Ceresa Genet, A. J., Fontana, F., Arzarello, M., & Peretto, C. (2020). The use of blades and pointed tools during Middle Palaeolithic, the example of Riparo Tagliente (VR). *Quaternary International, 554*(July), 45–59. https://doi.org/10.1016/j.quaint.2020.07.016

Berruti, G. L. F., & Cura, S. (2016). Use wear analysis of quartzite lithic implements from the Middle Palaeolithic site of Lagoa do Bando (Central Portugal). *Journal of Lithic Studies, 3*(2), 1–24. https://doi.org/10.2218/jls.v3i2.1400

Berruti, G. L. F., Daffara, S., Fuselli, P., & Arzarello, M. (2023). Planning a trip during Middle Palaeolithic. The mobile toolkit debate and some considerations about expedient vs curated technologies in the light of new data from the Ciota Ciara cave (NW Italy). *Journal of Archaeological Science: Reports, 49*, 103939. https://doi.org/10.1016/j.jasrep.2023.103939

Berruti, G. L. F., Rosina, P., & Raposo, L. (2016). The use-wear analysis of the quartzite lithic assemblage from the middle paleolithic site of Fox do Enxarrique (Rodao, Portugal). *Mediterranean Archaeology and Archaeometry, 16*(3), 107–126. https://doi.org/10.5281/zenodo.160961

Berruto, G. (2011). *Comportamento economico dei neandertaliani della grotta della Ciota Ciara (Borgosesia, VC): Analisi della provenienza delle materie prime*. Università degli Studi di Ferrara.

Berruto, G. (2016). *Approvvigionamento in materie prime litiche e paleo- ambiente: Comportamento economico dei neandertaliani della grotta della Ciota Ciara*. Università degli studi di Genova. Scuola di specializzazione in Beni Archeologici..

Berto, C., Bertè, D., Luzi, E., Lopez Garcia, J. M., Pereswiet-Soltan, A., & Arzarello, M. (2016). Small and large mammals from Ciota Ciara cave (Borgosesia, Vercelli, Italy): An Isotope stage 5 assemblage. *Comptes Rendus - Palevol, 15*(6), 669–680. https://doi.org/10.1016/j.crpv.2015.05.014

Beyries, S. (1993). Analyse fonctionnelle de l'industrie lithique du niveau CA: Rapport préliminaire et directions de recherche. In *Riencourt-les-Bapaume, Pas-de-Calais: un gisement du Paléolithique moyen, Editions de la MSH (DAF 37)* (pp. 53–61).

Beyries, S., Delamare, F., & Quantin, J.-C. (1988). Tracéologie et rugosimétrie tridimensionnelle. In S. Beyries (Ed.), *Industries Lithiques : Tracéologie et Technologie* (pp. 115–132).

Beyries, S. (1987). *Variabilité de l'industrie lithique au Moustérien: approche fonctionnelle sur quelques gisements français.* BAR International Series, 328. Archaeopress.

Binford, L. R. (1978). Dimensional analysis of behavior and site structure: Learning from an Eskimo hunting stand. *American Antiquity, 43*(3), 330–361. https://doi.org/10.2307/279390

Binford, L. R. (1980). Willow smoke and dog's tails: Hunter-gatherers settlement systems and archaeological site formation. *American Antiquity, 1*, 4–20. https://doi.org/10.2307/279653

Boëda, E. (1993). Le débitage discoïde et le débitage Levallois récurrent centripète. *Bulletin de La Société Préhistorique Française, 90*(6), 392–404. https://doi.org/10.3406/bspf.1993.9669

Boëda, E. (1994). *Le concept Levallois: Variabilité des méthodes*. Archéo éditions.

Boëda, E. (1995). Levallois: A volumetric construction, methods, a technique. In H. L. Dibble & O. Bar-Yosef (Eds.), *The definition and interpretation of Levallois technology* (pp. 41–68). Prehistory Press.

Boëda, E., Geneste, J.-M., & Meignen, L. (1990). Identification de chaînes opératoires lithiques du Paléolithique ancien et moyen. *Paléo, 2*, 43–80. https://doi.org/10.3406/pal.1990.988

Boëda, E., & Pelegrin, J. (1980). Approche technologique du nucleus levallois a éclat. *Etudes Préhistoriques, 15*, 41–48.

Bordes, F. (1961). *Typologie du Paléololithique ancien et moyen* (Vol. 1). Mémoires de l'institut Préhisorique de l'Université de Boreaux.

Borel, A., Ollé, A., Vergès, J. M., & Sala, R. (2014). Scanning electron and optical light microscopy: Two complementary approaches for the understanding and interpretation of usewear and residues on stone tools. *Journal of Archaeological Science, 48*, 46–59. https://doi.org/10.1016/J.JAS.2013.06.031

Borrazzo, K., & Etchichury, M. C. (2010). Distribución espacial y uso prehistórico de las materias primas líticas del Chorrillo Miraflores en el norte de la Isla Grande de Tierra del Fuego (Argentina). *Revista Chilena de Antropología, 22*, 77–97.

Boschian, G., & Saccà, D. (2015). In the elephant, everything is good: Carcass use and re-use at Castel di Guido (Italy). *Quaternary International, 361*, 288–296. https://doi.org/10.1016/j.quaint.2014.04.030

Brecciaroli Taborelli, L. (1994). Borgosesia. Monte Fenera. Insediamento temporaneo della tarda antichità nella grotta Ciota Ciara. *Notiziario Quaderni Della Soprintendenza Archeologica Del Piemonte, 12*, 356–357.

Broglio, A., & Kozlowski, S. K. (1984). Tipologia ed evoluzione delle industrie mesolitiche di Romagnano lll. *Preistoria Alpina, 19*, 93–148.

Buccheri, F., Bertè, D. F., Berruti, G. L. F., Cáceres, I., Volpe, L., & Arzarello, M. (2016). Taphonomic analysis on fossil remains from the Ciota Ciara Cave (Piedmont, Italy) and new evidence of cave bear and wolf exploitation with simple quartz flakes by Neanderthal. *Rivista Italiana Di Paleontologia e Stratigrafia, 122*(1223), 41–54. https://doi.org/10.13130/2039-4942/7674

Burroni, D., Donahue, R. E., Pollard, A. M., & Mussi, M. (2002). The surface alteration features of flint artefacts as a record of environmental processes. *Journal of Archaeological Science, 29*(11), 1277–1287. https://doi.org/10.1006/jasc.2001.0771

Busa, F., Gallo, L. M., & Dellarole, E. (2005). L'attività di ricerca nelle grotte del Monte Fenera. In R. Fantoni, R. Cerri, & E. Dellarole (Eds.), *D'acqua e di pietra. Il Monte Fenera e le sue collezioni museali* (pp. 218–223). Associazione culturale ZEISCIU Centro Studi.

Cahen, D., Keeley, L. H., & Van Noten, F. L. (1979). Stone tools, toolkits and human behavior in prehistory. *Current Anthropology, 20*(4), 661–683. https://doi.org/10.1086/202371

Calandra, I., Schunk, L., Rodriguez, A., Gneisinger, W., Pedergnana, A., Paixao, E., Pereira, T., Iovita, R., & Marreiros, J. (2019). Back to the edge: Relative coordinate system for use-wear analysis. *Archaeological and Anthropological Sciences, 11*(11), 5937–5948. https://doi.org/10.1007/s12520-019-00801-y

Campbell, B., & Lack, E. (1985). *A Dictionary of Birds*. T&AD Poyser.

Carbonell, E., García-Antón, M. D., Mallol, C., Mosquera, M., Ollé, A., Rodríguez, X. P., Sahnouni, M., Sala, R., Vergès, J. M. M., Dolores, G.-A., Mallol, C., Mosquera, M., Ollé, A., Rodriguez, X. P., Sahnouni, M., Sala, R., Vergès, J. M., Garcia-Anton, M. D., Mallol, C., et al. (1999). The TD6 level lithic industry from Gran Dolina, Atapuerca (Burgos, Spain): Production and use. *Journal of Human Evolution, 37*(3–4), 653–693. https://doi.org/10.1006/jhev.1999.0336

Carpentieri, M., & Arzarello, M. (2022). For our world without sound. The opportunistic debitage in the Italian context: A methodological evaluation of the lithic assemblages of Pirro Nord, Cà Belvedere di Montepoggiolo, Ciota Ciara cave and Riparo Tagliente. *Journal of Palaeolithic Archaeology, 5*(12). https://doi.org/10.1007/s41982-022-00117-9

Carpentieri, M., Berruti, G.L.F., Titton, S., Arzarello, M., & Peretto, C. (2023). *Brief interviews with hideous stone: A glimpse into the butchery site of Isernia La Pineta—A combined technological and use-wear approach on the lithic tools to evaluate the function of a Lower Palaeolithic context.* Archaeological and

Anthropological Sciences, 15 (93). https://doi.org/10.1007/s12520-023-01791-8
Cavicchi, R. (2018). *Biocronologia, paleoecologia e paleoambiente della grotta Ciota Ciara (Borgosesia, Vercelli, Piemonte): Nuovi dati dalla sequenza a grandi mammiferi*. Master thesis. Università degli studi di Ferrara.
Chacón, M. G., Bargalló, A., Gabucio, M. J., Rivals, F., & Vaquero, M. (2012). Neanderthal behaviors from a spatio-temporal perspective: An interdisciplinary approach to interpret archaeological assemblages. In N. J. Conrad & A. Delagnes (Eds.), *Settlement Dynamics of the Middle Paleolithic and Middle Stone Age* (Vol. 33). Kerns Verlag. https://doi.org/10.1073/pnas.0703993104
Chazan, M. (1997). Redefining Levallois. *Journal of Human Evolution, 33*, 719–735. https://doi.org/10.1006/jhev.1997.0167
Church, F., & Ellis, J. G. (1996). A use-wear analysis of obsidian tools from an Ana Kionga. *Rapa Nui Journal, 10*, 81–88.
Claud, E. (2012). Étude tracéologique de l'outillage moustérien de type Quina du bonebed de Chez-Pinaud à Jonzac (Charente-Maritime). Nouveaux éléments en faveur d'un site de boucherie et de traitement des peaux. *Gallia, 54*(2), 3–32.
Clemente-Conte, I., & Gibaja Bao, J. F. (2009). Formation of use-wear traces in non-flint rocks: The case of quartzite and rhyolite—Differences and similarities. In F. Sternke & L. Eigeland (Eds.), *Non-Flint Raw Material Use in Prehistory Old prejudices and new directions* (pp. 93–98). BAR International Series.
Conard, N. J., Serangeli, J., Bigga, G., & Rots, V. (2020). A 300.000-year-old throwing stick from Schöningen, northern Germany, documents the evolution of human hunting. *Nature Ecology & Evolution, 4*, 690–693. https://doi.org/10.1038/s41559-020-1139-0
Conti, C. (1931). Valsesia Archeologica. Note per una sua storia dalle origini alla caduta dell'Impero Romano. *Bollettino Della Società Storica Sudalpina, 123*, 1–61.
Costamagno, S., Liliane, M., Cédric, B., Bernard, V., & Bruno, M. (2006). Les Pradelles (Marillac-le-Franc, France): A mousterian reindeer hunting camp? *Journal of Anthropological Archaeology, 25*(4), 466–484. https://doi.org/10.1016/j.jaa.2006.03.008
Cruz, A., Berruti, G. L. F., Delfino, D., & Gaspar, F. (2016). The lithic hoard of hypogeum of Colos (Abrantes, middle Tagus valley - portugal): Shadows of rituals. *Mediterranean Archaeology and Archaeometry, 16*(1), 75–85. https://doi.org/10.5281/zenodo.35522
Curwen, C. E. (1930). Neolithic Camps. *Antiquity, 4*(13), 22–54.
d'Errico, F., & Backwell, L. (2009). Assessing the function of early hominin bone tools. *Journal of Archaeological Science, 36*(8), 1764–1773. https://doi.org/10.1016/J.JAS.2009.04.005
Daffara, S. (2018). *Non-flint raw materials in the European Middle Palaeolithic: Variability of Levallois and discoid knapping methods and study of the supply areas*. Universitat Rovira i Virgili.
Daffara, S., Arzarello, M., Berruti, G. L. F., Berruto, G., Bertè, D., Berto, C., & Casini, A. I. (2014). The Mousterian lithic assemblage of the Ciota Ciara cave (Piedmont, Northern Italy): Exploitation and conditioning of raw materials. *Journal of Lithic Studies, 1*(2), 63–78. https://doi.org/10.2218/jls.v1i2.1102
Daffara, S., Berruti, G. L. F., & Arzarello, M. (2021). Expedient behaviour and predetermination at the Ciota Ciara cave (north-western Italy) during Middle Palaeolithic. *Quaternary International, 557*, 71–92. https://doi.org/10.1016/j.quaint.2021.01.001
Daffara, S., Berruti, G. L. F., Berruto, G., Eftekhari, N., Vaccaro, C., & Arzarello, M. (2019). Raw materials procurement strategies at the Ciota Ciara cave: New insight on land mobility in north-western Italy during Middle Palaeolithic. *Journal of Archaeological Science: Reports, 26*. https://doi.org/10.1016/j.jasrep.2019.101882
Daffara, S., García-Rojas, M., Berruti, G. L. F., Caracausi, S., Gianella, M. A., Ferrario, M. M., Vanzi, R., & Mordeglia, L. I. (2022). New evidence about the Palaeolithic peopling of the southern margin of the western Alps. *The Colline novaresi area. Journal of Archaeological Science: Reports, 41*. https://doi.org/10.1016/j.jasrep.2021.103327
Daffara, S., Giraudi, C., Berruti, G. L. F., & Caracausi, S. (2021). Trino. Nuovo studio delle industrie litiche del Rilievo Isolato di Trino. *Quaderni Di Archeologia Del Piemonte, 5*, 353–359.
Dayet, L., Faivre, J., Le Bourdonnec, F., Discamps, E., Royer, A., Claud, E., Lahaye, C., Cantin, N., Tartar, E., Que, A., Gravina, B., & Turq, A. (2019). Manganese and iron oxide use at Combe-Grenal (Dordogne, Franc): A proxy for cultural change in Neanderthal communities. *Journal of Archaeological Science : Reports, 25*, 239–256. https://doi.org/10.1016/j.jasrep.2019.03.027
de la Peña, P., Taipale, N., Wadley, L., & Rots, V. (2018). A techno-functional perspective on quartz micro-notches in Sibudu's Howiesons Poort indicates the use of barbs in hunting technology. *Journal of Archaeological Science, 93*, 166–195. https://doi.org/10.1016/j.jas.2018.03.001
de Lombera-Hermida, A., & Rodríguez-Rellán, C. (2016). Quartzes matter. Understanding the technological and behavioural complexity in quartz lithic assemblages. *Quaternary International, 424*, 2–11. https://doi.org/10.1016/j.quaint.2016.11.039
Delagnes, A., & Rendu, W. (2011). Shifts in Neandertal mobility, technology and subsistence strategies in western France. *Journal of Archaeological Science, 38*(8), 1771–1783. https://doi.org/10.1016/j.jas.2011.04.007
Doronicheva, E. V., Kulkova, M. A., & Shackley, M. S. (2016). Raw material exploitation, transport, and mobility in the Northern Caucasus Eastern Micoquian. *PaleoAnthropology, 1–45*. https://doi.org/10.4207/PA.2016.ART98
Driscoll, K. (2011). Vein quartz in lithic traditions: An analysis based on experimental archaeology. *Journal of Archaeological Science, 38*(3), 734–745. https://doi.org/10.1016/j.jas.2010.10.027
Eixea, A., Chacón, M. G., Bargalló, A., Sanchis, A., Romagnoli, F., Vaquero, M., & Villaverde, V. (2020). Neanderthal spatial patterns and occupation dynamics: A focus on the Central Region in Mediterranean Iberia. *Journal of World Prehistory, 33*, 267–324. https://doi.org/10.1007/s10963-020-09143-3
Eixea, A., Romagnoli, F., Bargalló, A., Gómez de Soler, B., Vaquero, M., & Chacón, M. G. (2020). Micro-lithic production at Abric Romaní levels L and Ob: Exploring economic and evolutionary implications for Neanderthal societies. *Journal of Archaeological Science: Reports, 31*, 102280. https://doi.org/10.1016/j.jasrep.2020.102280
Faulks, N. R., Kimball, L. R., Hidjrati, N., & Coffey, T. S. (2011). Atomic force microscopy of microwear traces on Mousterian tools from Myshtylagty Lagat (Weasel Cave), Russia. *Scanning, 33*(5), 304–315. https://doi.org/10.1002/SCA.20273
Féblot-Augustins, J. (1997). *La circulation des matières premières au Paléolithique. Synthèse des données, perspectives comportementales*. Études et Recherches Archéologiques de l'Université de Liège, *75*, 1–2.
Fedele, F. (1966). La stazione paleolitica del Monfenera in Valsesia. *Rivista Di Studi Liguri, 1,2*(XXXII), 5–105.
Fedele, F. (1985). Il paleolitico in Piemonte le alpi occidentali. *Bollettino Del Gruppo Archeologico "Ad Quintum" Di Collegno (Torino), 7*, 23–44.
Fedele, F. (1988). Paleofaune del Montefenera (Valsesia) e loro correlazioni ecologiche e culturali. *Rivista Piemontese Di Studi Naturali, 9*, 3–42.

Fedele, F., Chiarelli, B., & Masali, M. (1966). Ricerche sui giacimenti quaternari del Monfenera. Nuovo scavo nella grotta "Ciota Ciara". *Rivista Antropologica, 53*, 101–111.

Fernandes, P., Raynal, J. P., & Moncel, M.-H. (2008). Middle Palaeolithic raw material gathering territories and human mobility in the southern Massif Central, France: First results from a petro-archaeological study on flint. *Journal of Archaeological Science, 35*, 2357–2370. https://doi.org/10.1016/j.jas.2008.02.012

Fernández Eraso, J., & García Rojas, M. (2013). Tipología Analítica. In M. G. Díez & L. Z. Peña (Eds.), *Métodos y técnicas de análisis y estudio en arqueología prehistórica: de lo técnico a la reconstrucción de los grupos humanos* (pp. 479–497).

Fisher, J. W., & Strickand, H. C. (1989). Ethnoarchaeology among Efe Pygmies, Zaire: Spatial organization of campsite. *American Journal of Physical Anthropology, 78*, 473–484.

Foley, R., & Gamble, C. (2009). The ecology of social transitions in human evolution. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1533), 3267–3279.

Gaudzinski, S., & Turner, E. (1996). The role of early humans in the accumulation of European Lower and Middle Palaeolithic bone assemblages. *Current Anthropology, 37*(1), 153–156.

Geneste, J. M. (1991). Systèmes techniques de production lithique: Variations techno-économiques dans le processus de réalisation des outillages paléolithiques. *Techniques et Culture, 17*, 1–36. https://doi.org/10.4000/tc.5013

Gómez de Soler, B., Soto, M., Vallverdú, J., Vaquero, M., Bargalló, A., Chacón, M. G., Romagnoli, F., & Carbonell, E. (2020). Neanderthal lithc procurement and mobility patterns through a multi-level study at Abric Romaní site (Capellades, Spain). *Quaternary Science Review, 237*, 106315. https://doi.org/10.1016/j.quascirev.2020.106315

Grace, R., Graham, I. D. G., & Newcomer, M. H. (2010). The quantification of microwear polishes. *World Archaeology, 17*(1), 112–120. https://doi.org/10.1080/00438243.1985.9979954

Grayson, D. K. (1984). *Quantitative Zooarchaeology: Topics in the analysis of archaelogical faunas*. Academic.

Groman-Yaroslavski, I., Prévost, M., & Zaidner, Y. (2022). Tool wielding and activities at the Middle Paleolithic site of Nesher Ramla, Israel: A use-wear analysis of major tool types from unit III. *Quaternary International, 624*, 67–79. https://doi.org/10.1016/j.quaint.2021.03.041

Grove, M. (2009). Hunter–gatherer movement patterns: Causes and constraints. *Juornal of Anthropological Archaeology, 28*, 222–233. https://doi.org/10.1016/j.jaa.2009.01.003

Gurova, M., Andreeva, P., Stefanova, E., Stefanov, Y., Kočić, M., & Borić, D. (2016). Flint raw material transfers in the prehistoric Lower Danube Basin: An integrated analytical approach. *Journal of Archaeological Science: Reports, 5*, 422–441. https://doi.org/10.1016/j.jasrep.2015.12.014

Hall, K. R. L., & Schalle, G. B. (1964). Tool-using behavior of the California sea otter. *Journal of Mammalogy, 45*(2), 287–298.

Hardy, B. L. (2004). Neanderthal behaviour and stone tool function at the Middle Palaeolithic site of La Quina, France. *Antiquity, 78*(301), 547–565. https://doi.org/10.1017/S0003598X00113213

Hardy, K. (2018). Plant use in the Lower and Middle Palaeolithic: Food, medicine, and raw materials. *Quaternary Science Reviews, 191*, 393–405. https://doi.org/10.1016/j.quascirev.2018.04.028

Hayden, B. (1979). *Lithic use-wear analysis*. Accademic Press.

Hernandez, M., Mercier, N., Rigaud, J.-P., Texier, J.-P., & Delpech, F. (2014). A revised cchronology for the Grotte Vaufrey (Dordogne, France) based on TT-OSL dating of sedimentary quartz. *Journal of Human Evolution, 75*, 53–63. https://doi.org/10.1016/j.jhevol.2014.05.010

Ibáñez Estévez, J. J., & González Urquijo, J. E. (1996). *From tool use to site function: Use-wear analysis in some final Upper Palaeolithic sites in the Basque country*. BAR International Series.

Igreja, M. (2009). Use-wear analysis of non-flint stone tools using DIC microscopy and resin casts: A simple and effective technique. In *Recent functional studies on non flint stone tools: Methodological improvements and archaeological inferences (Lisboa 2008). Proceedings of the Workshop*.

Inizan, M., Reduron-Ballinger, M., Roche, H., & Tixier, J. (1995). *Technologie de la pierre taillée*. *CREP.* http://ir.nmu.org.ua/handle/123456789/143443

Iwase, A. (2016). A functional analysis of the LGM microblade assemblage in Hokkaido, northern Japan: A case study of Kashiwadai 1. *Quaternary International, 425*, 140–157. https://doi.org/10.1016/j.quaint.2016.04.008

Jaubert, J., Kervazo, B., Bahain, J.-J., Brugal, J.-P., Chalard, P., Falguères, C., Jarry, M., Jeannet, M., Lemorini, C., Louchart, A., Maksud, F., Martin, H., Mourre, V., Quinif, Y., & Thiébaut, C. (2005). Coudoulous I (Tour-de-Faure, Lot), site du Pléistocène moyen en Quercy: Bilan pluridisciplinaire. *BAR International Series, 1364*, 227–251.

Jones, B. D. (2008). The simple and the complex: Two middle archaic small upland lithic sites in North stonington. Connecticut. In C. B. Rieth (Ed.), *Current Approaches to the Analysis and Interpretation of Small Lithic Sites in the Northeast, 508*, 77–88. NYS State Museum.

Keeley, L. H. (1980). *Experimental determination of stone tools uses*. University of Chicago press.

Keeley, L. H., & Toth, N. (1981). Microwear polishes on early stone tools from Koobi Fora. *Kenya. Nature, 293*(5832), 464–465. https://doi.org/10.1038/293464a0

Kimball, L. R., Kimball, J. F., & Allen, P. E. (1995). Microwear polishes as viewed through the atomic force microscope. *Lithic Technology, 20*(1), 6–28.

Knutsson, H., Knutsson, K., Taipale, N., Tallavaara, M., & Darmark, K. (2015). How shattered flakes were used: Micro-wear analysis of quartz flake fragments. *Journal of Archaeological Science: Reports, 2*, 517–531. https://doi.org/10.1016/j.jasrep.2015.04.008

Knutsson, K., & Lindé, K. (1990). No post-depositional alterations or wear marks on quartz tools, preliminary observations on an experiment with aeolian abrasion. In M. R. Séronie-Vivien & M. Lenoir (Eds.), *Cahiers du Quaternaire, Volume 17. Le Silex de sa Genèse à l'outil* (pp. 607–618). Éditions du C.N.R.S.

Kohler, T. A., & Parker, S. C. (1986). Predictive models for archaeological resource location. In M. B. Schiffer (Ed.), *Advances in Archaeological Method and Theory* (pp. 397–452). Academic Press.

Kotsakis, T., Abbazzi, L., Angelone, C., Argenti, P., Barisone, G., Fanfani, F., Marcolini, F., & Masini, F. (2003). Plio-Pleistocene biogeography of Italian mainland micromammals. *Deinsea, 10*, 313–342.

Kuhn, S. L. (1992). On planning and curated technologies in the Middle Paleolithic. *Journal of Anthropological Research, 48*(3), 185–214.

Laplace, G. (1964). Essai de typologie systematique. *Annali Dell'Università Di Ferrara, I*(2), 1–85.

Lazuén, T., & Delagnes, A. (2014). Lithic tool management in the early Middle Paleolithic: An integrated techno-functional approach applied to Le Pucheuil-type production (Le Pucheuil, northwestern France). *Journal of Archaeological Science, 52*, 337–353. https://doi.org/10.1016/j.jas.2014.08.029

Lazuén, T., & González-Urquijo, J. (2015). Recycling in the Early Middle Paleolithic : The role of resharpening flakes assessed through techno-functional analysis. *Quaternary International, 361*, 229–237. https://doi.org/10.1016/j.quaint.2014.04.008

Lemorini, C. (2000). *Reconnaitre des tactiques d'exploitation du milieu au Paleolithique Moyen. La contribution de!'analyse fonctionnelle. Etude fonctionnelle des industries lithiques* *de Grotta Breuil (Latium, Italie) et de La Combette (Bonnieux, Vaucluse, France)*. BAR International Series 858. Archaeopress.

Lemorini, C., Bourguignon, L., & Zupancich, A. (2016). A scraper's life history: Morpho-techno-functional and use-wear analysis of Quina and demi-Quina scrapers from Qesem Cave, Israel. *Quaternary International, 398*, 86–93. https://doi.org/10.1016/j.quaint.2015.05.013

Lemorini, C., Peresani, M., Rossetti, P., Malerba, G., & Giacobini, G. (2003). Techno-morphological and use-wear funtional analysis: An integrated approach to the study of a discoid industry. In M. Peresani (Ed.), *Discoid lithic technology: advances and implications* (pp. 257–275). BAR International Series 1120 Archaeopress.

Lemorini, C., Plummer, T. W., Braun, D. R., Crittenden, A. N., Ditchfield, P. W., Bishop, L. C., Hertel, F., Oliver, J. S., Marlowe, F. W., Schoeninger, M. J., & Potts, R. (2014). Old stones' song: Use-wear experiments and analysis of the Oldowan quartz and quartzite assemblage from Kanjera South (Kenya). *Journal of Human Evolution, 72*, 10–25. https://doi.org/10.1016/j.jhevol.2014.03.002

Lemorini, C., Stiner, M. C., Gopher, A., Shimelmitz, R., & Barkai, R. (2006). Use-wear analysis of an Amudian laminar assemblage from the Acheuleo-Yabrudian of Qesem Cave, Israel. *Journal of Archaeological Science, 33*(7), 921–934. https://doi.org/10.1016/j.jas.2005.10.019

Lemorini, C., Venditti, F., Assaf, E., Parush, Y., Barkai, R., & Gopher, A. (2015). The function of recycled lithic items at late Lower Paleolithic Qesem Cave, Israel: An overview of the use-wear data. *Quaternary International, 361*, 103–112. https://doi.org/10.1016/j.quaint.2014.07.03

Linscott, B., Pike, A. W. G., Angelucci, D. E., Cooper, M. J., Milton, J. S., Matias, H., & Zilhão, J. (2023). Reconstructing Middle and Upper Paleolithic human mobility in Portuguese Estremadura through laser ablation strontium isotope analysis. *Proceedings of the National Academy of Sciences, 120*(20). https://doi.org/10.1073/pnas.2204501120

Lo Porto, F. G. (1957). Tracce del Musteriano Alpino in una grotta del Monfenera presso Borgosesia. *Rivista Di Studi Liguri, 23*, 287–294.

Lombard, M. (2005). Evidence of hunting and hafting during the Middle Stone Age at Sibidu Cave, KwaZulu-Natal, South Africa: A multianalytical approach. *Journal of Human Evolution, 48*, 279–300. https://doi.org/10.1016/j.jhevol.2004.11.006

Longo, L. (1994). Le industrie litiche. L'analisi delle tracce d'uso. In C. Peretto (Ed.), *Le industrie litiche del giacimento paleolitico di Isernia la Pineta. La tipologia, le tracce di utilizzazione, la sperimentazione* (pp. 355–466). Cosmo Iannone.

Lourdeau, A. (2011). Stability in the Intermittence: A spatio-temporal approach to Mousterian behavior in the Near East based on the technological analysis of lithic industries of complex VI3 at Umm el Tlel (Central Syria). In N. J. Conard & J. Richter (Eds.), *Neanderthal lifeways, subsistence and technology: One hundred fifty years of Neanderthal study* (pp. 167–186). Springer. https://doi.org/10.1007/978-94-007-0415-2_16

Machado, J., Hernández, C. M., Mallol, C., & Galván, B. (2013). Lithic production, site formation and Middle Palaeolithic palimpsest analysis: In search of human occupation episodes at Abric del Pastor Stratigraphic Unit IV (Alicante, Spain). *Journal of Archaeological Science, 40*(5), 2254–2273. https://doi.org/10.1016/j.jas.2013.01.002

Machado, J., Molina, F. J., Hernández, C. M., Tarriño, A., & Galván, B. (2017). Using lithic assemblage formation to approach Middle Palaeolithic settlement dynamics: El Salt Stratigraphic Unit X (Alicante, Spain). *Archaeological and Anthropological Sciences, 9*(8), 1715–1743. https://doi.org/10.1007/s12520-016-0318-z

Márquez, B., Baquedano, E., Pérez-González, A., & Arsuaga, J. L. (2016). Microwear analysis of Mousterian quartz tools from the Navalmaíllo Rock Shelter (Pinilla del Valle, Madrid, Spain). *Quaternary International, 424*, 84–97. https://doi.org/10.1016/j.quaint.2015.08.052

Marreiros, J., Calandra, I., Gneisinger, W., Paixão, E., Pedergnana, A., & Schunk, L. (2020). Rethinking use-wear analysis and experimentation as applied to the study of past hominin tool use. *Journal of Paleolithic Archaeology, 3*, 475–502. https://doi.org/10.1007/s41982-020-00058-1

Marreiros, J., Mazzucco, N., Gibaja, J. F., & Bicho, N. (2015). Macro and micro evidences from the past: The state of the art of archeological use-wear studies. In J. Marreiros, J. F. Gibaja, & N. Bicho (Eds.), *Use-wear and residue analysis in archaeology. Manuals in archaeological method, theory and technique*. Springer. https://doi.org/10.1007/978-3-319-08257-8_2

Martínez, K., & Rando, J. M. (2001). Organización y funcionalidad de la producción lítica en un nivel del Paleolítico Medio del Abric Romaní. Nivel Ja (Capellades, Barcelona). *Trabajos de Prehistoria, 58*(1), 51–70. https://doi.org/10.3989/tp.2001.v58.i1.233

Martín-Viveros, J. I., & Ollé, A. (2020). Using 3D digital microscopy and SEM-EDX for in-situ residue analysis: A multi-analytical contextual approach on experimental stone tools. *Quaternary International, 569*(February), 228–262. https://doi.org/10.1016/j.quaint.2020.06.046

Masini, F., & Sala, B. (2007). Large- and small-mammal distribution patterns and chronostratigraphic boundaries from the Late Pliocene to the Middle Pleistocene of the Italian peninsula. *Quaternary International, 160*(1), 43–56. https://doi.org/10.1016/j.quaint.2006.09.008

Masini, F., & Sala, B. (2011). Considerations on an integrated biochronological scale of Italian quaternary continental mammals. *Il Quaternario, 24*, 193–198.

Mayor, A., Sossa-Ríos, S., Molina, F. J., Pérez, L., Galván, B., Mallol, C., & Hernández, C. M. (2022). An instance of Neanderthal mobility dynamics: A lithological approach to the flint assemblage from stratigraphic unit VIII of El Salt rockshelter (Alcoi, eastern Iberia). *Journal of Archaeological Science: Reports, 44*(March). https://doi.org/10.1016/j.jasrep.2022.103544

Mazza, P. P. A., Martini, F., Sala, B., Magi, M., Colombini, M. P., Giachi, G., Landucci, F., Lemorini, C., Modugno, F., & Ribechini, E. (2006). A new Palaeolithic discovery: Tar-hafted stone tools in a European Mid-Pleistocene bone-bearing bed. *Journal of Archaeological Science, 33*, 1310–1318. https://doi.org/10.1016/j.jas.2006.01.006

Mellars, P. (1996). *The Neanderthal legacy. An archaeological perspective from western Europe*. Princeton University Press.

Moncel, M. H., Ashton, N., Arzarello, M., Fontana, F., Lamotte, A., Scott, B., Muttillo, B., Berruti, G. L. F., Nenzioni, G., Tuffreau, A., & Peretto, C. (2020). Early Levallois core technology between Marine Isotope Stage 12 and 9 in Western Europe. *Journal of Human Evolution, 139*. https://doi.org/10.1016/j.jhevol.2019.102735

Moncel, M.-H., Chacón, M. G., Coudenneau, A., & Fernandes, P. (2009). Points and convergent tools in the European Early Middle Palaeolithic site of Payre (SE, France). *Journal of Archaeological Science, 36*, 1892–1909. https://doi.org/10.1016/j.jas.2009.04.018

Moncel, M.-H., Chacón, M. G., Vettese, D., Courty, M. A., Daujeard, C., Eixea, A., Fernandes, P., Allué, E., Hardy, B., Rivals, F., Béarez, P., Gallotti, R., & Puaud, S. (2021). Late Neanderthal short-term and specialized occupations at the Abri du Maras (South-East France, level 4.1, MIS 3). *Archaeological*

and Anthropological Sciences, 13(3). https://doi.org/10.1007/s12520-021-01285-5
Mourre, V. (1996). Les industries en quartz au Paléolithique. Terminologie, méthodologie et technologie. *Paléo, 8*, 205–223. https://doi.org/10.3406/pal.1996.1160
Odell, G. H. (1981). The mechanism of use-breakage of stone tools: Some testable hypothesis. *Journal of Field Archaeology, 8*(2), 197–209.
Odell, G. H. (1988). Addressing prehistoric hunting practices through stone tool analysis. *American Anthropologist, 90*(2), 335–356.
Odell, G. H., & Odell-Vereecken, F. (1980). Verifying the reliability of lithic use-wear assessment by "blind tests": the low-power approach. *Journal of Field Archaeology, 7*(1), 87–120.
Olivares, M., Tarriño, A., Murelaga, X., Baceta, J. I., Castro, K., & Etxebarria, N. (2009). Non-destructive spectrometry methods to study the distribution of archaeological and geological chert samples. *Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy, 73*(3), 492–497. https://doi.org/10.1016/j.saa.2008.12.036
Ollé, A., Sala, R., Pawlik, A., Longo, L., Skakun, N., & Gibaja, J. F. (2017). New contributions to the functional analysis of prehistoric tools. *Quaternary International, 427*, 2–5. https://doi.org/10.1016/j.quaint.2017.01.037
Ollé, A., & Vergès, J. M. (2014). The use of sequential experiments and SEM in documenting stone tool microwear. *Journal of Archaeological Science, 48*, 60–72.
Palmqvist, P., Martínez-Navarro, B., Toro, I., Espigares, M. P., Ros-Montoya, S., Torregrosa, V., & Pérez-Claros, J. A. (2005). Réévaluation de la présence humaine au Pléistocène inférieur dans le Sud de l'Espagne. *L'Anthropologie, 109*(3), 411–450. https://doi.org/10.1016/j.anthro.2005.06.001
Pandolfi, L., & Tagliacozzo, A. (2015). Stephanorhinus hemitoechus (Mammalia, Rhinocerotidae) from the Late Pleistocene of Valle Radice (Sora, Central Italy) and re-evaluation of the morphometric variability of the species in Europe. *Geobios, 48*(2), 169–191. https://doi.org/10.1016/j.geobios.2015.02.002
Patou-Mathis, M. (1993). Etude taphonomique et palethnographique de la faune de l'abri des Canalettes. In L. Meignen (Ed.), *L'Abri des Canalettes. Un habitat moustérien sur les grands Causses (Nant, Aveyron). Fouilles 1980-1986* (pp. 199–235). CNRS Éditions.
Pedergnana, A. (2019). "All that glitters is not gold": Evaluating the nature of the relationship between archeological residues and stone tool function. *Journal of Paleolithic Archaeology, 3*(3), 225–254. https://doi.org/10.1007/S41982-019-00039-Z
Pedergnana, A., & Ollé, A. (2016). Monitoring and interpreting the use-wear formation processes on quartzite flakes through sequential experiments. *Quaternary International, 427*, 35–65. https://doi.org/10.1016/j.quaint.2016.01.053
Pedergnana, A., & Ollé, A. (2019). Use-wear analysis of the late Middle Pleistocene quartzite assemblage from the Gran Dolina site, TD10.1 subunit (Sierra de Atapuerca, Spain). *Quaternary International, May*, 1–31. https://doi.org/10.1016/j.quaint.2019.11.015
Pedergnana, A., Ollé, A., & Evans, A. A. (2020). A new combined approach using confocal and scanning electron microscopy to image surface modifications on quartzite. *Journal of Archaeological Science: Reports, 30*, 102237. https://doi.org/10.1016/j.jasrep.2020.102237
Pelegrin, J., Karlin, C., & Bodu, P. (1988). "Chaînes opératoires": un outil pour le préhistorien. Technologie préhistorique. In *Notes et Monographies techniques* (Vol. 25). CNRS.
Peresani, M. (Ed.). (2003). *Discoid lithic technology: Advances and implications*. BAR International Series 1998. Archaeopress.
Peretto, C., Amore, F. O., Antoniazzi, A., Aantoniazzi, A., Bahain, J.-J., Cattani, L., Cavallini, E., Esposito, P., Falgueres, C., Gagnepain, J., Hedley, I., Laurent, M., Leberton, V., Longo, L., Milliken, S., Monegatti, P., Olle, A., Pugliese, N., Renault-Miskovsky, J., et al. (1998). L'industrie lithique de Ca'Belvedere di Monte Poggiolo : Stratigraphie, matière première, typologie, remontages et traces d'utilisation. *L' Anthropologie, 102*(4), 343–465.
Picin, A., & Carbonell, E. (2016). Neanderthal mobility and technological change in the northeastern of the Iberian Peninsula: The patterns of chert exploitation at the Abric Romaní rock-shelter. *Comptes Rendus Palevol, 15*(5), 581–594. https://doi.org/10.1016/j.crpv.2015.09.012
Picin, A., & Cascalheira, J. (Eds.). (2020). *Short-term occupations in Paleolithic archaeology*. Springer. https://doi.org/10.1007/978-3-030-27403-0
Pop, C. M., Wilson, L., & Browne, C. L. (2022). Evaluating landscape knowledge and lithic resource selection at the French Middle Paleolithic site of the Bau de l'Aubesier. *Journal of Human Evolution, 166*, 103152. https://doi.org/10.1016/j.jhevol.2022.103152
Rendu, W. (2010). Hunting behavior and Neanderthal adaptability in the Late Pleistocene site of Pech-de-l'Azé I. *Journal of Archaeological Science, 37*(8), 1798–1810. https://doi.org/10.1016/j.jas.2010.01.037
Rey-Rodríguez, I., López-García, J.-M., Bennàsar, M., Bañuls-Cardona, S., Blain, H.-A., Blanco-Lapaz, Á., Rodríguez-Álvarez, X.-P., de Lombera-Hermida, A., Díaz-Rodríguez, M., Ameijenda-Iglesias, A., Agustí, J., & Fábregas-Valcarce, R. (2016). Last Neanderthals and first anatomically modern humans in the NW Iberian Peninsula: Climatic and environmental conditions inferred from the Cova Eirós small-vertebrate assemblage during MIS 3. *Quaternary Science Reviews, 151*, 185–197. https://doi.org/10.1016/j.quascirev.2016.08.030
Rigaud, J.-P., & Geneste, J. M. (1996). L'utilisation de l'espace dans la Grotte Vaufrey. *La Grotte Vaufrey à Cenac et Saint-Julien (Dordogne). Paléoenvironments, chronologie et activités humaines, París: Mémoires de la Société Préhistorique Française, 19*, 593–611.
Romero, A. J., Carlos Díez, J., Arceredillo, D., García-Solano, J., & Jordá-Pardo, J. F. (2019). Neanderthal communities in the heart of the Iberian Peninsula: Taphonomic and zooarchaeological study of the Mousterian site of Jarama VI (Guadalajara, Spain). *Archaeological and Anthropological Sciences, 11*(5), 1713–1725. https://doi.org/10.1007/s12520-018-0625-7
Rosell, J., Cáceres, I., Blasco, R., Bennàsar, M., Bravo, P., Campeny, G., Esteban-Nadal, M., Fernández-Laso, M. C., Gabucio, M. J., Huguet, R., Ibáñez, N., Martín, P., Rivals, F., Rodríguez-Hidalgo, A., & Saladié, P. (2012). A zooarchaeological contribution to establish occupational patterns at Level J of Abric Romaní (Barcelona, Spain). *Quaternary International, 247*(1), 69–84. https://doi.org/10.1016/j.quaint.2011.01.020
Rots, V. (2008). Hafting traces on flint tools. In *"Prehistoric Technology" 40 Years Later. Functional Studies and the Russian Legacy* (Vol. 2, pp. 75–84). https://doi.org/10.4207/PA.2011.REV109
Rots, V. (2009). The functional analysis of the Mousterian and Micoquian assemblages of Sesselfelsgrotte, Germany: Aspects of tool use and hafting in the European Late Middle Palaeolithic. *Quartär, 56*, 37–66.
Rots, V., & Hardy, B. L. (2015). Residue and microwear analyses of the stone artifacts from Schöningen. *Journal of Human Evolution, 89*, 298–308. https://doi.org/10.1016/j.jhevol.2015.07.005
Rubat Borel, F., Arzarello, M., Buonsanto, C., & Daffara, S. (2013). San Carlo Canavese - San Francesco al Campo, località Vauda. reperti litici del Paleolitico medio. *Quaderni Della Soprintendenza Archeologica Del Piemonte, 28*, 267–270.
Sahnouni, M., Rosell, J., van der Made, J., Vergès, J. M., Ollé, A., Kandi, N., Harichane, Z., Derradji, A., & Medig, M. (2013). The first evidence of cut marks and usewear traces from the

Plio-Pleistocene locality of El-Kherba (Ain Hanech), Algeria: Implications for early hominin subsistence activities circa 1.8 Ma. *Journal of Human Evolution, 64*(2), 137–150. https://doi.org/10.1016/j.jhevol.2012.10.007

Sala, B., & Masini, F. (2007). Late Pliocene and Pleistocene small mammal chronology in the Italian peninsula. *Quaternary International, 160*, 4–16. https://doi.org/10.1016/j.quaint.2006.10.002

Sala, I. L. (1986). Use wear and post-depositional surface modification: A word of caution. *Journal of Archaeological Science, 13*(*3*), 229–244. https://doi.org/10.1016/0305-4403(86)90061-0

Santucci, E., Marano, F., Cerilli, E., Fiore, I., Lemorini, C., Palombo, M. R., Anzidei, A. P., & Bulgarelli, G. M. (2016). *Palaeoxodon* exploitation at the Middle Pleistocene site of La Polledrara di Cecannibbio (Rome, Italy). *Quaternary International, 406*(*Part B*), 169–182. https://doi.org/10.1016/j.quaint.2015.08.042

Semenov, S. A. (1964). *Prehistoric Technology: An experimental study of the oldest tools and artefacts from traces of manufacture and wear*. Cory Adams and Mackay.

Shen, C., & Chen, C. (2000). A use-wear study of lithic artifacts from Xiaochangliang and hominid activities in Nihewan Basin. *Acta Anthropologica Sinica, 19*, 119–125.

Soressi, M. (2004). L'industrie lithique des niveaux moustériens (fouilles 1998- 1999). Aspects taphonomiques, économiques et technologiques. In J. Airvaux (Ed.), *Préhistoire du Sud-Ouest* (pp. 79–95).

Spagnolo, V., Marciani, G., Aureli, D., Berna, F., Toniello, G., Astudillo, F., Boschin, F., Boscato, P., & Ronchitelli, A. (2019). Neanderthal activity and resting areas from stratigraphic unit 13 at the Middle Palaeolithic site of Oscurusciuto (Ginosa - Taranto , Southern Italy). *Quaternary Science Reviews, 217*, 169–193. https://doi.org/10.1016/j.quascirev.2018.06.024

Spagnolo, V., Marciani, G., Aureli, D., Martini, I., Boscato, P., Boschin, F., & Ronchitelli, A. (2020). Climbing the time to see Neanderthal behaviour's continuity and discontinuity: SU 11 of the Oscurusciuto Rockshelter (Ginosa, Southern Italy). *Archaeological and Anthropological Sciences, 12*(2). https://doi.org/10.1007/s12520-019-00971-9

Spurrell, F. C. J. (1892). Microscopic striations on flint sickle-blades as an indication of plant cultivation: Preliminary results. *World Archaeology, 17*(1), 121–126.

Stemp, W. J. (2014). A review of quantification of lithic use-wear using laser profilometry: A method based on metrology and fractal analysis. *Journal of Archaeological Science, 48*(1), 15–25. https://doi.org/10.1016/J.JAS.2013.04.027

Stemp, W. J., Macdonald, D. A., & Gleason, M. A. (2019). Testing imaging confocal microscopy, laser scanning confocal microscopy, and focus variation microscopy for microscale measurement of edge cross-sections and calculation of edge curvature on stone tools: Preliminary results. *Journal of Archaeological Science: Reports, 24*, 513–525. https://doi.org/10.1016/J.JASREP.2019.02.010

Stiner, M. C. (2013). An unshakable Middle Paleolithic? Trends versus conservatism in the predatory niche and their social ramifications. *Current Anthropology, 54*(S8), S288–S304. https://doi.org/10.1086/673285

Strobino, F. (1981). *Preistoria in Valsesia: Studi del Monte Fenera.* Società valsesiana di cultura.

Strobino, F. (1992). Nota sulla cronistoria delle ricerche sul Monte Fenera dalle origini agli anni Sessanta, prospettive per future indagini. *De Valle Sicida, 3*(1), 7–14.

Taipale, N. (2012). Micro vs. Macro. In *A microwear analysis of quartz artefacts from two Finnish Late Mesolithic assemblages with comments on the earlier macrowear results, wear preservation and tool blank selection*. Uppsala University/University of Helsinki.

Tallavaara, M., Manninen, M. A., Hertell, E., & Rankama, T. (2010). How flakes shatter: A critical evaluation of quartz fracture analysis. *Journal of Archaeological Science, 37*(10), 2442–2448. https://doi.org/10.1016/j.jas.2010.05.005

Tarriño, A., Elorrieta, I., & García-Rojas, M. (2015). Flint as raw material in prehistoric times: Cantabrian Mountain and Western Pyrenees data. *Quaternary International, 364*, 94–108. https://doi.org/10.1016/j.quaint.2014.10.061

Terradillos-Bernal, M., Diez Fernàndez-Lomana, J. C., Jordá Pardo, J.-F., Benito-Calvo, A., Clemente, I., & Marcos-Sáiz, F. J. (2017). San Quirce (Palencia, Spain). A Neanderthal open air campsite with short term-occupation patterns. *Quaternary International, 435*(Part A), 115–128.

Terradillos-Bernal, M., & Rodriguez-Alvarez, X. P. (2017). The influence of raw material quality on the characteristics of the lithic tool edges from the Atapuerca sites (Burgos, Spain). *Quaternary International, 433*, 211–223. https://doi.org/10.1016/j.quaint.2015.10.122

Testa, P. (2005). Il fenomeno carsico sul Monte Fenera. In R. Fantoni, R. Cerri, & E. Dellarole (Eds.), *D'acqua e di pietra. II Monte Fenera e le sue collezioni museali (pp. 152–163)*. Associazione culturale ZEISCIU Centro Studi.

Tixier, J. (1978). *Méthod pur l'étude des outillages lithiques. Notice sur le travaux scientifiques présentés en vue du grade de Docteur en lettres*. Université de Paris X –Nanterre.

Tringham, R., Cooper, G., Odell, G. H., Voytek, B., & Whitman, A. (1974). Experimentation in the formation of edge damage: A new approach to lithic analysis. *Journal of Field Archaeology, 1*, 171–196.

Vallejo Rodríguez, S., Urtiaga Greaves, K., & Navazo Ruiz, M. (2017). Characterization and supply of raw materials in the Neanderthal groups of Prado Vargas Cave (Cornejo, Burgos, Spain). *Quaternary International, 435*, 35–48. https://doi.org/10.1016/j.quaint.2015.09.054

Vallverdú, J., Allué, E., Bischoff, J. L., Cáceres, I., Carbonell, E., Cebrià, A., García-Antón, D., Huguet, R., Ibáñez, N., Martínez, K., Pastó, I., Rosell, J., Saladíe, P., & Vaquero, M. (2005). Short human occupations in the Middle Palaeolithic level i of the Abric Romaní rock-shelter (Capellades, Barcelona, Spain). *Journal of Human Evolution, 48*, 157–174. https://doi.org/10.1016/j.jhevol.2004.10.004

Van Gijn, A. L. (2014). Science and interpretation in microwear studies. *Journal of Archaeological Science, 48*, 166–169. https://doi.org/10.1016/j.jas.2013.10.024

Van Weers, D. J. (2006). A taxonomic revision of the Pleistocene Hystrix (Hystricidae, Rodentia) from Eurasia with notes on the evolution of the family. *Contributions to Zoology, 74*, 301–312.

Van Weers, D. J., & Montoya, P. (1996). Taxonomy and stratigraphic record of the oldest European porcupine Hystrix parvae (Kretzoi, 1951). In *Proceedings-koninklijke nederlandse akademie van Wetenschappen Natural Sciences* (pp. 131–141).

Vaquero, M., Bargalló, A., Chacón, M. G., Romagnoli, F., & Sañudo, P. (2015). Lithic reciclyng in a Middle Palaeolithic expedeint context: Evidence from the Abric Romaní (Capellades, Spain). *Quaternary International, 361*, 212–228. https://doi.org/10.1016/j.quaint.2014.05.055

Vaquero, M., Chacón, M. G., García-Antón, M. D., Gómez de Soler, B., Martínez, K., & Cuartero, F. (2012). Time and space in the formation of lithic assemblages: The example of Abric Romaní Level. *J. Quaternary International, 247*, 162–181. https://doi.org/10.1016/j.quaint.2010.12.015

Vaquero, M., & Pastó, I. (2001). The definition of spatial units in Middle Palaeolithic sites: The hearth-related assemblages. *Journal of Archaeological Science, 28*(11), 1209–1220. https://doi.org/10.1006/jasc.2001.0656

Vaquero, M., & Romagnoli, F. (2018). Searching for lazy people: The significance of expedient behavior in the interpretation of Paleolithic assemblages. *Journal of Archaeological Method and Theory, 25*(2), 334–367. https://doi.org/10.1007/s10816-017-9339-x

Vaquero, M., Vallverdù, J., Rosell, J., Pasto, I., & Allué, E. (2001). Neanderthal behaviour at the Middle Palaeolithic site of Abric Romaní, Capellades, Spain. *Journal of Field Archaeology, 28*(1/2), 93–114.

Vergès, J. M., & Ollé, A. (2011). Technical microwear and residues in identifying bipolar knapping on an anvil: Experimental data. *Journal of Archaeological Science, 38*(5), 1016–1025. https://doi.org/10.1016/j.jas.2010.11.016

Vietti, A. (2016). *Combined electron spin resonance and U-series dating (ESR/U-series) of fossil tooth enamel: Application to dental remains from different Palaeolithic Italian sites*. Universtià degli Studi di Torino.

Villa, G., & Giacobini, G. (1993). Borgosesia, Monte Fenera. Denti neandertaliani dalla grotta Ciota Ciara. *Quaderni Della Soprintendenza Archeologica Del Piemonte, 11*, 300–303.

Villa, G., & Giacobini, G. (2005). I resti umani neandertaliani del Monte Fenera. In R. Fantoni, R. Cerri, & E. Dellarole (Eds.), *D'acqua e di pietra. II Monte Fenera e le sue collezioni museali (pp. 234–238)*. Associazione culturale ZEISCIU Centro Studi.

Viola, S., & Besse, M. (2019). Borgosesia. Grotta dell'Eremita. Scavo dei livelli di media età del Bronzo (campagne 2015-2016) e sondaggio della zona atriale (campagna 2017). *Quaderni Di Archeologia Del Piemonte, 3*, 321–323.

Viseras, C., Soria, J. M., Durán, J. J., Pla, S., Garrido, G., García-García, F., & Arribas, A. (2006). A large-mammal site in a meandering fluvial context (Fonelas P-1, Late Pliocene, Guadix Basin, Spain). Sedimentological keys for its paleoenvironmental reconstruction. *Palaeogeography, Palaeoclimatology, Palaeoecology, 242*(3–4), 139–168. https://doi.org/10.1016/j.palaeo.2006.05.013

Wilson, L., Browne, C. L., & Texier, P. J. (2018). Provisioning on the periphery: Middle Palaeolithic raw material supply strategies on the outer edge of a territory at La Combette (France). *Journal of Archaeological Science: Reports, 21*, 87–98. https://doi.org/10.1016/j.jasrep.2018.07.001

Xhauflair, H., Pawlik, A., Forestier, H., Saos, T., Dizon, E., & Gaillard, C. (2017). Use-related or contamination? Residue and use-wear mapping on stone tools used for experimental processing of plants from Southeast Asia. *Quaternary International, 427*, 80–93. https://doi.org/10.1016/j.quaint.2016.02.023

Yellen, J. E. (1977). *Archaeological approaches to the present: Models for reconstructing the past*. Academic Press.

Zambaldi, M. (2015). *La Grotta della Ciota Ciara (Borgosesia, VC): Primi contributi per uno studio geoarcheologio. Master thesis*. Università degli studi di Ferrara.

Zambaldi, M., Angelucci, D. E., & Arzarello, M. (2016). First data on stratigraphy and formation processes at Ciota Ciara cave (Monte Fenera, Borgosesia, Vercelli). In *Il Paleolitico e il Mesolitico in Italia: Nuove ricerche e prospettive di studio The Palaeolithic and Mesolithic in Italy: new research and perspectives*.

Ziggiotti, S. (2011). Lo studio funzionale delle industrie litiche scheggiate. In M. Arzarello, F. Fontana, & M. Peresani (Eds.), *Manuale di tecnologia litica preistorica*. Carrocci Editore.

Zupancich, A., Lemorini, C., Gopher, A., & Barkai, R. (2016). On Quina and demi-Quina scraper handling: Preliminary results from the late Lower Paleolithic site of Qesem Cave, Israel. *Quaternary International, 398*, 94–102. https://doi.org/10.1016/j.quaint.2015.10.101