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Bones Being Ubiquitous: A Methodological Exploration of the Bone Industry of Grotta de Nadale, Northeastern Italy.

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Student's Declaration

This is an act of an independent research required for the final semester of the International Erasmus Mundus Masters of Quaternary and Prehistory for the 2023/2024 academic year in IMQP Consortium — the Università degli Studi di Ferrara (Italy), Muséum National d'Histoire naturelle (France), Universitat Rovira i Virgili (Spain), and Instituto Politecnico of Tomar (Portugal).

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Supervisor : Professor Marco Peresani (Università degli Studi di Ferrara, Italy)

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Student Registration Number: 189427 (Università degli Studi di Ferrara)

Date: 2nd September 2024, Ferrara.

With all the love I can possibly muster together, I dedicate this work

To my mother and my father

whose unwavering selfless sacrifices and boundless love have given me everything I could ever wish for.

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I apologise for any exclusions which are entirely inadvertent.

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Glossary

AMH	Anatomically Modern Human
MSA	Middle Stone Age
AFAS	l'Association Française pour l'Avancement des Sciences
SPF	la Société Préhistorique Française/ the French Prehistoric Society
UISPP	International Union for Prehistoric and Protohistoric Sciences
OIS	Oxygen Isotope Stage
SEM	Scanning Electron Microscope
LSA	Late Stone Age
ESA	Early Stone Age
MIS	Marine Isotope Stage
OSL	Optically Stimulated Luminescence
CT	Computerised Tomography
GM	Geometric Morphometrics
ZooMs	Zooarchaeology by Mass Spectrometry
SU	Stratigraphic Unit

Note on Language: British English

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Abstract

Bones Being Ubiquitous: A Methodological Exploration of the Bone Industry of Grotta de Nadale, Northeastern Italy.

The use of bone tools before the Upper Palaeolithic has been debated for more than a century. Multiple agents produce 'curiosities' that closely resemble human-made artefacts, making it difficult to distinguish between anthropogenic action and those of carnivores in cases of such as deer antler wear and breakage. Even sedimentary context plays a significant role in the formation of pseudo tools. This already-complex analysis is further complicated by the fact that caves and rock shelters occupied by Palaeolithic populations were also largely inhabited by carnivores. Therefore, a solid understanding of the archaeological context is essential before determining the status of bone tool identification in these remote periods. Thus, the question of the role of bone tools in the technical subsystem of the Middle Palaeolithic remains wide open, and this dissertation is addressing this vast problematic.

In Italy, evidence dating back to the Lower Palaeolithic (Marinelli *et al.* 2024; Villa *et al.* 2021) indicates that bones were used as tools alongside stone tools. The present study isolated several specimens from all stratigraphic units of grotta de Nadale, exhibiting traces that may indicate their use or manufacture, within the zooarchaeological assemblage: negative removals perpendicular to the long axis of the bone and negative removals parallel to the long axis of the bone. These stigmas form the basis hypotheses of this dissertation, *i.e.,* the study hypothesises that negative removals perpendicular to the long axis of the bone, indicates manufacture through percussion as intermediate tools, while negative removals parallel to the long axis of the bone suggest use as cutting or scraping tools.

The analytical methodology employed in this study involved adopting a *chaîne opératoire* approach, traditionally used for analysing stone tool reduction sequences, to examine a selected 'potential' bone tool assemblage. This approach aimed to employ available archaeological contextual information, including zooarchaeological data and the taphonomy of the bone assemblage, to investigate all recovered bones exhibiting traces of manufacture or use (including by-products, finished and unfinished tools, unmodified bones, worn items, re-shaped pieces, and broken tools). This methodology involved reconstructing the sequence of actions involved with each tool, beginning with the acquisition of the bone raw material, followed by the manufacturing process, subsequent tool use, and concluding with the disposal of the tool (for similar synthesis see Hahn 1976; Fosse 1999; Averbouh 2000). To differentiate true bone tools from 'pseudo-bone tools' created by natural processes and details the criteria and experimental approaches used to identify anthropic origin of the bone tools, ensuring that natural modifications are thoroughly considered and eliminated. A small-scale experiment was conducted to observe technological and use-wear traces on bone tools, using fresh *Bos taurus* long-bones and detailed microscopic examination to document alterations and wear patterns.

The first category, negative removals perpendicular to the long axis of the bone (n=60), indicating a consistent operating mode. The majority of these tools bear manufacture and use wear traces, typical for intermediate tools (Tartar, 2003, 2012). This category, termed intermediate tools, comprises diaphyseal fragments likely originating from food processing activities. These tools feature damage at both ends, with one end used for hammering to split or cut material (the distal end) and the opposite end serving as the point of contact with the working material (the proximal end). The second category, negative removals

parallel to the long axis of the bone (n=62) includes all tools with intentional retouching on one edge, and in rare cases, on both edges, as inferred from the observed pattern of removals on the bone blank. Most retouching appears on the cortical surface, followed by impact points on the medullary side. Retouches on the medullary side are more invasive, characterised by a flat and scalariform nature, indicating significant material removal to achieve a specific cutting or scraping edge. The flattening and extensive retouching at the distal end may reflect the need for a broader cutting edge or increased durability, suggesting repeated use or specific functional requirements. Among the entire chosen assemblage (n=122), 57 pieces exhibit retoucher marks, representing 47.1% of the specimens, indicating a multifunctional tool assemblage.

The ubiquity of bone tools at grotta de Nadale can be attributed to the absence of suitable lithic raw materials near the site, necessitating the procurement of chert from distant areas (20-80 km away) such as the eastern Berici hills, the western Euganean hills, and the central-western Lessini (Livraghi *et al.* 2021). With extensive exploitation of lithic cores at de Nadale (Delpiano *et al.* 2022; Delpiano, pers. comm), bones emerged as an alternative raw material, knapped in a manner similar to stone to manufacture tools. This likely occurred when stone resources became scarce, prompting Neanderthals to use bones to meet essential technological needs. These tools demonstrate the Neanderthals' adaptability and familiarity with the technological properties and availability of bones. As demonstrated in this study, Evaluating the role of bone tools within the technical systems of the Middle Palaeolithic remains challenging. The interdisciplinary approach of this study helps piece together the intricate puzzle of bone tool use and its role in the technological subsystems of the Middle Palaeolithic, contributing to the broader discourse on prehistoric human behaviours and adaptation. The findings highlight the importance of bones not only as dietary and ecological indicators but also as versatile materials for toolmaking, shedding light on the complex behaviours and environmental interactions of early human populations in the region.

Keywords: *Neanderthals, Northern Italy, Quina Mousterian, Retouched tools, Intermediate tools.*

Chapter 1

INTRODUCTION

Palaeolithic archaeology, the study of prehistoric human societies and their material remains, is heavily reliant on two critical components: bones and lithics. Bones, the preserved skeletal remains of animals, provide invaluable insights into dietary patterns, palaeoecological conditions, and even technological advancements. The aim of this chapter is to provide the necessary background and context of the research. It sets the stage for the subsequent chapters by outlining the research gap and significance of the study, while providing the objectives of this study.

This study is concerned with how bone materials were used as tools and tool supports by Neanderthals in the grotta de Nadale during the late Middle Palaeolithic. Existing literature confirms that bones were indeed used as tool supports during the Mousterian occupation of grotta de Nadale, evidenced by the discovery of abundant 'retouchers,' some of which have been published (Martellotta *et al.* 2021). This thesis, however, does not focus on retouchers, but rather on other bone pieces that could potentially serve as tools and may exhibit retoucher marks. The aim is to provide a preliminary description of these 'selected potential faunal specimens' and propose hypotheses regarding the origins of the marks, whether they are natural traces or anthropic and technological traces.

Initiation

Manufacturing a bone tool is a matter of expertise. It demands considerable skill to carefully shape bone into a tool that is both strong, efficient and durable. Additionally, it requires a thorough understanding of the material and the best techniques for working with it. Similarly, examining bone tools necessitates knowledge of the different tool types and the methods used to create them. Researchers must also be adept at identifying the relative age and usage of a bone tool to gain a deeper understanding of the culture it belonged to. This helps to paint a more comprehensive picture of past ways of life.

The interpretation of prehistoric bone tool industries requires meticulous attention from well-trained archaeozoologists. These tools were manufactured with skill and precision, utilising bones that, due to their durability, can persist for millennia under favourable preservation conditions, often retaining recognisable forms long after other organic materials, such as wood, have decomposed. Consequently, it's crucial to understand the potential for bone tool survival in archaeological contexts and to exercise caution during their interpretation. The presence of bone tools in archaeological layers can be problematic due to potential intrusions caused by both human activity and natural processes occurring long after the original deposition. These later intrusions may introduce artefacts from different time periods into the same archaeological context. Therefore, thorough consideration of taphonomic processes and site formation history is essential before confidently interpreting bones as evidence of past activities. Hence, robust and multidisciplinary approach is necessary for studying bone tools effectively. This approach should incorporate archaeological and anthropological evidence alongside chemical and radiometric dating techniques to accurately determine the age and cultural context of bone tools.

Bone technology, a more recent field compared to lithic technology, has drawn considerable inspiration from lithic analysis terminology and methodologies. Many terms in bone technology are either partially or entirely borrowed from the lithic vocabulary, particularly as outlined by Inizan *et al.* (1995). A significant milestone in the development of bone technology and its terminology was reached with Averbouh's thesis (2000) which provided concise definitions for key vocabulary. Additionally, Provenzano's seminal work "*Terminologie du travail des matières osseuses, du Paléolithique aux Ages des métaux*" in 2004 contributed to the betterment of the discipline.

Problematic Past

The use of bone tools prior to the Upper Palaeolithic has been a topic of debate spanning over a century (Brain 1967, 1981a; Binford 1981; Backwell & d'Errico 2001a, 2014; d'Errico & Backwell 2003). Early in the development of prehistoric sciences, clear evidence emerged for the manufacturing of tools from bones, antlers, and ivory during the Upper Palaeolithic. However, the evidence for bone tools in earlier times has historically been met with ambiguity and scepticism.

In the latter half of the nineteenth century, the study of objects made from osseous materials marked a significant development in archaeozoological research. Scholars (LeMoine 1994b; Desmond 2022) began describing and classifying these artefacts by drawing comparisons with contemporary or ethnographic objects. This comparative approach involved examining the shapes and functions of these bone tools, leading to the identification of recurring patterns and the establishment of an initial classification system. This was a crucial advancement in the understanding of archaeozoological remains during that time. By the end of the nineteenth century and into the early twentieth century, the periodisation of the Upper Palaeolithic period was further refined through the typology not only of lithic industries but also bone industries. Particularly notable were the developments in understanding cultures such as the Aurignacian and the Magdalenian, where the types of spearheads and other bone tools served as key chronological markers. This typological approach enabled archaeologists to compare different sites and establish contemporary chronological sequences, thus allowing for the determination of relative chronologies and greatly enhancing the understanding of the archaeological record.

The typological approach, however, centered on categorising bone tools based on their morphological characteristics, often overlooking the functional and technological aspects of their production and use. In more recent times, the field has seen a paradigm shift towards a techno-functional perspective, which emphasises the underlying technical processes and the specific ways in which these tools were designed and utilised. Thus, recent advancements in technology have facilitated novel approaches to the research and analysis of bone tools and their archaeological contexts.

Finding the culprits

Identifying whether certain artefacts are anthropogenic (human-made) or the result of natural processes, such as carnivore activity or sedimentary effects, can be a complex task in archaeozoology. This challenge is particularly evident in cases involving items like deer antlers, where wear and breakage can resemble human modification. Several factors contribute to this difficulty. Firstly, the sedimentary context in which artefacts are found plays a crucial role. Sedimentary processes can mimic human activities by shaping materials in ways that resemble tools or artefacts. This makes it essential to carefully consider the geological history of the site. Additionally, subtle differences in wear patterns and breakage between human-modified objects and naturally occurring ones can be key indicators. Human-made artefacts often exhibit distinct wear marks and patterns that reflect intentional shaping for specific functions, which differ from the wear and breakage typically caused by natural processes. Moreover, even when anthropogenic action is evident, demonstrating the intended purpose of such modifications is crucial. It must be established whether the modifications were intended for technical purposes, such as tool-making, rather than incidental actions related to food processing or other activities. Given these complexities, archaeozoologists employ a multidisciplinary approach that integrates detailed morphological analysis, wear pattern studies, experimental archaeology, and contextual interpretation to differentiate between natural formations and human-made artefacts. This holistic approach helps to unravel the complexities of prehistoric material culture and provides insights into the behaviours and technologies of ancient human populations.

The analysis of bone tools in Palaeolithic contexts is further complicated by the cohabitation of caves and rock shelters by both Palaeolithic populations and carnivores. This dual occupation means that bones often bear marks that could be attributed to both human activity and carnivore interactions (Binford 1981; Tartar 2012a; Goutas *et al.* 2018). This situation underscores the challenge of distinguishing between anthropogenic and natural processes when interpreting bone tool evidence. In such environments, both humans and carnivores may leave marks on bones, complicating efforts to identify the origins of specific modifications. The relationship between these two groups—where each sought survival in challenging environments—adds another layer of complexity to interpreting bone tools. Understanding which agent interacted with bones first, and how subsequent actions by both humans and carnivores may have altered the bones, requires careful consideration of archaeological context. Therefore, a thorough understanding of the archaeological context is essential before making conclusions about the identification of bone tools from these ancient periods. This task demands a multidisciplinary approach that integrates archaeology, zooarchaeology, taphonomy, and perhaps even ethology to reconstruct the complex interactions between humans and carnivores in these settings.

However, recent advanced technological developments have profoundly influenced the understanding of bone tool use in the Middle Palaeolithic, enabling researchers to re-examine existing evidence and uncover new insights into how early humans utilised bones as tools prior to the Upper Palaeolithic. Consequently, contemporary studies are increasingly illuminating the complexity and diversity of bone tool industries in earlier prehistoric times. This ongoing research underscores the imperative to continuously explore and refine our understanding of ancient tool-making practices, thereby enhancing our knowledge of early human cultures and behaviours.

Analogous to solving a jigsaw puzzle, the process of identifying and interpreting bone tools requires piecing together various lines of evidence. Initially, these pieces may not seem to fit together perfectly, but with meticulous analysis and the integration of diverse disciplines–specially rooting into the taphonomy and archaeological context, a clearer understanding can emerge. This ongoing research challenge is particularly pertinent in addressing the role of bone tools within the technical subsystem of the Middle Palaeolithic, a topic that remains open to investigation and interpretation. In essence, the study of bone tools in Palaeolithic contexts necessitates navigating a complex landscape of anthropogenic and natural influences, requiring a comprehensive approach that embraces interdisciplinary perspectives to unravel the complexities of prehistoric material culture.

Research Problem

However, despite extensive research on the bone tool industry, several grey areas remain. The study of bone tools is heavily concentrated in certain geographic regions, particularly Western Europe—Spain, France, and Germany, which may affect the regional variability and technological adaptation of the human cultural record. Also, the focus on 'retouchers' often overshadows other aspects of bone industry, such as worked bone fragments and modified long bones, which is often gone unnoticed or understudied. Early studies predominantly addressed typologies of artefacts without thoroughly exploring the underlying technology[1]. As a result, artefacts were sometimes forced into pre-defined tool categories, limiting conclusions about bone material acquisition and the *chaîne opératoire* of tool manufacture. In Northern Italy, the record of bone 'retouchers' is well-established, with notable examples from sites such as grotta de Nadale, Fumane

[1] See chapter 2 for more detailed synthesis.

Cave, Riparo Tagliente and grotta della Ghiacciaia. Conversely, Italy's Lower Palaeolithic bone tool culture, which includes percussion-shaped tools, dates back to around 400,000 years ago[2]. Taken together, the disparity in attention Europe and Italy likely reflects a combination of research biases, preservation issues, and a lack of systematic analysis.

Significance of the Study

This research addresses existing gaps by focusing on the underrepresented bone modifications at grotta de Nadale, extending beyond the well-documented evidence of 'retouchers.' By examining these lesser-known bone modifications, the study aims to provide new insights into the bone tool industry of Northern Italy—a region where the last Neanderthals sought refuge during the climatically turbulent period of MIS 4. This research seeks to challenge the fragmentary regional record and fills a critical gap in interdisciplinary study, offering a more comprehensive understanding of the behavioural and technological adaptations of the region's last Neanderthals.

Objectives of the study

This study comprises various taphonomical, techno-functional, and experimental investigations conducted primarily on the faunal specimens that bear indications of use or manufacturing. These specimens have been recently discovered at the Quina Mousterian site of grotta de Nadale.

Thus, the objectives of this study are:

I. **To analyse of the selected assemblage from a taphonomic viewpoint and a quantified and explicit description of features that define human action, as opposed to natural agencies.** Emphasis was placed on bone fragments demonstrating negative removals on their end or lateral edges, which were found in large quantities. Two categories were devised to test the hypothesis that negative removals on bone fragments are either intentional traces of use or manufacturing. The categories were determined based on the location of the negative removals.

II. **To describe the stages of bone modifications, by using available contextual information (achieved from the objective 1) and examining traces of use.** In order to expand the knowledge base of knapping methods and bone retouching techniques, a sequence of experimental activities utilising standard experimental protocols has been implemented.

[2] Villa *et al* (2021) and Marinelli *et al* (2024)

III. **To introduce and obtain a comprehensive understanding of the bone industry of Neanderthals (excluding retouchers) in northeastern Italy**, which has yet to be extensively studied. The objective is to describe the technological and morphological components of the tools to introduce them in comparison to the specific context of Middle Palaeolithic bone industries.

Although this thesis aims for a comprehensive understanding, it deliberately avoids placing the distinct bone tool assemblage from grotta de Nadale within an 'already well-established' and broader regional or chronological context to prevent oversimplification of complex behaviours or overlooking the diversity among Neanderthals in Europe. Instead, this dissertation introduces the unique assemblage for the first time and conducts a meticulous taphonomic study firmly grounded in its archaeological context. This approach preserves the integrity of the findings and sets a solid foundation for future research. By focusing on the uniqueness of the assemblage, the study ensures that subsequent analyses can engage with the findings in a manner that respects their distinctiveness, potentially leading to more precise and contextually rich interpretations of Neanderthal behaviours and technology in Northern Italy.

Organisation of the dissertation

This dissertation is presented in two parts.
The first part establishes the theoretical framework of the study. Chapter Two provides a historical overview of research, with a focus primarily on European contexts, while also incorporating some examples from Africa and Asia. Chapter Three, following a brief review of the previous chapter, shifts the focus to the use of bone tools by Neanderthals at the end of the Middle Palaeolithic.

The second part is dedicated to the presentation and analysis of data, characterised by a highly technical approach. Chapter Four introduces grotta de Nadale, detailing its geographical, geological, and archaeological context. Chapter Five presents the study's corpus and outlines the methodology used for analysis. Chapter Six includes detailed descriptions of the study materials and potential tools from grotta de Nadale. Finally, Chapter Seven evaluates the hypotheses regarding the potential tools and their typological implications.

Chapter 2

PLACING INTO THE CONTEXT: HISTORICAL AND THEORETICAL PERSPECTIVES

Ongoing debates around the timing and nature of the emergence of bone tool technology in Europe underscore the need for further research and re-evaluation of existing archaeological evidence. Therefore, the recognition of bone material uses or manufacture prior to the Upper Palaeolithic in Europe has long been a topic of debate, persisting throughout the twentieth century. These debates often hesitated between affirmations of the existence of purposefully manufactured tools and scepticism, suggesting that observed artefacts might merely be the result of natural taphonomic processes (referred as pseudo-tools). Research has indicated that while the presence of bone tools in the archaeological record is often attributed to the Upper Palaeolithic, evidence suggests that earlier hominins may have engaged in bone processing and use, raising important questions about the technological capabilities and subsistence strategies. Consequently, doubts have been frequently raised regarding the existence of bone-based tools prior to the Upper Palaeolithic (Vincent 1993).

To grasp the current state of art of bone material use prior to the Upper Palaeolithic, it is crucial to trace the trajectory of the recognition of bone tools from the late nineteenth century to the present day, creating space to identify loopholes in the existing research. This chapter aims to review the journey leading from the initial discovery of bone tools in Mousterian contexts to the contemporary methods of analysis employed to identify bone tools in the Lower and Middle Palaeolithic periods.

2.1 Where and when it all began: the first signs of enthusiasm

The study of bone tools in prehistoric contexts has evolved considerably since the nineteenth century. Early findings, such as the bone awl discovered in Engis Cave, Belgium, in the 1830s by C. Schmerling, sparked initial interest in bone artefacts attributed to '*antediluvian*' man (Richard 2008). This discovery was followed by harpoons and pierced sticks found in Haute-Savoie by F. Mayor between 1833-1838, marking the beginnings of bone tool recognition in Europe (Peltier 1992; Julien 1995). As prehistory became a recognised discipline, the classification and description of these artefacts expanded, most notably with the publication of "*Reliquiae Aquitanicae*" by E. Lartet and H. Christy in 1875. This work, filled with detailed illustrations of bone and antler tools, significantly validated the use of osseous materials during prehistoric times (Lartet & Christy 1875) [3].

[3] The previous year Lartet and Christy began systematically examining the caves in the Périgord region of France, and found incontrovertible evidence for the existence of Palaeolithic mobiliary art. Their 37-page paper with two

In two papers published in 1861, Lartet illustrated two prehistoric bones with carved representations of animals that had previously been considered 'Celtic'. He argued that these carvings, were indeed examples of prehistoric art (Lartet 1861a). In his second paper, Lartet proposed the first chronological framework that could accommodate both human skeletal and cultural remains, based on fossil faunal remains recovered from French cave sites. These cultural remains included flints and bone carvings, where he presented his initial concept of how human skeletons in the Aurignacian period had been arranged in a chamber; however, he later revised his opinion based on discoveries made in 1862 (Lartet 1861b).

2.2 The first Mousterian bone tools and their interpretations

The early twentieth century marked a turning point with the discovery of bone tools in Mousterian contexts, particularly at La Quina by H. Martin in 1906. He reported on specimens showing 'certain traces of human intervention' on the distal extremities of humerus and phalanges belonging to large herbivores (Martin 1906). According to Martin, these markings may represent evidence of 'mallets' (epiphyses of horse and bovidae humerus, phalanges of bovidae and deer) used for direct percussion operations, as well as 'anvils' (phalanges of horses) used as support for flint knapping. Consequently, Martin's findings were widely regarded as the first discovery of bone tools within a Mousterian context (Baudoin *et al.* 1906).

Subsequent discoveries at sites like Rebières and La Ferrassie led to the widespread acknowledgment of bone tools, though interpretations varied (Pittard 1907). He interpreted these markings as 'notched tools' and 'anvils.' Similarly, Martin discovered diaphyseal fragments resembling those found at La Quina (Martin 1907a). In short order, prehistorians reached a consensus, recognising these impressed bones (including phalanges, distal extremities of humerus, and fragments of diaphysis) as passive tools, likely serving as 'anvils' or 'blocks' used in butchery or flint retouching operations (Baudoin *et al.* 1906; Martin 1906, 1907b; Pittard 1907).

Controversially, opposition arose regarding Martin's interpretation suggesting that these pieces could have been used as support for sharpening wooden points using a cutting edge made of flint (Martin 1907a). For instance, Siret's experiments in 1925 supported the idea that these bones were used for retouching flint tools, emphasising their role as passive tools (Siret 1925)[4].

lithographed plates and numerous illustrations within the text, describing the results of those research, was the founding work on Upper Palaeolithic art, and one of the earliest publications to illustrate Palaeolithic mobiliary art.

[4] After conducting experiments involving the retouching of flint using mule (*Equus asinus*) phalanges and achieving retouching comparable to that observed on Mousterian lithics, Siret concluded that the impressed bones were likely used for retouching flint tools.

2.3 Retouchers vs Compressors

In the first quarter of the twentieth century, the number of discoveries of bones bearing impressions and scratches increased at Mousterian sites, often occurring during new excavations or re-examinations of faunal remains from previously explored sites. However, the terminology used to describe these findings remained inconsistent. For example, at sites like La Micoque and La Ferrassie in Dordogne, they were referred to as 'retouchers,' while at Pont-Lévêque in Charente, they were called 'compressors.' Sometimes, the terminology was more generic, such as 'impressions' observed at Petitÿ Puymoyen in Charente and Isturitz in Pyrénées Atlantiques, or simply described as 'used bones' at El Castillo in Cantabria, Spain. (Mozota Holgueras 2009a).

Subsequently, the two primary terms, 'retouchers' and 'compressors,' continued to coexist for several decades, applied to both bones with impressions and scratches discovered in Mousterian contexts and those found in more recent layers. While serving as evidence of bone tool use during the Mousterian period, attributed to Neanderthals, bones with impressions and scratches have long piqued the interest of prehistorians once their existence was acknowledged. However, the study of this category of tools, whether from Mousterian contexts or more recent ones, retained a relatively anecdotal status compared to the attention given to tools made from shaped bones in the Upper Palaeolithic.

2.3.1. Experimentation, traceology and validation

It was not until the 1990s that more research was carried out on bones with impressions, and these usually involved an experimental component: the production of supports, usually diaphyseal fragments, and the reproduction of modifications. These are obtained experimentally during the retouching of lithic tools using direct percussion; hence, only the use of bones with impressions as retouchers are considered. More recently, use-wear by Malerba and Giacobini (1998, 2022) has confirmed the use of bones with impression marks, particularly from the Middle Palaeolithic, in the retouching of lithic cutting edges using direct percussion.

However, the study of retouchers is no longer limited to a description of the supports and traces of use; "*the impressions in bones are no longer considered in isolation but integrated into its archaeological context in a multidisciplinary approach to the archaeological context'* (Tartar 2002). The experimental approach makes feasible to capture the production of archaeological materials[5], experimentation also makes it

[5] E.g., Holgueras (2009, 2014) experimentation with long bone fracturing either for the sole purpose of extracting marrow, then recovery of supports (diaphyseal fragments) suitable for use in retouching ('strategy A'), either with the aim of producing the maximum number of supports ('strategy C'), either with the aim of both extracting the marrow and obtaining suitable supports ('strategy B).

possible to understand the use of retouchers: technical gestures deployed in cutting operations[6], determination based on the morphology of the traces visible on the retouchers, raw material, in this case flint or quartzite, intervention of the retouchers at what level of the knapping operating chain[7]. Recently, an experimental study led by Martellotta *et al* (2024) gleaned information on decision-making processes among individuals who involved in manufacturing retouchers. They found that manufacturers developed individual habits and preferences related to their posture, gestures, bone positioning, and the selection of percussors. When they realised the anvil-rested technique was not always effective, so they tend to change their technique based on the specific objective and skeletal element.

Well-known in the recent Middle Palaeolithic, in grotte du Noisetier, (Hautes-Pyrénées) (Mallye *et al.* 2012), Isturitz (Pyrénées-Atlantiques) (Schwab 2002), La Quina (Chase 1990a; Verna & d'Errico 2011), there were some molar teeth of Horse. Also, some retouchers on diaphyseal fragments in older Middle Palaeolithic contexts, to name a few, Lazaret- MIS 6 (Alpes-Maritimes) (Valensi 1996), Biache-Saint-Vaast- MIS 7 and 6 (Pas-de-Calais) (Auguste 2002), Orgnac 3- MIS 8 (Moncel *et al.* 2005) and in the Lower Palaeolithic- MIS 9 at Gran Dolina (Atapuerca, Burgos, Spain) (Rosell *et al.* 2011), Bolomor cave (Valencia, Spain) and at Qesem Cave (Israel) (Blasco *et al.* 2013b), as well as Schöningen (Lower Saxony) (Van Kolfschoten *et al.* 2015). In this site bone fragments were used as retouchers but also, in the case of some exceptions, as hammerstones for fracturing bones.

Not only retouchers, but also antler hammers were also a part of the prehistoric tool kit. Antler hammers have been identified in collections of Palaeolithic artefacts since the early twentieth century (Girod & Massenat 1900; Martin 1907a, 1910). Among ten European sites which yield antler hammers, Boxgrove is the oldest yet, dated back to 500,000 BCE (Parfitt & Roberts 1999; Smith 2013; Stout *et al.* 2014). Their initial implementation dates back to the Lower Palaeolithic (Stout *et al.* 2014; Van Kolfschoten *et al.* 2015), where soft hammers were used to form bifacial tools. However, most of these tools are attributed to Upper Palaeolithic sites lined to Solutrean and Magdalenian cultures, to name a few Laugerie-Haute (Bordes 1974; Bello *et al.* 2016), Solutre (Stodiek 1990; Rigaud *et al.* 2013; Baumann & Maury 2023), Roc de Sers (Bello *et al.* 2016), Enlene and Le Placard (Averbouh 1995, 1999) in France, and Arbreda in Spain (Estévez 1978), a single specimen reported Geissenklösterle site in Germany (Bolus 2003) linked to Aurignacian, and Gravettian assemblage is observed from the Pavlov I site in the Czech Republic (Goutas 2001). Finding hammers made of organic materials amongst excavated archaeological material is still quite rare.

[6] e.g., Armand and Delagnes (1998), highlighting of parameters (percussion angle, percussion trajectory, etc.) whose different combinations make it possible to produce different types of stigmas), lithic raw materials worked.
[7] e.g., Chase (1990) illustrates probable use of retouchers from Quina locus 2 in regrinding operations of lithic edges.

Long neglected, often reduced to mere description, the study of bones with impressions has been completely renewed over the past decades through experimentation which validated certain functional hypotheses (use as retouchers) and made it possible to rule out others (e.g., the hypothesis, proposed by Martin (1907a), of a use of bones at impressions as support to sharp wooden points, tested and invalidated by Tartar (2002).

2.4 Technology vs Functionality

The concept of 'bone cultures,' which suggested that certain prehistoric societies relied heavily on bone tools, emerged in the early twentieth century. Some have also claimed that this bone tools were prior to the stone tool, and that like the latter it could define ‘cultures’ – or ‘bone cultures’ (Vincent 1993). In 1907, E. Pittard published, following the ‘notched bones[8]’ of the Rebières, a series of Mousterian ‘worked bones’ from the same site: fragments of diaphysis that he described as points and on which he sometimes observes retouching, as well as fragments with their epiphysis, having served, according to the author, as punches or wedges

German prehistorians like E. Bächler described bone tools in the 'Alpine Palaeolithic,'[9] arguing for a distinct 'bone age' that preceded the 'stone age' (Bächler 1906, 1909). They argued that Bone tools make up for a very poor lithic industry but, they are diverse – the mandibles can serve as a hoe or a scraper, the acetabular cavities can be used as containers– and often have a polished surface (Bächler 1906, 1909, 1912, 1940, cited in Vincent 1993 and Fosse 1999). O. Menghin (1931) further testifies E. Bächler’s point of view that a ‘bone age’ preceded the ‘stone age’. He thus affirms that in the ‘Protolithic’ (*i.e.,* in the Lower Palaeolithic and Middle, the Upper Palaeolithic being, according to the chronology established by O. Menghin, the ‘Miolithic’) Eurasia and Africa were divided into territories that could be grouped into three major cultural areas: the culture of blades, the culture of bifaces, and finally the culture of the bone (‘Knochenkultur’), who initially did not know stone tools and who deployed in the Alps and, to a lesser extent, in Eastern Europe and Siberia (Menghin 1931).

Ancient human’s ability to substitute raw materials were first proposed by Abbé Breuil, who postulates that the reasons prevailed over stone tools, perhaps due to a lack of quality lithic raw materials in certain regions (Breuil 1938). He therefore defends the existence of bone tools in the Lower Palaeolithic, in Europe, and in China, and describes in particular the ‘industry’ of Zhoukoudian (China) where the ‘Sinanthropes’ used variety of taxa and variety of skeletal parts used as various tools: thus, the scapulae served as shovels, the

[8] *ossements entaillés*
[9] See Badino *et al.* (2020) for an overview of Alpine and Mediterranean palaeogeography.

distal extremities of the radius and of tibia were used as beakers, long bone flakes were shaped by retouching and used parallel to lithic tools (Breuil 1939, cited in Fosse 1999).

However, these theories faced significant opposition, with critics like Koby and Pei demonstrating that many alleged bone tools were likely the result of natural processes rather than human manufacture (Koby 1943; Pei 1938). In particular, Koby (1943) deconstructs the 'Alpine Palaeolithic' polished tool existence, citing cave bear actions in the caves[10]. W.C. Pei largely refutes H. Breuil's allegations about bone tools from Zhoukoudian; in order to answer the question '*How to recognise the action human on a bone debris*? (Pei 1938, quoted in Binford 1981), he describes the modifications produced on the bones by animals (rodents, carnivores) as well as agents inanimate and thus shows that most of the tools of Zhoukoudian do not actually bear any traces of anthropogenic modification (See also Shen *et al.* 2016). Mozota Holgueras (2012), in contrast, argues that the primary definition of a tool should be based on its function rather than typological criteria. However, it is acknowledged that *'the concept of function [remains] more than hypothetical'* (Patou-Mathis 1999: 50): objects shaped from bone often show signs of use and/or shaping, yet their specific function may not be clearly discernible. Furthermore, a tool may not have been intentionally manufactured by shaping a bone or bone fragment. Instead, the tool's use can be identified by the marks left on it (Johnson *et al*. 2000). Conversely, a shaped tool may not have been used at all (Backwell and d'Errico 2004).

2.5 Dart's *Osteodontokeratic* Culture and its legacy

Despite scepticism from scholars like Koby, Pei, and others regarding the existence of bone tools, Raymond Arthur Dart staunchly defended the concept of the *'osteodontokeratic culture'* in his research (Dart 1956). Dart argued that *Australopithecines* used bone, teeth, and antlers as tools, proposing that these materials played a crucial role in early human toolmaking (Dart 1956). Thus, Dart's ideas influenced subsequent research and expanded the understanding of early tool use beyond Europe. Dart's research based on faunal remains recovered from the Makapansgat cave in South Africa, as well as from other sites such as Sterkfontein and Taung. He proposed that Australopithecines collected hard animal materials, including bone, teeth, and antlers, from food waste they manufactured tools. Dart observed that these tools were manufactured from whole or fractured bones using repetitive techniques, and even used teeth still attached to mandibles.

[10] But in their publications, Koby (1943) and Fosse (1999) acknowledges the displacement of bones caused by trampling by the bears in the caves.

He thus put forward the notion that this diverse array of materials represented a rich assortment of tools, challenging prevailing doubts about the sophistication of early toolmaking practices (Dart 1957). He vehemently refutes the notion of bone accumulation resulting from carnivore activity, arguing instead that the South African Australopithecines were adept hunters. He posits that carnivores do not accumulate bones in such abundance, a viewpoint he articulated prominently in his influential article, *'The Myth of Bone-Accumulating Hyena*,' published in 1956. His assistant, Alun Hughes, also challenged the idea that hyenas were responsible for these taphonomic patterns after extensive fieldwork in Kruger National Park, South Africa (Hughes 1954). Hughes observed that hyenas did not tend to gather bones inside their dens; instead, they consumed prey immediately after the kill or at open-air scavenging sites, showing little evidence of bone transport behaviour. Prior to Hughes's studies in Kruger National Park, there had been no connection between modern zoological research on hyenas and the palaeontological or paleoanthropological studies examining such behaviours. This concept extended beyond South Africa, with Dart suggesting its presence in Geula, Israel (Dart 1967, quoted in Binford, 1981) or through supporters–in Pin Hole (Great Britain) (Kitching 1963, quoted in Fosse, 1999) or in India (Ghosh 1974).

However, Dart's primary critic was Washburn (Washburn 1957, 1959; Washburn & Howell 1960; Washburn & Lancaster 1968) who conducted fieldwork in Zimbabwe. Washburn observed that after large predators, such as lions, brought down prey, smaller carnivores often engaged in disarticulation. In some cases, carnivores selectively transported parts of the prey, resulting in skeletal patterns similar to those Dart identified in the Member 3 bone assemblages from Makapansgat (see also Maguire *et al.* 1980).

Despite this, Dart continued to advocate for the concept of the *osteodontokeratic* culture (Dart, 1957, 1957, 1958b, 1958a, 1959b, 1959a, 1960), with the help of Wolberg, who insisted *'applicability of modern or ancient analogies must be rigorously questioned, for the palaeoecology of the australopithecine situation is in many respects but little understood'* (Dart & Wolberg 1971; Wolberg 1970). Despite his '*over-emphatic style of writing'* (as quoted by many authors), Dart had rigorously examined and consulted the taphonomy and other accumulations that might be responsible (Dart 1956, 1985a). However, Dart's theories faced increasing scrutiny by the late 1950s, with scholars like von Koenigswald (1953), Oakley (1954a, b) and Brain (1958), questioning his rationale. Robinson (1954, 1960) sided on the fact that Dart's evidence *'does seem to show, tool-users but not toolmakers'*

Dart's challenge to the idea that hyenas collect bones was quickly overturned, as extensive research has since shown that hyenas do indeed accumulate bones in caves that serve as their dens. The advent and growing importance of taphonomic and palaeozoological research in these areas have now firmly established that hyenid species transport and gather bone material in cave systems they use as dens, leading to the formation of fossil assemblages (Maguire *et al.* 1980; Kuhn *et al.* 2010).

2.6 The Scepticism began

By the 1970s, the study of bone tools had become more integrated into the broader investigation of lithic industries. However, these discoveries did not lead to the establishment of distinct 'bone cultures'; instead, the bone material was integrated into the already well-established cultures of the Lower and Middle Palaeolithic. While bone tools were recognised at sites like Pié-Lombard and Bilzingsleben, they were often studied within the context of existing Palaeolithic cultures rather than as distinct 'bone cultures' (Texier 1974a; Bonifay 1974).

In cave 1 of the Mas des Caves in Lunel-Viel, within archaeological contexts dated to the Mindel-Riss interglacial, Bonifay (1974) identified these removals as likely resulting from longitudinal pressure applied at the ends of a number of bone tools. However, there is a risk of confusion with 'pseudo-tools' due to natural phenomena (Bonifay 1974: 159). The author suggests that these removals are likely the result of longitudinal pressure exerted at the end of the bone fragment, indicating a usage analogous to lithic tool's negative removals. Casting doubts on Bonifay (1974), Fosse (1996) described the Cave 1 at Lunel-Viel, as being a hyena den[11]. Further doubts continue to arise, there were clues indicate that the Hyena would have occupied the cave and accumulated and fractured bone remains, long bones that have preserved part of the diaphysis are relatively abundant, teeth marks are very common, as are traces of digestion, coprolites are frequent, also are Hyena deciduous teeth (See also Blumenschine & Selvaggio 1991).

Moreover, Vincent (1993) in his study in Bois-Roche noted many fragments are bearing a pseudo 'percussion marks' attributable to carnivores but maintained that some fragments had been shaped by prehistoric man. The study by Villa and Bartram (1996) argues in favour of attributing all negative removals to the Hyena. The bone modifications identified by Vincent (1993) at Bois-Roche and Pech de l'Azé II were directly re-evaluated by d'Errico and Villa (1997) who considered them to be modifications caused by natural agents, carnivores (punctures with edges polished by gastric juices); the same hypothesis is proposed for the Kulna specimen by authors.

At Bilzingsleben, a Middle Pleistocene open-air site located in northern Thuringia, Germany, bone tools, often manufactured from the remains of large elephants, and associated with *Homo erectus*, have been reported since the 1970s (Mania 1975). Over subsequent decades, a series of publications by D. and U.

[11] Bois-Roche has also been interpreted as a Hyena den; according to Villa and Bartram (1996), the cave was not occupied by man in the Middle Palaeolithic, nor later, due to the low ceiling height (between 20 and 70 cm before excavation); there is no hearth, a single bone remains bears a cutmark, and the lithic industry is very rare and would have brought into the cave from the outside.

Mania (Mania 1975, 1995; Mania & Mania 2005) have provided further insights into these tools, detailing the *chaine operatoire*—the sequence of steps involved in their production.

However, one of the most significant discoveries comes from Cueva Morín in Cantabria, Spain. In level 17 (Mousterian), Freeman, as noted by Gonzales Echegaray & Freeman in 1971, identified over 300 bone tools, mostly on diaphysis fragments, shaped by percussion[12], polished[13] or impressed[14]. According to the author, similar tools likely went unnoticed at other Mousterian sites.

From the 1980s many bone tools, notably 'bifaces', were reported in several Lower Paleolithic sites in the Roman region, mainly at Fontana Ranuccio (Biddittu & Serge 1982, 1984), Malagrotta (Cassoli *et al.* 1982) and Castel di Guido (Pitti & Radmilli 1984). Fontana Ranuccio, the oldest of these sites, was dated to approximately 458,000 years ago, yielded several dozen bone tools, primarily made from elephant bones (*Palaeoloxodon antiquus*), which outnumbered the lithic tools (Serge & Ascenzi 1984). Excavations at Malagrotta, dated around 250,000 years ago, have shed light to some tools on pachyderm[15] bones, including a biface. The Castel di Guido site (OIS 9) delivered over years the most abundant bone tools: the monograph of Radmilli and Boschian (1996) lists 373 tools, including 99 bifaces exclusively drawn from Elephant bones, presenting various stages of preparation (from the draft to the finished product) (See also Villa *et al* 2021).

A few very rare tools, but no bifaces, have also been reported at La Polledrara, Casal de' Pazzi and Torre in Pietra level m, still in the Rome area (Anzidei *et al.* 2001). In these three sites (Anzidei, 2001) as in Castel di Guido (Radmilli and Boschian, 1996) or at Fontana Ranuccio as we have seen above, the use of tools in bone is attributed to the scarcity of lithic raw materials. Radmilli and Boschian (1996) do not exclude, however, not the hypothesis of a 'cultural tradition' of the use of bone, at a certain time in the Lower Palaeolithic in the Roman region (Villa *et al.* 2021).

In Westphalia, Germany, the Rhede quarry yielded a biface manufactured from a mammoth femur fragment, described by Walker in 1999 as one of the most convincing examples of its kind. This artefact, discovered among hundreds of fluvial deposits and dated to around 80,000 years ago by Tromnau in 1983, was notable for its lack of associated lithic artefacts or anthropic traces on the bone material. Walker (1999) questioned whether such a convincing artefact could result from natural processes, given the ambiguous context of its discovery.

[12] *piezas talladas'*
[13] *piezas abrasionadas'*
[14] *piezas machadas'*
[15] Pachydermata: any of various nonruminant mammals (such as an elephant, a rhinoceros, or a hippopotamus) of a former group (Pachydermata) that have hooves or nails resembling hooves and usually thick skin.

Vincent's 1993 thesis on *'Bone tools in the Middle Palaeolithic'*[16], contributed further to the understanding of bone assemblages from various chronologies. Vincent identified bones shaped by percussion, which he referred to as *'pieces with altered surfaces*,' characterised by successive retouching along one or both edges. These artefacts, often produced from diaphysis fragments about one centimetre thick and at least five centimetres long, were among the more remarkable examples cited in subsequent research (Mozota Holgueras 2014a; Romandini *et al.* 2015) Vincent also highlighted the use of wear techniques such as perforation, cutting, and abrasion[17] during the Middle Palaeolithic. Perforations were identified on diaphysis fragments from Pech de l'Azé II and BoisÿRoche (Dordogne) (Knecht 1993), and Kulna (Czech Republic) (Neruda & Lázničková-Galetová 2018). It should also point out that a fragment of stag rib from layer 3 of the Abri des Canalettes (Aveyron) presents '*a polish at one end (with an unnatural rounding). There is no setting form, this aspect would result from wear*' (Patou-Mathis 2002: 219). She proposes the hypothesis of use as a *lissoir*, pending the results of 'a study under the scanning electron microscope (SEM)[18] in progress', of which unfortunately did not find any trace.

The Vaufrey cave is also a part of a broader context of 'points', 'spears', made from bone or ivory, reported throughout the twentieth century in a Lower or Middle Palaeolithic context (Villa & d'Errico 2001). Most often, only one or a few specimens of spears exceptions are the sites of Torralba and Ambrona (Castile and León, Spain) and Salzgitter-Lebenstedt (Basse-Saxe, Germany), several dozen points have been found (Howell 1966; Howell & Freeman 1983; Villa & d'Errico 2001).

In the open-air site of Salzgitter-Lebenstedt, Gaudzinski documents in context 1 and 2 (dated between 55,000 and 48,000 BP) 23 Mammoth ribs and fibulas (*Mammuthus primigenius*) which have been thinned and sharpened by polishing and abrasion, as well as a point on a long bone fragment of Mammoth or Rhinoceros along with two ribs which have been intentionally split longitudinally (Gaudzinski 1999a). Although the function of these objects remains unknown, the author emphasises the uniqueness of this assemblage. Finally, three sites in Katanda (upper Semliki Valley, Zarie) yielded several bone tools: three 'non-barbered' points, eight barbed points and a dagger, dated around 80,000- 90,000 years ago, therefore, associated with anatomically modern humans (Yellen *et al.* 1995).

[16] The work of A. Vincent focuses on collections from different archaeological levels of Hauteroche, Boisÿ Roche, La Quina (Charente), Combe Grenal, Vaufrey (Dordogne) and Kulna (Moravia, Czech Republic) (attributed to different facies of Mousterian, Micoquian and to the Taubachian), to which are occasionally added a few pieces from other sites.

[17] perforation, sciage et abrasion (in French).

[18] Quote: '*Most of these objects have been published without a validating microscopic analysis of the bone surfaces to show possible traces of manufacture and use. This kind of documentation is necessary because we know that natural processes can produce pseudo bone points similar to those attributed to humans'* (Villa & d'Errico 2001).

Turning into African continent, Olduvai in Tanzania, beds I and II, dating between 1 to 2 million years ago, Mary Leakey identified over 125 bone and tooth specimens linked to *Homo habilis.* These specimens were either manufactured by percussion or recognised by traces of wear, as documented by Leakey in 1971, and further supported by research from Backwell & d'Errico in 2005 and 2008. In 1980s, Shipman revised the number of bone tools found at Olduvai Bed I and II (Potts & Shipman 1981a; b; Lewin 1984; Shipman 1989), and after by Backwell and d'Errico in 2000's (Backwell & d'Errico 2001a, 2005). Based on small number of bone tools known from the ESA site of Olduvai Gorge, Tanzania (Pante *et al.* 2020), confirmed a set of tools include the oldest preform of a barbed bone point from at least 700 kyr, probably attached to *Homo erectus*.

At Boxgrove (Sussex, England), one of the most important paleontological deposits of the Lower Pleistocene in Europe, the presence of Man is attested by numerous Acheulean bifaces made of local flint found in sedimentary deposits dated between 524,000 and 420,000 years ago (MIS 13 and 12), especially a tibia attributed to *Homo heidelbergensis* was also exhumed. In the monograph on the Boxgrove site by Parfitt & Roberts (1999) and Wenban-Smith (1999) are convinced of the use of retouchers in the shaping of certain bifaces: certain types of retouches observed on the lithic tools have not could be experimentally reproduced only with bone hammers. This certainty has been confirmed by the discovery of several Cervidae bone and antler fragments bearing the traces of use as a percussor (Smith 2013).

In Africa, a few MSA retouchers have been reported; Blombos cave, South Africa (d'Errico & Henshilwood 2007), several in El Hahroura 2 (Morocco) (Campmas 2012). Two complete bones of a Giraffe talus and an Elephant patella, from the same archaeological context as Olduvai's percussion-shaped tools, also bear impressions which could result from the use of these bones as retouchers (Backwell & d'Errico 2005). They would, therefore, testify to a very ancient use of bone as a hammerstone.

2.7 The Birth of African Cave Taphonomy

The detailed study of animal bones recovered from archaeological sites has resulted in the recognition of roughly formed bone objects that are believed to represent tools. Many scholars have published a wealth of knowledge (Binford 1981; Blumenschine & Selvaggio 1991a; Fisher 1995; Auguste 2002; Giacobini & Patou-Mathis 2002; Malerba & Giacobini 2002; Lyman 2014) in distinguishing the modifications resulting from hominid activity on modified bones as opposed to those marks left by carnivores and other natural agents. Many of these criteria employed to identify bone tools have been questioned (Binford 1981) and the literature contains assertions and rebuttals concerning the validity of particular identifications of bone tools (Guthrie 1980, 1981; Bonnichsen 1981). Particularly, Binford thoroughly questioned many of the traces of manufacture and use-wear modification mentioned in published literature (e.g., Johnson 1978, 1980, 1982; Bonnichsen & Young 1980; Frison 1982; Wheat 1982).

While this discipline had precursors dating back to the nineteenth century, it gained significant momentum in the mid-twentieth century and reached a level of 'maturity' by the 1980s (Lyman 1984, 2014). One notable moment in the history of taphonomic studies occurred in 1981 with the publication of two influential works: *The Hunters or the Hunted? An Introduction to African Cave Taphonomy* by Brain, and *Bones: Ancient Men and Modern Myths* by Binford. Binford's work was particularly significant as it challenged many of the assumptions surrounding the recognition of bone tools, especially those attributed to hominid activity before the Upper Palaeolithic. He emphasised the need to differentiate between marks made by natural agents and those made by humans, drawing on observations from remains consumed by dogs and wolves in Alaska (Binford 1978). His methodological shift led to widespread scepticism regarding the identification of bone tools from the Lower or Middle Palaeolithic.

The concept of 'taphonomy' is introduced by palaeontologist I.A. Efremov, following the principle of 'biostratinomy' put forward by German palaeontologist Weigelt (1927) refers to the study of the burial of animal remains, their transformation from the biosphere to the lithosphere[19] (Efremov 1940). This field of study uses an actualist approach, which involves observing present-day situations to explain archaeological or paleontological contexts (Chaix & Meniel 1996; Reitz & Wing 2008; Gifford-Gonzalez 2018:62). By integrating ethology (animal behaviour studies), ethnology (human behaviour studies) and archaeological experiments, archaeologists were able to construct hypotheses about the various processes causing bone damage, which was frequently seen in any given archaeological assemblage. These actualistic studies has proven effective in various given archaeological contexts (e.g. Martin 1910; Breuil 1938; Leroi-Gourhan 1952; Dart 1957; Poplin 1973; Blumenschein 1988; Oliver 1989; Anconetani 1999; Pickering & Egeland 2006; Galán *et al.* 2009; Blasco *et al.* 2013, 2014; Njau & Gilbert 2016; Moclán and Domínguez-Rodrigo 2018; Parkinson 2018).

Brain (1981) demonstrated that the accumulation of bone remains in South African caves, including Sterkfontein, Swartkrans, and Kromdraai, as well as Makapansgat and Taung, is primarily attributed to carnivores rather than hominids. His study of current South African carnivores, including hyenas and leopards, revealed a pattern of selective consumption of specific parts of the prey's skeleton, which explained the presence of certain skeletal remains[20] in these caves (Brain 1969). This led Brain to conclude

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[19] Definition of taphonomy by I.A. Efremov (1940:85): '*the study of the transformation of animal remains from the biosphere into the lithosphere, i.e., the study of the process in the upshot of which the organisms pass out of the different part of the biosphere and, being fossilised, become part of the lithosphere'*.

[20] such as the frequent presence of distal ends of humeri while proximal ends were rare.

that Australopithecines were not responsible for the accumulation of remains in South African caves, thus refuting the notion of an '*osteodontokeratic* culture' (Brain 1967, 1981a). Thus, the debate continues.

Binford's scepticism towards bone tools extended to his critique of the so-called *'Binford syndrome*,' a phenomenon of exaggerated doubt regarding the identification of bone tools prior to the Upper Palaeolithic. Binford drew upon his own observations, particularly from remains consumed by dogs and wolves in Alaska (Binford 1978). He emphasised the risk of conflating natural modifications with anthropogenic ones and urged readers to consider multiple hypotheses when interpreting archaeological contexts, rather than hastily embracing *'modern myths'.* Binford (1981), attributed many of these myths to the purported use of bone tools before the Upper Palaeolithic in Europe, a notion he refuted. For instance, he noted that out of 134 specimens from the Middle Palaeolithic site of Combe Grenal in Dordogne, none exhibited marks of use but instead bore carnivore teeth marks such as 'pitting' and 'scoring'. In the last chapter of his seminal book (1981) Binford claims that '*my analysis will represent the application of a methodology developed from control information obtained in actualistic studies*[21]'.

For instance, in response to an article by White *et al.* (1982), Binford suggested that the objects from Cueva Morín level 17, which were identified as bone tools, were likely the result of carnivore consumption. Freeman (1983) later pointed out that the pseudo-tools presented by Binford were all made from reindeer-sized animal bones[22], whereas the bones from Cueva Morín were from larger animals, leading Freeman to question the applicability of Binford's conclusions. According to Vincent (1988), Binford's work sparked a phenomenon of exaggerated scepticism, termed the *'Binford syndrome*,' regarding any potential bone tools prior to the Upper Palaeolithic. In fact, Freeman (1983) questioned the methodological shift advocated by Binford, suggesting it might simply represent an inflexible opposition to 'modern myths: '*he [Binford] has really just substituted one oversimple interpretation for another. Not surprisingly, that seems to have escaped most of his readers. The substitution is masked by misdirecting our attention with polemic to attract the reader to the prospect of a good fight, and it is disguised by complex logistics and impressive seeming mathematical manipulation.*' After having noted various biases and errors in the work *Bones: Ancient Men and Modern Myths*, Freeman harshly criticises him: '*After walking through his [Binford's] tables to the extent possible, I am convinced that using Binford's procedures one ought to be able to 'prove' that any assemblage is a carnivore accumulation.*'

[21] Binford (1981:253) In other words, he will use his ethnoarchaeological work to help determine which process gave rise to which pattern in the archaeological record. Binford develops a series of propositions from his Nunamiut material, thereby predicting the static results of certain dynamics (See Johnson 1999 for theoretical debate).

[22] The studies subsequent faunal materials from Cueva Morín level 17 reports the absence of tools shaped by percussion, but clearly confirm the presence of retouchers (Martínez-Moreno *et al.* 2010; Yravedra *et al*. 2011; Yravedra & Gómez-Castanedo 2014; González *et al.* 2023).

Thus, Binford's work catalysed an increased and widespread attitude of scepticism in the 1980s-1990s towards most of the bone tools identified in Lower or Middle Palaeolithic contexts.

2.8 Bone marrow extraction vs bone tool manufacture

The recognition of Palaeolithic marrow extraction and bone tool making reflects a deep understanding of early human survival strategies. Since the beginning of the twentieth century there have been numerous studies to comprehend the rationale behind the bone splinters in the prehistoric faunal assemblages (Martin 1910; Black *et al.* 1933; Breuil 1938; Pei 1938; Breuil & Boyle 1939), coupled with some experimental archaeological studies. Thus, two explanations/ hypotheses were formulated regarding the existence of these bone breakage: *bone marrow extraction and bone tool making* (Martin 1910; Breuil 1938; Pei 1938; Dart 1957, 1960; Poplin 1973, 1978; Dauvois 1974; Noe-Nygaard 1977; Bonnichsen 1979; Morlan 1979, 1980). Bones used for marrow extraction often show cut marks or fractures focused to reach the nutrient-rich marrow inside, typically with limited reshaping of the bone itself. In contrast, bone tool making involves intentional shaping, smoothing, or notching of the bones to create specific tools, with evidence of more precise and repetitive modifications reflecting craftsmanship. But the challenge, however, lies in the fact that in earlier periods of human evolution these technological modifications were only shed light after meticulous examination of various factors. The more you go down in the chronology, more difficult it becomes to identify/ explain these technological modifications.

Who were the accumulators?

Drawing upon ethological and ethnological studies and experiments, researchers were able to provide a clue of who were responsible for these long breakage patterns. While some rooted for carnivores (*i.e.,* spinal fractures) (Washburn 1957; Miller 1975; Hill 1976; Bonnichsen 1979; Binford 1981; Brain 1981; Haynes 1982; Haynes and Stanford 1984; Gonzales 1991), actualistic research pointed out that both carnivores and human can be responsible for such accumulations. This has led to the notion that both humans and carnivores could have occupied the same sites, possibly at different times. Carnivores might have fed on human leftovers, and humans could have scavenged from carnivores, with both potentially contributing to the transport and accumulation of bones, leading to mixed bone deposits (e.g. Potts & Shipman 1981; Brain 1981; Blumenschine 1986; Bunn *et al.* 1986; Hill 1989; Cavallo & Blumenschine 1989; Blumenschine & Selvaggio 1991; Bunn 1991; Marean *et al.* 1992; Blumenschine & Marean 1993; Selvaggio 1994; Capaldo 1995, 1997; Blumenschine *et al.* 1996).

Meanwhile, Binford (1978, 1981) emphasised marrow extraction breakage patterns among the Nunamiut in Alaska, depending on number of factors. He made an interesting observation that actors, deliberately chose the position of the blow, focusing on most fragile areas of the bone. This has led Binford (1984) to theorise scavenging behaviours, drawing upon strong ethnographic observations.

In addition, some researchers have found that the environmental context may also be responsible for bone fragmentation as temperatures and humidity. Myers *et al.* (1980) and then Behrensmeyer *et al.* (1989) also proven that trampling by ungulates can cause breakage features. As a result, researchers were able to build up a standard criteria to distinguish between contemporary factors (i.e. green bone) and post-depositional factors (i.e., dry bone) (See also Haynes 1983; Morlan 1984; Johnson 1985). Resulting a culmination, Villa and Mahieu (1991) established a solid theorised basis for differentiate between those factures: paying attention to outline, edge texture and angle and long bone shaft length and circumference. Following this, Outram (1999, 2001, 2002) combined these criteria proposing the Fracture Freshness Index (FFI) more efficient to categorise the breakage temporality. Herein now it is established that hominins, carnivores or other environmental factors were able to create similar green bone spiral fractures.

Building upon ethnological observations, several research have reported a specific pattern that contemporary hunter-gatherers extract the marrow, thus producing a consistent breakage pattern (Binford 1978; Enloe 1993; Abe 2005; Costamagno & David 2009). Indeed, some groups may systematically hit each bones element at a same location. Thus, the percussion marks distribution could design specific patterns to break bones. Therefore, zooarchaeological analyses tested the presence of butchering traditions for Middle and Upper Palaeolithic periods based on the distribution of percussion marks on long bones (Vettesse *et al* 2020).

In summary, the study of bone tools in archaeology has been shaped by a long history of debate and scepticism. While many early identifications of bone tools have been questioned, and in some cases dismissed, the field has also seen the development of more rigorous methodologies that have helped clarify the origins of these objects. The contributions of scholars like Binford and Brain have been instrumental in advancing our understanding of taphonomy and the processes that shape the archaeological record, leading to a more nuanced interpretation of bone modifications and the activities of early humans.

2.9 Changing the approach

Recognition of the use of bone materials in the Lower and Middle Palaeolithic has therefore been much less obvious than for the Upper Palaeolithic. This is mainly due to the fact that these tools are essentially *posteriori* or shaped by percussion. Retouchers, the first bone tools identified in a pre-Upper Palaeolithic context, are the most representative tool type, at least quantitatively, for the Lower Palaeolithic and even more so for the Middle Palaeolithic. Far from recognition of the use of bone materials was not a gradual process, especially in the first half of the twentieth century, from the excesses of identifying ‘tools’, often frequent in prehistoric contexts, without taking sufficient precautions to ensure the anthropic origin of the modifications observed. In fact, most of these tools turned out to be 'pseudo-tools' when considered more rigorously, under the impetus of the taphonomical discipline. As a result, past excesses were severely censored in the last decades of the twentieth century. The opposite excess, that of a scepticism on principle to bone tools from before the Upper Palaeolithic, has sometimes been encountered. Today, thanks to rigorous research methodology, a certain balance seems to have been achieved.

Now the recognition of these tools systematically involves the cross-referencing of taphonomical data with technological data, the hypotheses formulated tend to get tested more often through experimentation, in an approach that Backwell and d'Errico (2001) define as 'an interdisciplinary approach[23]. In 2023, Martellotta proposes a new approach to the use-wear study of bone retouchers through the application of 3D imaging microscopy. She suggests[24] rethinking their definition as expedient tools through deeper use-wear analyses.

Microwear studies have accompanied bone retouchers since their first identification in the archaeological record (Semenov 1964; Vincent 1993; Auguste 2002; Tartar 2012a). In more recent years, there have been more in-depth investigations of the functional features of retouch-induced use-wear, and its variations based on the type of retouching activity and the retouched lithic tools. Some studies have used experimental archaeology to enrich our knowledge on identification and use-wear (Semenov 1964; Mourre 2003; Tartar 2012a; Mallye *et al.* 2012; Mozota Holgueras 2014b; Doyon *et al.* 2019; Vettese & Daujeard 2021). Some other research has offered insights into bone retouchers' functionality based on their morphology and relationship to their archaeological context (Baumann *et al.* 2020; Martellotta *et al.* 2020; Alonso-García *et al.* 2020). Here, innovative technologies have been used to study retouch-induced use-wear, such as SEM (Mallye *et al.* 2012; Blasco *et al.* 2013b; Abrams *et al.* 2014; Daujeard *et al.* 2014; Van Kolfschoten *et al.* 2015; Moigne *et al.* 2016), computerised tomography (CT) (Neruda & Lázničková-Galetová 2018), and geometric morphometrics (GM) (Kolobova *et al.* 2020a)[25].

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[23] In order to distinguish between pseudo tools and true tools, it is necessary to adopt an interdisciplinary approach, combining taphonomic analysis of the associated fossil assemblages, microscopic studies of possible traces of manufacture and use, and the experimental replication of the purported tools (Backwell & d'Errico 2001a).

[24] Martellotta (2023:34) argues microwear studies is *a practice usually carried out by zooarchaeologists, who are not trained in reading technical or functional features of artefacts, focuses on rough descriptions of use-wear to distinguish bone retouchers from the rest of the faunal assemblage*, which hinders the full potentiality in recognising bone retouchers.

[25] Martellotta (2023:35) argues, '*getting access to some of this equipment is not always an option. Indeed, a certain amount of training is required to acquire proper technical knowledge, although more user-friendly technologies have been recently proposed (e.g., Desktop SEMs). Moreover, the interpretation and handling of raw data can be highly time-consuming because such methods have not been specifically designed for the study of bone tools. This issue results in the recurring choice to apply these technologies only to specialised technological studies, whereas the identification phase remains part of the taphonomic study of faunal assemblages.*

For the Middle Palaeolithic, in addition to the retouchers mentioned above, a few a *posteriori* tools have been reported at Axlor dated to final Middle Palaeolithic (Mozota Holdueras 2012). He documents two specimens in Axlor, levels N and C respectively, which he calls '*ciseaux*'. They are, on the one hand, negative removals, some visible to the naked eye and the rest under the microscope, and also presence of some, 'microstriae', parallel to each other and oriented according to the gestures of the tool during use[26] (Burke & d'Errico 2008).

Other Axlor[27] bone carry the traces of use. A diaphysis fragment from level N shows small negative removals on one edge; observed under the microscope, the edge reveals a polish and fine short striations, present only on the thread and which could result from use on bone or vegetable wood.

The site Marathousa 1 (MAR-1), Megalopolis, Greece yields bones, including those of elephants, show clear anthropogenic flaking scars, cut-marks and fracture patterns indicating deliberate breakage and modification by early humans. And then they briefly present a small sample of bone artefacts, which suggest that hominin exploitation of the animal carcasses was not restricted to marrow extraction and bone processing for nutritional needs, but also included the knapping of bones, potentially with the aim of using the knapped products as tools (Tourloukis *et al*. 2018). The assemblage includes diaphysis fragment of probably from an elephant, clustered with notable features such as percussion marks, utilised edge and cut marks, this specimen is interpreted presumably as a bone percussor (cf. von Kolfschhoten et al. 2015; Moigne et al. 2016) and a soft hammer (See Daujeard *et al.* 2014 for a similar synthesis).

A few tools shaped by percussion have recently been reported in contexts dated to the final Middle Palaeolithic: at Axlor, level N (Mozota Holgueras 2012), and at Fumane (Veneto, Italy), level A5+A6 (Romandini *et al.* 2015). In their study of the Fumane specimen, a 'scraper' on a fragment of a Deer radius diaphysis, Romandini and colleagues note the lack of clear criteria for identifying bone shaping by percussion[28].

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[26] He notes a certain resemblance with Aurignacian rough intermediate tools, as well as with the Middle Palaeolithic 'wedge' from Karabi Tamchin (Crimea, Ukraine), level III (MIS 3) (Burke & d'Errico 2008).

[27] Axlor is a prehistoric archaeological site in the village of Dima in Biscay in the Autonomous Basque Community of Spain, dating from the Middle Palaeolithic or Mousterian period.

[28] Romandini *et al.* 2015: *To date, criteria for identifying technological retouches on bones have never been made fully explicit. The interpretation of anthropic retouched bones has mainly followed the same criteria used in stone knapping. Diagnosis and identification of anthropic retouch has mostly been based on the occurrence of invasive removals with classic attributes of percussion flaking. The repetition and uniformity of the blows (with percussion bulb scars) as well as the regular outline of the retouched sides have also been considered as important markers of technological retouch. In particular, the regular pattern of symmetric detachments excludes the activity of carnivores and/or butchery marks produced while fracturing bone for recovering marrow. While few modified bones have been interpreted as tools on the basis of experimental data related to the use of percussion techniques (Vincent, 1988,*

The study of the Fumane scraper, proposed by the authors as a methodological basis for understanding other presumed bone tools modified by percussion, also calls for an interdisciplinary approach. This combines a taphonomical study (at Fumane level A5+A6, low Carnivore impact, high frequency of cutmarks, burnt bones, intense bone fracturing) and an experimental program, which includes fracturing Deer radius to extract the marrow, recovering supports likely to be shaped by percussion, shaping them and finally using these experimental 'scrapers' on different materials. Furthermore, retouchers from Fumane studied in a novel approach by Martellotta and colleagues (2020) is being evidently the first assessment on the spatial correlation of the bone and stone tools, in addition to technological and techno-functional analysis of both lithic and bone tool assemblages. The authors exclusively observed a relationship between the shape of the retoucher, the morphology of the retouched edge and the categories of traces of use (cf. Neruda 2017).

Finally, four fragments of *lissoirs* from Mousterian layers, yielding wear techniques according to the authors, have also been recently published (Soressi *et al.* 2013). Three of them come from Abri Peyrony, layer 3, dated (^{14}C) to between around 48,000 and 41,000 cal BP, and the fourth from Pech de l'Azé I, layer 4, dated (OSL) to 51,400 +/- 2,000 years ago[29]. Out of four fragments, one has retained its mesial part; of the other three, only the distal part has been preserved and shows a bending fracture on fresh bone, compatible with a 'smoother' type of use[30]. Microscopic observation and comparison with experimental smoothing tools reveal the traces of use, which could be the result of skin processing. Recently, in 2023, Orłowska and colleagues presents a Palaeolithic hammer made of Antler, found in Biśnik Cave in southern Poland. Trajectory to Polish Prehistory, the discovery bears the only tool of this type known from Palaeolithic period. Novelty by Mateo-Lomda *et al* (2024), a Neanderthal bone spear point has been identified through meticulous combination of taphonomical, functional, tracelogical and 3D scan of the specimen, demonstrating its use as a spear.

In South Africa, the same interdisciplinary approach made it possible to specify the use of bone tools and a few diaphyseal fragments at Swartkrans, Drimolen and Sterkfontein, in levels Sterkfontein, in levels dated at 1.8-1 Ma, 2-1.5 Ma and 1.7-1.4 Ma respectively (Brain & Shipman 1993a; d'Errico *et al.* 2001; Backwell & d'Errico 2001b). Their conclusion was that these tools had been used for hiding working or as or as digging sticks. d'Errico and colleagues (d'Errico *et al.* 2001; Backwell & d'Errico 2001b), following further experimentation and a detailed study of the width and orientation of the microscopic striations, propose a

1993), the results are not always convincing when bone assemblage formation processes are taken into consideration (Villa & Bartram 1996).

[29] At both sites, there are no Upper Palaeolithic levels above the Mousterian layers, and the impact of carnivores on both bone assemblages is scarce.
[30] For better synthesis on experimental activities and traceological analyses on this ground see Orłowska *et al.* 2022.

new interpretation: *the tools would have been used to dig inside termite mounds*[31], whose very fine sediment leaves clearly recognisable on the bones. In a later study, d'Errico and Backwell (2003) hypothesised that the active part of four Swartkrans tools were created shaping by abrasion.

The South African MSA reveals an increasingly diverse range of bone tools at Blombos Cave, Sibudu Cave and a number of other sites (Henshilwood *et al.* 2001; d'Errico & Henshilwood 2007; d'Errico *et al.* 2012b). Numerous bone points on diaphysis fragments or bones with a naturally pointed shape have been unearthed; they were entirely or largely shaped by wear techniques (abrasion, polishing) and sometimes also by percussion (development of the basal part of the point) (Henshilwood *et al.* 2001). The aforementioned Blombos cave retoucher, on a Bovide long bone fragment, is also remarkable for its series of continuous negative removals on the cortical face of one end, evoking a scraper face; the hypothesis of a percussion-modified tool is supported by the presence of a slight polish only on the presumed 'active part'[32] (d'Errico & Henshilwood 2007). In addition to points and related tools, such as *lissoirs* and *esquillés*, have also been documented (d'Errico *et al.* 2012b)[33].

Finally, it is worthy to note that the North African MSA may have yielded similar tools. In his thesis, Campmas (2012) notes the presence in the bone assemblage of El Mnasra (Morocco), layers 5 and 6 involves rib fragments bearing traces of abrasion which could potentially be traces of manufacture or use; the author suggests that these objects were used as smoothers. However, unlike south African MSA tools, the El Mnasra[34] objects are currently awaiting microscopic examination. In 2023, Stammers and colleagues (2023) presents 124 potential bone tolls from the 2.04–1.95 Ma early hominin-bearing Drimolen Main Quarry palaeocave deposits in South Africa. The specimens were subjected to comparative analysis of fossil and bone collections with known taphonomical accumulator/s, actualistic experiments, and comparative analysis relative to published data in taphonomical literature. Thus, they identified 51 specimens as bone tools, which were made of diaphyseal fragments as the most common raw material selected for tool use. They also suggest a multi-use application depending on striation patterns, identified through visual comparisons.

[31] Also evidenced from higher primates (Goodall 1964, 1986; Roffman *et al.* 2012; Doran *et al.* 2002; Haslam 2014)
[32] One end is modified by continuous scaled removals that created a morphology similar to that of an end-scraper. Microscopic analysis of these removals reveals a light smoothing of the protrusions that can be attributed to use-wear, particularly as the rest of the object is so well-preserved.
[33] See also Bradfield 2016; Bradfield et al. 2020.
[34] Similar bone tools have found from north Africa (See Bouzouggar *et al*. 2007, 2018; Hallett *et al.* 2021)

Particularly to Asia, Palaeolithic bone industry have been identified in Denisova Cave[35] in Altai mountains. Among more than ten thousand bone fragments, 51 specimens were selected based on taphonomical, technical, and utilisation traces. On the basis of location of use-wear traces that varied according to function, unshaped bone tools such as retouchers, awls, intermediate tools, and knives were revealed for the first time in Denisova Cave. The results of the morphological and use-wear analysis suggest that those tools were used for processing organic materials such as leather, plant fibres, and wood (Kozlikin *et al.* 2020a). Out from the discussed context, in India, described techno-functional analysis of two perforated bone artefacts recovered from Indor Khera and Rohana Khurd, North India, dated to c. sixth-second century BCE and fourth century BCE, is worth mentioning (Vinayak 2023). The credit of being the oldest known evidence of indisputable barbed point manufacture outside Africa goes to China, where a cave in southern China, Ma'anshan Cave, conceded 17 bone tools as a result of techno-functional analysis. Stratum 6 dated back to 35 ybp has yielded three sharp awls, whereas stratum 5 comes with six probable spear points, awls and a cutting tool. The authors have also observed a change in their toolkit which may indicate a shift in prey preference from medium to small sized mammals and fish, requires further verification (Zhang *et al.* 2016)[36]. Getting more ancient, Doyon and colleagues (2018), report the discovery of seven bone soft hammers at the early hominin Lingjing site (Xuchang County, Henan) dated to 125,000–105,000. This discovery provides a new dimension to the debate surrounding the existence of the Middle Palaeolithic in the region.

In South Asia and Sri Lanka in particular, has yielded some of the earliest examples of such tools in the region, shedding light on the adaptive context of osseous technology during Late Pleistocene human dispersals beyond Africa (Perera *et al.* 2016). The authors detail 204 bone points excavated from archaeological layers dating back to 36,000 years BP. These findings have the potential to enrich the discourse on osseous technologies within the context of a specialised rainforest subsistence strategy. In 2020, Langley and colleagues interpreted the evidence for bow-and-arrow technology from 48 000 years BP in the wet zone of Sri Lanka, could be the oldest projectile technological toolkit outside the Africa. Three years later, a team of French scientists appeared with solid evidence of bow-and-arrow or spear-thrower-and-dart combinations, in Europe 54 000 Years BP, attributed to AMH which has been demonstrated via use-wear and impact damage analyses (Metz *et al.* 2023). In Southeast Asia, Ono and colleagues (2021) discusses the development of bone and lithic industries potentially caused by AMH in the Pleistocene and Holocene in Sulawesi and Wallacea. Interestingly, they insist that a significant shift of

[35] The site that is key for understanding a complex interaction between various groups of early humans and the middle to Upper Palaeolithic transition. The Initial Upper Palaeolithic layers of the cave yielded fossil remains of Denisovans, and the earliest ornaments and bone tools in north and central Asia.

[36] For a complete research history see Ma & Doyon (2021).

lithic technologies and the dramatic increase of retouched tools. Furthermore, use-wear analysis of bone and lithic materials resulted in some specific retouched stone tools that were likely used for the production of bone implements.

Similar to the scope of the present study, Baumann and colleagues (2023) presents retouchers, beveled tools, retouched artefacts and a smooth ended rib. This is despite the 1,200 bone tools at the Neanderthal site of Chagyrskaya (Altai, Siberia, Russia) (Baumann *et al.* 2020; Kolobova *et al.* 2022) and Abri Lartet, France (Baumann *et al.* 2022). Neanderthal bone industry will be discussed in length in the following chapter.

2.10 Zooming into Northern Italy

Particularly from Northern Italy, which is the loci of this thesis, have yielded bone retouchers among the archaeological contexts, to name few, Riparo Tagliente (Bertola *et al.* 1999), Grotta della Ghiacciaia (Hohenstein *et al.* 2018), Rio Secco cave (Peresani *et al.* 2014; Romandini *et al.* 2018a), Riparo Fumane (Jéquier *et al.* 2012, 2013, 2018; Martellotta *et al.* 2020) and San Bernardino cave (Giacobini & Malerba 1998). In Rio Secco cave two fragmented bones from layer 5 described as retouchers made from elk bone (*Alces alces*). Specially, In Rio Secco cave four retouchers manufactured from rib diaphysis of *Ursus spp* and *Ursus spelaeus* are recorded and analysed (Romandini *et al.* 2018a)[37]. At Riparo Fumane, retouchers appear throughout the archaeological contexts extending Middle Palaeolithic to early Upper Palaeolithic, which also includes Uluzzian. The assemblage included is dominated by red deer, and then followed by giant deer, chamois, elk and roe deer to a lesser extent. The assemblage is entirely long bone diaphysis[38], dominated by use of tibia. It is observable that the frequency of the identifiable bone shaft portions used as retouchers varies depending upon the skeletal element.

Grotta de Nadale, which is the foci of this thesis, the only Quina Mousterian context currently being investigated in Italy and in south-central Europe (Jéquier *et al.* 2015; Livraghi *et al.* 2021) is an important milestone. Some of the unearthed retouchers are already presented in a preliminary context (Jéquier *et al.* 2015, 2018). Techno-functional studies on bone retouchers of Grotta de Nadale is freshly published (Martellotta *et al.* 2021) while its archaeozoological results are presented with important implications in hunting behaviour and subsistence strategies (Livraghi *et al.* 2021). More than 300 bone retouchers obtained from cervid and bovids limb bones, which were manufactured and used during MIS 4 were studied. A few doubles retouchers were also observed. The aim of this thesis is to study modified bone specimens, in a

[37] To date, five brown bear bone retouchers (Auguste 2003; Valensi & Psathi 2004) and seven cave bear bone retouchers (Abrams *et al.* 2014) are recorded in Middle Palaeolithic in Europe. Details will be discussed in the next chapter.

[38] Except for one mandible of red deer.

taphonomical, technological and experimental frame of reference, in order to provide a comprehensive description of their techno-functional features to contextualise them in a specific technocomplex of the Middle Palaeolithic.

2.11 Existing research gaps

Upon careful evaluation of the existing knowledge, several gaps have been identified:

I. **Disproportionate Attention to Bone Tools**: While certain categories, such as points and retouchers, have received significant scholarly focus, others, like worked bone fragments and modified long bones, have been relatively gone unnoticed or understudied.

II. **Geographic Distribution of Research:** The focus on bone tool research shows distinct patterns. Western Europe (*e.g.,* Spain, France, Germany) is relatively well-represented, while other regions have a more limited presence in the current understanding of human cultural evolution.

III. **Function vs Typology**: Although scholars argue that *"the concept of a tool's function remains more than hypothetical"* (Patou-Mathis 1999: 50), it is deemed that the function of tools should be prioritised over typologies. However, the earliest studies of the bone industry are based on certain typologies, which are often succumbed into existing cultural paradigms.

IV. **The Case of Italy:** The bone tool industry in Italy has received relatively less attention overall, except for the well-established 'retoucher' category.

This research aims to address these gaps by focusing on the underrepresented bone modifications at grotta de Nadale, moving beyond the well-documented evidence of 'retouchers'. By exploring these lesser-known bone modifications, the study seeks to uncover new insights into the bone tool industry particular to Northern Italy, a region where the last Neanderthals sought refuge during the climatically turbulent period of MIS 4. This research challenges the fragmentary regional record and fills the void in interdisciplinary studies, offering a more comprehensive view of the behavioural and technological adaptations of the region's last Neanderthals.

Chapter 3

BONE TOOLS VS NEANDERTHALS

The use of bone tools by Neanderthals represents a significant component of their technological repertoire, offering valuable insights into their adaptive strategies and cognitive abilities. While traditionally depicted primarily as skilled big-game hunters employing stone tools, recent archaeological discoveries have unveiled a more nuanced perspective of Neanderthal tool use. This includes evidence of deliberate manufacturing and use of bone implements, which played a pivotal role in their daily lives. These bone tools serve as critical artefacts for understanding various aspects of Neanderthal behaviour, social organisation, and interactions with their environment. They provide tangible evidence of their ingenuity and resourcefulness, challenging outdated stereotypes and enriching our understanding of their cultural complexity.

This chapter offers an overview of the archaeological evidence supporting the use of bone tools by Neanderthals. It explores key discoveries that have illuminated Neanderthal lifeways, shedding light on their technological advancements and their ability to adapt to diverse ecological settings. By examining these artefacts and their contexts, the chapter aim to deepen our appreciation of Neanderthal capabilities and the dynamic nature of their interactions with their surroundings.

Evidence is increasingly suggesting that the Neanderthals, who resided in Europe and Asia[39] until approximately 40,000 years ago, possessed a greater level of sophistication than was previously believed. Excavations at Neanderthal sites over 40,000 years old have unearthed hundreds of tools which can be attributed to Neanderthals. Around 48-45,000 years ago, the migration of AMH brought significant changes in archaeological material culture, resulting in a transition from Upper to Middle Palaeolithic, which also includes the diverse set of artefacts that testified to new practices (Mellars 1989; Klein 1995; Bar-Yosef 2002; D'Errico 2003; Zilhão 2007). Therefore, bone materials became a coveted medium for manufacturing a variety of objects. However, it is noted that the scepticism in the Middle Palaeolithic suggests the doubts that Neanderthal did not engage in bone tool production. But it was until 2020, the groundbreaking discovery of more than 1,200 bone tools at the Neanderthal site of Chagyrskaya (Altai, Siberia, Russia)[40] by Baumann *et al* (2020).

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[39] Southwest Asian Neanderthals were a group of Neanderthals who inhabited Turkey, Lebanon, Syria, Israel, Iraq, and Iran—the southernmost region of the recognised Neanderthal range. Early Neanderthals settled in the area until roughly 100,000 years ago, although their arrival in Asia remains poorly dated.

[40] A seasonal camp inhabited in the early cold period, for 60,000-50,000 BP, largely used to process the carcasses of hunted bisons (See Kolobova *et al*. 2020b; Mafessoni *et al.* 2020).

The use of bone tools by the Neanderthals has been confirmed by the discovery of 74 human remains and lithic industry at the Chagyrskaya cave, dating back to MIS 4. A technological and functional analysis of the faunal remains revealed the identification of over 1,000 retouchers and approximately 100 bone tools that fall under other functional categories. Although percussion was the primary method involved in their manufacture, with minimal use of scraping and abrasion, the sheer number, diversity, and recurrence of these tools prompt their consideration as an industry—meaning their production was systematic and organised (Baumann *et al.* 2020, 2023). To this bone industry, the attribution of AMH cannot be considered (d'Errico *et al.* 2004, 2012a; Gravina *et al.* 2018).

Also in the Denisova cave, bone tools have been reported as an isolated find (Baumann *et al.* 2017, 2018; Kozlikin *et al.* 2020b). From the southern chamber of the Denisova cave, bone retouchers and a retouched bone fragment (layer 12) and lightly (yet significantly) modified bone tools such as retouchers and retouched pieces from layer 11 are reported in association with the lithic industry. Use-wear analysis of the points, needles, and smoothers has revealed unambiguous indications of use, and a variety of deformation characteristics linked to their utilisation. It is possible that these were partly produced by Neanderthals.

The Prolom II cave site, located in the eastern part of the Crimean Peninsula, presents evidence of repeated habitation during the Middle Palaeolithic period. In a broader context, the Ak-Kaya culture of Crimea can be considered one of the variants of the East European Micoquian. The identification of a curved, arc-shaped accumulation containing bones of mammoth, horse, bison and other animals within the second layer of the site, combined with a substantial collection of bone artefacts, serve to augment the exceptional quality of the location. Certain bone artefacts cannot be feasibly accounted for as purely utilitarian and quite possibly point to the presence of a spiritual culture apparent in Neanderthal Man. It is possible to identify two sections of diaphysis that exhibit both parallel and fan-shaped engraved lines, along with a distal section of *Saiga tatarica's* first phalange featuring fan-shaped engraved lines and a horse canine bearing deep subparallel engravings (Stepanchuk 1993).

As reported by Burke and d'Errico (2008a), a fragment of equid tibia has been shaped through knapping, similar to flint, in order to create a tool during a period of dwindling stone resources. This tool is evidence of the Neanderthal's ability to adapt to the local environment and their knowledge of bone's technological properties. Also, dubious evidence comes from Moravia region of the Czech Republic, as they are not with the 'standard' shape of the tools coming from the Upper Palaeolithic, but the arrangement of grooves may suggest the non-utilitarian practices of Neanderthals (Neruda 2010) Moreover, Gaudzinski (1999) comprehensively described 28 bone tools made of *Mammuthus primigenius* ribs and fibulae from the Middle Palaeolithic site of Salzgitter-Lebenstedt (Germany). Not only for tools, but as building materials, Neanderthals found Mammoth remains as durable, declaring evidence from Molodova I, Ukraine (Dniester valley) (Demay *et al.* 2012).

Examples of bone tools from the Mousterian period in Europe are increasingly abundant. At the site of Bison Cave in Arcy-sur-Cure, Yonne, France, there exists a bone specimen that serves as a multi-purpose tool on the proximal fragment of the diaphysis of a reindeer femur. Technological characterisation of the specimen confirms Neanderthals' familiarity with using bone as a raw material for toolmaking (Hardy *et al.* 2014). The famous Combe-Grenal, Dordogne, Tartar and colleagues (2022) present morphometric and functional analysis of ten bone tools with smoothed ends from the Quina and Levallois levels. This research demonstrates the potential of informal bone tools thus enhancing the understanding of the complexity and diversity of Neanderthal behaviour.

The first use of *lissoirs* (french: to make smooth, smoother) were identified by Soressi and colleagues (2013), described from Pech-de-l'Azé I (Pech I) and Abri Peyrony in southwest France. Both sides produced almost identical bone fragments with smooth edges and a rounded tip. These bones constitute the first proof of this behaviour connected with Neanderthals. Moreover, from Montgaudier (Debénath & Duport 1971), Vaufrey (Vincent 1993), Noisetier (Oulad El Kaïd 2016), Canalettes (Patou-Mathis 1993), Gatzarria (Tartar 2012b). In Spain, Bolomor Cave (Blasco *et al.* 2013b), Abric Romaní (Rosell *et al.* 2012) and in Nothern Italy, Fumane cave (Romandini *et al.* 2015; Jéquier *et al.* 2013), grotta de Nadale (Martellotta *et al.* 2021; Livraghi *et al.* 2021), Riparo Tagliente, grotta della Ghiacciaia (Hohenstein *et al.* 2018) and in Roccia San Sebastiano (Romandini *et al.* 2023) from Southern Italy.

Also, the growing enthusiasm of the bone industry some of these findings, many of which have been studied more recently, prompt a revaluation of previously overlooked discoveries like those at La Quina (Martin 1910, 1923), Ourbières (Pittard 1907), Tourtoirac (Daniel 1932), Néron (Veyrier & Combier 1952), Pié-Lombart (Texier 1974b), Cuva Morín (Freeman & Freeman 1978), Rigabe (Defleur 1988), Hauteroche or Bois-Roche (Vincent 1993).

In a pioneering study, Baumann and colleagues (2022) present a collection of six bone implements with smooth-ends made from reindeer long bones and medium-sized ungulate ribs. The tools seem to have been mainly flaked using direct percussion. These bone artefacts discovered at Abri-Lartet, France, in conjunction with other recent and past findings, hint at a wide functional range in the usage of bone tools by Neanderthals (Baumann *et al.* 2022). In 2023, Baumann and colleagues uncovered Neanderthal-made bone tools at the Chez-Pinaud site in France. As many bone tools were discovered; not only the familiar retouchers, but also beveled tools, retouched artefacts and a smooth-ended rib. Their diverse nature presents opportunities for a wide range of activities not typically encountered at a butchering site, and not recorded by the flint tools, all engaged in carcass processing. The reuse of 20% of the bone blanks, primarily sourced from large ungulates within the largely reindeer dominated faunal remains, prompts query into their procurement and management. This evidence provides new insights into Middle Palaeolithic subsistence strategies (Baumann *et al.* 2023).

More recently, a bone spear point from the Middle Palaeolithic site of Abric Romani (Barcelona, Spain) is discovered (Mateo-Lomba *et al.* 2024). The spear point exhibits clear signs of intentional knapping, and the presence of microscopic linear impact marks, an impact fracture at the tip and potential internal stress fractures indicates its use as a spear. What is interesting about this study is, micro-CT scanning revealed an internal crack in the base of the artefact, likely caused by the thrust of the handle. This discovery is a further testament of the fact that Neanderthals Neanderthal groups used bone as a raw material for hunting and made spear armatures and projectiles.

Were they being picky?

A recent study by Martisius and colleagues (2020) indicates that Neanderthals specifically selected bones of particular animals to fashion them into implements with a particular function - transforming hides into leather. By using ZooMS (Zooarchaeology by Mass Spectrometry), the findings indicate that the '*lissoir*' were primarily sourced from bovine-type animals such as bison or aurochs - an extinct wild relative of contemporary cattle. Nonetheless, the deposition also contained other animal bones which demonstrated that reindeer were more frequent and regularly hunted as a source of food. Consequently, we can infer that, when it came to manufacturing their tools, the Neanderthals opted to solely use ribs that originated from specific animal types. Bovine ribs are larger and sturdier than deer ribs, making them more appropriate for demanding tasks, such as rubbing skins, as they are less likely to wear out or fracture. In other words, Neanderthals really knew what they were doing, and they understood that particular tasks demanded specific tools. They identified the most effective tools and acquired them whenever possible[41].

The selection of particular anatomical elements was favoured by long bones in most Mousterian sites, including de Nadale, but other bones are not so rare: ribs were used at Les Pradelles (Costamagno *et a.l* 2018), frequent mandible and phalanxes use spotted at La Quina, Abri Lartet and Les Pradelles (Verna & d'Errico 2011; Valnesi 2022; Ready & Morin 2019), also pelvis and scapula notes in at Les Pradelles (Costamagno *et al* 2018). In grotta de Nadale it was tibia and radius being most frequently used (Martellotta *et al.* 2021).

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[41] See Martisius (2019) for Neandertal bone tool material selection, manufacture, and use.

Grotta de Nadale: the den of bone retouchers

The site has produced over 300 bone retouchers from the limb bones of cervids and bovids. In particular, double retouchers were created using ungulates' radius (Martellotta *et al* 2021:8). Out of these, 48 specimens possess surfaces with double-use wear, and two are triple retouchers. A total of 385 retouchers have been identified as belonging to MIS 4. The bone surfaces have been exceptionally well preserved (Livraghi *et al.* 2021). These retouchers indicate that cervids such as *Megaloceros giganteus* and *Cervus elaphus*, and large bovids like Bos/Bison and *Bison priscus* are commonly exploited. Given the fact that the selection of certain species for creating retouchers may have been due to the availability of resources or specific technological criteria, however, it is worth noting that this wasn't always the case. In exceptional cases, certain fragments were carefully selected based on their morphological, metrical, and technological features. The case in de Nadale is the primary species chosen to create retouchers align with the composition of the animal remains found in the site.

However, until the present day, the bone industry of grotta de Nadale has not undergone technological, morphological, or experimental studies apart from bone retouchers. Since grotta de Nadale provides a prime illustration in Neanderthal subsistence and economy during MIS 4 (Mousterian Quina complex) in northeastern Italy, it is worthwhile to conduct a comprehensive study of the cave's bone industry from multiple perspectives. This analysis of grotta de Nadale bone industry has the potential to enhance our understanding of the of the tools used by the Neanderthals. In long term, painting this complete picture of Neanderthals economy, would largely contribute to the trace the progress of human history from primitive origins through to the modern day with particular emphasis on technological advancements.

Thus, the first part of this dissertation has provided a comprehensive overview of the bone tool industry, laying a robust foundation for the subsequent chapters of this thesis. The primary objective of this part was to establish the contextual framework, presenting both archaeological and taphonomic perspectives. Through an extended review of historical research, relevant theories, debates (such as the Binford syndrome), and key concepts have been explored, forming a solid theoretical underpinning for the study. This initial part has effectively set the stage for the subsequent chapters, ensuring a clear and coherent progression of ideas. The upcoming sections will delve into detailed presentations of archaeological sites and the applied research methodology. This will encompass the approach, techniques, and protocols employed for data collection and analysis, alongside the formulation of hypotheses. Ultimately, the empirical findings and analysis presented in the ensuing chapters will illuminate the research objectives, making significant contributions to the existing body of knowledge within the field of bone tool industries.

PART II

Chapter 4

PRESENTATION OF THE SITE

A Cave of Peculiar Technology: Grotta de Nadale, Northeastern Italy.

This chapter is an attempt to present the chosen site, grotta de Nadale, located in the southern slope of the Berici hills. After briefly introducing northern Italy, the chapter provides a comprehensive overview of the site, including its location, stratigraphy, lithic and bone industries, and previous research. The aim of this chapter is to thoroughly explain the significance of the site within an archaeological frame of reference by detailing its geographical and archaeological features, history, and techniques utilised.

The last few years of research have seen the geographical range (Blinkhorn *et al.,* 2021; Sánchez Goñi, 2022), cultural productions (Discamps *et al.,* 2011; Niven *et al.,* 2012; Rendu, 2010; Rendu *et al.,* 2019), and ecological adaptations (Conard & Prindiville, 2000; Delagnes & Rendu, 2011; Rendu, 2010) of Neanderthals receive a significant reconsideration (Peresani *et al.,* 2019; Romandini *et al.,* 2014, 2018). The northeastern part of Italy has become increasingly significant in this regard given a growing number of investigated Mousterian lithic deposits (the stone tool assemblage often associated with Neanderthals), including within montane portions of the Italian Alps (Peresani, 2008, 2009; Peresani *et al.,* 2015; Picin et *al.,* 2013). Significantly, an ephemeral, single-layered Quina Mousterian dated to 70.2 + 1/-0.9 ka BP at grotta de Nadale suggests that Neanderthals inhabited these environments during a glacial period of cold conditions in the northern hemisphere (López-García *et al.,* 2018, 2019).

4.1 Northern Italy

The region's geography is characterised by a broad plain, surrounding mountain ranges, and numerous waterways. Northern Italy consists of the basin of the river Po, encompassing the wide plain that extends from the foothills of the Apennines to that of the Alps, and includes the valleys and slopes on both sides of it, as well as the Venetian Plain and the Ligurian coast. Northern Italy is bounded by the Alps to the north and west, and the Apennine Mountains to the south. Spread between these two mountain ranges, there lies a vast plain consisting of the Venetian Plain and the Po Valley, which hosts the largest river in Italy. The Po River flows for 652 km (405 miles) in an easterly direction from the Cottian Alps to the Adriatic Sea. The river acts as a receptacle for all the waters originating from the Apennines and flowing northwards, as well as for those descending from the Alps towards the south. The Po Valley, which is the largest plain in Italy, is home to the vast majority of the population in Northern Italy (Peresani & Sauro 2024).

The Berici hills consist of a carbonatic plateau covering an area of around 200 km^2 in the sub-alpine region. Located to the south of Vicenza, they are separated from other formations that share similar geological and morphological attributes, including the Lessini Mountains situated 3-4 kms towards the north-west. The flat plains created by the Astico and other river systems separate the two. In the south-east, the hills area bordered by the Brenta mega fan. The Bacchiglione river flows through this mega fan and is confined by the Euganean hills to its southeast (Jéquier *et al.* 2015).

The Berici is a karst terrain[42] cleaved by two primary valleys, namely the Val Liona and the Fimon Valleys, which divide it into two sections. The eastern region is an extensive and intricate tableland that ends abruptly towards the alluvial plain on its southeast side. The western region merges with the alluvial plain and forms a mild landscape. (Mietto 2003; Jéquier *et al.* 2015; Peresani & Sauro 2024).

The Berici landscape has undergone karstic and fluviokarstic processes since the Middle Miocene epoch, resulting in the creation of sinkholes, dry valley systems with sinkholes, and valley segments that have developed into sizable, enclosed basins. It is notable that these formations were not a sudden occurrence, but an ongoing geological process (Sauro 2002). After an early stage of river erosion during the middle-upper Miocene period, tectonic up-lift occurred in conjunction with lowered hydrologic drainage levels towards the end of the Miocene (Messinian). As a result, the current V-shaped, fluvio-karstic canyon-type valley system was formed in different regions of the plateau. Inner zones of the valley boast active water springs, such as those found in the Calto valley. During the Upper Villafranchian period, the development of vertical hydrological drainage and karst systems was a result of further uplifting, which caused a reduction in the phreatic subterranean system and the deactivation of suspended drainages. Consequently, inner karstic processes were deactivated, and suspended cavities emptied (Jéquier *et al.* 2015; (Peresani & Sauro 2024).

4.2 Middle Palaeolithic Sites in Berici hills

Northeastern Italy is a crucial area for researching the Neanderthal lifestyle over an extended time period. Over 20 open-air Mousterian sites, caves or shelters have been identified in the Berici Hills (Bertola & Peresani 2000; Peresani 2001, 2015; Fiore *et al.* 2004; Duches & Peresani 2008, 2009) also some sites in the Euganean Hills (Peresani & Perrone 1999; Duches & Peresani 2008; Peresani 2013). Caves and shelters are exclusively set along the eastern side of the Berici Hills, where Broion Cave, Broion rockshelter, Paina Cave, Col de la Stria Cave, and San Bernardino Caves (Delpiano *et al.* 2022). In all of these sites, one common feature is observed: a dominance of Levallois knapping (Peresani 1995; Peresani & Porraz 2004;

[42] Karst is a geological landscape formed by the dissolution of soluble rocks, resulting in features such as sinkholes, sinking streams, caves, and springs.

Picin *et al.* 2013). In addition to cave sites, open air sites such as Broion rockshelter are observed through the lithic artefacts integrated with pedo-stratigraphic sequences or scattered on the surface (Peresani 2000).

Although the sites on the Berici vary in elevation across the plateau, the sites on the Euganean are consistently situated on carbonatic and marly carbonatic bedrocks containing flint nodules, rather than on volcanic bedrocks (Jéquier *et al.* 2015). Unfortunately, the absence of any stratigraphic context, archaeological deposit and faunal remains hinders any attempt at understanding their function. Regrettably, any attempt to understand their function is hampered by the lack of stratigraphic context, archaeological deposits and faunal remains. The significance of these sites is revealed by their location on the top of a hill or the edge of a terrace, with dominance over the surrounding plains and valleys, and the availability of lithic resources. The lithic industries are predominantly comprised of cores and Levallois products, created using either a preferential or recurrent method, and are larger in size than those discovered in caves.

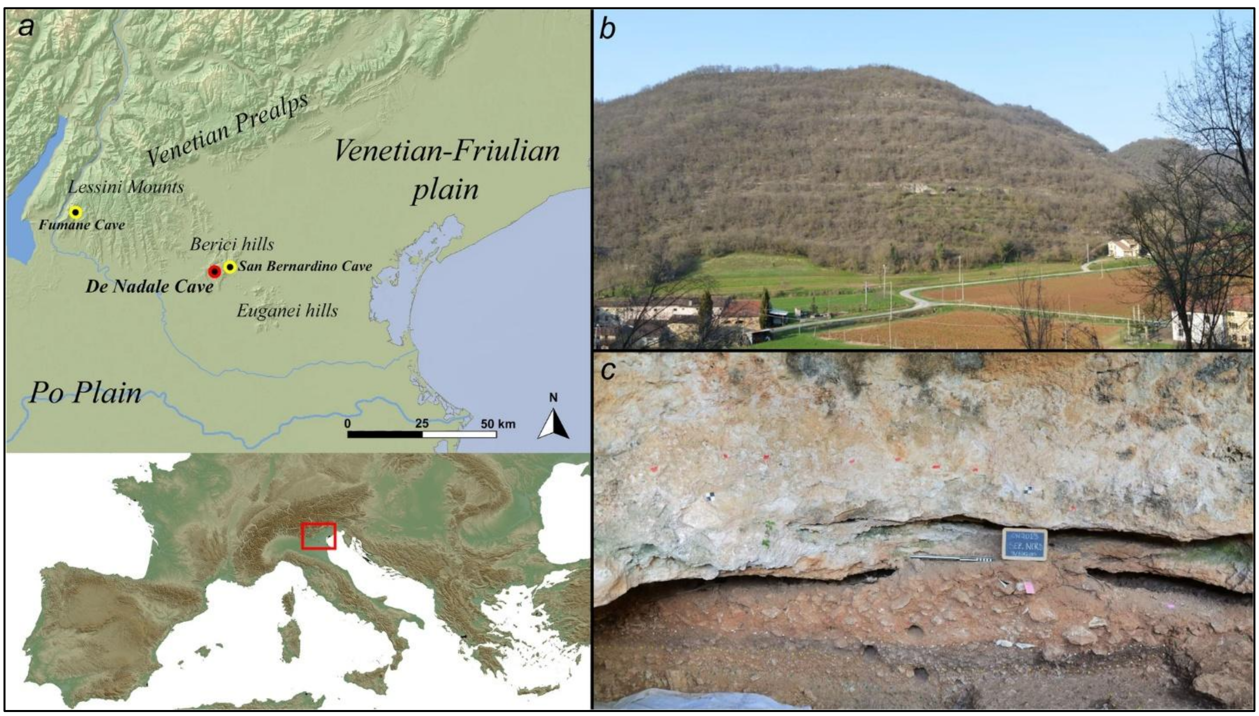

Figure 1:North-Eastern Italy with the location of grotta de Nadale and other major regional sites (a); the souther slope of Berici plateau in the Liona valley (b) and the section of the deposit, with the visible dark SU 7 (c) Adopted from Delpiano *et al* (2022).

4.2.1 Open air sites in Berci hills

A substantial number of artefacts stemming from Levallois flake-making techniques have been unearthed at Monticello di Barbarano. The analysis highlights a discrepancy between the number of finished tools and the number of cores present. The relatively simple extraction of Scaglia Rossa flint from the nearby hilltop could be indicative of human activity being primarily focused on lithic production and the subsequent exporting of end-products and potentially some tools (Duches & Peresani 2009; Jéquier *et al.* 2015).

The techno-typological variability in the lithic assemblages of Gualivone and Monte del Cason is demonstrated by two factors. Firstly, by the presence of scrapers with stepped-scaled retouch, and secondly by artefacts generated through the discoid method applied to various types of flint (Bertola & Peresani 2000).

4.2.2 Caves and Shelters in Berci hills

A number of significant caves and shelters are located solely on the eastern side of the Berici Hills. To name a few,

I. Broion cave and Broion shelter
II. Paina cave
III. Col de la Stria cave
IV. San Bernardino cave.

Although Bartolomei and colleagues (1988) discovered only a small number of artefacts in Paina, Col de la Stria and San Bernardino minor caves, De Stefani and colleagues (2005) require more detailed excavations of the Broion shelter. On the other hand, the Broion cave and San Bernardino major cave have yielded substantial evidence.

4.2.2.1 San Bernardino cave

On the eastern slope of the Berici, 135 meters above sea level, San Bernardino cave overlooks the alluvial plain of the Bacchiglione river and the western side of the Euganean hills. The deposit is a complex body of sediment in the form of an elongated prism, extending from the inside of the cave to part of the outside (Terlato *et al.* 2021). Archaeological excavations conducted during the 1960s and 1980s-90s have unearthed evidence of human inhabitation throughout the entire sequence, with greater consistency observed in units VIII, VI, and II, and sporadically in units VII, V, and IV (Cassoli & Tagliacozzo 1994). The lithic industry is defined by the extensive use of local and external chert, leading to a reduction in the size of cores, flakes, and retouched tools. Flake production relied solely on the recurrent unidirectional and centripetal Levallois techniques (Picin *et al*. 2013). Consequently, this site is considered a long-term habitation zone due to the various phases of core reduction (Peresani 1995; Terlato *et al.* 2021). The faunal spectrum reveals that site occupation generally occurred with temperate conditions, suggesting a forest landscape interspersed with clearings and wetlands. San Bernardino cave’s subsistence was mostly based on ungulates exploitation, especially red deer and roe deer, whereas the procurement of large ungulate and small chamois was sporadic (Terlato *et al.* 2021).

4.2.2.2 Broion Cave

Broion Cave is known as a Mousterian site spanning from late MIS5 to MIS3 (Peresani *et al.* 2019). Assemblages that are mostly composed of retouched tools. The initial excavations were conducted between 1998 and 2008 by Prof. Alberto Broglio and subsequently pursued by archaeologists from the University of Ferrara in 2015. In total, research focused on a 20m² area sheltered by rock walls to the north and west. Discoveries of faunal remains from the Pleistocene era, in addition to a cultural sequence from the Middle to Upper Palaeolithic period, were made (De Stefani *et al.* 2005). The most prevalent species are wild boar (*Sus scrofa*), succeeded by chamois (*Rupicapra rupicapra*) and ibex (*Capra ibex*). Cervids probably include the giant deer (*Megaloceros giganteus*), elk (*Alces alces*), or red deer (*Cervus elaphus*) (Peresani *et al.* 2019).

4.2.2.3 Paina Cave

The cave is situated within the Berici Hills in north-eastern Italy. The cave sits atop a steep slope connecting the plateau to the alluvial plain, at an altitude of approximately 350 meters above sea level. Field archaeological sessions identified a stratigraphic sequence of approximately 1.50 m in depth, consisting of 12 layers containing artefacts from the Middle (Units 12–10) and Upper Palaeolithic (Units 9–5). Layers 5 and 6 have zooarchaeological remains dated via radiocarbon to 20,120 ± 220 to 19,430 ± 150 14C years BP (Layer 6) and to 19,861 ± 70 14C years BP (Layer 5). These remains were sourced from cave bear bones (Parere *et al.* 2005; Gurioli *et al.* 2006). The lithic artefacts have been classified as belonging to the Early Epigravettian period, characterised by shouldered points (Bartolomei *et al.* 1988). The faunal remains of contexts record the predominance of carnivores (such as cave bear, fox, and mustelids) and outnumber the ungulates. Of the latter group, the cervids (*Cervus elaphus* and *Alces alces*) are the most populous, with caprids and wild boar following closely behind (Terlato 2018; Terlato *et al.* 2019a).

4.3 Grotta de Nadale

Grotta de Nadale (45° 25′ 16″ N; 11° 29′ 22″ E) is a late Middle Palaeolithic site that has recently been unearthed on the south slope of the Berici Hills, a karstic plateau located midway between the Lessini Mountains and the Euganean Hills (Arnaud *et al.* 2017; Delpiano *et al.* 2022). The cave has only one layer (layer 7) impacted by human activity. This layer contained a collection of animals dominated by ungulates such as cervids and bovids, accompanied by a few carnivores (Jéquier *et al.* 2015). Using the Uranium-

Thorium dating method, the cave's anthropic layer has been dated to a minimum age of 70.2 +1/-0.9 thousand years before present[43] (Jéquier *et al.* 2015).

Existing pollen records from the region suggest that this would have indeed been a cold, dry period (Vidal-Matutano *et al.* 2022), however these lake archives remain detached from the archaeological assemblages themselves (Pini *et al.* 2009, 2010). Zooarchaeological analysis of small mammals from the site itself provide further environmental indicators (López-García *et al.* 2018), while an abundance of open grassland large-mammal species *Bison priscus* (steppe bison) and *Megaloceros giganteus* (giant deer) in Unit 7 provide further indications of dry ecosystems (Livraghi *et al.* 2021). However, these records face taphonomical issues (e.g., the small mammals may have been accumulated by raptors) and the ecological and climatic tolerances of some larger species in the past remain difficult to determine (Andrews 2006; López-García *et al.* 2018).

Considering the chronology of the site, the cave has been associated with the very beginning of MIS 4 (López-García *et al.* 2019), a period still relatively unexplored from the perspective of hominin ecological adaptations in the north of Italy. Environmental and climatic information thus far obtained for Unit 7 are very similar to those obtained for Unit IV of grotta Maggiore di San Bernardino (López-García *et al.* 2017), with a predominance of open woodland formations and open dry meadows in a cold climate. Meanwhile, although there are no reliable small-mammal data for MIS 4, the micromammal assemblages from the MIS 3 layers of the grotta del Broion (Berto 2013), which is also in the close vicinity of the grotta de Nadale, requires a proper scientific investigation.

The first deciduous molar of a Neanderthal, designated as de Nadale 1, was unearthed in Unit 7 of square M13g during the excavation campaign of 2014 (Arnaud 2017; Arnaud *et al.* 2017). The presence of an early tuberculum molare[44] coincides with several Neanderthal infant's dentition cases, including those found at Roc de Marsal (Madre-Dupouy 1992). The discovery of the Nadale 1 Neanderthal tooth is highly significant, as it is associated with a well-defined archaeological context and can be attributed to the Quina Mousterian culture.

Diverging from the lithic assemblages found in the rest of northern Italy, the lithic industry in grotta de Nadale displays distinctive and individual technological and typological attributes, "*which is as evident by the flexibility of lithic reduction, to name a few, the presence of surface-oriented reduction systems and the*

[43] Geochronological analysis was conducted on the herbivorous maxillary sample CN2014 retrieved from unit 7, square N11d. A fully intact tooth attached to the jawbone was chosen for Uranium-series (U-Th) dating analysis.
[44] Molar tubercle or *tuberculum molare (in latin)* is an extra cusp on the mesiobuccal surfaces of first molars (E-Anatomy.com) .

adoption of diverse core-knapping techniques: that is, the direct percussion with hard hammer and with soft hammer and possibly bone retouchers" (Delpiano *et al.* 2022).

4.4 Archaeological Context of the site

The grotta de Nadale was first reported in 2006 by a collaborator of the University of Ferrara (G. Baruffato), he discovered an assemblage of mammal bones and lithic artefacts on the surface of reworked sediments resulting from cultivation and bioturbation, probably caused by badgers. After the removal of the reworked sediments (unit 1 rim) in 2013, the excavation team unearthed plethora of animal bone fragments and lithic artefacts. Two excavation campaigns, in May and October 2014, were undertaken. After 2015, 2017, 2019, 2020, 2021 and 2022 excavation campaigns were undertaken by the archaeologists from the University of Ferrara. The excavations disclosed a brief stratigraphic succession comprising of eight distinct stratigraphic units (SU). Among these, a solitary anthropogenic layer (SU 7) was detected, encased within Pleistocene infertile sediments (SU 6 and SU 8) (Jéquier *et al.* 2015). The pieces examined in this study were gathered from all stratigraphic units, encompassing reworked sediments and the fillings of badger dens. The rationale for including all these pieces in the analysis is based on their preservation condition being comparable to the osseous materials found in Unit 7, thus leaving no uncertainty regarding their Mousterian origin. This approach mirrors the synthesis applied to the entire zooarchaeological sample (Terlato *et al.* 2019b; Livraghi *et al.* 2021, 2022) and bone retouchers (Martellotta *et al.* 2021).

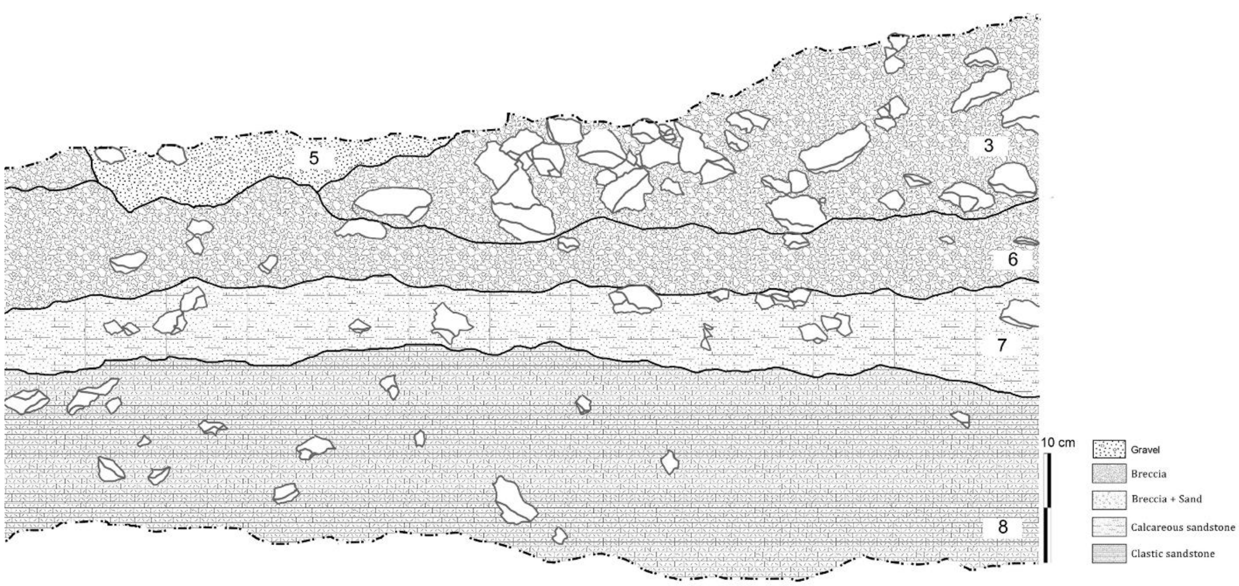

Figure 2: Stratigraphic Profile of grotta de Nadale (North)

SU 7 consists of dark brown-grey silt loam with medium-small sized, sub-rounded rocks and it extends on almost entirely the cavity. It yielded a cultural assemblage attributed to the Quina Mousterian techno complex (Jéquier *et al.* 2015; Livraghi *et al.* 2021; Delpiano *et al.* 2022), a large quantity of well-preserved animal bone (López-García *et al.* 2018; Livraghi *et al.* 2021), bulks of datable charcoal (Vidal-Matutano *et al.* 2022), and most importantly a deciduous (M1) Neanderthal tooth (Arnaud 2017; Arnaud *et al.* 2017). Bone retouchers from grotta de Nadale also offer valuable insights into the study of retouch-induced traces, which has revealed the extensive modifications to the on-site lithic industry. This larger-scale approach contributes to our understanding of the cultural and economic choices made by Neanderthals within the Quina complex in Europe (Jéquier *et al.* 2018; Martellotta *et al.* 2021).

This chapter offers an initial presentation of the archaeological site at grotta de Nadale, emphasising its significant role in the Neanderthal palaeorecord, particularly in northern Italy. Its uniqueness and importance are explored within this preliminary analysis. The forthcoming chapter shall rationale the methodology of this study, incorporating previous research, contextual factors from archaeological campaigns, and a rigorous research approach.

Chapter 5
THE METHODOLOGY

Recent years have witnessed a significant expansion in the study of the Neanderthal bone industry, driven by advancements in methodologies and technologies. This growth underscores the imperative of conducting rigorous and methodologically sound research to deepen our understanding of this important, yet critical discipline. Within this context, this study aims to investigate whether Neanderthals exhibited symbolic and technologically advanced behaviours, as evidenced by their bone industry. This chapter provides a comprehensive elaboration of the methodology employed in the present study. It outlines the research design, sampling techniques, data collection procedures, and data analysis approaches utilised to ensure the validity and reliability of the findings. By elucidating these methodological aspects, this chapter seeks to offer insights into the strategies adopted to navigate the inherent complexities of research in the bone industry.

5.1 Adaptation of terminology

This study adopts d'Errico *et al*'s definition of formal bone tools as '*functional artefacts shaped with techniques specifically conceived for bone, such as scraping, grinding, grooving, and polishing*' (d'Errico *et al.* 2012b). Thus, formal bone tools can be distinguished by their deliberate shaping and the presence of manufacture marks. Additionally, following Tartar's definition, intermediate bone tools are identified as those that are *'not formally worked and only recognisable by the percussion marks at their ends'* (Tartar 2012b). Therefore, informal bone tools are those unshaped pieces of bone that were used without prior shaping, lacking manufacture marks.

5.2 Formation of hypothesis

Alessandra Livraghi (PhD) and the author of this dissertation have studied the faunal remains from the grotta de Nadale through excavations carried out in 2013-2022 stored at the Section of Prehistoric and Anthropological Sciences, Department of Humanities, University of Ferrara (Italy). Among the whole zooarchaeological assemblage, several specimens (considering from all stratigraphic units) exhibit traces that may indicate their use or manufacture, which can be grouped into two categories. Such traces form the basis of the present dissertation:

I. ***Negative removals perpendicular to the long axis of the bone:*** Negative removals on both ends of the bone (one end has negative removals and other edge is flat/crushed). **The hypothesis put forward here is that these negative removals would be traces of manufacture using percussion**

technique, i.e., an intermediate tool.

II. ***Negative removals parallel to the long axis of the bone:*** Negative removals (perhaps continuous) on one lateral edge[45], sometimes extends to the tip. **The hypothesis put forward here is that these negative removals would be traces of manufacture and use most probably as a cutting support or scraping.**

Analytical methodology: The analytical methodology employed in this study involved adopting a *chaîne opératoire* approach, traditionally used for analysing stone tool reduction sequences, to examine a selected 'potential' bone tool assemblage. This approach aimed to employ available archaeological contextual information, including zooarchaeological data and the taphonomy of the bone assemblage, and to investigate all recovered bones exhibiting traces of manufacture or use (including by-products, finished and unfinished tools, unmodified bones, worn items, re-shaped pieces, and broken tools). This methodology involved reconstructing the sequence of actions involved with each tool, beginning with the acquisition of the bone raw material, followed by the manufacturing process, subsequent tool use, and concluding with the disposal of the tool (for similar synthesis see Hahn 1976; Fosse 1999; Averbouh 2000).

The methodology of this thesis is influenced by the '*actualism*', which involves '*observing present day events and their effects in order to give meaning to the prehistoric archaeological record*' (Gifford 1981:367; Simpson 1970; Lyman 1994: 46-69; Probiner & Braun 2005), and 'a *methodologically uniformitarian approach*' defined by Gifford-Gonzalez (2018:62)[46]. These actualist studies can provide information on the agents that caused the breakage and help to identify the responsibles who broke the bones (*e.g.* Martin 1910; Breuil 1938; Leroi-Gourhan 1952; Dart 1957; Poplin 1973; Blumenschine 1988; Oliver 1989; Anconetani 1999; Pickering & Egeland 2006; Galán *et al.* 2009; Blasco *et al.* 2013, 2014; Njau & Gilbert 2016; Moclán & Domínguez- Rodrigo 2018; Parkinson 2018).

5.3 Zooarchaeological and taphonomical frame of reference

The principal subjects of this dissertation are the faunal remains from grotta de Nadale, (Berci hills) northeastern Italy. At present, comprehensive zooarchaeological analyses have been conducted on the entire osteological sample, which comprises bones and teeth. They were scrutinised and categorised from both the taxonomic and taphonomic perspective. Taxonomic and anatomical identifications for this study relied on the complete Alpine faunal reference collection from the Department of Humanities at the University of

[45] These negatives are continuous and often overlapping.

[46] Based on Lyell (1856) and Binford (1969)

Ferrara. Well-established literature also provided valuable assistance for this analysis (Davis 1987; Reitz & Wing 2008; France 2009; Lyman 2014; Broughton 2015).

Both identified remains and those considered unidentifiable on the basis of morphological or size characteristics, have been grouped into five mammal body-size classes, following Bunn and colleagues (1988): I - small (i.e. *Lepus* sp. and other lagomorphs, Mustelidae, *Vulpes vulpes*); II - small-medium (i.e. *Capreolus capreolus, Rupicapra rupicapra, Canis lupus*); III - medium (i.e. *Capra ibex, Sus scrofa*); IV-medium-large (i.e. *Cervus elaphus, Ursidae*); V- large (i.e. *Megaloceros giganteus, Bovinae*). This categorisation has been considered more useful to evaluate the faunal assemblage of grotta de Nadale since it underlines the difference in body-size between red deer and giant deer/bovids.

According to modern animal birth criteria, the age at which animals die and the state of epiphysis fusion have been determined using tooth eruption, replacement sequences, and dental wear. Priority was given to Ungulates, such as *Capreolus capreolus* (Aitken 1974), *Cervus elaphus* (Mariezkurrena 1983; D'errico & Vanhaeren 2002; Hillson 2005), and bovids (Silver 1969; Habermehl 1975; Bunn & Pickering 2010). To avoid distortions in the proportions of age groups in various units, the study calculated estimates for remains typically identified as Bovines. This was achieved by focusing solely on the age or size of the animal not included in the two determined taxa categories (*Bison priscus* and *Bos primigenius*). The Settepolesini di Bondeno paleontological site collection from Italy has provided insights into the age of *Megaloceros giganteus* specimens. Five categories have been identified using the criteria proposed by Bunn and Pickering (2010) and Marín et al (2017).

I. Young juvenile (I – 0–5 months; deciduous teeth);
II. Subadult juvenile (J – 5–30 months; M3 in eruption);
III. Early prime adult (AD I – 30–78 months; complete permanent dentition without wear traces);
IV. Late prime adult (AD II – 78–144 months; complete dentition with light wear traces);
V. Old adult or senile (S – > 144 months; permanent dentition with heavy wear traces).

All taxonomically identified specimens, including shaft fragments, were considered in the analysis of skeletal part profiles. NISP (Number of Identified Specimens) (Grayson 1984) and MNI (Minimum Number of Individuals) (Bökönyi 1970), indexes were used in order to evaluate species abundance. MNI was estimated considering all skeletal elements.

The identification of taphonomic alterations, whether organic (microorganism, animal, plant, etc.) or inorganic (weathering, water circulation, sediment compaction, etc.), is reliant upon data presented in published materials (Brain 1967, 1981a; Behrensmeyer 1978; Binford 1981; Shipman 1981; Blumenschine & Selvaggio 1988a; Capaldo & Blumenschine 1994; Blumenschine 1995; Fisher 1995; Domínguez-

Rodrigo & Piqueras 2003; Lyman 2014; Fernandez-Jalvo & Andrews 2016a; b). The evidence of anthropic modification was found by examining the position, type, and their orientation of cutmarks. Incisions and scraping marks were identified as types of cutmarks (Binford 1981; Shipman 1981; Potts & Shipman 1981b; Shipman & Rose 1983; Lyman 2008). A concise analysis of cutmarks was conducted in order to infer possible actions carried out on the bone, such as skinning, de-fleshing, and periosteum removal. The analysis considered the number of striations, their location and distribution, and orientation. Furthermore, the presence of chop marks was observed. Chop marks refer to broad and relatively short linear depressions with a V-shaped cross section (Fisher 1995; Lyman 2014). Anthropic traces resulting from bone breakage for extracting marrow were analysed and categorised into two types: percussion marks and impact flakes. Percussion marks take the form of semi-circular cavities located on the fracture edges, with corresponding negative removals. Impact flakes, on the other hand, are positive flakes of the percussion notches that result from breaking the diaphysis (Blumenschine & Selvaggio 1988a, 1991b; Capaldo & Blumenschine 1994; Blasco *et al.* 2013a; Vettese *et al.* 2017). Deliberate bone fracturing to reach marrow can be identified by analysing the form of the shattered extremities of the shafts themselves (Villa & Mahieu 1991; Blumenschine 1995; Fisher 1995; Outram 2001; Grunwald 2016; Coil *et al.* 2017). Bone surfaces were assessed comprehensively at both microscopic and macroscopic levels. The initial examination involved the use of a hand lens with 10x magnification, conducted under low-angle lighting conditions. Subsequently, a Leica S6D Greenough stereomicroscope with a magnification range of 0.75-70x was employed for a more detailed and precise analysis.Particular attention has given to the origin of bone fractures, especially those considered as anthropogenic. Such fractures occur on 'fresh' bone shortly after the animal's death and are characterised by a helicoidal shape with a slick surface and acute or obtuse angles with the cortical side. In contrast, post-depositional fragmentation occurs on 'dry' bone, which has lost either all or most of its organic matter, and the fracture surfaces are straight and rough with a near 90-degree angle to the cortical side[47] (Bonnichsen 1979; Haynes 1983; Johnson 1985; Villa & Mahieu 1991; Outram 2002; Karr & Outram 2015).

The maximum length, width, and thickness of the fragments were measured in millimetres. For diaphyseal fragments, two thickness measurements were taken: one at the edge of the fragment to gauge the thickness of the compact tissue, and another to determine the maximum thickness, referred to as the 'overall' thickness. This dual approach enables the identification of fragments with a distinct convex-concave cross-section, a

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[47] The process of bone drying involves a gradual and non-uniform transition from fresh to dry bone. As a result, the proposed criteria do not facilitate the identification of anthropogenic fractures on drying bones or post-depositional fractures on fresh bones. Fracture surfaces in archaeological material often display mixed features, necessitating the analysis of trends according to the studied corpus and consideration of all available discriminating criteria, such as hammer impacts, general morphology, location, and variability within the frame of reference (Sadek-Kooros 1972; Blumenschine & Selvaggio 1988; Pickering & Egeland 2006; Galán *et al.* 2009).

detail we have duly recorded. Fragments with a thickness (compact tissue) equal to or exceeding 10 mm are classified as 'robust'.

The examination of anthropogenically fractured materials relies heavily on the identification of cortical flakes within the faunal assemblage, as well as the detection of percussion marks and notches resulting from direct percussion on bone surfaces. The characteristics of fracture facets, such as their smooth surfaces, curved or V-shaped outlines, and oblique angles, provide clear indicators of percussion activities conducted on fresh bone specimens (Blumenschine & Selvaggio 1988a; Brugal & Defleur 1989; Villa & Mahieu 1991; Outram 2002; Pickering & Egeland 2006; Galán *et al.* 2009). Observations of both technological features and wear patterns were compared with published archaeological and experimental references for comparative analysis (Semenov 1964; Ettos 1985; Vincent 1985, 1993; Averbouh & Provenzano 1999; Villa & d'Errico 2001; Liolios 2003).

5.4 Methods for eliminating 'pseudo-bone modifications'

Studies conducted by various researchers have established guidelines for discerning bone tools. However, natural processes can sometimes alter bones in ways that mimic human modification or use. Hence, this study considers a range of natural processes that may result in the creation of 'pseudo-bone tools.' Criteria commonly used to identify human modification of bone include surface striations, sheen, polish, and breakage. Nonetheless, numerous non-human processes can also produce similar modifications. For instance, striations on bone surfaces can arise from rockfall (Oliver 1989; Fisher 1995), sedimentary abrasion (Shipman & Rose 1983; Andrews & Cook 1985; Behrensmeyer *et al.* 1986; Haynes 1988; Olsen & Shipman 1988; Fisher 1995), trampling (Andrews & Cook 1985; Behrensmeyer *et al.* 1986; Haynes 1988; Olsen & Shipman 1988), root etching (Andrews & Cook 1985; Haynes 1988) vascular grooves (Shipman & Rose 1984), bone remodelling during the life of the animal (D'Errico 1993), carnivore gnawing (Behrensmeyer 1978; Binford 1981; Shipman & Rose 1983; Blumenschine 1988; Fisher 1995), herbivore gnawing (Sutcliffe 1973a), rodent gnawing (Andrews & Cook 1985), insect burrowing (Shipman 1981), and snail, beetle, and larvae damage (Dirks *et al.* 2015), among others. Similarly, sheen and polish on bone surfaces can result from natural processes such as water transport (Behrensmeyer 1982; Jalvo 2003), sediment freezing/thawing or clay shrinking/swelling (Wood & Lee Johnson 1978), carnivore gnawing and repeated licking (Sutcliffe 1970; Haynes 1982), digestion by carnivores and raptors (Sutcliffe 1970; Fisher 1981, 1995; Marean 1991), and use as a juvenile carnivore play item (Haynes 1982), among others. Thus, this study eliminates all possible modification from a natural agent.

5.5 Methods for identifying the possible 'man-induced bone modifications'

Throughout the study, criteria for identifying human modification and/or use of bone were based on experimental and archaeological studies that took natural processes into consideration, including striations on bone surfaces resulting from scraping with a lithic edge during manufacture (Campana 1989; D'Errico 1993; d'Errico & Backwell 2003); striations from grinding bone against a fine or rough-grained surface during manufacture (d'Errico *et al.* 1984; Campana 1989); striations from use (d'Errico & Backwell 2003; d'Errico *et al.* 2012b; Tartar 2012b); hammerstone percussion marks and notches from shaping during manufacture (Henshilwood *et al.* 2001; d'Errico *et al.* 2012b; Tartar 2012b; Vettese *et al* 2020); and step-fractures from shaping and/or use (Henshilwood *et al.* 2001), and polish and sheen from use as a tool (Frison 1982; Shipman & Rose 1988; Campana 1989; Backwell & d'Errico 2001b; d'Errico *et al.* 2012b).

Following the methodology for bone tool recording presented in Henshilwood *et al.* (2001), a typological approach that incorporates manufacturing was used to analyse the Contrebandiers Cave bone tools. This approach was selected to allow for detailed descriptions of the steps taken in the manufacture and use of each piece. Each bone that displayed evidence of manufacture or use was recorded using the same criteria in order to reconstruct the sequences of actions taken. In addition, this study recognise that similarly shaped bone tools might have been used for different tasks.

Methods for recording the bone specimen: Identification of the raw material selected to manufacture or use each bone tool includes, when possible, taxonomic identification, size class, skeletal element, and skeletal element side. The manufacture of each piece was recorded using the following categories: Localisation and extent of worked areas, manufacturing technique used, occurrence of wear, presence, and location of breakage, burning, ochre or mineral staining, cut marks, and post-depositional traces of damage, which is extended in the section 6.6. Length, width, and thickness were recorded for each bone. Shaping techniques and use-wear were recorded for each piece using bright low-angle light coupled with a hand magnifier (10x), as well as a Leica S6D Greenough microscope (focus 0.75/70x) equipped with an integrated high-definition digital camera, Leica EC3.

5.6 The list of criteria to document the specimens

For each end, the following parameters were recorded.

I. *The general morphology of the tip*: straight, spiral, pointed, saw-toothed, convex, concave, or mixed (i.e. combining different morphologies on the same tip)
II. *The total number of negatives removals per extremity, and their position*: cortical, medullary, cortical/medullary
III. Where a bevel is present, the measurement of its angulation.

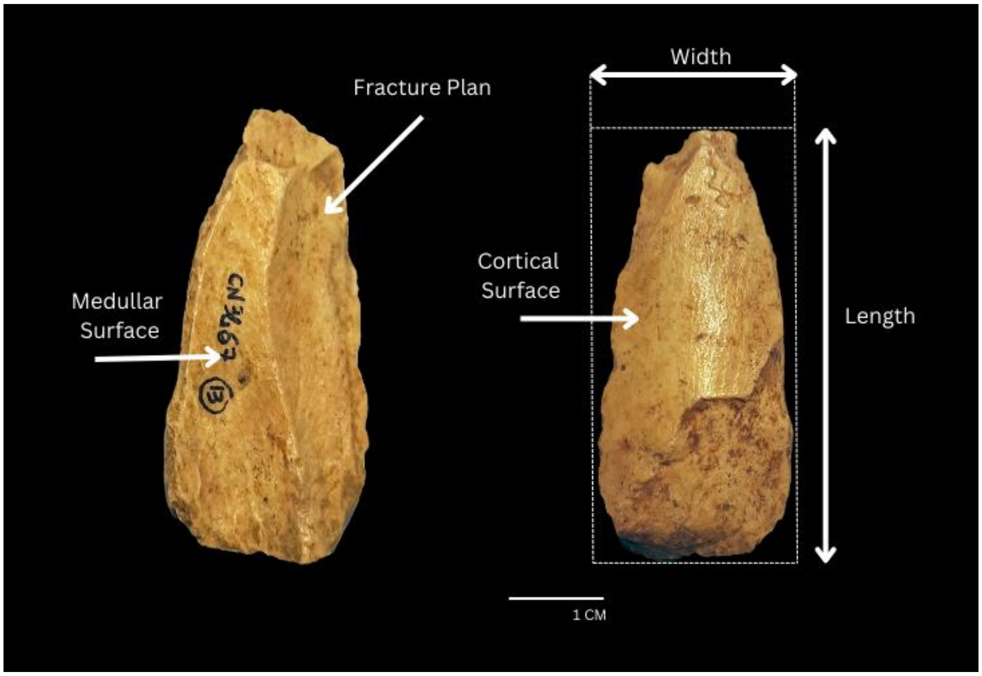


Figure 3: Description and measurements of the bone specimen

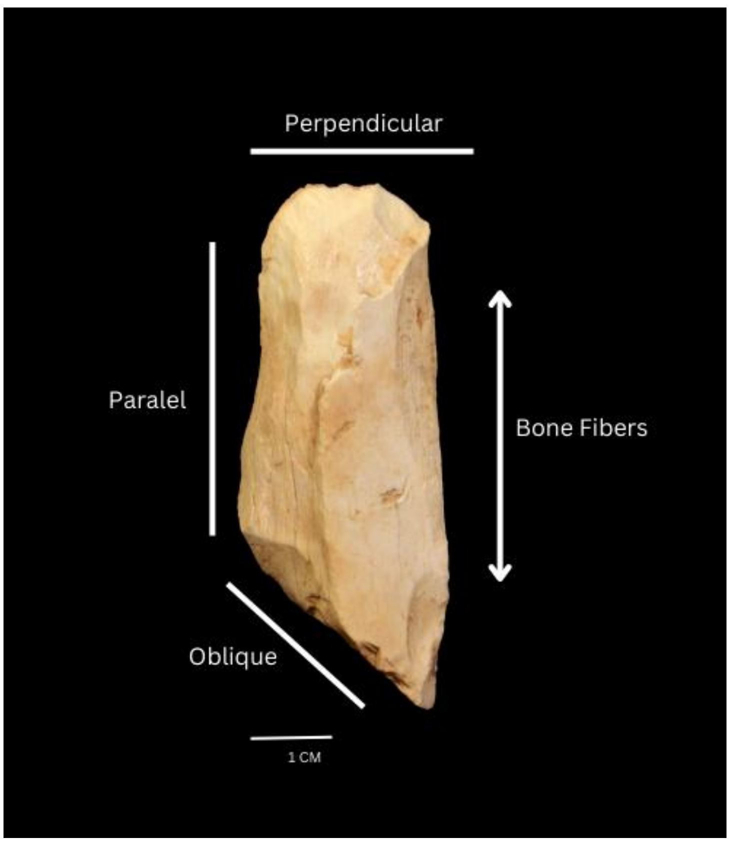


Figure 4: Orientation of the edge in relation to the bone fibres

For each negative removals, the following parameters were recorded.

I. *The position*: cortical or medullary
II. *The integrity of the negative*: is it complete or has part of it disappeared due to an overlap with another negative
III. *The length (in mm) of the negative*: from the end of the part to the distal end of the negative
IV. *The morphology of the negative*: the shape of its contour (i.e., rounded, quadrangular, triangular and flake-shaped). When the shape of a contour was a (more or less) straight line, it was recorded as 'indeterminate'
V. The presence of a counter-bulb
VI. Where possible, *i.e.,* where negative removals overlapped, they were recorded in chronological order of appearance: from oldest to most recent.

The abbreviations used in the tables in the following chapter are defined here:

I. *Negative name*: corresponds to the registration number of the negative, from the oldest to the most recent where this can be deduced from an overlap. This name begins with E1 (for 'end 1') or E2 (for 'end 2') and is followed by the negative's own number, starting from 1 for each end. The corresponding number can be found on the illustrations in the appendix.
II. *Position*: indicates the cortical or medullary position of the negative.
III. *Length*: measurement (in mm) of the length of the negative.
IV. *Contour shape* indicates the type of contour of the negative; rounded, quadrangular, triangular, Indeterminate

The characterisation of the cross-section of the part, such as convex-concave, sub-rectangular, or sub-triangular, along with the two thickness measurements, provides insight into the volume of the bone. While documenting these characteristics of the ends and negatives, it is important to note that their presence does not necessarily indicate usage. Nevertheless, this documentation enables to describe these elements and discern any recurring patterns or features.

In order to investigate the second hypothesis, a specific set of parameters was employed. The general descriptive attributes of retouched lithic edges were delineated following the framework established by Inizan and colleagues (1995), which was modified to accommodate bone material.

I. *Position*: cortical, medullary, on a fracture surface

II. *Distribution*: continuous, discontinuous (each part has continuous removals, otherwise it would not have attracted attention; however, it is possible that not all the removals are continuous on the same edge)
III. *Span*: short, long
IV. *Inclination*: steep, semi-abrupt, grazing, straight, convex, concave.
V. *Morphology* (of the removals as a whole): scaly, scalariform (scaly: broad, rather short removals reminiscent of fish scales; scalariform.

Thus, employing the recorded characteristics of the negative removals from the pieces within the initial corpus, the study proceeded to enumerate and characterise the negative removals themselves. This information was presented in the form of tables, detailing their position, integrity (whether their contour remains intact or is truncated by overlapping), length (measured in millimetres), type of distal termination and contour, as well as the presence of a counter-bulge. The latter is often cited in support of shaping by percussion (Romandini *et al.* 2015), along with the presence of a patina of distinct colour compared to the rest of the piece, or the presence of blunt edges.

5.7 Bone tool imaging methods

Colour photographs of bone tools and 5 cm scales were taken with a Nikon D5100 Digital camera using a 35mm macro lens and 85 mm micro lens. The photographs were first imported into Adobe Photoshop 2024 for adjustments including white balance, tone, contrast, and colour correction using the white portion of the scale in each image as reference. The background was then removed, and a scale bar of 1 CM was added. Each bone specimen underwent refinement using the threshold option to adjust the levels of whiteness and blackness in order to enhance the visibility of surface modifications and removals. Retouching of images was performed as needed using the burn and dodge tools.

Microscope images of bone tools were captured using a Leica S6D Greenough microscope (focus 0.75/70x) equipped with an integrated high-definition digital camera, Leica EC3. These microscope photographs underwent a similar process in Adobe Photoshop 2024, including background removal where necessary. Finally, the finalised microscope and bone tool photographs were assembled into figures using Adobe Photoshop 2024 and Adobe Illustrator 2021 as needed for each occasion.

5.8 Experimentation

In order to observe and characterise technological and use-wear traces, a small-scale experiment was conducted on August 11, 2023, at the premises of the Department of Humanities, University of Ferrara. The experiment was led by experienced experimental flint knapper and lithic specialist Davide Delpiano (PhD), along with Alessandra Livraghi (PhD), Gloria Cattabriga (PhD [reading]), and the author of this dissertation. The experimentation was designed to observe patterns of traces of manufacture and use wear:

a) To observe bone breakage patterns (in case of pseudo-removals)
b) Retouching edges

All experimental bone tools were obtained from fresh *Bos taurus* long-bones (2 femurs, 2 tibias, 2 ulnas and 2 radius). These bones were acquired post-slaughter from butchery, ensuring their freshness and suitability for experimentation (referred to as stage 0, following Behrensmeyer's classification from 1978). All debitage were carried out in direct percussion with a hard hammer (pebbles from 1-1.5 kg) on anvil. Careful selection was made within each group to identify bones with optimal edge angles for knapping, ensuring the highest quality tools were produced.

Following initial shaping, the blanks underwent retouching via direct percussion executed by the aforementioned knappers. The primary objective of this retouching was to establish a sharp cutting edge or to refine any natural cutting lines formed during the initial fracture. Depending on the configuration of the blank, the retouching technique employed could be either unifacial or bifacial. The extent of retouching, measured by the number of removals, varied among individual specimens.

Before and after their production and subsequent use, thorough examination of these tools was conducted. This examination process involved the use of a Leica S6D Greenough microscope, offering precise magnification capabilities with a focus of 0.75/70x, augmented by observations made using a hand magnifying glass (10x). Such examinations sought to discern any alterations or wear patterns, providing valuable insights into the tools' functionality and utilisation over time.

5.9 Limitations of the study

The aim of this thesis is to test the hypotheses formulated in 5.2. As pointed out in Chapter 2; in order to answer all the questions raised, the study of these specimen would have required an 'interdisciplinary approach' combining taphonomic and experimental studies. The validation of these particular bone objects was conducted through meticulous microscopic analyses of their surfaces. These analyses aimed to document any potential traces of manufacture and use. Importantly, this validation process was carried out in deeply enrooted to their taphonomic contexts, allowing for a focused examination of the bone objects themselves. This approach helps refine our understanding of the objects' origins, usage, and potential significance within the broader archaeological or anthropological context.

While this dissertation benefited from a substantial amount of experimental materials, there were notable limitations stemming from the extensive experimentation program. One major constraint was the time allocated for the dissertation, which may have restricted the breadth of the experimentation conducted. Additionally, the availability of resources, including equipment, materials, and personnel, may have imposed limitations on the scope of the experimentation. The bones employed in the experimentation were in a fresh state. Regrettably, due to time limitations, dry bones—classified as stage 5 according to Behrensmeyer's schema from 1978 and typically acquired after prolonged exposure to open air—were unavailable for use.

Furthermore, the reliance on experimental data may introduce inherent biases or limitations in the interpretation of results. Factors such as sample size, variability in experimental conditions, and the generalisability of findings should be carefully considered when drawing conclusions from the study. Overall, while the dissertation benefited from ample experimental materials, the limitations imposed by time constraints and other practical considerations should be acknowledged when interpreting the findings and implications of the research.

Ultimately, this study utilised 70X magnification to detect use wear traces, yet some researchers have employed magnifications ranging from 100X to 500X to identify potential use traces on bone surfaces[48]. This discrepancy poses a imitation to the study. Future analyses of the same bone tool assemblage should consider using magnifications between 100X and 500X to further validate the utilisation of the bone tools, as suggested herein.

In summary, the methodology chapter addresses a significant challenge posed by the limited availability of references for bone intermediate and retouched tools. To overcome this challenge, a comprehensive framework was constructed encompassing archaeological, taphonomic, and experimental approaches. Substantial investments were made in research and experimentation to establish a robust comparative framework. This effort involved rigorous scrutiny and analysis of archaeological discoveries alongside experimental data. The primary goal was to elucidate the technological characteristics and use wear patterns of the bone tools under investigation. By undertaking these endeavours, the methodology aimed to enhance understanding of bone tool manufacture, use, and application within archaeological contexts. Overall, the methodology chapter underscores the importance of systematic research and methodological rigor in advancing knowledge of Neanderthal bone industries and their cultural implications.

[48] Consult Almeida Évora (2015) for a review and discussion of various magnification strengths, for bone surface use wear analysis in Archaeology.

Chapter 6
RESULTS AND FINDINGS

Through an exhaustive exploration of archaeological data using the methodologies elaborated on chapter 5, this thesis seeks to unravel the complexities surrounding the bone industry, shedding light on its evolution, significance, and implications for understanding Neanderthal behavioural complexities. The subsequent sections delve into the specifics of the research findings, organising them thematically to facilitate a comprehensive exploration of the multifaceted nature of the bone industry and its significance in the broader context of human history. At grotta de Nadale, a total of 122 'prospected' bone tools were discovered within Middle Palaeolithic deposits, which can be attributed to Layers 3, 5, 6, 7, 13, and 14.

6.1 First things first: a glimpse of the total assemblage

6.1.1 State of Preservation

From the total number of identified specimens, only 3.4% (292 out of 7146) exhibit carnivore marks, such as punctures and pits caused by teeth impacts, fracture scars resulting from scooping out of matter, coring, and furrowing due to friction of teeth, as well as smoothing resulting from ingestion, characterised by a dimpled aspect or a shiny surface (Campmas & Beauval 2008). Bones fragments exhibiting signs of acid corrosion, characterised by strong dullness and dimpling, constitute a mere 1.6% of the total. Vermiculation traces, on the other hand, are more prevalent, accounting for 21.9% of the overall assemblage. The figure below provides a summary of the various natural agents that have affected the faunal assemblage.

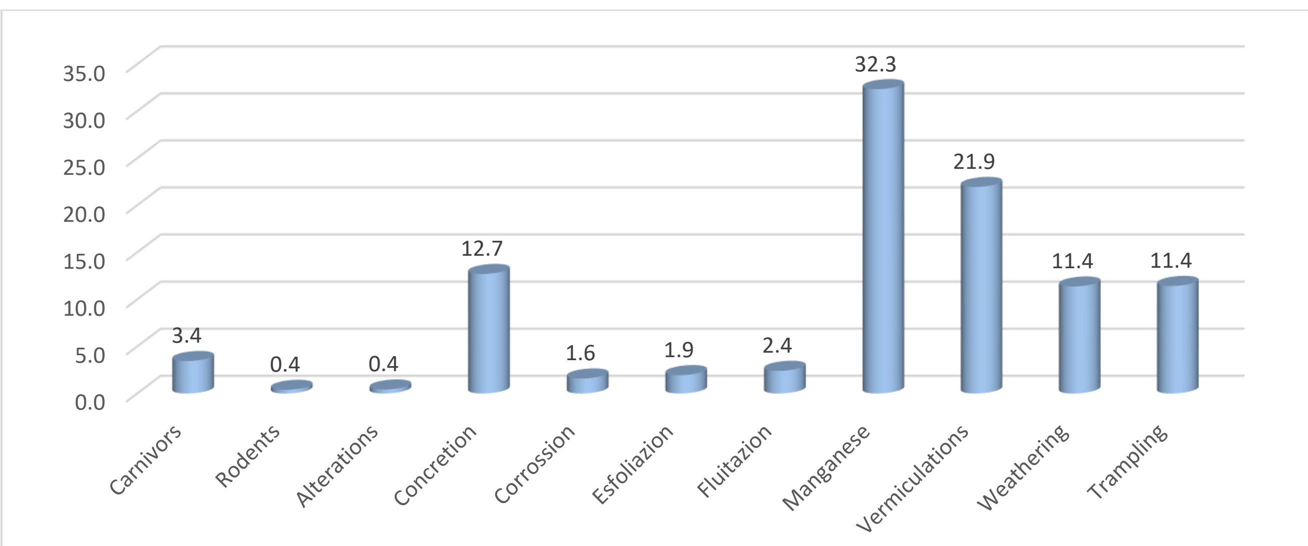


Figure 5: Percentage of natural taphonomic modifications observed on the total bone assemblage

The specimens within the studied methodological framework are generally well-preserved. However, their technological and tracelogical analysis was somewhat constrained by material desiccation, which resulted in longitudinal fragmentation of approximately 10% of the pieces due to post-depositional breaks. Additionally, transverse disintegration occasionally occurred, causing deformation of volumes or desquamation of outer layers, although this was less common. Despite the presence of manganese oxide deposits on nearly all pieces, these deposits do not significantly impede surface analysis.

6.1.2 Provenance of Blanks

The anatomical parts and taxa used for the bone toolkit are not diversified. These are all limb bone diaphysis of medium (14%), medium-large (40%), and large (31%) ungulates. Additionally, 15% of the bone blanks were indeterminable in terms of animal size, owing to insufficient anatomical data (figure 7).

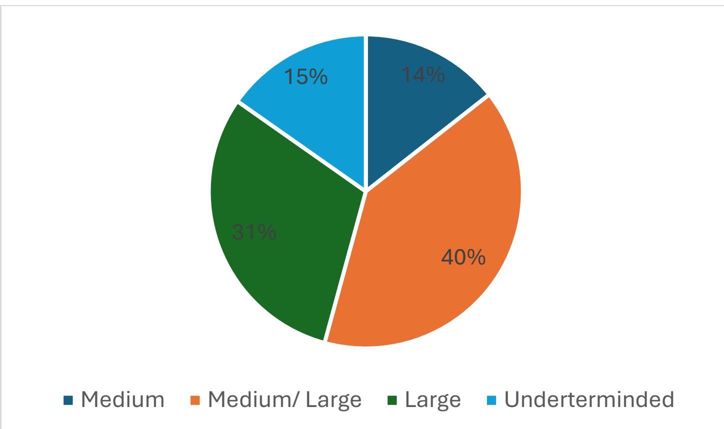


Figure 6: Percentages of provenance of blanks according to the size of the animal

Within the selected assemblage, ungulates account for 51% of the taxa identified, with Genus *Bos* and *Megaloceros giganteus* collectively representing 11% of the total identified species. *Cervus elephus* constitutes 23%, while *Cervidae* and *Alces/Megaloceros* each make up 2% and 3%, respectively (figure 7).

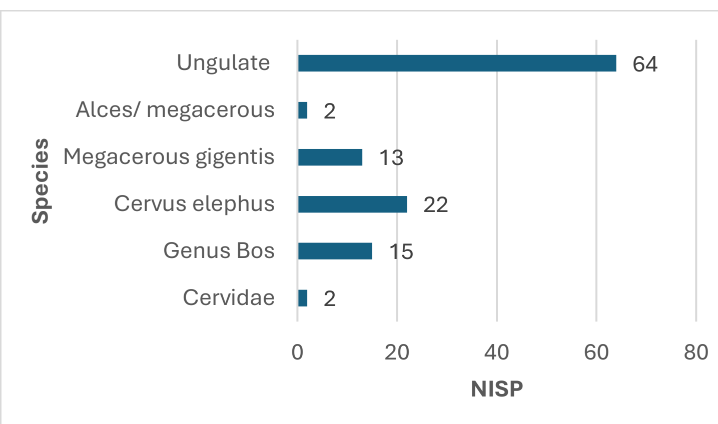


Figure 7: Percentages of the taxa within the assemblage

Within the assemblage, the anatomical selection predominantly emphasises limb bones, which constitute a significant portion of the identified remains. Specifically, a substantial proportion, accounting for 45%, comprises unidentified limb bones. Identified limb bones include 14% tibia, 13% humerus, 11% femur, and 7-8% each for metacarpals and metatarsals, with only 3% representing the radius (figure 8).

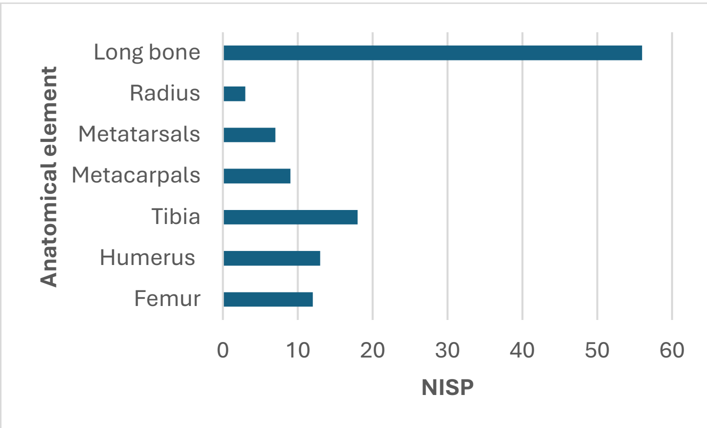


Figure 8: Anatomical selection within the assemblage

In an anthropic assemblage, the fracturing of limb bones is almost always a component of the food consumption process, primarily aimed at extracting marrow. Consequently, the acquisition of bone blanks for technical applications is commonly regarded as retrieving flakes from the leftovers of butchering activities (Tartar 2012b). Among the entire chosen assemblage (n=122), 57 pieces are identified as bearing retoucher marks, representing 47.1% of the specimens described in this study.

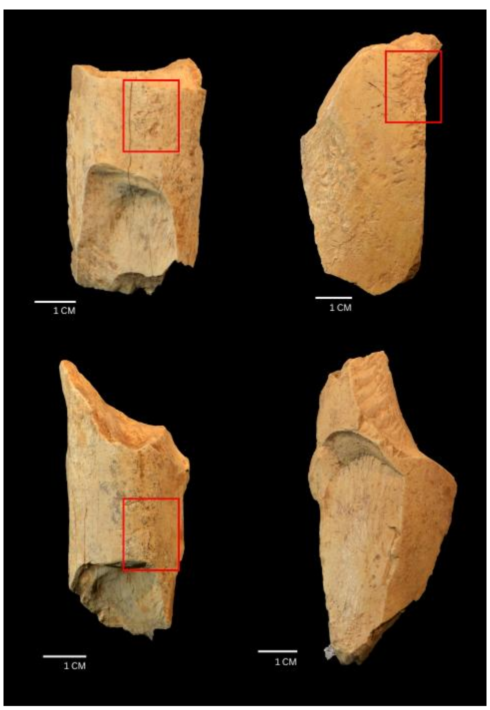


Figure 9: Specimens initially selected for analysis but subsequently excluded from further analysis processes due to non-anthropic bone breakage patterns, as detailed by (Blumenschine & Selvaggio 1991b; a; Villa & Mahieu 1991; Capaldo & Blumenschine 1994; Moclán & Domínguez-Rodrigo 2018).

6.2 Preliminary Results

During the sorting of bone fragments from the layers of grotta de Nadale, 122 unshaped fragments were found. Two categories of artefacts were distinguished according to the particular pattern of their presumed traces of use and their resemblance with tools identified Middle Palaeolithic ones according to similar tracelogical and/or morphological criteria: Negative removals perpendicular to the long axis of the bone (N = 62), Negative removals parallel to the long axis of the bone (N = 60).

Table 1: Distribution of the bone tools by layer

Category	US 1 rim	US 3	US 5	US 6	US 7	US 13	US 14	US 18	Total
Negative removals perpendicular to the long axis of the bone	4	1	3	4	12	28	10	1	62
Negative removals parallel to the long axis of the bone	3	1	4	6	14	18	8	6	60
Total									**122**

Bone modification category 1: Negative removals perpendicular to the long axis of the bone

Negative removals on both ends of the bone (one end has negative removals and other edge is flat/crushed)

Stage I: Acquisition of raw materials– 'the choice'

The category one comprised of ungulate long bones, predominant taxa being medium sized ungulates, followed by *Cervus elephus* and large sized ungulates (figure 10, 11; table 2).

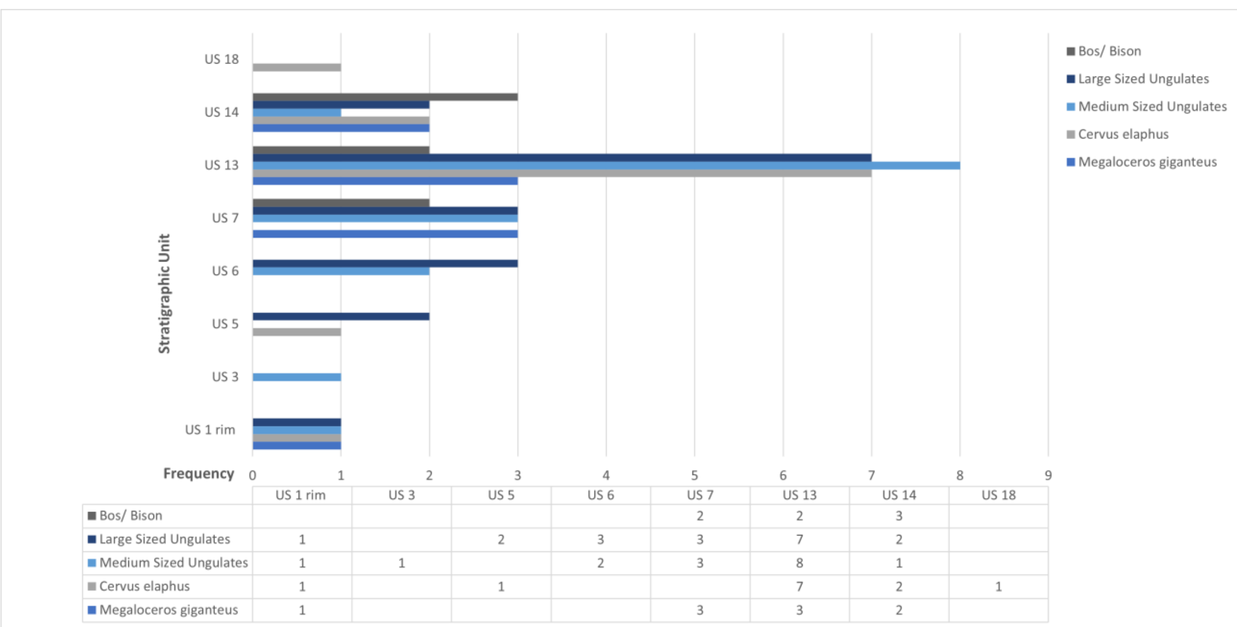
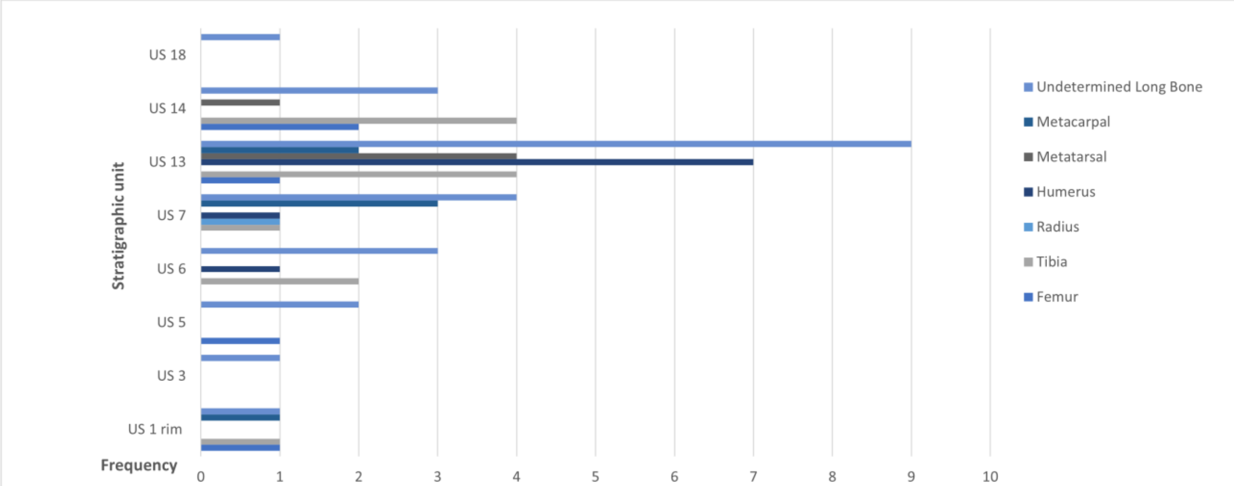


Figure 10: Comparison of the taxonomic origins of the category 1 among stratigraphic units of grotta de Nadale



	US 1 rim	US 3	US 5	US 6	US 7	US 13	US 14	US 18
Undetermined Long Bone	1	1	2	3	4	9	3	1
Metacarpal	1				3	2		
Metatarsal						4	1	
Humerus				1	1	7		
Radius					1			
Tibia	1			2	1	4	4	
Femur	1		1			1	2	

Figure 11: Comparison of the anatomical origins of the category 1 among stratigraphic units of grotta de Nadale

For the retouchers, tibia and radius were the frequently used anatomical element (Martellotta *et al.* 2021), but in this study, radius is the least represented (figure 11, 12).

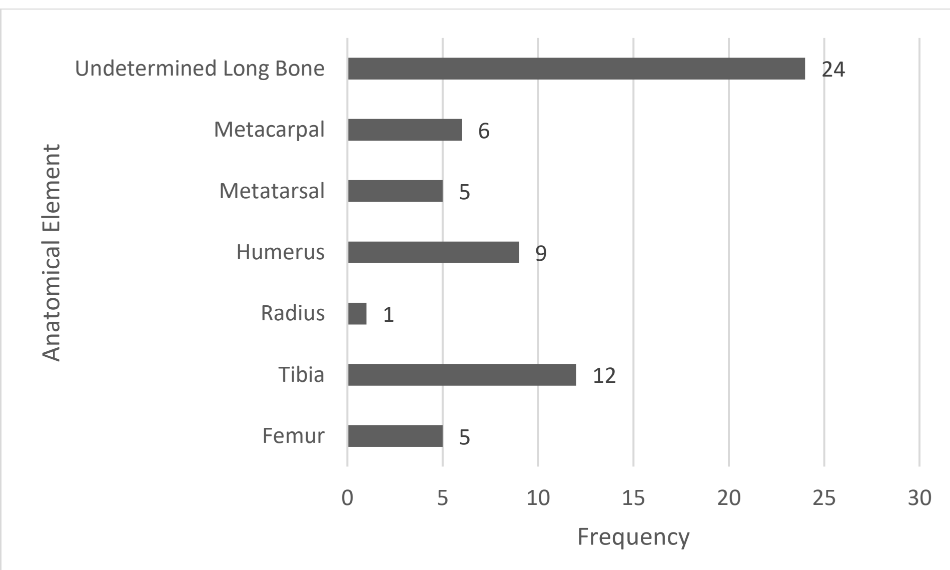


Figure 12: Overview of the anatomical origin of the category 1

The FFI of the various assemblages is relatively low (between 1.3 and 1.7) and is compatible with anthropogenic fracturing to extract the marrow (Outram, 2001). The bones were therefore fractured rather freshly, which probably explains the presence of helical fractures that sometimes-produced pseudo-negative removals.

The dimensions of the tools exhibit significant variability, suggesting that the criteria for selecting bone pieces are not highly stringent. Complete specimens, on average, measure approximately 7 cm in length, with the longest specimen recorded at 12.4 cm. In terms of width, the average is approximately 2.9 cm, with the maximum width reported being 4.9 cm (figure 13, 14).

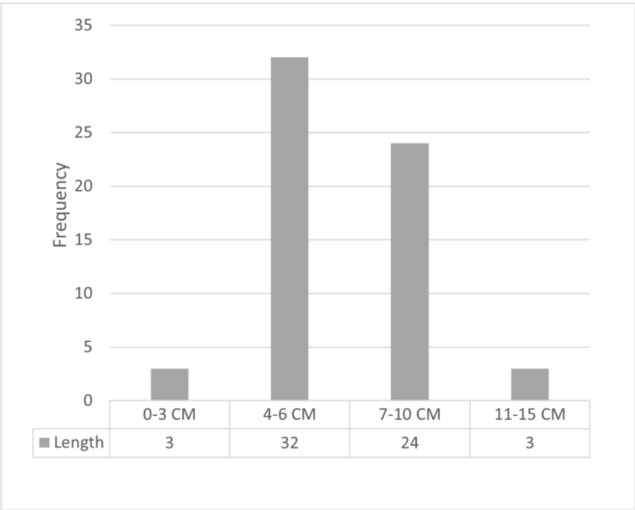


Figure 13: Variability of the length of category 1

The observed variability in the dimensions of the tools suggests that the criteria for selecting bone pieces were not rigidly constrained by specific dimensional requirements. Instead, it indicates a degree of flexibility and adaptability in the choice of raw materials for tool production. The maximum lengths of the tools exhibit a considerable range, spanning from 3.5 to 12.4 cm, while the maximum widths vary between 0.8 and 4.9 cm.

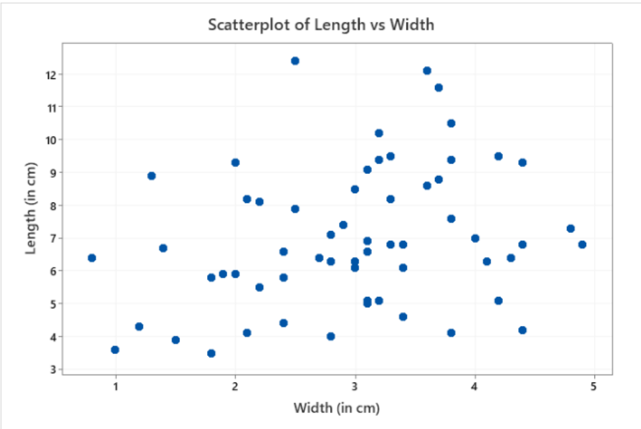


Figure 14: Scatterplot diagram of the values of length and width of category 1

This variability in tool dimensions may arise from several factors:

Availability of Raw Materials: These materials are probably a by-product of breaking limb bones for marrow extraction; therefore, it is likely that they were made out of bone materials that were readily accessible within their environment. As a result, the size and shape of available bones would have varied, influencing the dimensions of the resulting tools.

Functional Considerations: While certain tasks may have necessitated specific tool dimensions, such as the length or width of a scraping tool, others may have allowed for more flexibility. The tool may have adapted the size and shape of the tools to suit the requirements of different tasks, resulting in a range of dimensions among the produced tools.

Technological Constraints: The tools may have been manufactured using techniques that allowed for flexibility in shaping the bone material. Stone tools or abrasive materials could have been used to shape the bone, enabling craftsmen to work with bones of varying sizes and shapes.

Longitudinal fracture planes, the most frequent, result from fractures starting at one extremity and following the bone's fibres along a sagittal (perpendicular to the bone surface), frontal (parallel to the bone surface) or intermediate axis (Tartar 2012b).

Stage II: Manufacture

In this case, the particular arrangement of the damage, at both ends, refers to a same operating mode. The tools are hammered on one end for splitting or cutting a material with the opposite end. The present lack of comparative base on intermediate bone tools prevents from identifying here the tasks carried out or the worked materials, *i.e.,* from subcategorising this group, whether worked on wood or antler splitting. The majority of them bear manufacture and use wear traces, best fit for the criteria described for 'intermediate tools' (Tartar 2012; Kozlikin *et al.* 2020b; Baumann *et al* 2020). One piece may belong to several categories. In most cases, both categories also have evidence of use as retouchers (table 2, 6), in a former step of the blank when the chronology is discernible. Part of these retouchers is already published (Martellotta *et al.* 2021). The motivation for this dissertation is, however, excludes the examination of retouchers. This study also excludes helical fracture-shaped negative removals on a pointed end. This is not a grazing negative, as it takes up the entire thickness of the bone fragment; it is in fact a 'pseudo-negative', more precisely a fracture surface that extends beyond the cortical surface of the bone fragment.

Following this, category 1, best fit for the criteria described for 'intermediate tools' (Tartar 2012; Kozlikin *et al.* 2020b; Baumann *et al* 2020), hereafter referred as intermediate tools, comprises diaphyseal fragments likely originating from food processing activities. These tools encompass pieces exhibiting damage at both ends indicative of a consistent operational mode. They are utilised by hammering at one end to split or cut the material being worked (known as distal end), with the opposite end serving as the point of contact with the working material (known as proximal end). The wear characteristics of intermediate tools have been discerned based on this raw material. The distal end is discernible by the presence of a compacted surface where bone fibres are impacted. Additionally, hammering may result in the formation of a crushing flange around the edge of the impact surface (as described by Rigaud, 1984), or the removal of chips of varying invasiveness (resulting from the rupture of bone fibres). The traces of use at the other end vary depending on the type of material processed (as noted by Tartar, 2012). On the active portion, often beveled, compactions and removals are occasionally accompanied by striations of variable lengths originating from the front line or use wear polish (Kozlikin *et al.* 2020b; Baumann *et al*. 2020).

Table 2: Terminology and the characteristics of the category 1 artefacts

Terminology	Similar terms used	Characteristics[49]	Notes
Distal End (Tartar 2012b)	- Apical End (Kozlikin *et al.* 2020b) - Hammered end (Baumann *et al.* 2020)	- Presence of an impacted surface where bone fibres are compacted (Tartar 2012b; Baumann *et al.* 2020) - Deformation of bone fibres or removal of more or less invasive chips (rupture of bone fibres) (Baumann *et al.* 2020, 2023) - Formed by the natural bevel at the intersection of the cortical face and of the fracture plane (Burke & d'Errico 2008a; Baumann *et al.* 2020) - Solid in square in section (Tartar 2012b) - Chipping on the medullary surface at the distal end (Baumann *et al.* 2023) - A blunt over removals on both cortical and medullar surfaces (Baumann *et al.* 2023)	- Categorisation of the distal ends based on the morphology: (a) Straight and (b) Convex (Baumann *et al.* 2020) - An emerging correlation is observed between the dimensions of distal extremities and the frequency of invasive removals, as well as between narrower extremities and a reduced occurrence of marked removals. This relationship is likely attributed to differences in resistance at the initial active end. - Tartar (2012) and Baumann *et al.* (2020) assert that blunting primarily manifests as a distal scar, often found

[49] The concentration and nature of marks observed at both ends of a tool are contingent upon several factors, including the characteristics of the working material, the type of hammerstone used, and the angle at which the striking occurs (Rigaud 1984; Provenzano 1998; Tartar 2012b). Firstly, the composition and properties of the working material significantly influence the marks left on the tool. Variations in material hardness, texture, and resilience dictate how it responds to the force of percussion. For example, softer materials tend to exhibit deeper and more distinct marks, while harder substances may yield shallower impressions.

Secondly, the choice of hammerstone plays a crucial role in shaping the marks on the tool. Hammerstones vary in size, shape, and density, each imparting unique patterns and depths of impact. Coarser hammerstones, for instance, may produce rougher and more irregular marks compared to smoother ones.

Additionally, the angle of impact during the striking process impacts the distribution and intensity of marks on the tool. Different angles of striking can generate varied patterns and concentrations of marks. A perpendicular strike, for instance, may result in deeper and more concentrated marks, whereas a glancing blow might produce shallower and more dispersed impressions.

Overall, the interaction between the properties of the working material, characteristics of the hammerstone, and the angle of striking determines the degree of mark concentration and the specific types of marks observed at both ends of the tool. A comprehensive understanding of these factors is crucial for interpreting archaeological evidence and reconstructing past technological practices.

			at the edge and extending across both faces, although it may not always be easily identifiable.
Proximal End (Tartar 2012b)	- Basal end (Kozlikin *et al.* 2020b) - Active end (Baumann *et al.* 2020)	- Generally flat perpendicular to the longitudinal axis of the bone (Tartar 2012b) - Have transverse fractures in flexion, indicating a violent and sudden rupture of the bone fibres (Baumann *et al.* 2020) - Removal scars are more abundant and larger in the proximal end (Tartar 2012b) - Compaction is more difficult to detect on the proximal end (Tartar 2012b) - Sawtooth morphology (*i.e.,* fracture initiation from the lateral side) or hinged morphology (*i.e.,* fracture initiation from the upper side) (Baumann *et al.* 2023) - Crushing, consequence of the compression of the bone fibres caused by hammer's repeated blows, is very pronounced in the distal part (Baumann *et al.* 2020)	- Categorisation based on the locality of the negative removals: (a) Transversal bending fractures (mesial part); (b) Oblique or more or less curved fractures (closer to the distal end) - Categorisation based on the morphology of the removals: (a) Wide and relatively flat (with small chipping); (b) End is narrow and pointed. (Baumann *et al.* 2020)

Table 3: Compilation and interpretation of all traces observed on the pieces belonging to category 1 from grotta de Nadale

ID	Year	Layer	Species	Size	Generic Anatomical Element	Specific Anatomical Element	Anthropic Marks	Retoucher Marks
CN3486	2019	3	Ungulate	III	Limb bone		Longitudinal and Oblique. Grouped in the Mid portion of the bone surface.	x
CN3482	2019	5	Ungulate	IV/V	Limb bone		Longitudinal and oblique cut marks are present all over the bone surface. Mid portion.	
CN4531	2021		*Cervus elaphus*	III/IV	femur	Mid diaphysis	Oblique cut marks	x
1032	2017	6	Ungulate	III/IV	Limb bone		Long longitudinal cut marks (very few), not deep very light, are scattered on the bone surface. Isolated.	
443	2014		Ungulate	IV/V	Tibia		Long and short (longitudinal and oblique) cut marks are present all over the bone surface. Isolated.	x
181	2017		Ungulate	III/IV	Limb bone		Longitudinal and Oblique. Grouped in lateral of the bone.	x
198	2017		Ungulate	IV/V	Limb bone		Longitudinal. On the lateral edge of the bone surface	
CN3552	2022		Cervus/Megaloceros	IV/V	Tibia	Mid diaphysis		x
112	2014	7	Ungulate	IV/V	Metacarpal		Tiny cut marks are scattered through the bone surface. Isolated. Grouped cut marks near the retoucher marks.	x
386	2014		Ungulate	III/IV	Humerus		Oblique, relatively short cutmarks present at the lateral portion of the bone	
445	2014		Bos/Bison	IV/V	Humerus		Oblique. Grouped in lateral part of the bone.	x
CN2173	2015		Ungulate	III/IV	Limb bone		2-3 oblique cut marks are grouped in the Mid portion of the bone surface.	

627	2015		Ungulate	III/IV	Limb bone		Longitudinal. Relatively long cut marks all over the bone surface	x
577	2014		*Megaloceros giganteus*	IV	Metacarpal			x
20	2014		Cfr. *Megaloceros giganteus*	IV	Radius		Oblique. Grouped in lateral part of the bone.	
565	2014		Ungulate		Limb bone		Oblique. Lateral portion of the bone surface.	
1155	2022		Alces/Megaloceros	V	metacarpal	Mid diaphysis, anterior portion	Oblique and longitudinal cut marks scattered through the bone surface.	
1103	2021		Bos/Bison/Megaloceros	V	tibia	Distal diaphysis +posterior portion	Numerous oblique to the axis, short and insistent	x
795	2017		Ungulate	V	Limb bone	Diaphysis	Longitudinal scraping marks (removal of the periosteum)	x
CN3134	2017	13	*Cervus elephus*	III	Metacarpal	Mid diaphysis, Anterior portion	Longitudinal cut marks are present on the Mid portion of the bone surface. Grouped on one side.	
CN3485	2019		*Megaloceros giganteus*	IV	Metatarsal		Oblique cut mark is present on the lateral portion of the bone surface.	
CN3197	2017		Ungulate	IV/V	Tibia	Diaphysis	Oblique. Scattered in the Mid part of the fragment. Isolated.	
CN3230	2017		Ungulate	III/IV	Limb bone	Diaphysis	Tiny cut marks on the lateral portion of the bone surface	x
CN3483	2019		*Cervus elephus*	III	Humerus	Proximal diaphysis	Longitudinal and Oblique. Grouped in the Mid portion of the bone surface.	
CN2730	2017		Ungulate	IV	Limb bone		Oblique cut marks are scattered (isolated) all over the bone surface.	
CN3393	2017		Ungulate	IV	Limb bone		Small isolated cut marks on lateral sides	
CN3185	2017		Ungulate	IV/V	Metatarsal	Mid diaphysis		
CN3491	2019		*Cervus elephus*	III	Humerus	Mid diaphysis, Lateral portion	Tiny oblique cutmarks on lateral side of the bone.	

CN3232	2017		Ungulate	III	Tibia	Diaphysis	Longitudinal. Grouped at the tip of the bone.	
CN2455	2017		*Cervus elephus*	III	Femur	proximal shaft, anterior lateral portion	Few cutmarks on the tip of the bone.	
CN2372	2017		Bos/Bison	IV/V	Tibia	Diaphysis	Tiny cut marks are scattered through the bone surface.	
CN2461	2017		Ungulate	IV/V	Limb bone		Oblique. Scattered in the Mid and lateral part of the bone.	
CN3157	2017		Ungulate	IV/V	Humerus	Distal diaphysis, Lateral portion	Longitudinal. Isolated. Present in the Mid portion of the bone.	
CN2410	2014		Ungulate	III/IV	Undetermined		Relatively long longitudinal cutmarks present at lateral portions of the bone surface	
CN3490	2019		*Cervus elephus*	III	Metatarsal	Mid diaphysis		
CN2387	2017		Cfr. Bos/Bison	IV/V	Tibia		Tiny cut marks scattered through the bone surface.	
CN3421	2019		Ungulate	III/IV	Limb bone			
CN2492	2017		Ungulate	III/IV	Limb bone		Oblique. Mid portion of the bone surface. Grouped by two.	
CN3412	2014		Ungulate	III/IV	Limb bone		Longitudinal. Lateral portion of the bone surface.	
CN3492	2019		Ungulate	III/IV	Limb bone		Relatively long longitudinal cutmarks present all over the bone surface.	
CN2499	2017		Ungulate	III/IV	Humerus		Oblique. Mid portion of the bone.	
CN4328	2019		*Cervus elephus*	III/IV	humerus	Mid diaphysis	Oblique and longitudinal cut marks scattered through the bone surface.	x
CN4071	2019		*Cervus elephus*	III/IV	metacarpal	Mid diaphysis, anterior portion	Tiny cut marks scattered along the lateral edges	x - Double
CN3638	2019		Cfr. Alces/Megaloceros	III/IV	Humerus	Distal diaphysis, caudal portion	Short and Long Cut marks are scattered	x - Double
CN4068	2019		Cfr. Megaloceros/Bos	V	humerus	Diaphysis		x

CN3811	2019		Ungulate	V	Metatarsal	Diaphysis medial-proximal, tibial crest	Numerous, oblique to the axis; some scraping marks	x
CN3493	2017	14	Ungulate	IV/V	Limb bone		Tiny oblique cutmarks on lateral side of the bone.	x
CN3553	2022		Cfr. Cervus elaphus	IV/V	Femur	Mid diaphysis	Long and short cut marks are scatted through the bone	x
CN3549	2022		Ungulate	III/IV	Limb bone		Tiny cut marks	
CN3548	2022		Cfr. *Megaloceros giganteus*	IV/V	tibia	Diaphysis	Tiny cut marks	x
CN913	2014		Cfr. *Cervus elaphus*		Metatarsal		Longitudinal tiny cutmarks.	
CN3494	2017		Ungulate	IV/V	Limb bone			
CN3577	2017		Cfr. Bos/Bison/Megaloceros	IV/V	Tibia		Numerous, oblique to the axis	
CN3761	2017		Cfr. Bos/Bison/Megaloceros	IV/V	femur	Mid diaphysis	Few longitudinal cut marks are scattered.	x
CN3756	2017		Cfr. Alces/Megaloceros/Cervus	V	Tibia	Mid diaphysis, median portion	Oblique and longitudinal cut marks scattered through the bone surface.	x
CN3874	2022		Bos/Bison	V	tibia	Diaphysis	Oblique and longitudinal cut marks scattered through the bone surface.	x
CN4238-1	2022	18	*Cervus elaphus*	III/IV	Limb bone	Diaphysis	tiny cut marks	
CN339	2013	1 rim	Cfr. *Cervus elaphus*	III	Femur		Oblique and Longitudinal. Isolated. Mid portion of the bone.	x
CN1074	2013		Ungulate	III	Limb bone			
CN311	2013		Cfr. *Megaloceros giganteus*	V	Metacarpal		Long longitudinal cut marks all over the bone surface.	x
CN321	2013		Ungulate	IV/V	Tibia		Relatively short cut marks at the Mid of the bone.	x

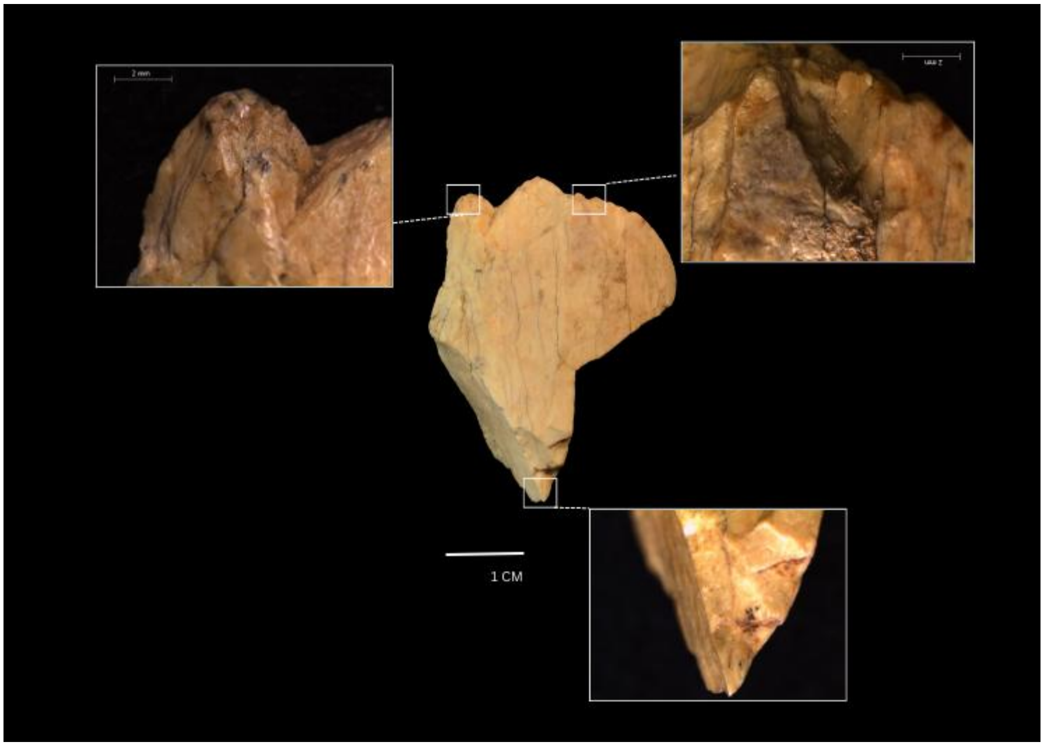


Figure 15: Interpreted as an Intermediate tool from Layer 7 (n°565). (Note that the distal end is compressed and the proximal end shows battering and some removal scars on the upper surface.)

The distal end of intermediate bone tools having a broadly convex shape with a naturally beveled profile is an interesting observation. But it cannot be excluded that certain intermediate tools have a distal end with a different morphology, a pointed morphology in particular (e.g., CN3553, CN3489). This morphology holds implications for both the functionality of these tools and the techniques employed in their manufacture. The negative removals present on intermediate tools are only found on their ends and are systematically associated with crushing from use in indirect percussion (Tartar 2012b).

Regarding functionality, the convex shape and beveled profile of the distal end likely conferred advantages for specific tasks. For instance:

- In activities involving scraping or cutting, the convex curvature would provide a smoother surface, facilitating more efficient contact with materials such as leather, wood, or hide.
- The beveled profile would enhance the cutting or scraping action, enabling the tool to penetrate materials with reduced resistance and affording greater precision in controlling the tool's movement.

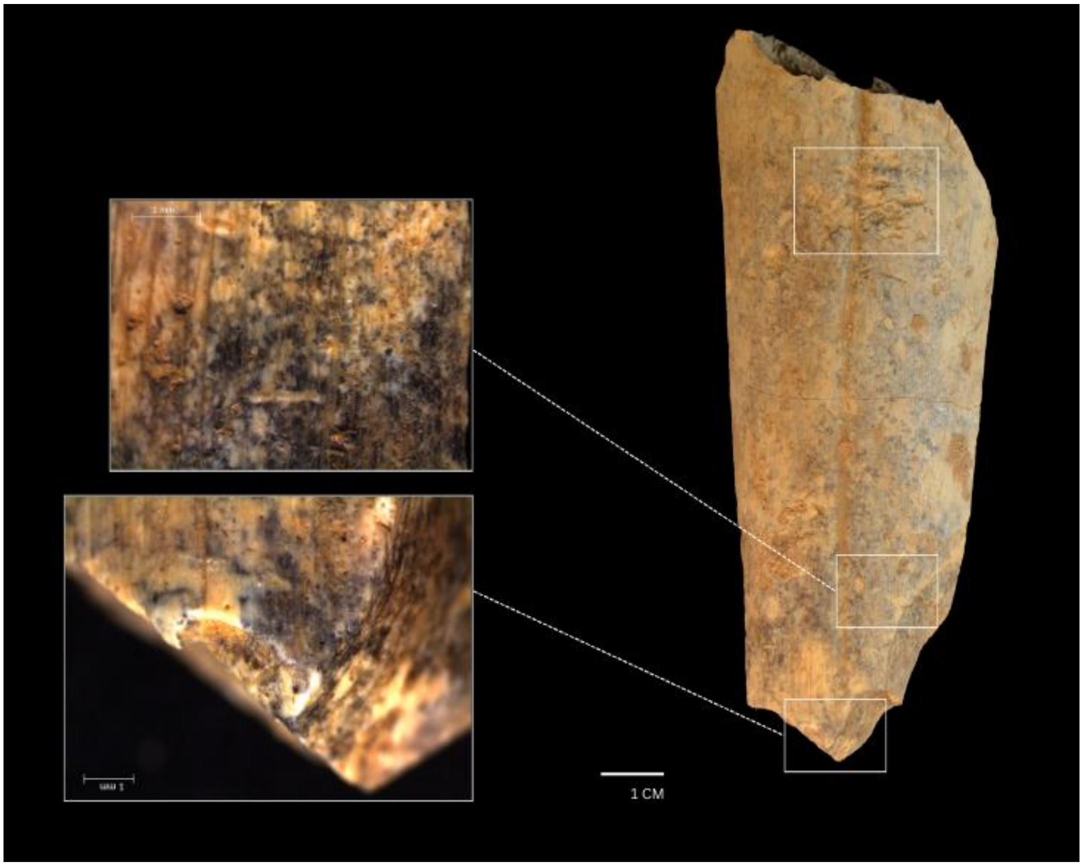


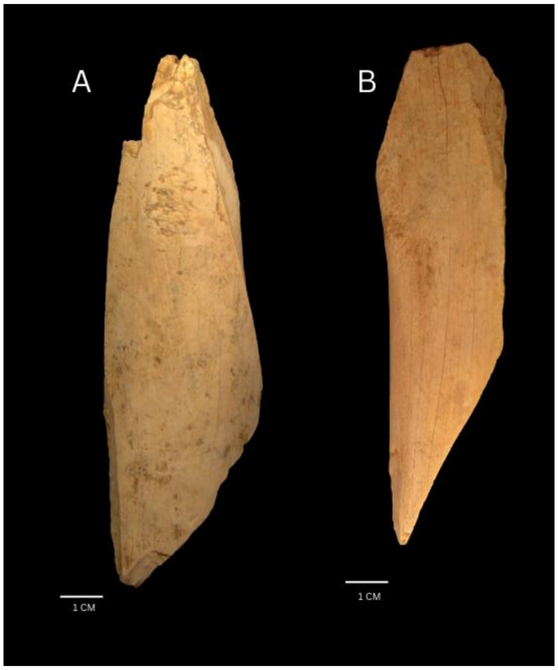
Figure 16: Interpreted as an intermediate tool from Layer 7 (n°112). On the proximal end, the artefact shows crushing, on the distal end, several flake removal scars. The artefact has also been used as a retoucher (marked in white).

Moreover, the convex shape and beveled profile likely contributed to the durability and efficiency of the tool:

- The convex configuration would distribute force more uniformly across the tool's surface, mitigating the risk of localised stress and potential breakage during use.
- The beveled profile would minimise friction between the tool and the material being worked on, facilitating smoother and more efficient cutting or scraping motions.

Moreover, it produces an angle that can range from 15° to 40° but is mainly between 20° and 35°.

A rectilinear profile characterised by a two-dimensional, flat shape with straight sides, serves to effectively disperse the force of blows and resist transverse fractures. Additionally, the deliberate selection of bone fragments predominantly from large size classes, such as those sourced from large ungulates such as bovids, *Megaloceros giganteus*, and mature cervids, ensures the production of tools with considerable length, breadth, and solidity (figure 8). This approach to tool manufacture likely reflects an understanding of the mechanical properties of bone and the functional requirements of the tools. By adopting a rectilinear profile, tool makers could enhance the structural integrity of the tools, reducing the likelihood of fractures during use. Moreover, the strategic utilisation of bones from large ungulates ensures the availability of robust raw materials capable of withstanding heavy usage and providing extended tool longevity.



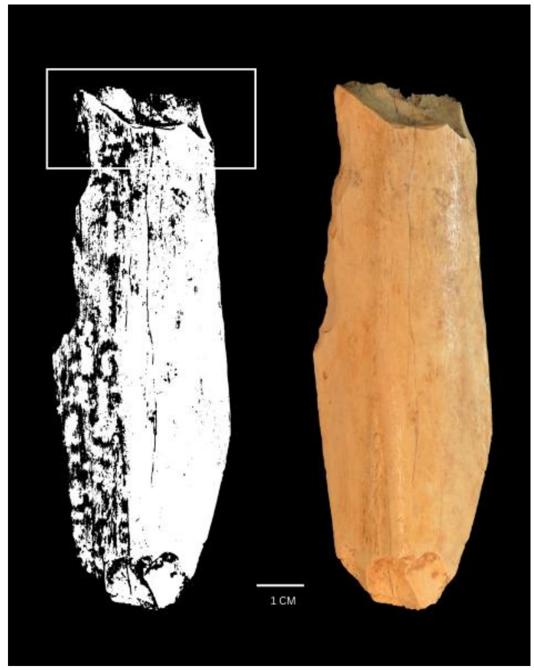


Figure 17 (Left): Interpreted as an Intermediate Tools showing rectilinear profiles. (A) From layer 13 (CN3553), made from *Cervus* femur, also bears retoucher marks; (B) From layer 14 (CN3489), made from Bovid tibia.

Figure 18 (Right): Interpreted as an intermediate tool recovered from layer 13 (CN3172), manufactured from a tibia of *Cervus elephus*. Notably, the distal end of the tool exhibits a squared and compacted morphology, attributed to the impact of hammering activities.

'The distal end of intermediate bone tools commonly exhibits a solid square section composed of compact bone. However, more frequently observed is a convex-concave section, where the marrow canal forms the concave side' (Tartar 2012b). This particular morphology may serve multiple functional and structural purposes. The solid square section, typical of compact bone, offers inherent strength and resistance to deformation, enhancing the tool's durability and resilience during use. Moreover, this configuration disperses applied forces efficiently, mitigating the risk of fractures and ensuring sustained functionality.

The prevalence of a convex-concave section, with the marrow canal forming the concave side, a configuration optimises material usage by maintaining structural integrity while minimising weight. Furthermore, the concave side, formed by the marrow canal, offers additional reinforcement to the tool's overall strength without compromising its functionality. The hammer's repeated blows having progressively compressed and flattened the bone fibres (Tartar 2003, 2012b).

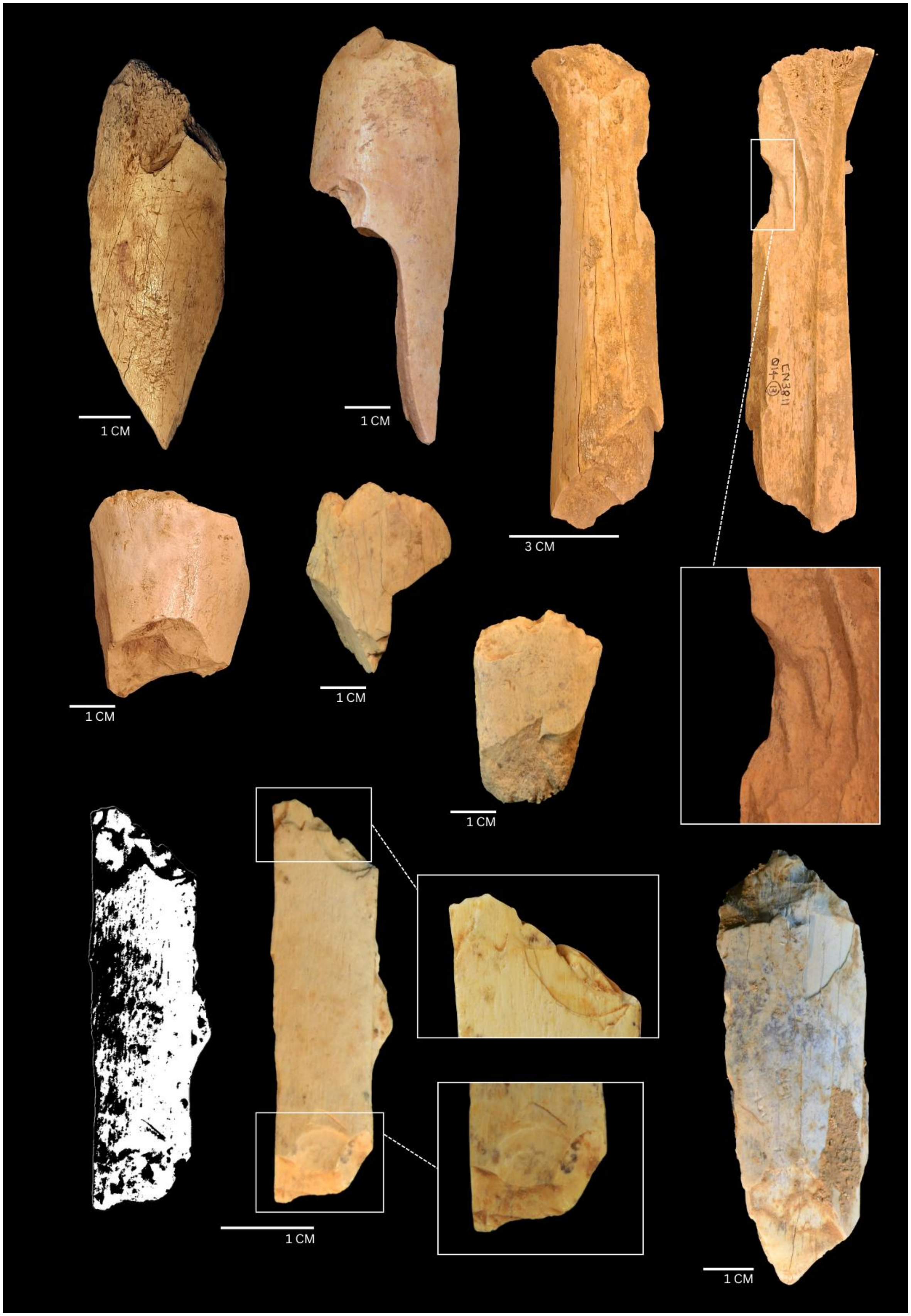


Figure 18: Interpreted as Intermediate tools from grotta de Nadale

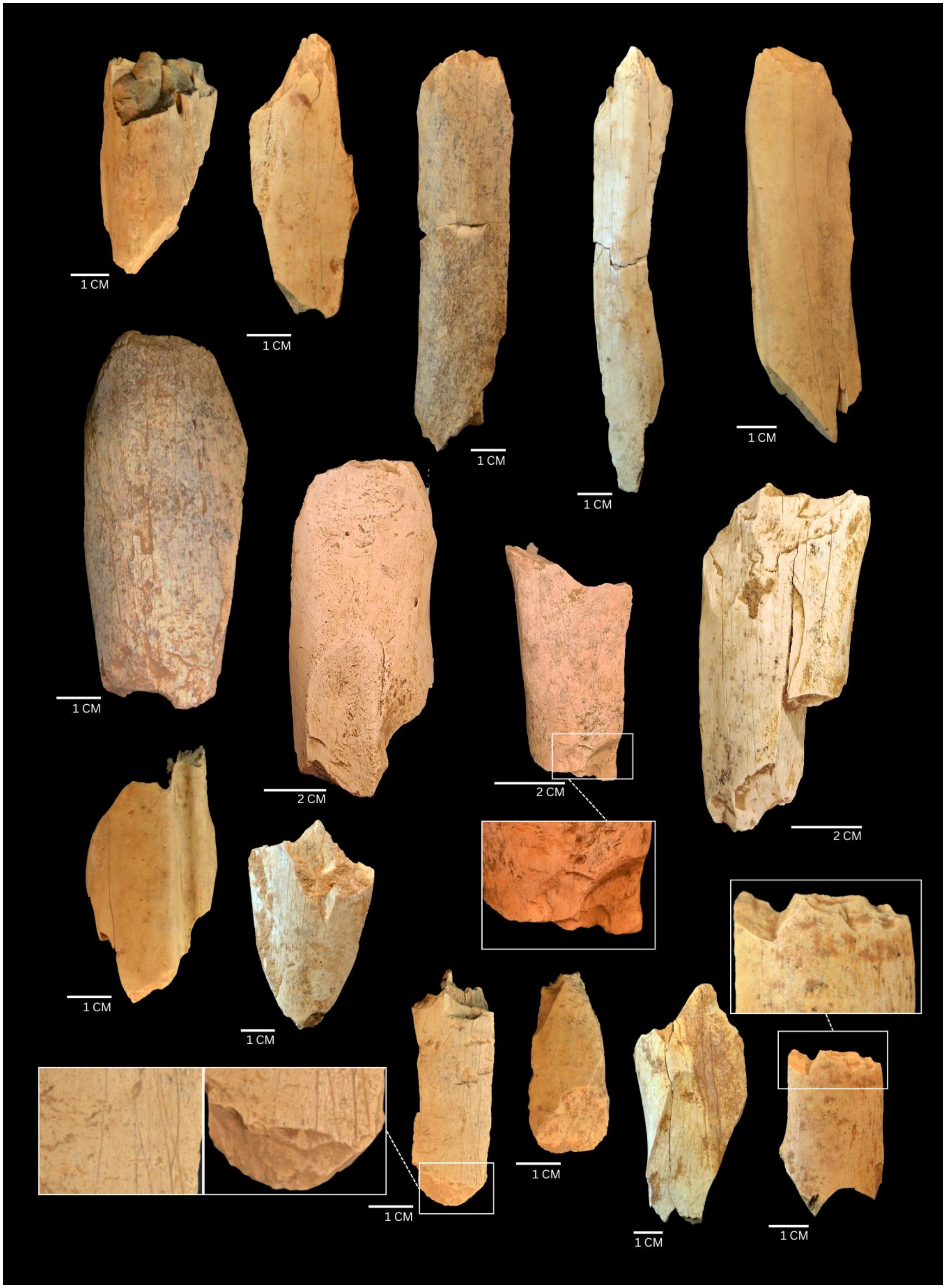


Figure 19: Interpreted as Intermediate tools from grotta de Nadale

Stage III: Use

Traces of use recorded from the Category 1

Research on use wear studies conducted on stone tools is well-documented, aiming to elucidate the tasks performed by these implements in prehistoric societies (Dubreuil & Savage 2014; Delpiano *et al.* 2019; Berruti & Arzarello 2020; Delpiano & Uthmeier 2020; Carpentieri *et al.* 2023). However, functional analyses of bone tools are infrequently undertaken. Notable exceptions include the investigations by Backwell and d'Errico (Backwell & d'Errico 2004; d'Errico & Henshilwood 2007; Backwell *et al.* 2008; d'Errico *et al.* 2012b; c), which primarily focused on artefacts from the Early and Middle Stone Age, and the research by Baumann and colleagues working on Middle Palaeolithic and Initial Upper Palaeolithic (Baumann *et al.* 2017, 2018, 2020, 2022, 2023; Kozlikin *et al.* 2020b). In essence, use wear analysis is a blend of micro- and macroscopic features that manifest on objects following contact with each other, whether during usage or manufacture. Use wear analyses offer a means to discern potential activities at archaeological sites where other evidence may be lacking. For instance, the manufacturing of leather clothing may impart discernible traces on the tools employed, even in the absence of preserved leather within the archaeological context (Griffitts 2001; d'Errico *et al.* 2012c). Consequently, the presence of such traces serves as a basis for inferring function and, by extension, the principal economic pursuits of prehistoric communities (Keeley 1974; Rots 2010). Broadly speaking, there are four processes through which bone tools can develop use-traces. These are abrasive, fatigue, adhesive and chemical (LeMoine 1994a). These processes may occur independently or concurrently, contingent upon the specific tasks executed with the bone tool and the prevailing environmental conditions.

Table 4: Definitions of terms used to describe modifications to bone (modified after Bradfield 2015)

Type	Indicators	Reference
Abrasion	Caused by the interaction of two materials, one harder than the other, which often results in scratches on the surface of the softer materials	(LeMoine 1994a; Fisher 1995)
Crushing	The inward displacement of the bone cortex into the spongy bone space within; fragmentation of cortical bone due to pressure	(Fisher 1995)
Cut Marks	V-shaped in cross-section with flat sides. Fine parallel striations occur along the walls of the main groove and at the bottom of grooves.	(Cook 1986; Fisher 1995)
Polish	Consists of smoothing and flat surfaces, usually accompanied by rounded edges. It is usually acquired through contact with secondary surfaces and is the abrasive removal of material from the contact surface. Polish differs depending on duration of use and hardness of contact material. Best viewed under high-power magnification.	(Fisher 1995; Griffitts 1997, 2001)
Striations	Striations show the general direction of tool movement. Size and depth of striations vary depending on the texture of the contact material.	(D'Errico 1993; Griffitts 2001)
Weathering	Displays as cracking, splitting, exfoliation, disintegration and decomposition. The rate of weathering reflects environmental factors, not of time.	(Cook 1986; Fisher 1995)

Table 5: Data on use wear for the category 1 artefacts from grotta de Nadale

ID	Crushing		Polish		Striations			Retoucher marks
	location	*intensity*	*location*	*intensity*	*location*	*intensity*	*orientation*	
CN3486	both	high	proximal tip	mod	random	high	oblique, perpendicular	x
CN3482	both	high	proximal tip	slight	random	high	longitudinal/ deep	
CN4531	both	slight	proximal tip	mod	random	mod	oblique	x
1032	both	mod	proximal tip	mod				
443	both	high			edges	mod	oblique	x
181	both	mod	proximal tip	mod	edges	high	perpendicular, longitudinal	x
198	both	mod			edges	high	longitudinal, long, deep, parallel	
CN3552	both	high	proximal tip	slight				x
112	both	high	proximal tip	slight	edges	mod	oblique, perpendicular	x
386	both	high						
445	distal	high	proximal tip	mod	random	mod	longitudinal/ parallel	x
CN2173	distal	mod			random	slight	short/ parallel	
627	both	high			edges	high	longitudinal	x
577	both	slight						x
20	both	mod			tip	mod	short/ parallel	
565	both	high						
1155	both	mod			random	slight	oblique	x
1103	both	high			random	high	longitudinal	x
795	both	high	proximal tip	mod	edges	high	longitudinal	x
CN3134	distal	mod	proximal tip	slight	random	mod	longitudinal, shallow	
CN3485	both	high			edges	mod	longitudinal	
CN3197	distal	high			tips, edges	high	longitudinal, long	
CN3230	both	high	proximal tip	slight				x
CN3483	both	high	proximal tip	slight				
CN2730	both	mod			edges	mod	perpendicular	x
CN3393	both	mod						
CN3185	both	mod	proximal tip	slight	edges	mod	short/ parallel	
CN3491	both	mod	proximal tip	mod				x
CN3232	both	mod			random	slight	oblique, short	x
CN2455	both	mod						
CN2372	distal	high			edges	slight	short, oblique	x
CN2461	distal	mod	proximal tip	slight	random	slight	short, deep, oblique	
CN3157	both	mod	proximal tip	slight	edges	high	longitudinal	
CN2410	both	mod			random	slight	short, oblique	
CN3490	both	mod			random	mod	perpendicular	
CN2387	both	high			random	mod	oblique	
CN3421	both	slight						
CN2492	both	high			random	high	longitudinal	x
CN3412	both	mod			edges	mod	random/ longitudinal	
CN3492	both	mod			random	high	short, oblique	x
CN2499	both	high						
CN4328	both	mod			edges	high	random/ longitudinal	x

CN4071	proximal	mod			lateral	mod	random/ short, deep	
CN3638	distal	mod			edges	high	parallel, oblique	x
CN4068	proximal	mod			lateral	slight	random	x
CN3811	distal end	mod						
CN3493	distal	high	proximal tip	mod				x
CN3553	both	high	proximal tip	mod	edges	mod	perpendicular/ longitudinal	x
CN3549	both	high			random	mod	longitudinal	x
CN3548	both	mod	proximal tip	mod	random	high	longitudinal	x
CN913	both	high						
CN3494	distal	high			random	high	oblique, perpendicular	
CN3577	distal	mod			edges	mod	oblique	
CN3761	both	slight			edges	mod	oblique	x
CN3756	both	mod			random		longitudinal	x
CN3874	both	high			random	slight	oblique	
CN4238-1	distal	high	proximal tip	slight				x
CN339	both	high	proximal tip	mod	edges	high	short, oblique	x
CN1074	both	mod	proximal tip	mod				
CN311	both	mod	proximal tip	mod	edges	high	longitudinal	x
CN321	both	mod	proximal tip	slight	random	slight	short, oblique	x

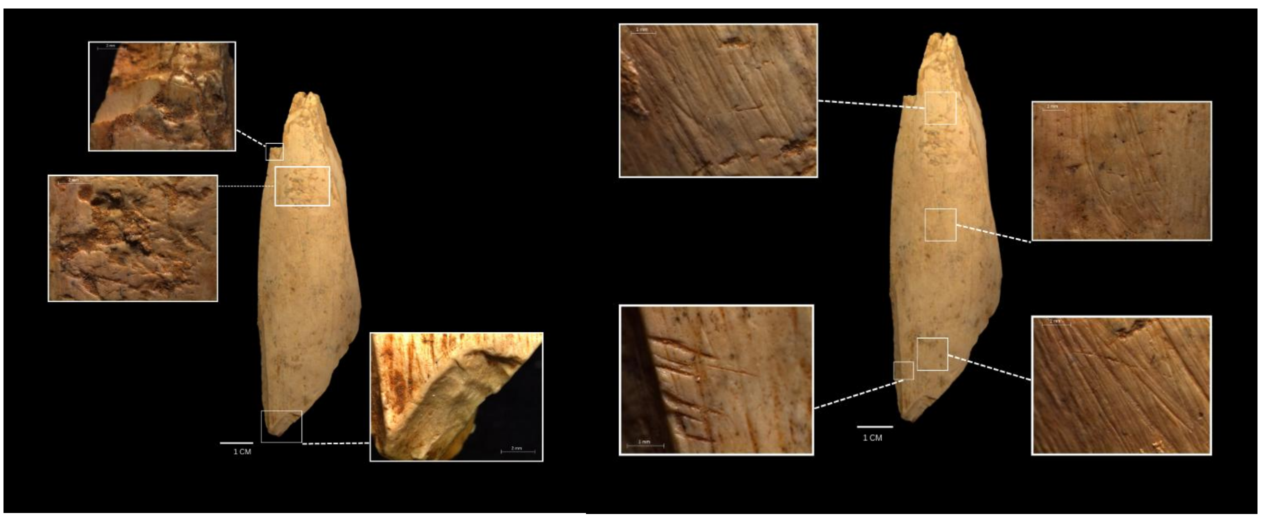


Figure 20: Interpreted at an Intermediate tool, from Layer 14 (CN3553). Modifications on the ends of the specimen and traces of use (striations near the edges and slight polish) are recorded.

Three primary types of use marks have been distinguished at the ends of the bone specimens, namely blunting and crushing (Tartar 2012b).

Blunting is identified as a distal scar (Tartar 2012b; Baumann et al. 2020), characterised by surface deformation on the bone resulting from the tool's repeated contact with the worked material. This wear-induced deformation extends across both faces of the tool's edge. However, it is noteworthy that the identification of blunting is not consistently evident, likely influenced by factors such as the nature of the worked material and the intensity of tool usage (Tartar 2012b).

Crushing, on the other hand, is observable at both ends of the tool and is attributed to the compression of bone fibres. This process can lead to various causes, including surface faceting and the separation and folding back of bone fibres. At the proximal end, crushing is notably pronounced, often accompanied by conspicuous folding of the bone fibres. In contrast, crushing at the distal end tends to be less marked, primarily concerned as compacting.

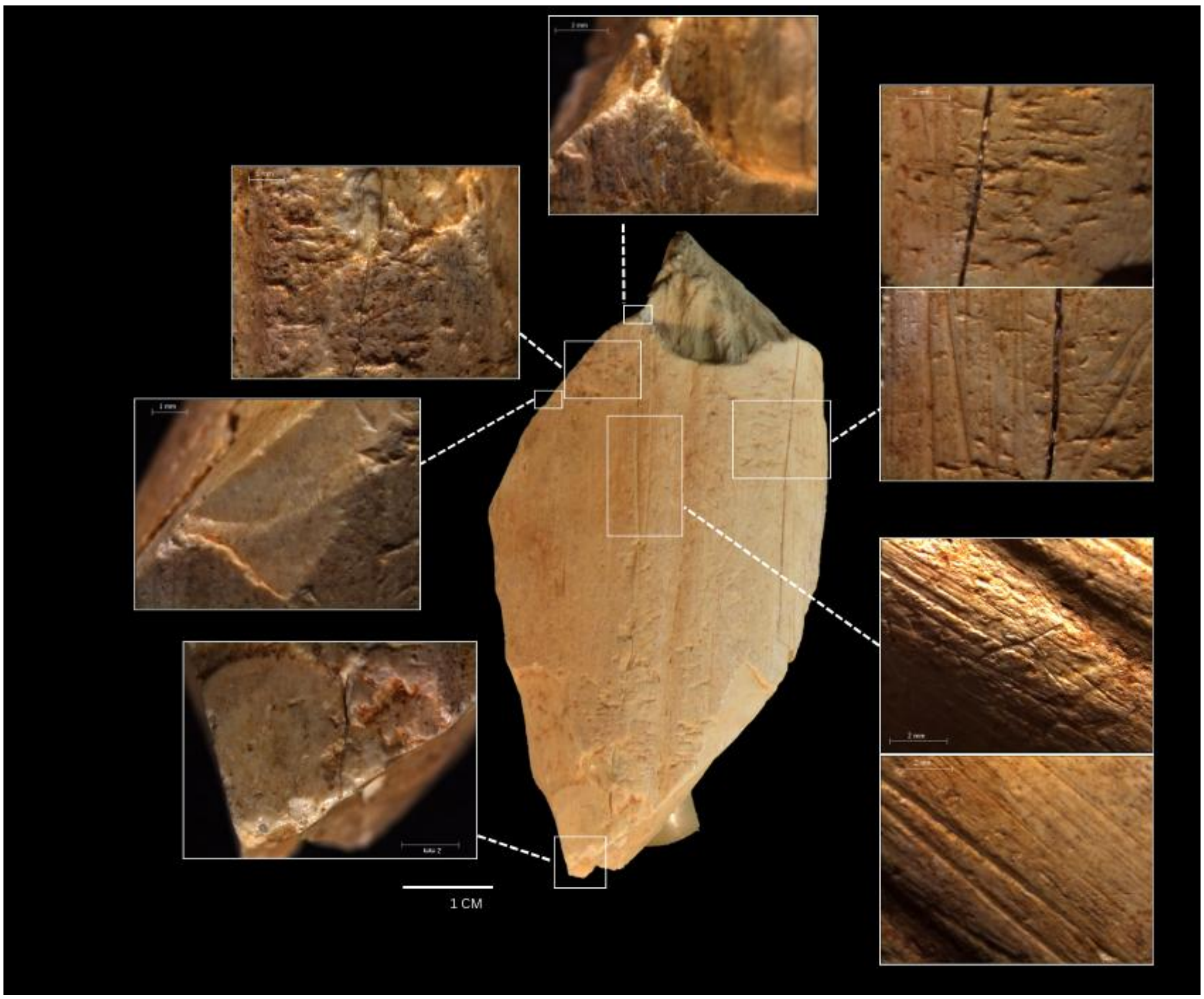


Figure 21: Interpreted at an Intermediate tool, from Layer 13 (CN311). Striations and polished (slight luster) extremities are brought into attention.

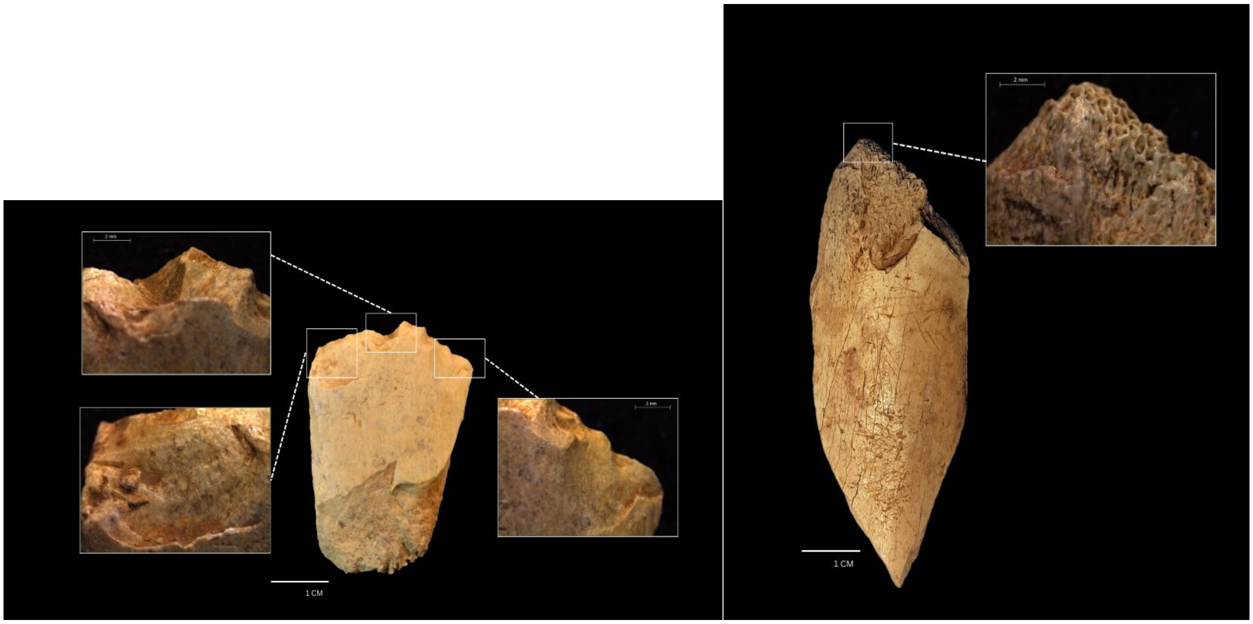


Figure 22: Interpreted as Intermediate tools from layer 13 (CN2492) (left) and layer 3 (CN3486) (right). Crushing, blunting and removal scars are brought into attention (Microscopic scale is 2 mm).

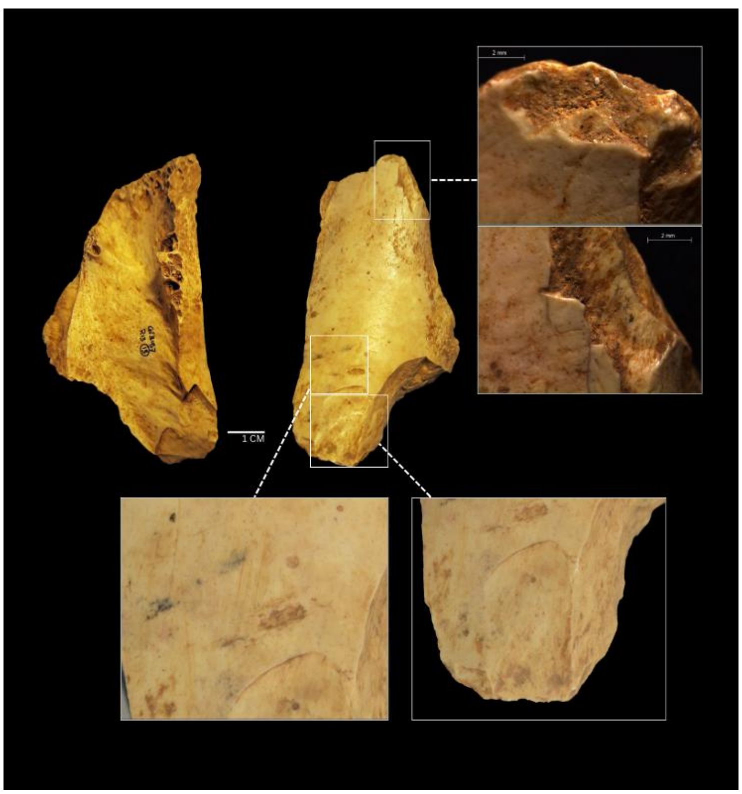


Figure 23: Interpreted as Intermediate tool from layer 13 (CN3157). Crushing and polished area on the distal end is brought to attention. In the proximal end, removal scars on both cortical and medullar sides are present. Striations near the removal scar on the proximal end are visible.

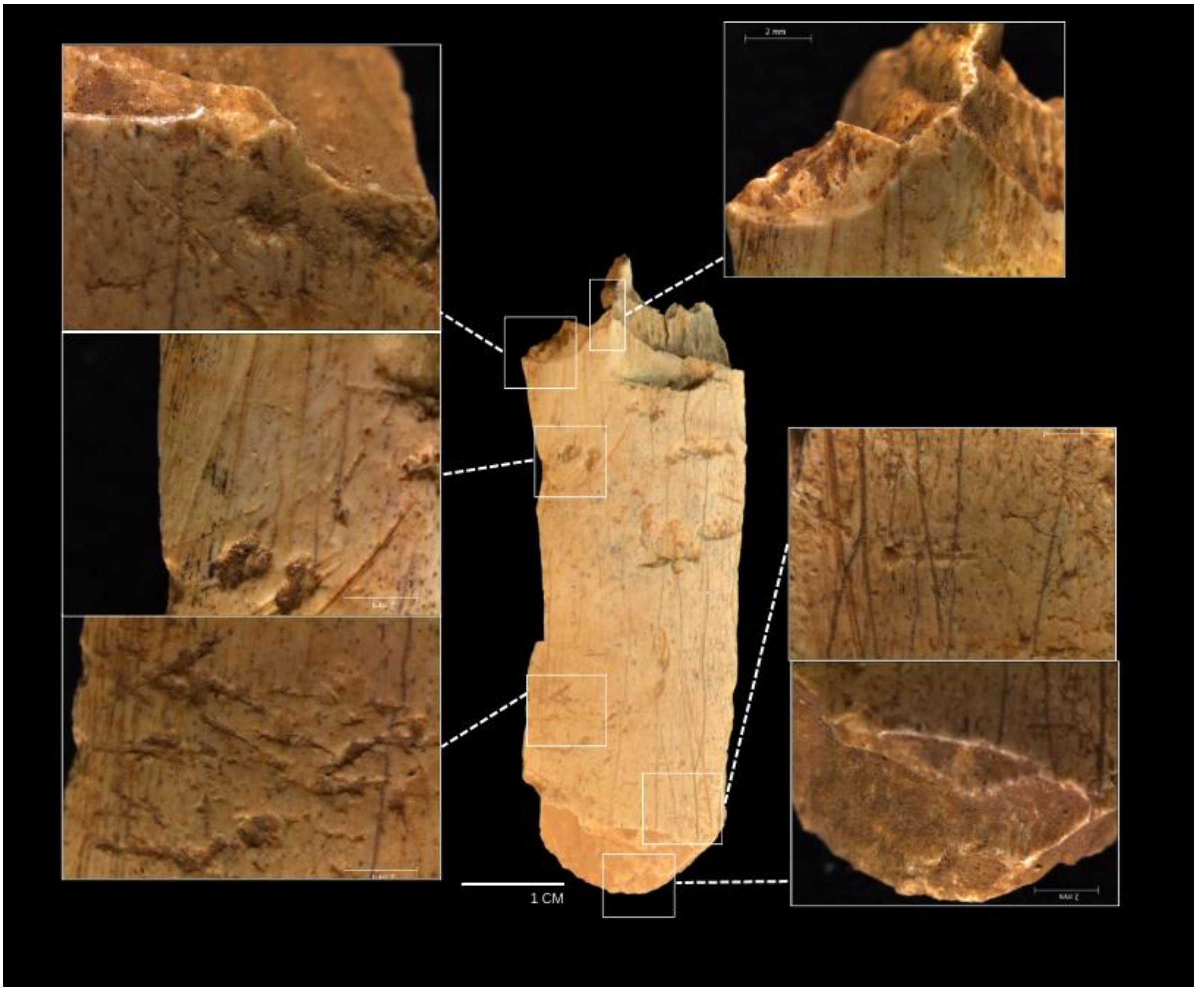


Figure 24: Interpreted as Intermediate tool from layer 13 (CN3492). Compacted bone fibres, crushing and polishing is present on the distal edge. The tool is also used as a retoucher (right bottom). Parallel and sub-parallel striations are present along the edges, indicating the traces of use on a hard medium (i.e., wood). Scale 1 cm.

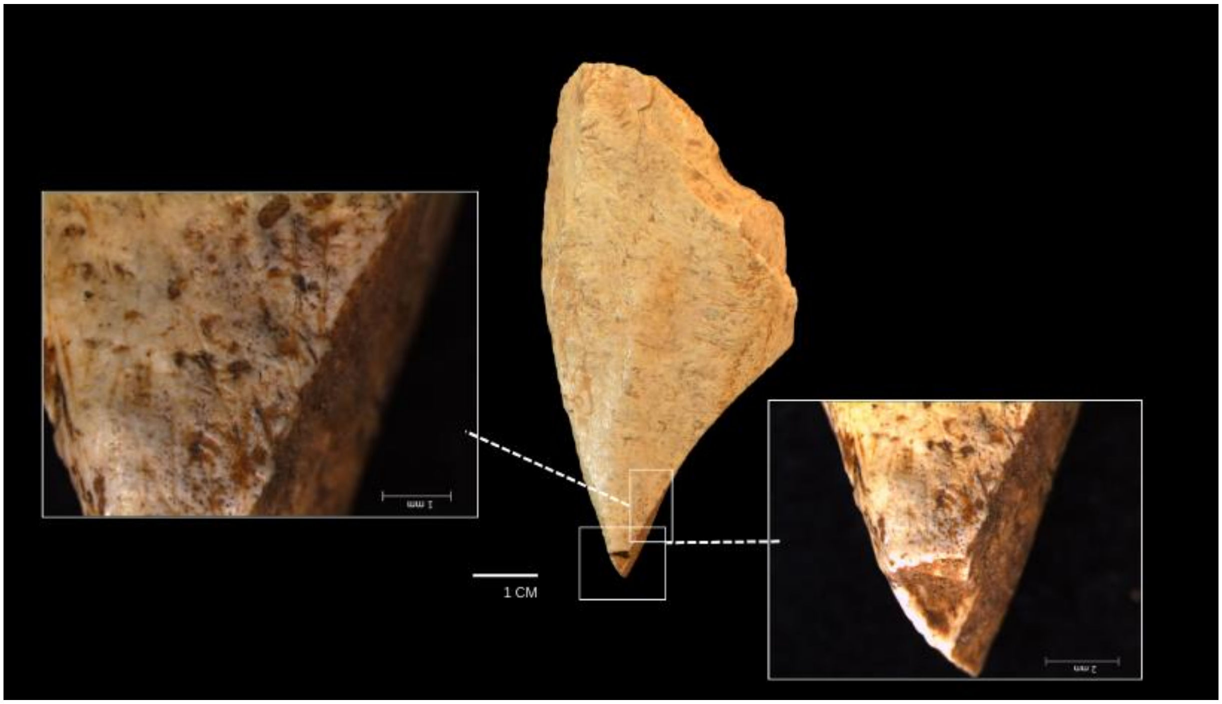


Figure 25: Interpreted as Intermediate tool from layer 13 (CN3232). On the proximal end par with the negative removal, polishing and manufacture marks at the edge. Short but deep parallel and perpendicular striations are brought into attention.

Figure 26: A microscopic photograph from a specimen (CN3493) interpreted as Intermediate tool from layer 14. The photograph is to bring it to attention as an example of short, deep nonparallel striations and polish on the tip restricted to the edge of the bone tool.

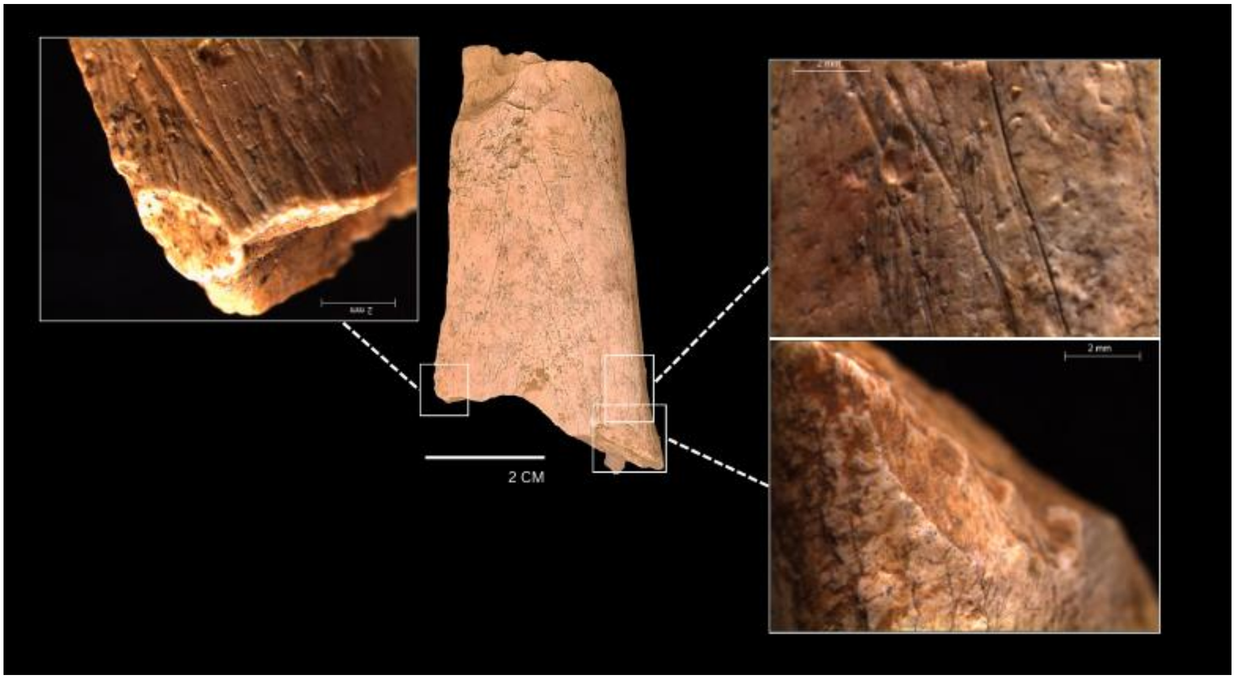


Figure 27: Interpreted as Intermediate tool from layer 13 (CN3638). The proximal end of the tool showing sub parallel striations and near to the negative removals, as a result of the contact of the material being worked.

Bone modification category 2: Negative removals parallel to the long axis of the bone

Negative removals (perhaps continuous) on one lateral edge[50]*, sometimes extends to the tip. The hypothesis put forward is that these negative removals would be traces of manufacture and use as a cutting support or scraping.*

The removal of bone from one edge can be attributed to various causes (Blasco *et al.* 2008), which include:

I. Intentional breakage by hominids for accessing bone marrow,
II. Carnivore-related damage,
III. Post-depositional processes influenced by sediment pressure,
IV. Trampling by biological agents, and
V. Production of a bone tool.

Following a thorough literature review focusing on these hypotheses, all explanations except the last (cause V) have been excluded as potential reasons for the observed artefact characteristics belongs to the hypothesis two of this study.

Intentional bone breakage by hominids to access bone marrow is suggested by the extensive fragmentation of bones in the selected assemblage, indicating green (fresh) bone breakage commonly associated with hominid activities aimed at extracting marrow. Previous studies (Binford 1981; Johnson 1985; Bonnichsen

[50] These negatives are continuous and very often overlapping.

1989; Giusberti & Peretto 1991; Pickering & Egeland 2006) have described marks on bones resulting from human activity related to marrow extraction. However, the specific presence of notches and regular, overlapping cortical removals observed in our study has not been reported in previous research. Therefore, the bone modifications observed are unlikely to be caused by activities specifically associated with marrow extraction.

Carnivore damage is characterised by the presence of crenulated edges on bones (known as chipping back; Lyman 2014). (Binford 1981, 1983) used this evidence[51] in the 1980s to argue against the existence of a bone industry at Morín Cave in Spain (Freeman 1983). While carnivores can produce similar modifications, they typically leave tooth marks across the bone surfaces (Haynes 1982, 1983; Villa & Bartram 1996). At grotta de Nadale, the impact of carnivores on the assemblage is minimal (3.4%), and there is no association between bones showing retouch marks and those bearing carnivore toothmarks.

Post-depositional processes, like sediment compaction on bone surfaces, can cause notable taphonomic alterations. These alterations often manifest as deformations and fractures (Shipman 1981). Dry bones tend to fragment, displaying angular shapes and scalariform patterns (Villa & Mahieu 1991). However, the specific presence of notches and cortical removals resembling those found at grotta de Nadale has not been evident before.

Trampling by biological agents, as noted by Gifford-Gonzalez *et al.* (1985) in relation to lithic tool edges, can produce small notches. Similarly, trampling can cause similar modifications on bones (Blasco *et al.* 2008). However, the occurrence of bifacial, planar, continuous, and overlapped negatives has not been observed during trampling process.

The manufacture of bone tools during the Middle Pleistocene and some Upper Pleistocene sites in Europe presents challenges in identifying intentionally modified faunal remains for tool production. Notable cases include Castel di Guido in Italy (Radmilli & Boschian 1996), Bilzingsleben in Germany (Mania 1995), Salzgitter-Lebenstedt (Gaudzinski 1999a), and Abric Romaní in Spain (Carbonell *et al.* 1996; Rosell *et al.* 2012). Apart from a few isolated examples, bone tools from these periods typically result from objects modified by direct percussion to achieve specific morphologies like handaxes, points, side-scrapers, and denticulates. In this study, the modified bones exhibit technological characteristics similar to the side-scrapers and denticulated tools recovered in the lithic assemblage (Delpiano *et al.* 2022).

[51] See also Chase & Dibble 1987; Rolland & Dibble 1990

Stage I: Acquisition of raw materials– 'the choice'

Among the entirety of the faunal assemblage unearthed during systematic archaeological excavations at grotta de Nadale, a total of 60 bone specimens have been identified with negative removals along one longitudinal edge, occasionally extending to the extremities. This anthropogenic alteration, referred to herein as retouch, exhibits a either unifacial or bifacial nature, with marginal application on the dorsal side while covering the marrow canal or spongiosa on the internal surface.

This category incorporates all tools in which one edge, and in rare cases both edges, display intentional retouching, as inferred from the pattern of removals observed on the bone blank. It is important to note that without clear evidence of intentional shaping of the tool, there's uncertainty about whether the retouch observed is of anthropic origin. This uncertainty arises because other natural processes, such as bone breakage for marrow extraction (Pickering & Egeland 2006), or bone consumption by carnivores (Blumenschine & Selvaggio 1988a) can create markings resembling retouch along bone edges. Additionally, percussion is generally not considered an effective method for shaping bone materials[52], but fresh bones have material and elastic properties that make them resistant to forced percussion. Also, bones can share characteristics with hard materials of conchoidal fracture (Baumann *et al.* 2020).

Here in best fit for criteria for 'retouched bone shaft', thus hereafter 'retouched tools' from grotta de Nadale are often made from large ungulate bones due to several practical advantages which can be conferred by these materials. Firstly, large ungulate bones provide ample raw material for manufacturing sturdy and durable tools, as they offer substantial mass and strength compared to smaller bones. Their ability to absorb the percussion shock from a hard material is commendable. This robustness ensures that the resulting tools can withstand the rigors of use over extended periods.

Moreover, the size and density of large ungulate bones make them particularly suitable for shaping into tools with desired forms and functionalities. The ample surface area provided by these bones allows for the creation of larger implements, such as scrapers or points, which can be utilised for a wide range of tasks including butchering, hide processing, woodworking, and even hunting activities. Furthermore, the availability of large ungulate bones in hunting and scavenging contexts may have made them more accessible to ancient populations, facilitating their widespread use in tool production. The ubiquity of these materials would have ensured a steady supply for toolmaking activities, contributing to their popularity as preferred raw materials.

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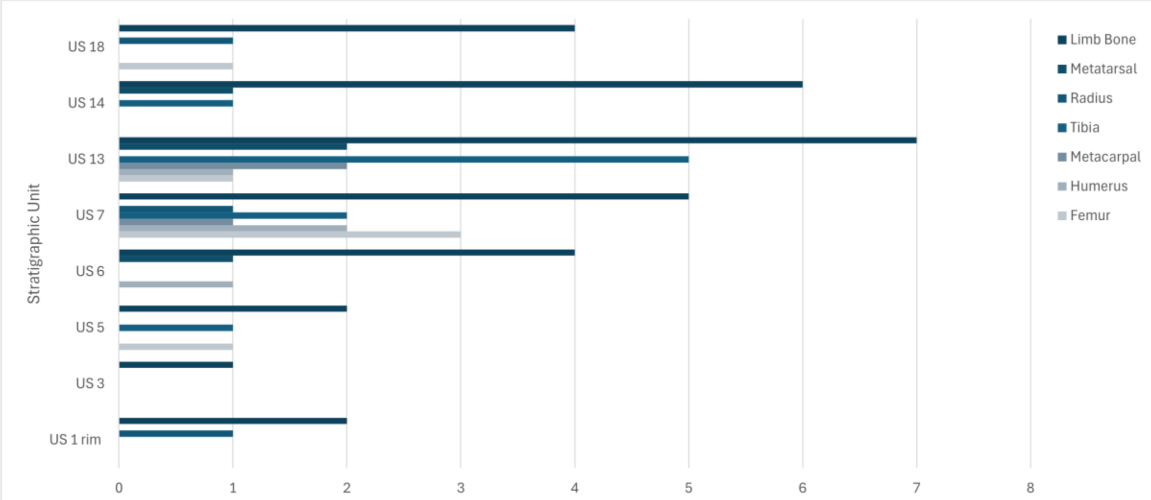
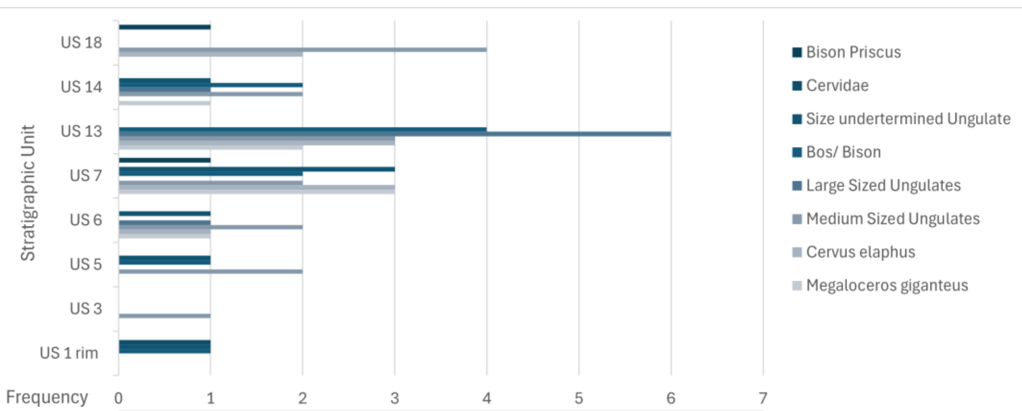
[52] *The craftsman of these periods [Middle Palaeolithic] did not recognize the specific nature of bone […] and applied to the bone blanks techniques borrowed from the shaping of stone; these techniques, perfectly adapted to the rigidity and cohesion of the lithic material, are more or less inadequate for the work of such a substance* (Vincent 1985: 23).



	US 1 rim	US 3	US 5	US 6	US 7	US 13	US 14	US 18
Limb Bone	2	1	2	4	5	7	6	4
Metatarsal				1		2	1	
Radius	1				1			1
Tibia			1		2	5	1	
Metacarpal					1	2		
Humerus				1	2	1		
Femur			1		3	1		1

Frequency

Figure 28: Comparison of the anatomic origins of category 2 artefacts among stratigraphic units of grotta de Nadale



	US 1 rim	US 3	US 5	US 6	US 7	US 13	US 14	US 18
Bison Priscus					1			1
Cervidae	1							
Size undertermined Ungulate	1		1	1	3		1	
Bos/ Bison	1		1		2	4	2	
Large Sized Ungulates				1		6	1	
Medium Sized Ungulates		1	2	2	2	3	2	4
Cervus elaphus				1	3	3		2
Megaloceros giganteus				1	3	2	1	

Figure 29: Comparison of the taxonomic origins of category 2 artefacts among stratigraphic units of grotta de Nadale

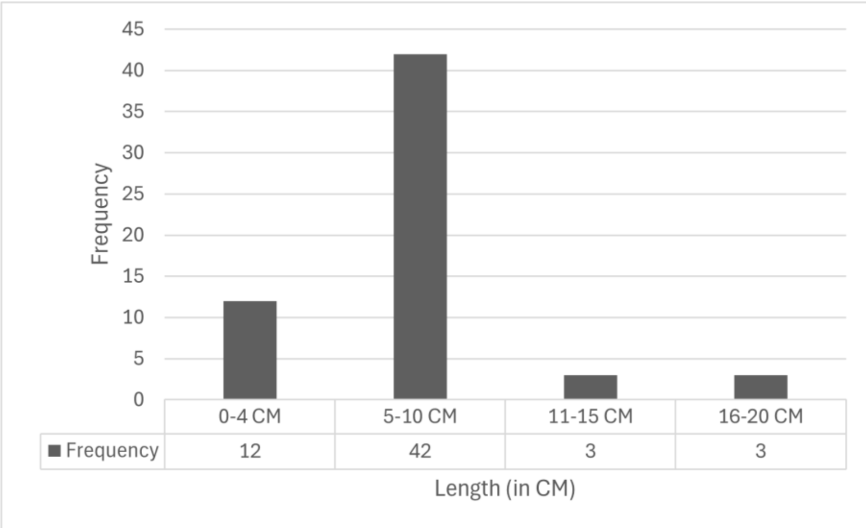


Figure 30: Variability of the lengths of category 2 artefacts from grotta de Nadale

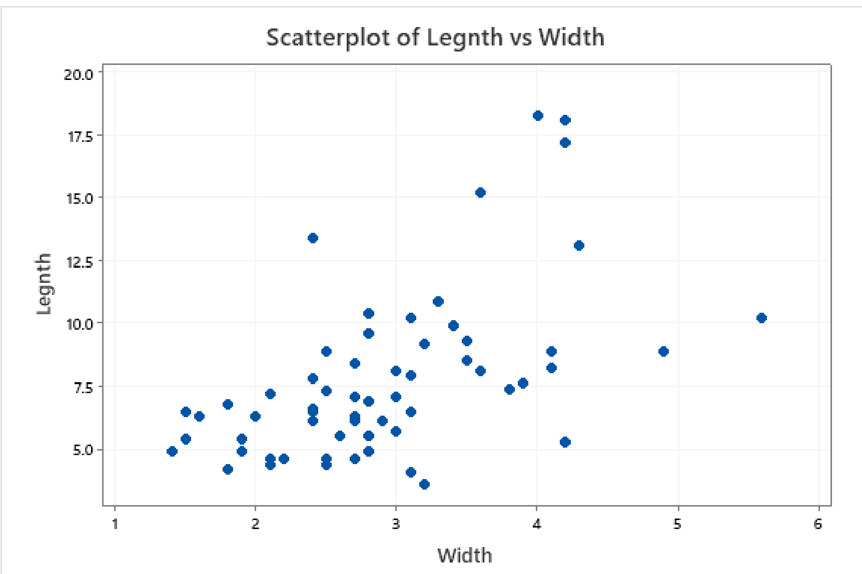


Figure 31: Scatterplot diagram of the values of length and width of category 2 artefacts

The category 2 specimens demonstrate a consistent average length, yet notable exceptions exist, particularly in the case of the largest specimens, which reach lengths of up to 18.3 cm. Furthermore, these larger tools exhibit retouched edges extending up to 10.1 cm, indicative of their considerable dimensions and potential functional significance. Manufactured from the limb bones of large ungulates, specifically sourced from the genus *Bos/Bison priscus* and *Megaloceros giganteas*, certain specimens stand out due to their exceptional thickness and width. Identified through their respective numerical designations (N°365, CN3586, CN 4135, N°512), these tools are distinguished not only by their size but also by the materials used for manufacture.

Table 6: Compilation and interpretation of traces observed on the category 2 artefacts from grotta de Nadale

ID	Year	Layer	Species	Size	Anatomical Element	Specific Anatomical Elements	Anthropic Modifications	Retoucher Marks
6	2017	3	Ungulate	III/IV	Limb Bone		Relatively short, tiny cut marks scattered all over the bone surface. Scattered. Oblique.	
2	2014	5	Ungulate		Limb Bone			
23	2017		Ungulate	III/IV	Limb Bone		Oblique. Scattered through the bone surface. Not deep.	
CN4048	2019		Ungulate	III/IV	Femur	Diaphysis		x
CN3618	2019		Bos/Bison	V	Tibia	Medial face+ caudal face, tibial crest		x
191	2017	6	Cfr. *Megaloceros giganteus*	IV	Metatarsal			
251	2014	7	Cfr. *Cervus elaphus*	III	Femur		Tiny, light and relatively short cut marks scattered all over the bone surface. Cut marks are concentrated near retoucher marks.	x
161	2014		Cfr. *Megaloceros giganteus*	IV	Femur		Tiny cut marks are present. Isolated	
750	2015		Ungulate		Limb Bone		Longitudinal and oblique cut marks scattered all over the bone surface. Not grouped. Relatively isolated.	
366	2014		Ungulate		Limb Bone		Very few cut marks. Oblique. Scattered.	
365	2014		Bos/Bison	IV/V	Humerus	Diaphysis	Oblique and Longitudinal. Isolated tiny cut marks at the tip of the bone and relatively long isolated cut marks in the middle of the bone surface.	x
408	2014		*Megaloceros giganteus*	IV	Femur	Proximal Diaphysis	Few tiny, light cut marks scattered. Concentration on the middle portion of the bone.	
891	2017		Ungulate	III	Limb Bone			
512	2014		Cfr. *Megaloceros giganteus*	IV	Radius		Oblique. Grouped in lateral part of the bone.	
388	2014		Ungulate		Limb Bone			

406	2014		*Bison priscus*	IV/V	Tibia			
365	2014		Bos/Bison	IV/V	Humerus	Diaphysis		x
CN4848	2017		Ungulate	III/IV	Limb Bone	Diaphysis		x
CN3177	2017	13	Ungulate	II/III	Limb Bone		Cortical. Relatively long oblique cut mark is present on the tip of the bone surface. Another short cut mark is beneath the aforementioned.	
CN2327	2017		Ungulate	IV	Metacarpal		Oblique. Grouped in the distal part of the fragment.	
CN3126	2017		Ungulate	III/IV	Limb Bone		Short and deep cut marks scattered all over the bone surface. Oblique. Isolated	
CN2371	2017		Bos/Bison	IV/V	Humerus	Medium Diaphysis, Lateral Portion	Oblique. Major and tiny cut marks all over the bone surface. 3 parallel lines are visible in the lateral portion of the bone.	x
CN3496	2019		Ungulate	III/IV	Limb Bone		Relatively short and tiny cut marks scattered (isolated) on the cortical part of the bone.	
CN3172	2017		*Cervus elephus*	III	Tibia	Distal Diaphysis, Lateral Portion	Tiny, light and relatively short cut marks scattered all over the bone surface.	
CN2472	2017		Ungulate	II/III	Limb Bone		Tiny cut marks scattered through the bone surface.	
CN3488	2019		Ungulate	IV/V	Limb Bone		Longitudinal and Oblique. Isolated. Lateral portion of the bone surface.	x
CN3484	2019		Ungulate	II/III	Limb Bone		Longitudinal. Grouped on the lateral portion of the bone surface. Relatively short.	
CN3495	2019		*Megaloceros giganteus*	IV	Metatarsal		Oblique. Tiny and short cut marks on the lateral portion of the bone surface.	
CN2452	2017		Cervus elephus	III	Metatarsal			
CN2457	2017		Ungulate	IV/V	Tibia		Discontinuous tiny cut marks on the lateral side of the bone.	
CN3467	2017		Ungulate	IV/V	Limb Bone		Oblique. Grouped in lateral part of the bone.	
CN4059	2019		Cfr. Alces/Megaloceros/Cervus	III/IV	Metacarpal	Middle diaphysis, anterior portion		x
CN2330	2017		Cfr. Bos/Bison/Megaloceros	IV	Femur	Distal Diaphysis, Posterior Portion		x
CN4359	2017		*Cervus elephus*	III/IV	Tibia	Middle diaphysis, anterior portion		x

CN2352	2017		Cfr. Bos/Bison	IV/V	Tibia	Proximal Diaphysis, Posterior Portion		x
CN3489	2019		Bos/Bison	IV/V	Tibia	Mid Diaphysis		x
CN3304	2017	14	Ungulate	IV/V	Limb Bone	Diaphysis	Long and Longitudinal cut marks present all over the bone surface	x
CN903	2014		Ungulate		Limb Bone		Relatively short cut marks grouped in the middle portion of the bone surface, and few are isolated on the tip of the bone surface.	x
CN3586	2017		Cfr. Bos/Bison/Megalocero s	IV/V	Tibia	Proximal Diaphysis	Few longitudinal cut marks are scattered.	
CN3588	2017		Cfr. Bos/bison	IV/V	Limb Bone	Mid Diaphysis		
CN5026	2022		Ungulate	III/I V	Limb Bone	Mid Diaphysis		x
CN5022	2022		Ungulate	III/I V	Limb Bone	Diaphysis		x
CN3545	2017		*Megaloceros giganteus*	V	Metatarsal	Middle diaphysis, posterior Portion		x
CN3551	2021	18	Cfr. *Cervus elaphus*	III/I V	Limb Bone		Short and Long Cut marks are isolated in the periphery of the bone.	
CN3550	2021		Cfr. *Cervus elaphus*	III	Femur		Relatively short cut marks are grouped in the edges	
CN4801	2022		Ungulate	III/I V	Limb Bone	Diaphysis		x
CN4778	2022		Ungulate	III/I V	Limb Bone	Diaphysis		x
CN4815	2022		Ungulate	III/I V	Limb Bone	Diaphysis		x
CN4135	2022		Cfr. *Bos Priscus*	V	Radius	Mid diaphysis, lateral + anteroir portion		x
CN468	2013	1 rim	Cervidae		Limb Bone		Longitudinal cut marks are present on the lateral edge portion of the bone	
CN99	2013		Cfr. Bos/Bison		Radius		Tiny and short cut marks scattered all the bone.	
CN1075	2013		Ungulate		Limb Bone		Few tiny cut marks are scattered.	
CN4162	2022	14	Ungulate	II	Limb Bone	Diaphysis		x

960	2017	6	Ungulate		Limb Bone		Long and short (longitudinal and oblique) cut marks are present all over the bone surface. Isolated.	x
217	2021		*Cervus elephus*	III/IV	Humerus	Diaphysis	Tiny cut marks are present.	
CN4240	2022		Ungulate	III/IV	Limb Bone	Diaphysis		x
960	2017		Ungulate	V	Limb Bone	Diaphysis		x
CN4718	2022		Ungulate	III/IV	Limb Bone	Diaphysis		x
1175	2022	7	*Cervus elaphus*	III/IV	Metacarpal	Middle diaphysis, anterior portion	few longitudinal cut marks	x
1133	2021		*Cervus elaphus*	III/IV	Tibia	Mid Diaphysis		x

Figure 32: Interpreted as a retouched tool from layer 1 rim (CN339). The percussion direction is highlighted by the white arrow. Bilateral edges appear to have been subjected to attempted retouching. On the left side, scraping marks are evident, likely indicating an effort to remove periosteum for the purpose of creating a smoother working surface.

Stage II & III: Manufacture and Use

Most of the negative removals appear on the cortical surface, followed by impact points on the medullar side. Cut marks on the bone surfaces are cutmarks are mainly associated with butchery activities (generally long, regular, and straight incisions). The angle of most of these removals is planar or semiplanar, continuous, and deep whilst on the distal segment. They are marginal and continuous (sometimes discontinuous), probably due to the reshaping or reattempting. In this sense, it seems these represents as *denticulated side-scrapers* (not exhausted).

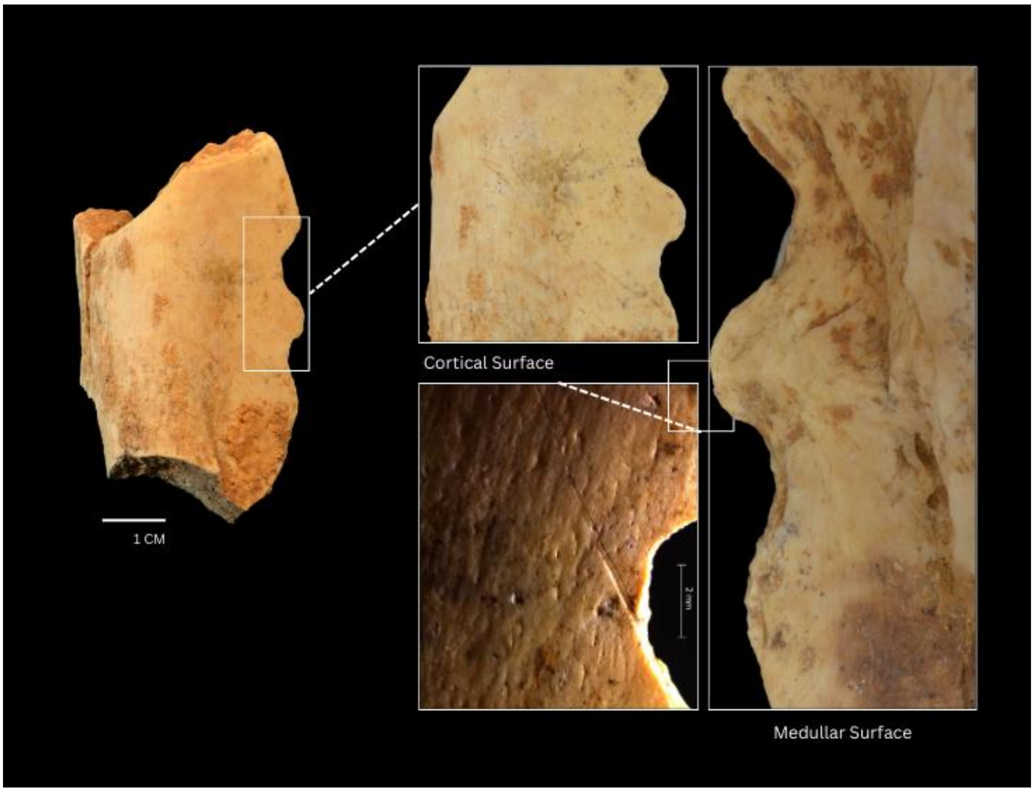


Figure 33: Interpreted as a retouched tool from layer 14 (CN3577). Note that the parallel, shallow striation marks appear near the retouched edge. Removals are discontinuous and independent.

Table 7: Recorded Morphology of the category 2 artefacts from grotta de Nadale (Continuous removals)

				Position					Localization						Distribution			Deliniation					Extent				Inclination			Morphology				Notes
ID	Year	US	Square	Direct	Inverse	Alterno	Alternante	Bifacial	Distal	Medial	Proximal	Left	Right	Basal	Partial	Continous	Total	Straight	Concave	Convex	Notched	Denticulated	Short	Long	Intrusive	Covering	Steep	Semi-Steep	Grazing	Hurled	Scaliforms	Sub-Parallel	Parallel	
2	2014	5	M12b	x								x			x			x						x			x			x				Retocuhed along one edge and tip. Consistence pattern observed.
1032	2017	6 Base/7	L12	x					x								x			x				x				x				x		
161	2014	7	N12g	x				x	x			x			x			x		x				x		x		x			x			Different generations of retouch is present.
251	2014	7	M12g	x								x	x		x			x				x(?)		x			x			x				Margins are controlled?
CN3126	2017	13	R12	x							x	x			x			x		x				x				x			x			Two generations of negative removals.
CN3304	2017	14	M13	x					x				x		x					x			x					x				x		
960	2017	6 Base/7	N13i	x									x		x			x					x					x			x			
CN3496	2019	13	P14	x					x			x	x	x		x		x				x(?)		x		x			x	x				Retouched along both edges.
23	2017	5	N13b	x								x					x			x				x				x			x			
CN3172	2017	13	R13	x								x			x			x						x				x				x		Controlled gesture. Two geenrations of retouch is oberved.
CN1074	2013	1 rim	atriale	x								x					x	x						x			x						x	
CN3483	2019	13	P14					x				x					x	x						x			x						x	Controlled gesture
CN468	2013	1 rim	atriale	x									x		x					x			x				x				x			Consistant pattern observed.
CN217	2021	6 Base	L11c	x					x			x			x			x						x				x		x				
CN2472	2017	13	P13	x								x			x						x		x					x			x			
750	2015	7	P12e	x								x		x		x	x			x				x			x						x	Controlled gesture.
366	2014	7	N12e	x								x		x			x			x				x			x					x		Controlled gesture. Consistant pattern observed.
CN2330	2017	13	R12	x								x				x		x						x			x						x	Consistant pattern observed.
365	2014	7	N12e	x								x			x			x					x				x					x		Controlled gensture along the margins.
CN3552	2022	6 rim	I12	x					x						x					x			x					x		x				
CN3551	2021	18	L11	x								x	x			x						x		x			x					x		
CN3550	2021	18	L12	x								x				x				x				x					x			x		
CN913	2014	14	M13a-d	x					x	x							x			x			x				x				x			
CN1075	2013	1 rim	atriale	x								x			x			x						x			x				x			Overlapped negative removals.
CN3490	2019	13	R14	x										x	x					x			x						x			x		
CN3488	2019	13	Q14	x										x			x	x							x			x			x			
388	2014	7	N12b	x										x	x					x			x				x				x			
CN3586	2017	14	L13	x							x		x	x	x					x		x	x				x						x	Consistant pattern observed. Intervals between retouches are seems equal in distance.
CN3588	2017	14	L13	x		x			x				x		x							x		x				x					x	Tip is pointed. Retouched two sides of the tip.
1175	2022	7 base	I11c	x						x			x		x			x			x		x				x			x				
CN4059	2019	13	Q14		x			x		x		x				x		x			x	x		x		x		x		x				Controlled gesture. Impact points are clearly visible.
CN4240	2022	6 rim	I12	x					x				x				x			x				x			x					x		Controlled gesture. Impact points are clearly visible.
CN4801	2022	18	I11		x				x				x			x				x				x		x			x				x	
CN4048	2019	5	Q14	x						x		x			x			x			x	x(?)	x						x		x			Isolated removals, Impact point is clearly visible.
CN4778	2022	18	I11		x				x			x	x			x				x			x				x				x			Controlled distances along the retouched edge. Same pattern observed.
CN4848	2017	7	Q12b	x					x			x	x	x	x			x				x(?)	x						x		x			Controlled gesture
CN4359	2017	13	Q13	x					x	x			x	x	x			x					x						x	x				Use marks are visible along the retouched areas.
CN4162	2022	14/8	I12	x					x				x		x					x		x	x				x			x				Two solo removals, distanced from 1mm, Impact points are clearly visible.
CN2352	2017	13	Q13	x						x		x			x			x					x				x				x			
CN4815	2022	18	I11	x					x				x			x		x						x			x						x	Controlled gesture. Intervals between retouched are appear to be equal.
CN5026	2022	14	I11	x						x		x			x			x					x					x			x			
CN4718	2022	6 rim	I13		x					x			x		x			x					x				x				x			Great control along the retouched margin.
1133	2021	7SII	L11c	x					x	x		x	x	x		x		x						x			x			x				Controlled gesture
1155	2022	7	I11g	x	x							x	x	x	x			x						x			x				x			Used as a retoucher as well
CN3145	2022	18	I11	x									x			x				x				x				x				x		
CN3545	2017	14	L13	x							x	x	x	x		x		x			x(?)		x						x		x			Percussion point is present. Used as a retoucher as well.
CN3618	2019	5	R14	x								x				x		x						x			x					x		Covered with concretion, but can clearly see the impact points.
CN99	2013	1 rim		x			x						x	x	x			x			x	x	x						x			x		Impact points are clearly visible.
CN3495	2019	13	Q14	x									x					x			x					x			x	x				Two generations of negative removals.
CN2457	2017	13	P13		x				x			x			x			x					x						x		x			Sheer polished tip (?)
191	2017	6	L12b	x						x		x				x		x						x			x				x			Impact points are clearly visible.
CN2371	2017	13	Q13	x						x			x		x			x					x				x					x		
CN3177	2017	13	R13	x					x	x		x	x	x		x		x						x			x				x			Retouched two edges with controlled gesture.
891	2017	7	Q12h	x					x			x	x		x				x		x		x			x		x		x				Two/ three generations of negative removals.
512	2014	7	M11f	x						x			x			x		x						x				x			x			
CN903	2014	14	M13 a-d	x						x			x				x	x							x		x				x			Two large negative removals with impact points. Different generations of retouches are present. Deep and short cut marks are perpendicular to the removals.
406	2014	7	N12f	x						x		x	x			x		x			x	x		x			x					x		One large notch is present on the left with impact point. Right edge is present with discountinous two negative removals with impack points (ripples also can be seen).

Table 8: Recorded Morphology of the category 2 artefacts from grotta de Nadale

				Characteristics of Removals						
ID	Year	US	Square	Total Number of Removals	ID of Removal	Position	Intergrity	Length	Morphology of Contours	Orientation
CN3177	2017	13	R13	4	CN3177-1	Cortical	Overlapping		Trapeziodal	Oblique
					CN3177-2	Cortical	Overlapping		Elongated	Oblique
					CN3177-3	Cortical	Solo		Trapeziodal	Oblique
					CN3177-4	Cortical	Solo		Triangular	Oblique
443	2014	6 Base/7	N13d	4	443-1	Cortical	Solo		Elongated	Longitudinal
					443-2	Cortical	Solo		Triangular	Longitudinal
					443-3	Cortical	Overlapping		Squarish	Longitudinal
					443-4	Cortical	Overlapping		Rectangular	Longitudinal
CN339	2013	1 rim	atriale	4	CN339-1	Cortical	Overlapping		Oval	Longitudinal
					CN339-2	Cortical	Overlapping		Squarish	Longitudinal
					CN339-3	Cortical	Overlapping		Trapeziodal	Longitudinal
					CN339-4	Cortical	Overlapping		Oval	Oblique
CN2327	2017	13	Q13		CN2327-1	Cortical	Solo		Oval	Longitudinal
CN3134	2017	13	R12	4	CN3134-1	Cortical	Overlapping		Oval	Oblique
					CN3134-2	Cortical	Overlapping		Squarish	Oblique
					CN3134-3	Cortical	Overlapping		Oval	Longitudinal
					CN3134-4	Cortical	Solo		Elongated	Oblique
181	2017	6	L12e	2	181-1	Cortical	Solo		Elongated	Oblique
					181-2	Cortical	Solo		Elongated	Oblique
CN3485	2019	13	P14	1	CN3485-1	Cortical	Solo		Squarish	Longitudinal
112	2014	7	N11g	3	112-1	Cortical	Solo		Oval	Oblique
					112-2	Cortical	Solo		Squarish	Longitudinal
					112-3	Cortical	Solo		Elongated	Longitudinal
CN3197	2017	13	R13	1	CN3197-1	Cortical	Solo		Triangular	Longitudinal
CN3304	2017	14	M13	2	CN3304-1	Cortical	Solo		Elongated	Perpendicular
					CN3304-2	Cortical	Solo		Elongated	Perpendicular
CN3230	2017	13	P13	1	CN3230-1	Cortical	Solo		Squarish	Longitudinal
CN903	2014	14	M13a-d	2	CN903-1	Cortical	Overlapping		Elongated	Perpendicular
					CN903-2	Cortical	Overlapping		Elongated	Perpendicular
					CN903-3	Medullar	Solo		Elongated	Perpendicular
CN2371	2017	13	Q13	1	CN2371-1	Cortical	Solo		Elongated	Longitudinal
CN3172	2017	13	R13	7	CN3172-1	Cortical	Overlapping		Triangular	Longitudinal
					CN3172-2	Cortical	Overlapping		Squarish	Longitudinal
					CN3172-3	Cortical	Overlapping		Trapeziodal	Longitudinal
					CN3172-4	Cortical	Overlapping		Elongated	Longitudinal
					CN3172-5	Cortical	Overlapping		Squarish	Longitudinal
					CN3172-6	Cortical	Overlapping		Squarish	Longitudinal
					CN3172-7	Cortical	Overlapping		Oval	Longitudinal
CN3483	2019	13	P14	1	CN3483-1	Cortical	Solo		Elongated	Longitudinal
CN3393	2017	13	Q13	4	CN3393-1	Cortical	Solo		Oval	Longitudinal
					CN3393-2	Cortical	Solo		Elongated	Longitudinal
					CN3393-3	Cortical	Solo		Triangular	Oblique
					CN3393-4	Cortical	Solo		Squarish	Oblique
CN3185	2017	13	R13	1	CN3185-1	Cortical	Solo		Oval	Oblique
CN3493	2017	14	L13	2	CN3493-1	Cortical	Solo		Oval	Longitudinal
					CN3493-2	Cortical	Solo		Squarish	Oblique
CN3491	2017	13	Q13	4	CN3491-1	Cortical	Solo		Oval	Longitudinal
					CN3491-2	Cortical	Solo		Elongated	Oblique
					CN3491-3	Cortical	Solo		Elongated	Oblique
					CN3491-4	Cortical	Solo		Elongated	Oblique
CN3177	2017	13	R13	4	CN3177-1	Cortical	Solo		Elongated	Oblique
					CN3177-2	Cortical	Solo		Elongated	Oblique
					CN3177-3	Cortical	Solo		Triangular	Oblique
					CN3177-4	Cortical	Solo		Triangular	Oblique
CN3486	2019	13	P14	3	CN3486-1	Cortical	Solo		Elongated	Perpendicular
					CN3486-2	Cortical	Overlapping		Trapeziodal	Longitudinal
					CN3486-3	Cortical	Overlapping		Squarish	Oblique
CN3232	2017	13	R12	3	CN3232-1	Cortical	Overlapping		Squarish	Longitudinal
					CN3232-2	Cortical	Overlapping		Squarish	Longitudinal
					CN3232-3	Cortical	Overlapping		Trapeziodal	Longitudinal
CN2455	2017	13	R12	2	CN2455-1	Cortical	Solo		Elongated	Longitudinal
					CN2455-2	Cortical	Solo		Oval	Perpendicular
386	2017	7	N12d	3	386-1	Cortical	Overlapping		Squarish	Longitudinal
					386-2	Cortical	Overlapping		Oval	Longitudinal
					386-3	Cortical	Overlapping		Trapeziodal	Longitudinal
CN2461	2017	13	P13	4	CN2461-1	Cortical	Solo		Oval	Longitudinal
					CN2461-2	Cortical	Solo		Oval	Longitudinal
					CN2461-3	Cortical	Overlapping		Trapeziodal	Longitudinal
					CN2461-4	Cortical	Overlapping		Elongated	Oblique
408	2017	7	N12f	3	408-1	Cortical	Overlapping		Elongated	Longitudinal
					408-2	Cortical	Overlapping		Oval	Longitudinal
					408-3	Cortical	Solo		Squarish	Longitudinal
CN99	2013	1 rim	atriale	3	CN99-1	Cortical	Solo		Squarish	Perpendicular
					CN99-2	Cortical	Overlapping		Elongated	Perpendicular
					CN99-3	Cortical	Overlapping		Oval	Longitudinal
CN3483	2019	13	Q14	3	CN3483-1	Cortical	Solo		Oval	Longitudinal
					CN3483-2	Cortical	Overlapping		Elongated	Oblique
					CN3483-3	Cortical	Overlapping		Trapeziodal	Oblique
891	2017	7	Q12h	5	891-1	Cortical	Overlapping		Oval	Longitudinal
					891-2	Cortical	Overlapping		Trapeziodal	Longitudinal
					891-3	Cortical	Solo		Elongated	Perpendicular
					891-4	Cortical	Overlapping		Elongated	Oblique
					891-5	Cortical	Overlapping		Elongated	Oblique
CN3157	2017	13	R13	2	CN3157-1	Cortical	Solo		Elongated	Oblique
					CN3157-2	Cortical	Solo		Squarish	Longitudinal
445	2014	6 or 7	N13d	2	445-1	Cortical	Solo		Oval	Longitudinal
					445-2	Cortical	Solo		Oval	Longitudinal
198	2017	6	L12d	3	198-1	Cortical	Overlapping		Trapeziodal	Longitudinal
					198-2	Cortical	Overlapping		Squarish	Oblique
					198-3	Cortical	Overlapping		Oval	Oblique
CN2173	2015	7	P12c	2	CN2173-1	Cortical	Overlapping		Squarish	Longitudinal
					CN2173-2	Cortical	Overlapping		Trapeziodal	Longitudinal
CN3482	2019	5	R14	5	CN3482-1	Cortical	Overlapping		Trapeziodal	Oblique
					CN3482-2	Cortical	Overlapping		Trapeziodal	Oblique
					CN3482-3	Cortical	Overlapping		Trapeziodal	Oblique
					CN3482-4	Cortical	Overlapping		Trapeziodal	Oblique
					CN3482-5	Cortical	Overlapping		Trapeziodal	Oblique
CN3553	2022	18	I11	1	CN3553-1	Cortical	Solo		Elongated	Longitudinal
CN2387	2017	13	Q13	3	CN2387-1	Cortical	Overlapping		Squarish	Longitudinal
					CN2387-2	Cortical	Overlapping		Rectangular	Longitudinal
					CN2387-3	Cortical	Overlapping		Trapeziodal	Longitudinal
CN311	2013	1 rim	atriale	4	CN311-1	Cortical	Overlapping		Elongated	Oblique
					CN311-2	Cortical	Overlapping		Oval	Longitudinal
					CN311-3	Cortical	Solo		Trapeziodal	Longitudinal
					CN311-4	Cortical	Solo		Trapeziodal	Longitudinal
512	2014	7	M12f	1	512-1	Cortical	Solo		Rectangular	Longitudinal
CN3421	2019	13	R14	2	CN3421-1	Cortical	Overlapping		Trapeziodal	Longitudinal
					CN3421-2	Cortical	Overlapping		Rectangular	Longitudinal
CN3484	2019	13	Q14	1	CN3484-1	Cortical	Solo		Oval	Oblique
CN2492	2017	13	R12	4	CN2492-1	Cortical	Solo		Oval	Longitudinal
					CN2492-2	Cortical	Solo		Squarish	Longitudinal
					CN2492-3	Cortical	Solo		Elongated	Longitudinal
					CN2492-4	Cortical	Solo		Oval	Perpendicular
CN321	2013	1 rim	atriale	3	CN321-1	Cortical	Solo		Oval	Longitudinal
					CN321-2	Cortical	Overlapping		Squarish	Longitudinal
					CN321-3	Cortical	Overlapping		Elongated	Longitudinal
CN3495	2019	13	Q14	1	CN3495-1	Cortical	Solo		Elongated	Perpendicular
627	2015	7	Q12i	2	627-1	Cortical	Overlapping		Rectangular	Longitudinal
					627-2	Cortical	Overlapping		Trapeziodal	Oblique
CN3412	2014	13	Q13	2	**CN3412-1**	Cortical	Overlapping		Triangular	Oblique
					CN3412-2	Cortical	Overlapping		Oval	Longitudinal
CN2452	2017	13	Q13	1	CN2352-1	Cortical	Solo		Oval	Longitudinal
406	2014	7	N12f	1	406-1	Cortical	Solo		Elongated	Perpendicular
577	2014	7	M12f	2	577-1	Cortical	Overlapping		Elongated	Oblique
					577-2	Cortical	Overlapping		Trapeziodal	Perpendicular
191	2017	6	L12b	2	191-1	Cortical	Solo		Triangular	Longitudinal
					191-2	Cortical	Solo		Trapeziodal	Longitudinal
CN2457	2017	13	P13	3	CN2457-1	Cortical	Overlapping		Elongated	Oblique
					CN2457-2	Cortical	Overlapping		Trapeziodal	Longitudinal
					CN2457-3	Cortical	Overlapping		Oval	Oblique
20	2014	7	O10c	2	20 1	Cortical	Solo		Oval	Longitudinal
					20 2	Cortical	Solo		Triangular	Oblique
565	2014	7	M12e	1	565-1	Cortical	Solo		Oval	Longitudinal
CN3494	2017	14	L13	2	CN3494-1	Cortical	Solo		Trapeziodal	Longitudinal
					CN3494-2	Cortical	Solo		Oval	Longitudinal
CN3467	2017	13	R13	2	CN3467-1	Cortical	Solo		Trapeziodal	Longitudinal
					CN3467-2	Cortical	Solo		Elongated	Oblique
CN3586	2017	14	L13	2	CN3586-1	Cortical	Overlapping		Trapeziodal	Longitudinal
					CN3586-2	Cortical	Overlapping		Trapeziodal	Longitudinal

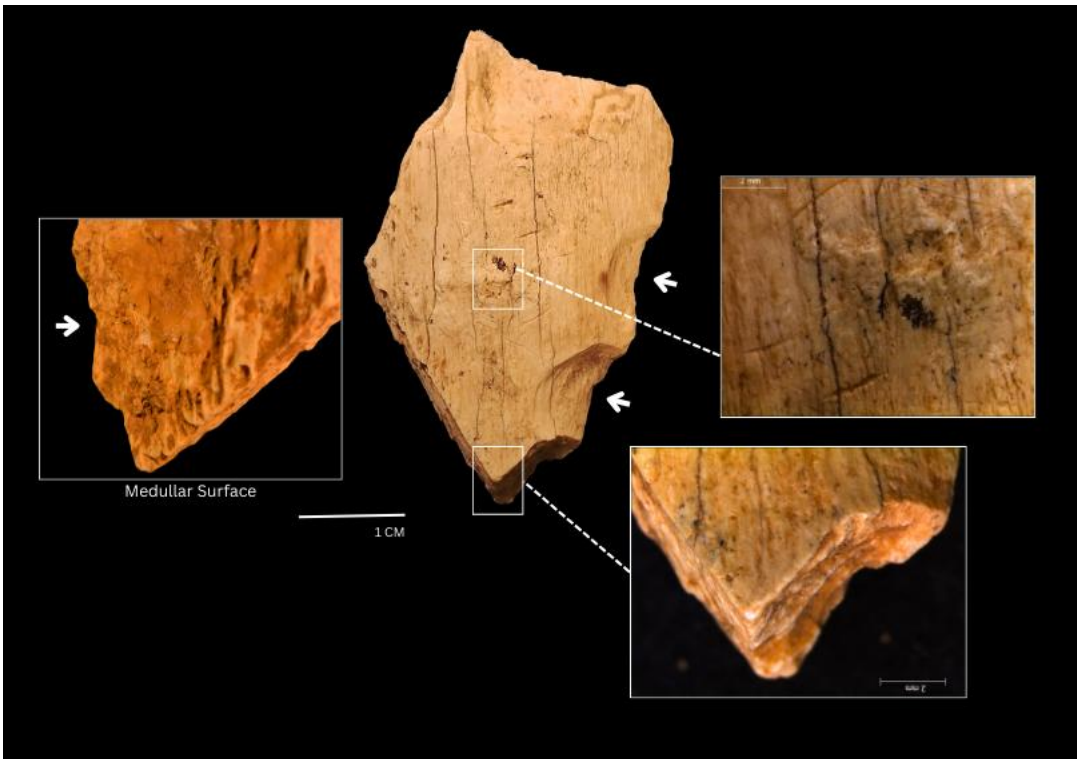


Figure 34: Interpreted as a retouched tool from layer14/8 (CN4162). Two distinct discontinuous removals with visible impact points are evident. Additionally, the proximal edge shows slight polishing (or luster).

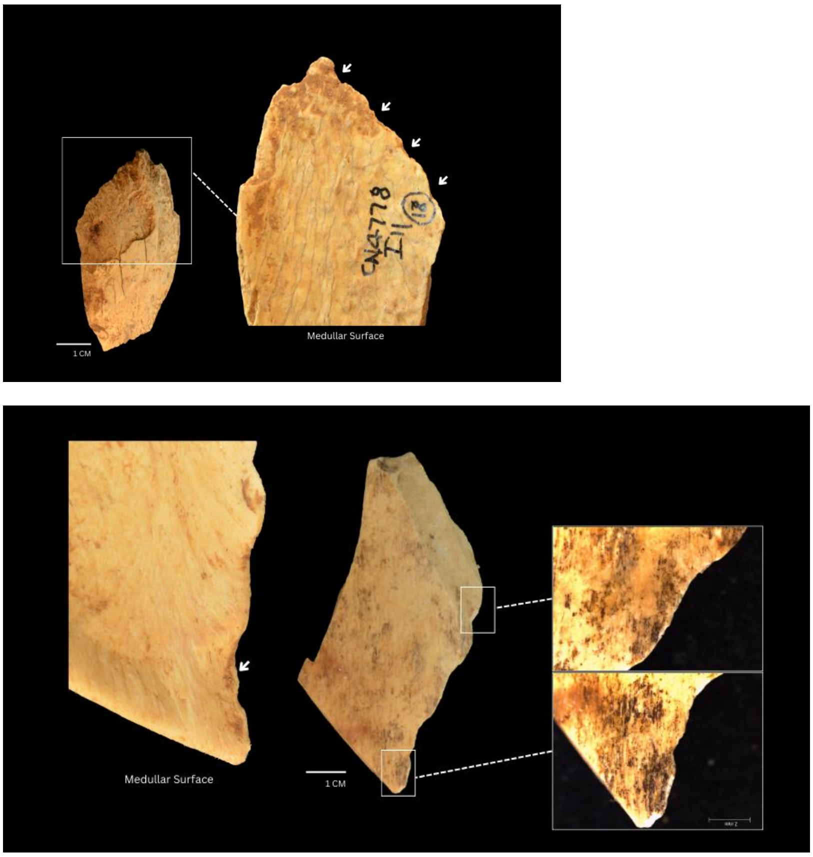


Figure 35: Interpreted as a retouched tools from layer 18. Top CN4778 and bottom CN4815. The artefacts exhibit continuous removals with consistent intervals between them, forming a regular and repetitive pattern. This consistent pattern suggests deliberate retouching or shaping of the tool for a specific purpose

(i.e., scraping). Intervals between each ridge is 2-3 mm, and perhaps resulting from low-angle removals. Both tools are made from ungulate (II/III) limb bones.

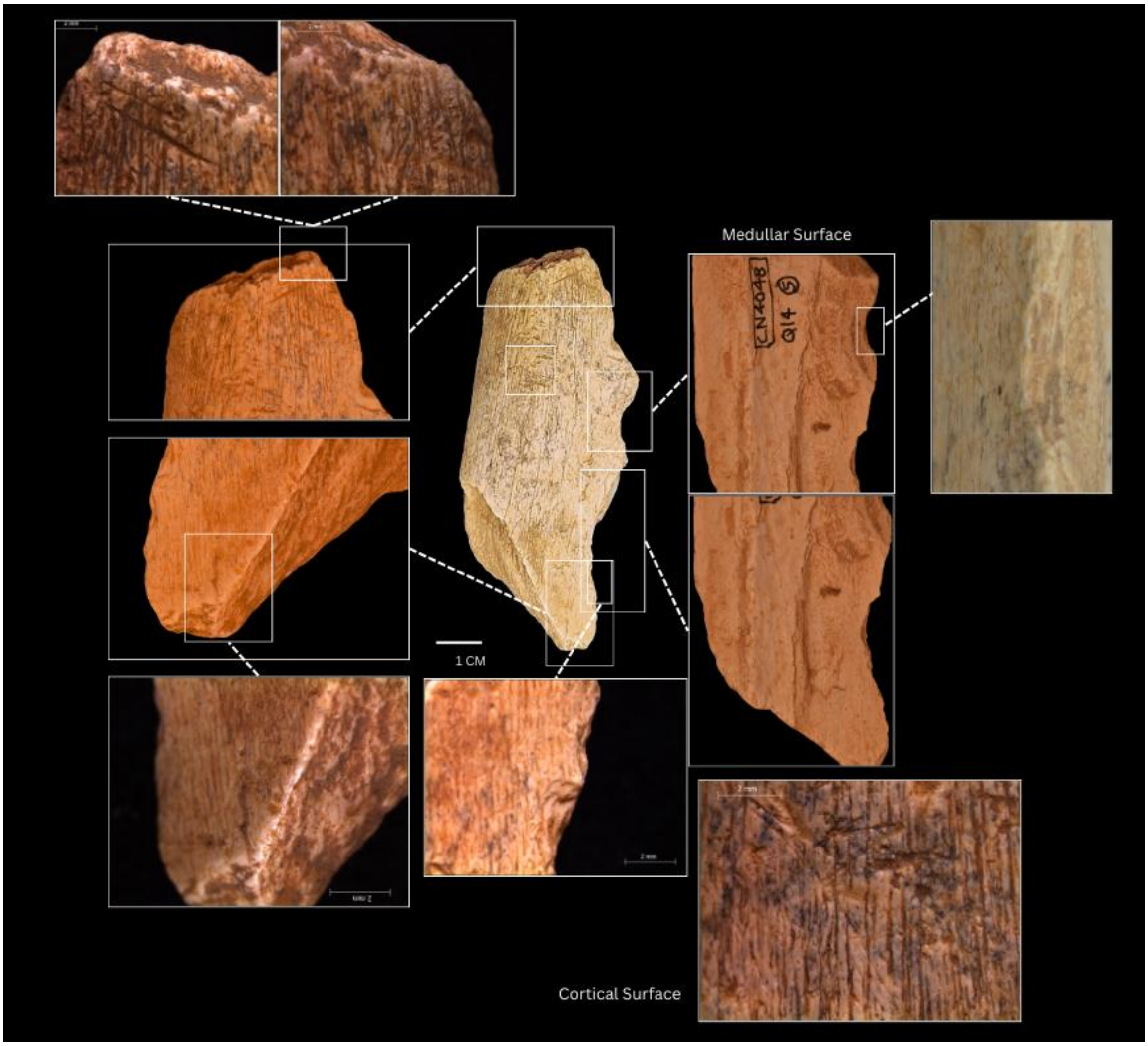


Figure 36: Interpreted as a retouched tool originating from layer 5 (CN4048). The artefact displays a somewhat denticulated appearance attributed to the discontinuous percussion marks. Impact points are noticeable on the cortical surface, accompanied by flake removals evident on the medullar surface. Parallel and longitudinal striations across the bone surface indicate abrasion from the working material. Small scalariform removals are observed at the tip as well. Additionally, the distal end appears crushed, possibly due to percussion from a hard stone material.

On the medullar side of the bone, the retouches appear to be more invasive, characterised by a flat and scalariformous nature. This indicates that the shaping or modification of the tool involved significant removal of material, resulting in a pronounced and uniform surface texture. The scalariform retouches suggest deliberate and systematic shaping, possibly to achieve a specific cutting or scraping edge. Conversely, on the cortical side of the tool, the retouches are less numerous and tend to be discontinuous This can be attributed to the naturally convex shape of the cortical surface, which provides an unfavourable edge for retouching[53]. They are shorter in length and steeper in angle compared to those on the medullar side. This suggests a different approach to retouching, possibly indicating that the cortical side was subjected to less intensive modification or was used for different tasks requiring a less refined edge.

It is noteworthy that the retouches on the cortical side become flatter and more extensive towards the distal end of the tool. This suggests a transition in retouching technique or purpose along the length of the artefact. The flattening and increased extent of retouches at the distal end may indicate a need for a broader cutting edge or increased durability in this area, possibly reflecting repeated use or specific functional requirements.

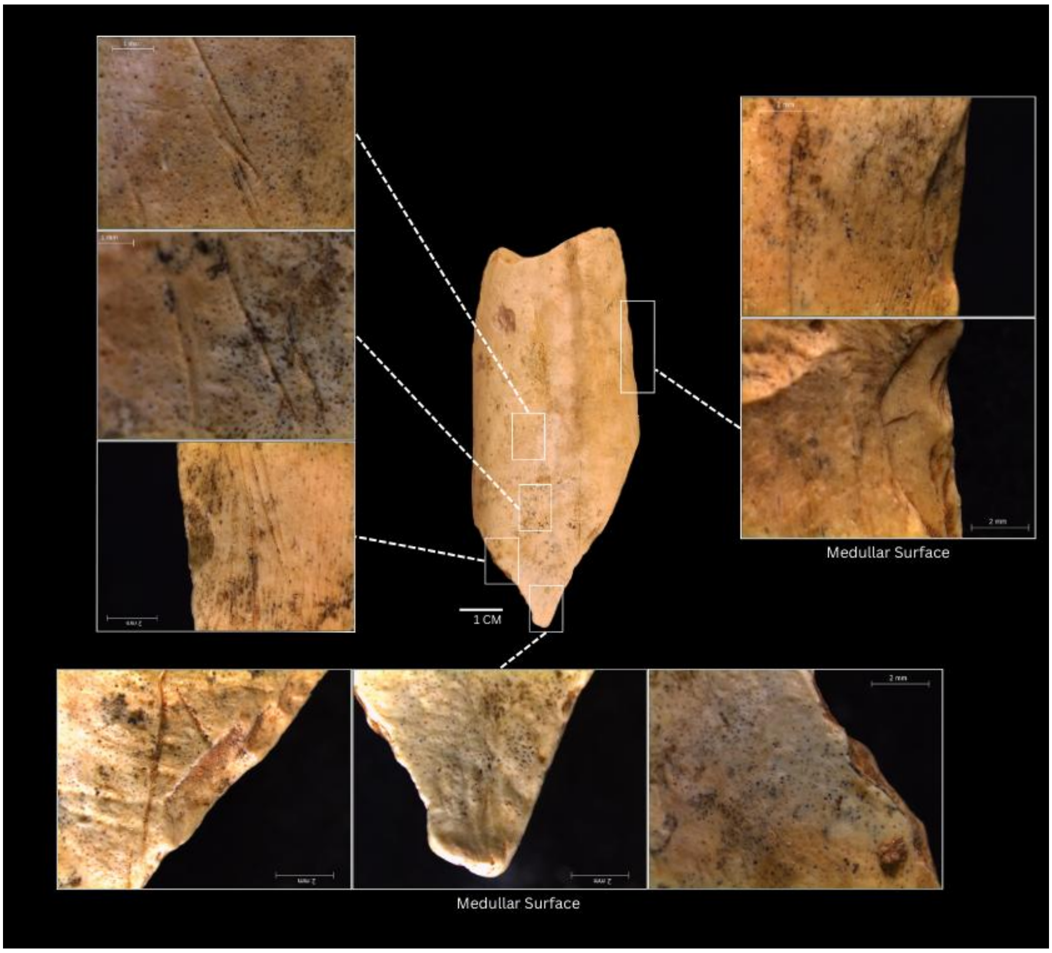


Figure 37: Interpreted as a retouched tool originating from layer 14 (CN3545), this artefact exhibits retouching along both its edges and tip. Manufacturing marks are discernible on the bone surface and edges, while polishing is primarily concentrated at the tip. Negative removals display a scalariform appearance, often overlapping and contributing to the overall morphology of the tool.

Specimen n°2 (figure 38) exhibits scalariform and low angle retouching created across various generations on a piece of ungulate limb bone. Notably, this specimen displays a slender profile (5 mm and weight 7.5

[53] The curvature of the cortical surface makes it more challenging to achieve consistent and continuous retouches compared to the flatter medullar side. As a result, retouches on the cortical side may be shorter in length and less uniform in distribution, reflecting the technical difficulties posed by the convex surface. This observation underscores the importance of considering the anatomical characteristics of the bone material when interpreting manufacturing the tools.

grams), with extending retouching along half of one edge, with the retouching extending over the tip and continuing to the adjacent edge characterised by multiple generations of invasive retouching along the blank periphery. Based on the published literature and microscopic observations, it has been determined that both series of removals were executed on the cortical side of the specimen. The first series of removals is characterised by large, scaled actions. In contrast, the second series involves smaller removals, featuring alternating and stepped retouching that resulted in a saw-edged profile. Upon closer examination, it is noted that the overlapping first series of retouches exhibit partial blunting, with a slight polish discernible on the affected areas. Despite the presence of the described manufacture traces, which indicate deliberate shaping and refinement processes, there are no visible signs of wear or alteration resulting from the artefact's use.

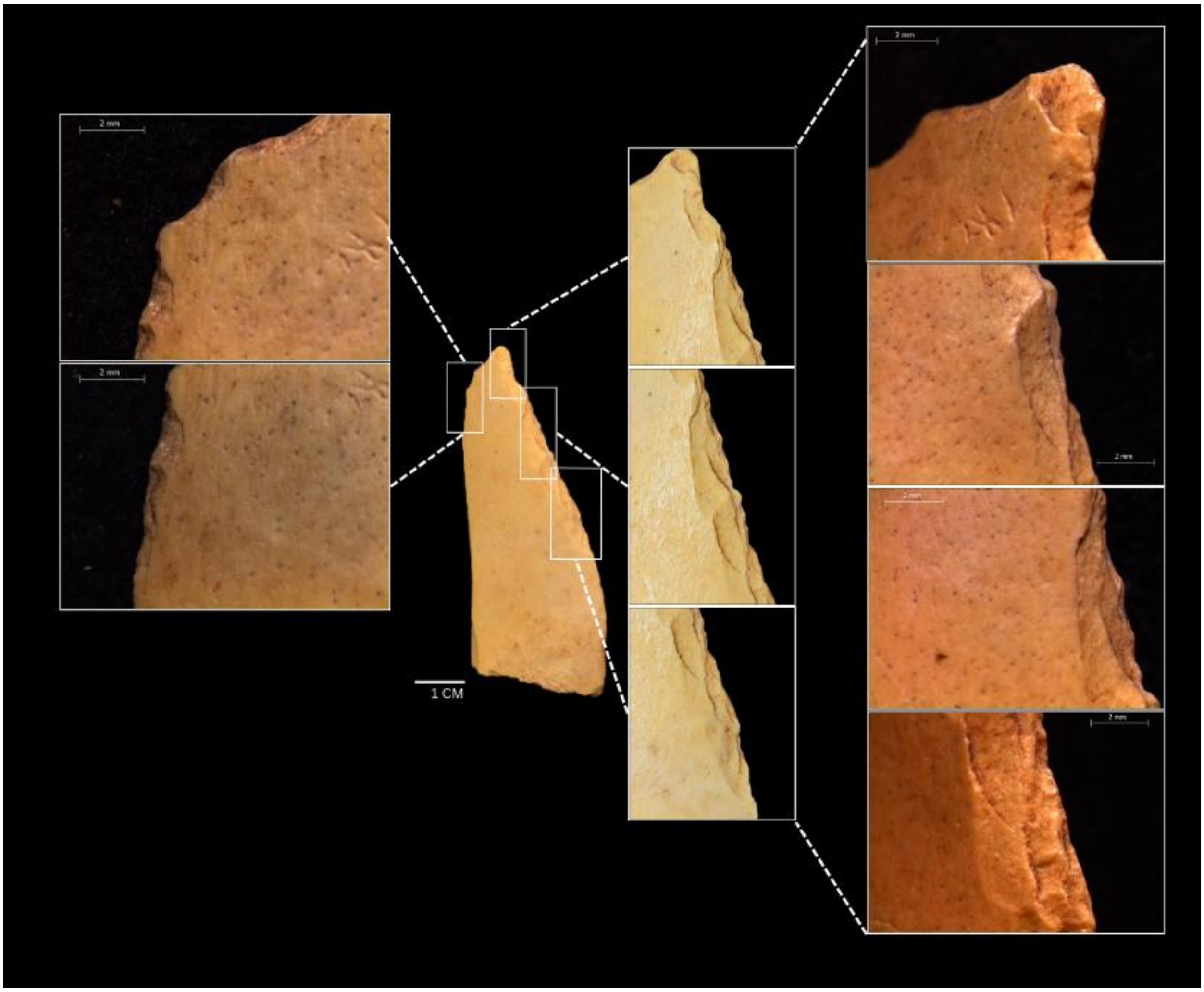


Figure 38: Interpreted as a retouched tool originating from layer 5 (n°2), this artefact displays retouching along half of one edge, with the retouching extending over the tip and continuing to the adjacent edge. Scalariform low-angle retouches are clearly observed on this artefact, indicative of deliberate shaping and modification for specific functional purposes. The retouching pattern, characterised by a series of closely spaced, low-angle modifications, suggests careful and skilled craftsmanship aimed at refining the tool's cutting edge or overall shape.

Another exceptional specimen originating from layer 13, CN4359 (figure 39) exhibits retouching along the lateral edge, covering approximately one third of the edge. Slight polished areas are concentrated specifically along the edges of the specimen. On the medullar side of the bone, percussion marks are clearly visible, followed by small removals along the edge. The manufacturing traces on this artefact are closely associated with evidence of use wear, including short, deep, non-parallel striations concentrated along the retouched edge. These features are interpreted as resulting from the functional use of the tool. Furthermore, slight polishing is observed at the tips of the tool, suggesting prolonged use or contact with materials that could produce a smoothing effect over time. This polishing may indicate the areas of the tool that were most frequently engaged in tasks, offering insights into the specific functions it served within its cultural context.

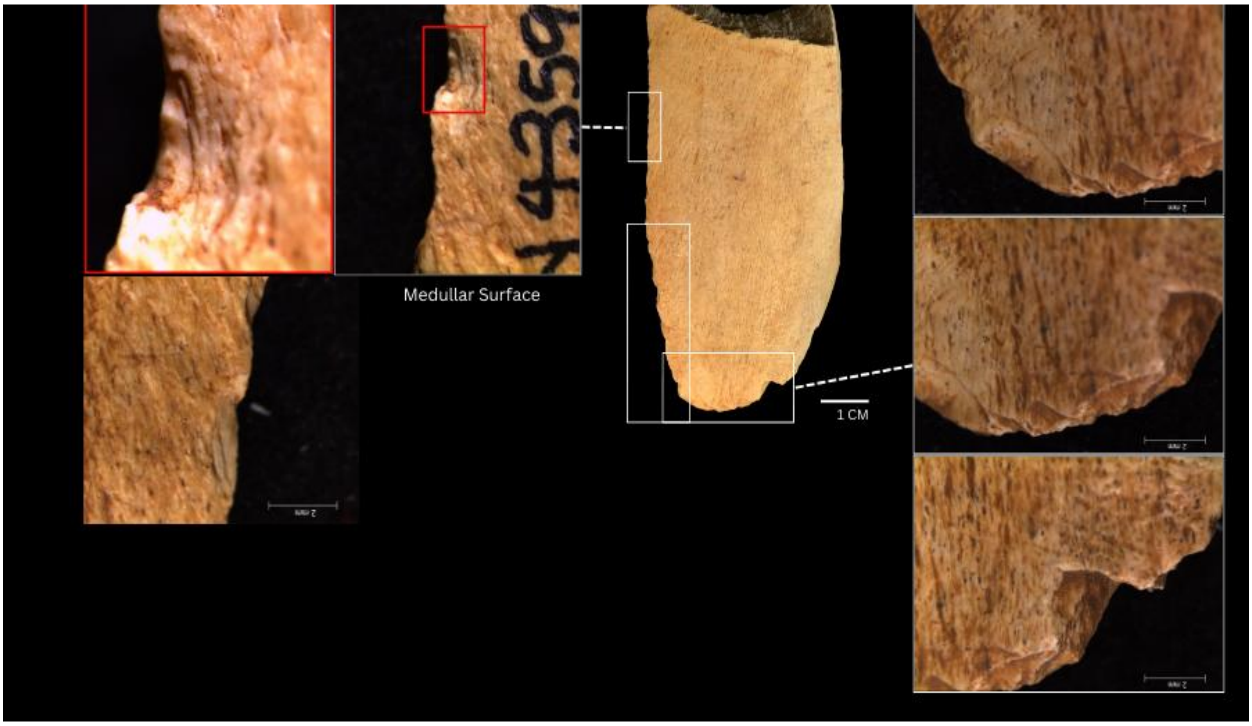


Figure 39: Interpreted as a retouched tool from layer 13 (CN4359), this artefact displays several notable features. Smaller percussion marks are visible on the surface, indicating the shaping and refinement process during manufacture. Additionally, short, deep, and nonparallel striations are concentrated along the retouched edge, strongly suggesting the functional use of the tool for specific tasks. These striations are likely the result of repetitive actions performed with the tool, leaving characteristic wear patterns indicative of its intended purpose.

Another noteworthy specimen from layer 13 (CN3596, figure 41) is made from a relatively large size ungulate limb bone and exhibits characteristics of an end scraper. Two distinct generations of large negative removals are present on the tip and lateral edge of the bone. These removals were intentionally made to thin the cortical surface of the bone, creating a suitable scraping edge. Despite the modification, there are no visible use wear marks, striations, or polishing on the lateral edges, suggesting limited or specialised use of the tool. The retouching process involved a centripetal exploitation technique, focusing on the central areas of the bone to shape and refine the scraping edge. Following the retouching, an elongated flake was produced on the laterally inclined edge. This flake likely served as an additional functional cutting edge, enhancing the versatility and utility of the tool.

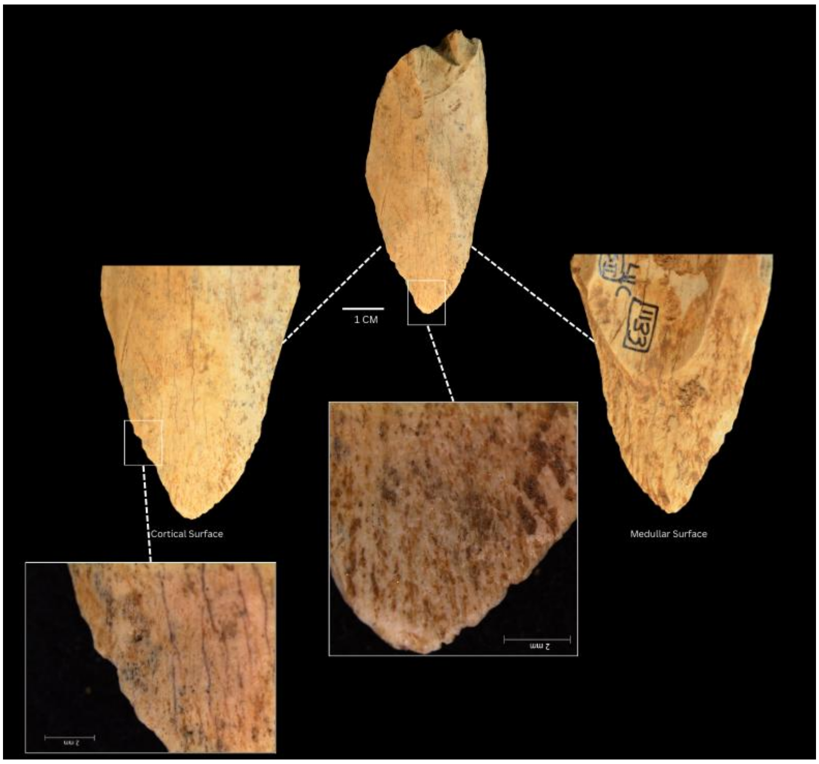


Figure 40: Interpreted as a retouched tool from layer 7SII (n°1133), shares a similar morphology to CN4359 (Figure 39). Additionally, a slightly polished tip and slight striations are evident on this tool, suggesting use or contact with materials result in surface smoothing.

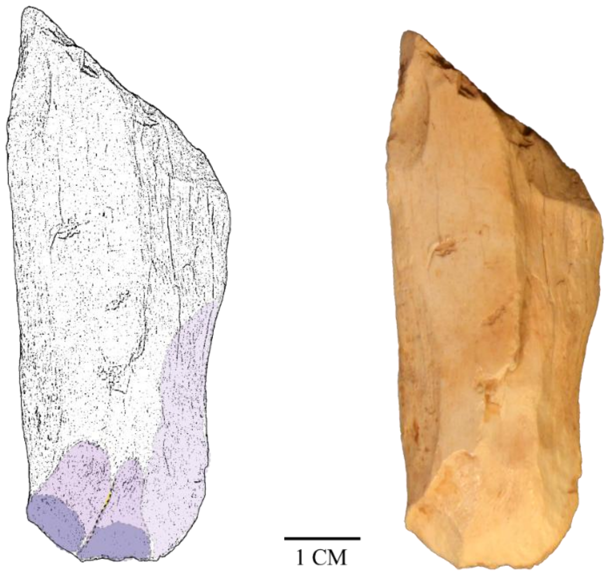


Figure 41: Interpretated as a retouched tool (CN3596) displays remarkable negative removals on both the lateral edge and the tip of the bone. These removals are categorised into two generations: the second generation of removals appears darker in shade compared to the lighter first generation of removals.

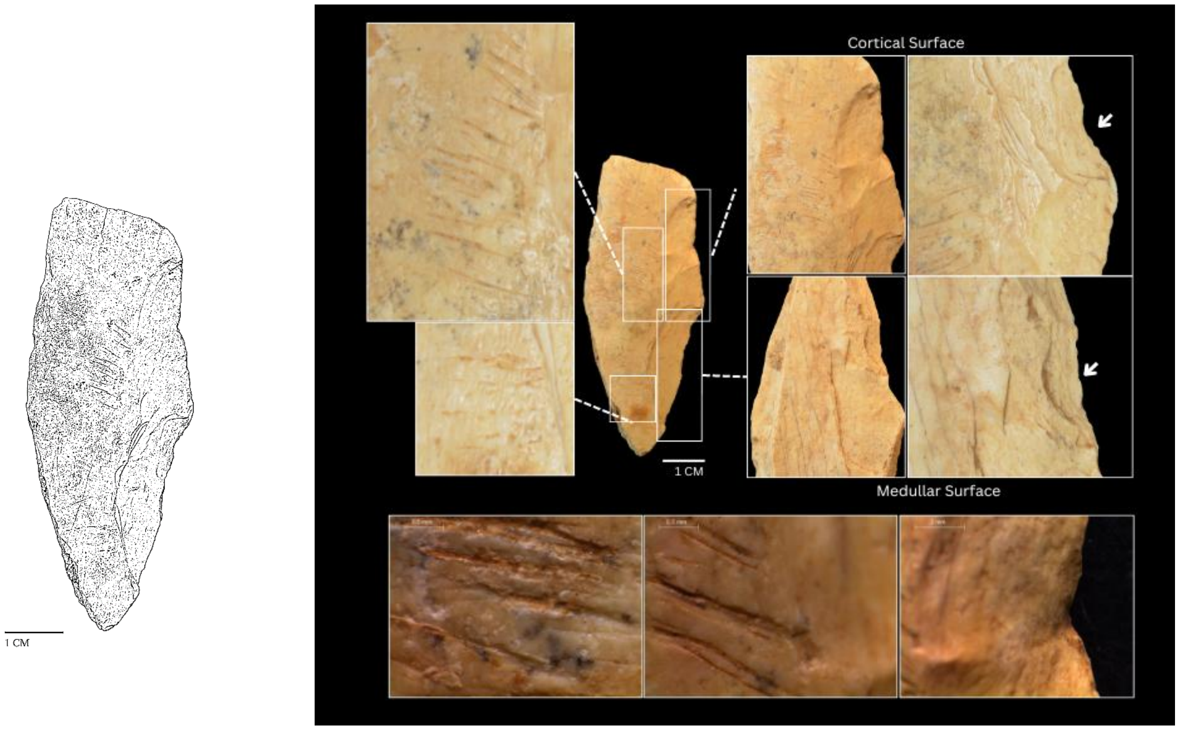


Figure 42: Interpreted as a retouched tool from layer 14 (CN903), this specimen exhibits large negative removals at the lateral edge visible impact points, along with short, deep, and parallel cut marks. Additionally, the tool shows evidence of being used as a retoucher, with visible impact points present on both surfaces.

Figure 43: Interpreted as a retouched tool from layer 13 (CN3172), this specimen also exhibits an end morphology and functions as an intermediate tool. The retouch running along the left lateral edge shows a scalariform and stepped pattern.

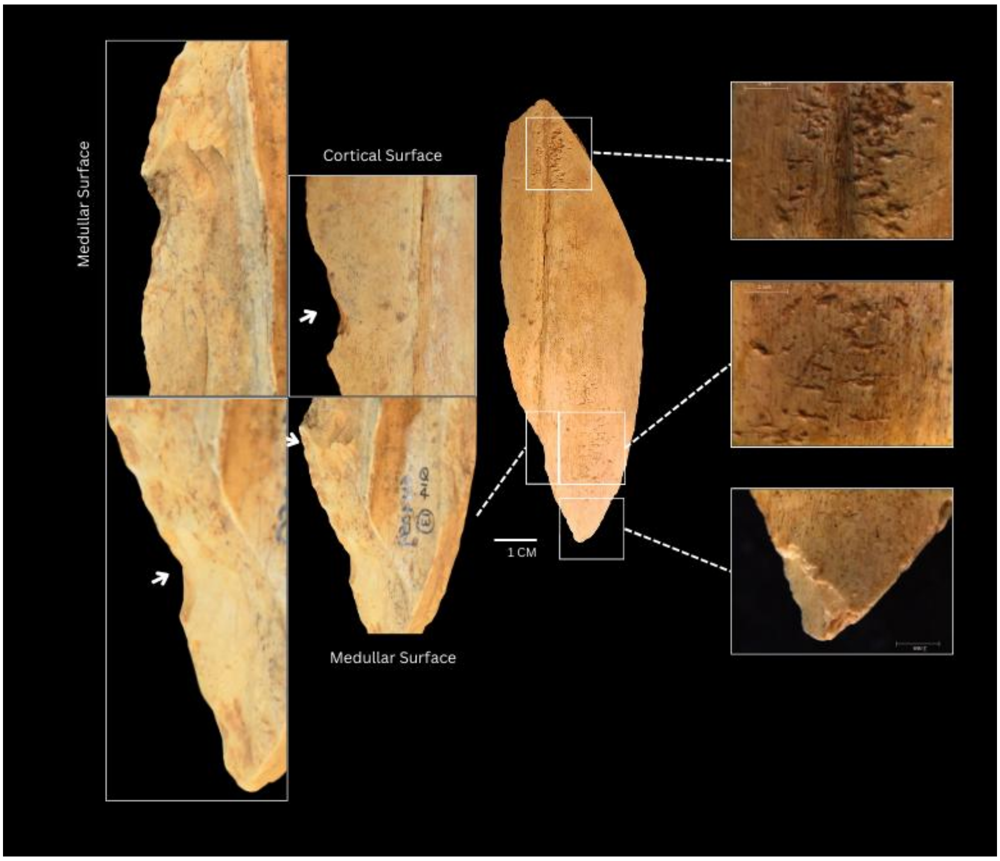


Figure 44: Interpreted as a retouched tool from layer 14 (CN4059), this specimen displays two notched areas. Between these notches, there is abrupt and small-scale retouching evident. Additionally, the tool shows evidence of being used as a retoucher in a double capacity.

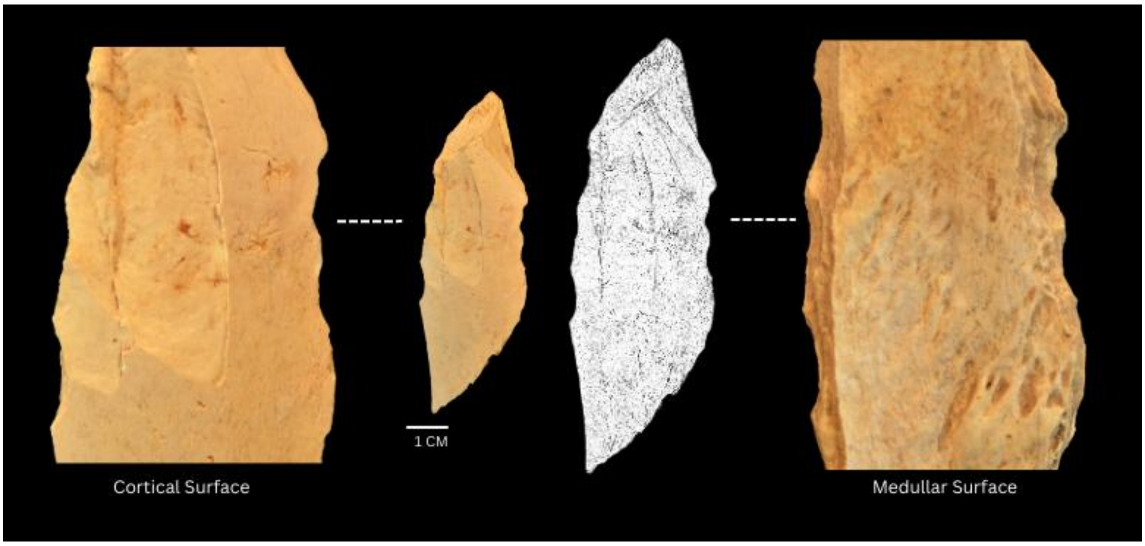


Figure 45: Interpreted as a retouched tool from layer 13 (CN3177), this specimen exhibits deliberate shaping of both lateral edges with a consistent pattern observed. There is a large removal present, although it is challenging to determine whether this removal is anthropogenic or of natural origin. Following this removal, evidence of acute low-angle, scaled retouching is visible on the left edge. A similar manufacturing pattern is observed on the right edge as well, with retouching lengths being relatively equal on both sides.

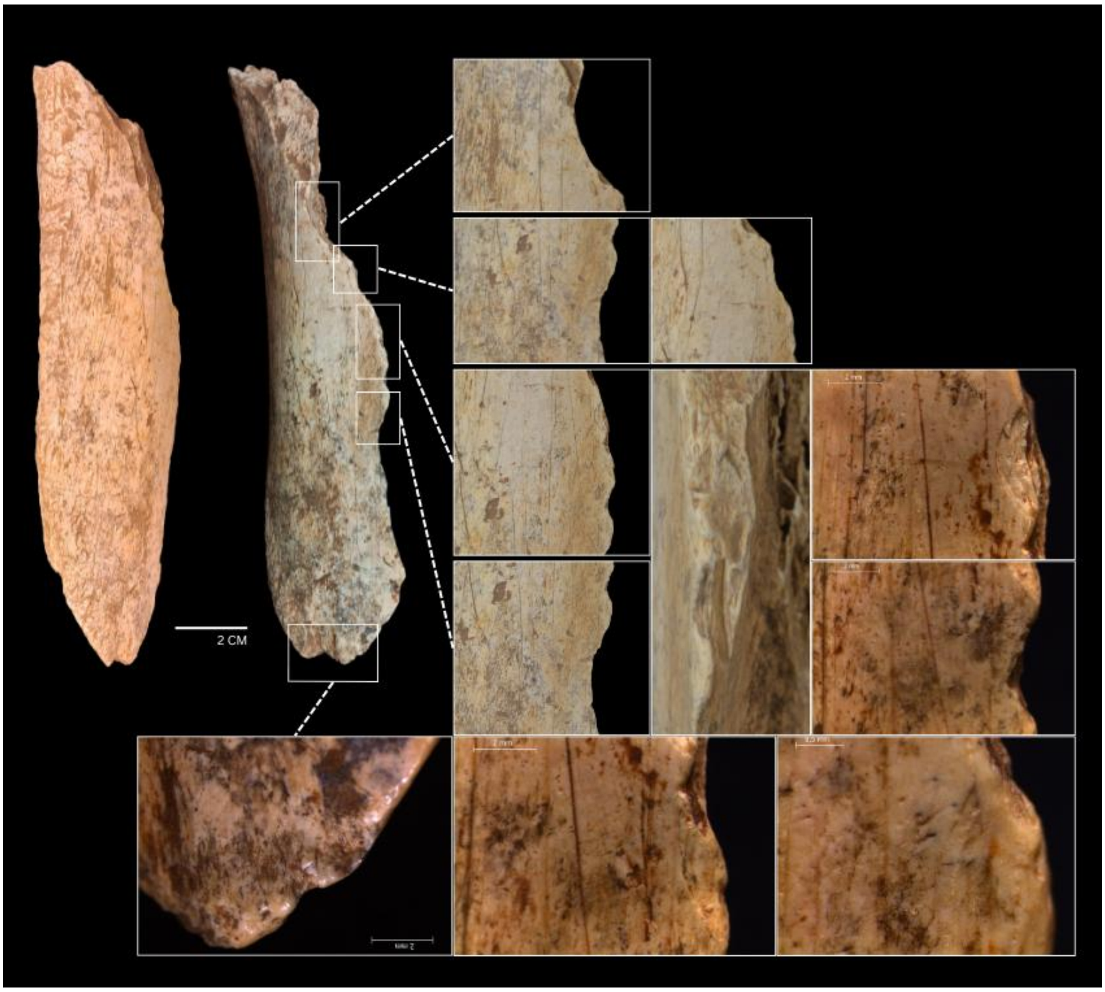


Figure 46: Interpreted as a retouched tool (CN4135) from layer 18, manufactured from a radius belonged to cfr. *Bos Priscus*, this specimen shows retouch characterised by a simple scaled retouch along approximately one third of the margin. The edge and tip exhibit slight polishing, drawing attention to these areas. Use wear traces along the edges are noticeable, characterised by longitudinal, deep, and straight cut marks.

Figure 47: (Continued) Interpreted as a retouched tool from layer 7, manufactured from *Megaloceros giganteus* radius. These polished areas often exhibit longitudinal deep and extensive striations on the bone surface. The retouch is observed on the medial surface of the radius, characterised by isolated impact points. Microscopic examinations reveal slight polishing along the edge and tip of the bone shows evidence of surface abrasion, likely resulting from contact with a rough surface. Despite a lower frequency of retouching, the tool shows multiple wear patterns indicative of extensive use, including abrasion. The areas near the retouched sections frequently display these striations, suggesting preparation of the striking platform by scraping off the periosteum. This process would have facilitated the creation of a workable edge and striking platform for performing the retouching.

Figure 48: Interpreted as a retouched (notched) tool (n°406) with two impact points on the opposite edge.

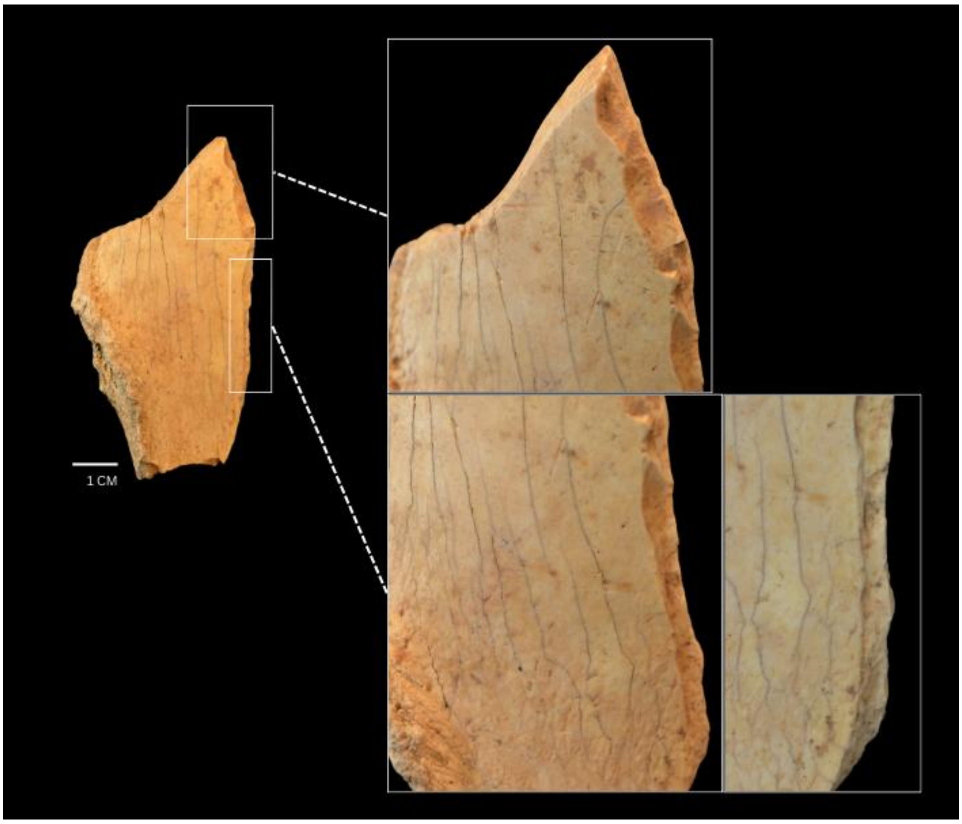


Figure 49: Interpreted as a retouched tool from layer 13 (CN2330). A gradual thinning along the edge is observed.

Figure 50: Interpreted as a retouched tool from layer 4 (CN4718). Despite its smaller dimensions, this tool displays careful retouching along the left margin characterised by scalariform retouch, as indicated by distinct impact points.

Figure 51: Interpreted as a retouched edge from layer 1 rim (CN1074). The tool is triangular in shape, with one edge exhibiting deliberate and precise retouching.

Figure 52: Interpreted as a retouched tool from layer 13 (CN3489), this specimen features marginal abrupt retouch along the edges. The tips and retouched edge exhibit slight polishing. The retouches are continuous, scaled, and bifacial, suggesting intentional modification for specific functional purposes i.e., scraping. Part of the retouch was done on medullary face, which consists of several low-angled chips, that form a sharp active edge. This active edge is slightly blunt.

Figure 53: Use wear marks observed on CN 4071 (layer 13), characterised by a regular, consistent pattern of removals and cut marks concentrated on the active edge, arranged either perpendicularly or obliquely, suggesting preparation of the striking platform by scraping off the periosteum. Chronologically the scraping marks appear first, as they have been overlapped by the negative removals.

6.3 Experimental results on bone retouching

The experiment described in this study aimed to replicate the initial stages of bone tool production, from the initial breakage to shaping, including retouching each element according to its intended use in specific activities. Morphometric analysis revealed significant variability in the shapes and sizes of the tools, with the retouched tools demonstrating larger dimensions. This selection of larger sizes was driven by the fact that of considerations for manual use, ensuring practicality (*i.e.,* ability to grip steadily) in different tasks.

The fragments resulting from bone breakage influence the shape of the simple tools, which tend to be elongated due to the nature of the limb bone diaphysis. However, the overall shape and characteristics of the potential cutting edge largely determined the selection of these fragments. Additionally, analysis of the bone breakage patterns in the experimental assemblage revealed typical patterns consistent with fresh breakage (Villa & Mahieu 1991). The presence of notches and scars on both the medullary and cortical surfaces, along with cortical and medullary flakes, as well as percussion marks on the surfaces, are indicative of intentional breakage by human activity (e.g., Bunn 1981, 1983; Blumenschine 1988, 1995; Blumenschine & Selvaggio 1988b, 1991b; Pickering & Egeland 2006). All these characteristics have been observed in the experimental assemblage.

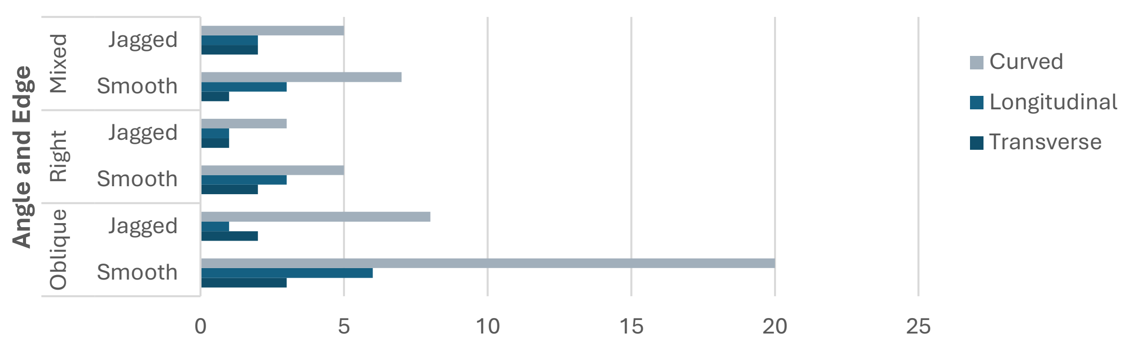
Refinement through retouching and knapping did not result in notches; instead, it produced clusters of removals with consistent sizes, oriented perpendicularly to the tool's edge and exhibiting continuous delineation. Regarding extractions resulting from activities related to nutrition, both cortical and medullary extractions typically appeared isolated and varied in size.

Table 1: List of bone breakage experiments

ID	**Anatomical element**	**Hammerstone**	**Number of fragments (Total)**	**N frag >4 cm**
FM/01/22/08/2023	Femur	Cobble	18	9
FM/02/22/08/2023	Femur	Cobble	20	11
TI/01/22/08/2023	Tibia	Cobble	23	14
TI/02/22/08/2023	Tibia	Cobble	14	8
UL/01/22/08/2023	Ulna	Cobble	14	7
UL/02/22/08/2023	Ulna	Cobble	11	6
RA/01/22/08/2023	Radius	Cobble	16	9
RA/01/22/08/2024	Radius	Cobble	20	11
Total			**136**	**75**

Table 10: Results of experimental bone retouching

ID	*Species*	*Anatomical element*	*Length*	*Width*	*Thickness*	*Weight*
E-01	*Bos taurus*	Femur	17.3	3.8	1.1	153.50g
E-02	*Bos taurus*	Tibia	7.9	5.6	1.2	47.80g
E-03	*Bos taurus*	Tibia	11	2.9	0.9	44.30g
E-04	*Bos taurus*	Femur	9.1	3.8	1.3	40.2g
E-05	*Bos taurus*	Humerus	10.2	3.5	0.8	52.60g
E-06	*Bos taurus*	Humerus	11.2	4.8	1.1	102.60g
E-07	*Bos taurus*	Tibia	19.5	5.1	1.2	100.20g



	Oblique		Right		Mixed	
	Smooth	Jagged	Smooth	Jagged	Smooth	Jagged
Curved	20	8	5	3	7	5
Longitudinal	6	1	3	1	3	2
Transverse	3	2	2	1	1	2

Figure 54: Fracture plan of the fragments of the experiment (>4cm)

Table 21: Supplementary materials used for the experimental bone retouching

ID	**Material**	**Length**	**Width**	**Thickness**	**Weight**
S-01	Stone pebble	9.4	4.4	1.1	76.50g
S-02	Stone pebble	6.1	4.8	3.7	171.80g
S-03	Stone pebble	6.9	4.7	4.6	251.30g
S-04	Flint flake	4.1	0.9	0.4	3.02g

The methodology employed in this phase applicable for analysing the experimental collection of knapped and minimally modified bone tools. The criteria used, drawn from taphonomic and technological research, allowed for a comprehensive description of the assemblage based on consistent analytical standards, thereby facilitating the systematic technological analysis of these tool sets. Unlike analysis systems based solely on morphological typology, which may not capture the full variability of these assemblages in sufficient detail (Dibble 1991), other studies have applied common methods used in lithic industry studies without modification to investigate minimally modified bone tools (Sano *et al.* 2020; Pante *et al.* 2020; Villa *et al.* 2021). The criteria proposed by Villa *et al.* (1999) and Villa & Bartram (1996) for identifying knapped bone tools primarily consist of technological parameters, incorporating classic attributes commonly used in lithic industry studies. This study also identifies a resemblance between their criteria. Specially, retouched tools are distinguished by:

a) Continuous and uniform delineation of the retouching,
b) Employing more complex reduction strategies such as bifacial shaping, and
c) Exhibiting a certain degree of symmetry, which are considered the most diagnostic criteria for identifying knapped bone artefacts.

Another important diagnostic feature involves identifying groups of wide, parallel striations concentrated at a specific location along the active edge, arranged either perpendicularly or obliquely to that edge, and located on the opposite face of a removal (*i.e.*, figures 30, 31, 34, 35, 37, 38,40, 45 and 53)

Table 32: Morphological data on experimentally retouched bones

Criteria analysed for experimentally retouch bones	**Specimen ID**						
	E-01	**E-02**	**E-03**	**E-04**	**E-05**	**E-06**	**E-07**
Knapping faces							
Unifacial	x			x	x	x	x
Bifacial		x	x				
Multifacial							
Removals disposition							
Unipolar (Up)	x	x	x	x	x	x	x
Bipolar opposite (Bo)							
Extent of the retouched edge							
Retouched zone equivalent to less than 1/8 of the edge							
Retouched zone equivalent between 1/8 and 3/8 of the edge							
Retouched zone equivalent between 3/8 and 5/8 of the edge		x		x	x		
Retouched zone equivalent between 5/8 and 7/8 of the edge	x		x			x	x
All edge is occupied by the retouches							
Inclination							
Shallow-acute or Plain						x	
Acute	x	x			x		
Abrupt			x	x			x
Depth of the retouch							
Very marginal							

Marginal	x	x					
Deep			x	x	x	x	
Very deep							x
Extent of the scars originated because of the retouch							
Marginal		x	x			x	
Extensive	x			x	x		
Very extensive							x
Total							
Direction of the retouch							
Direct[54]	x	x	x	x			
Inverse or indirect[55]					x	x	x
Alternate[56]							
Alternating[57]							
Bifacial[58]							
Delineation of the retouch							
Continuous	x	x	x		x	x	x
Non continuous							
Notch							
Denticulate				x			
Morphology of the retouched edge							
Straight	x					x	x
Convex		x	x	x	x		
Concave							
Localisation of the retouched edge							
Cortical	x	x	x	x	x		x
Ventral or Medullary						x	
Frontal edge morphology							
Convex		x	x	x	x		
Concave							
Straight	x					x	x
Denticulate							
Sagittal edge morphology							
Incurved				x			x
Straight	x	x	x		x	x	

[54] Removals on the cortical surface.
[55] Removals on the medullary surface.
[56] One edge with removals on the cortical surface and removals on a different edge on the medullary surface.
[57] Removals on the cortical surface that change to the ventral surface on the same edge.
[58] Removals present on the same edge in both cortical and medullary surfaces.

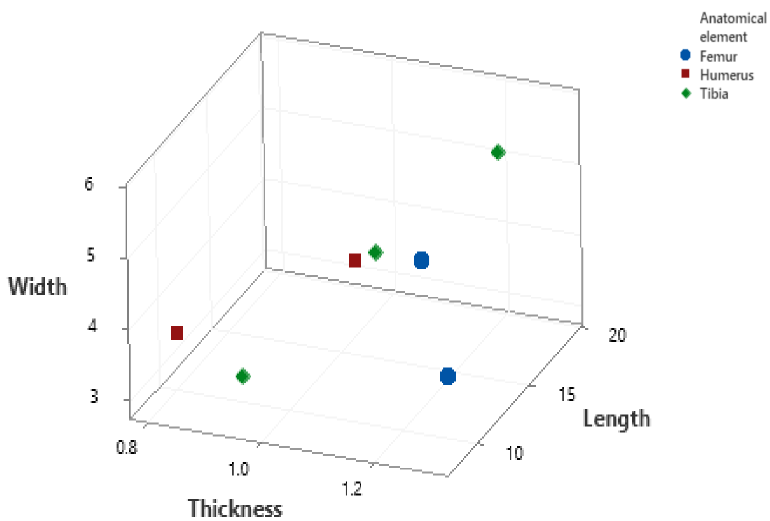


Figure 55: Dimensions of the retouched specimens used in this study.

In related studies, findings from other experiments involving bone tool knapping (e.g., Baumann *et al.* 2020) have highlighted differences in the resulting scars on knapped bones depending on whether hard or soft hammers were used. Hard hammers, such as those employed in this experiment, tend to produce marginal removals, whereas the use of a soft hammer typically results in smoother retouches.

Experimental studies on knapped bone tools are crucial for understanding how bones behave under different manufacturing techniques. Bone knapping requires skill and adaptability due to the unique physical properties of bone compared to lithic materials. While numerous bone knapping experiments have been conducted and documented (referenced in the Introduction), few provide detailed descriptions of the resulting products (Sadek-Kooros 1972; Freeman 1983; Vincent 1985, 1993; Walker 1999: 26-34; Baumann et al. 2020). These studies typically outline the experimental process and describe the achieved retouching, often highlighting challenges encountered in controlling knapping due to the bone's anisotropic nature. Most experiments involve freehand retouching with direct percussion, although Romandini et al. (2015) using an anvil-supported approach.

It would be valuable to conduct additional knapping experiments using anatomical elements from larger animals and soft hammers. A thicker cortical surface would enable exploration of different configurations and facilitate the creation of experimental sets resembling some of the most iconic archaeological knapped bones, such as those from Olduvai Gorge (Pante *et al.* 2020), Konso (Beyene *et al.* 2013), Castel di Guido (Radmilli & Boschian 1996), Fontana Ranuccio (Biddittu *et al.* 1979), and Bilzingsleben (Bruhl 2003).

Figure 56: Experimental retouched tool (E-01). Microscopic images of the retouched edge indicating the striations and cracks

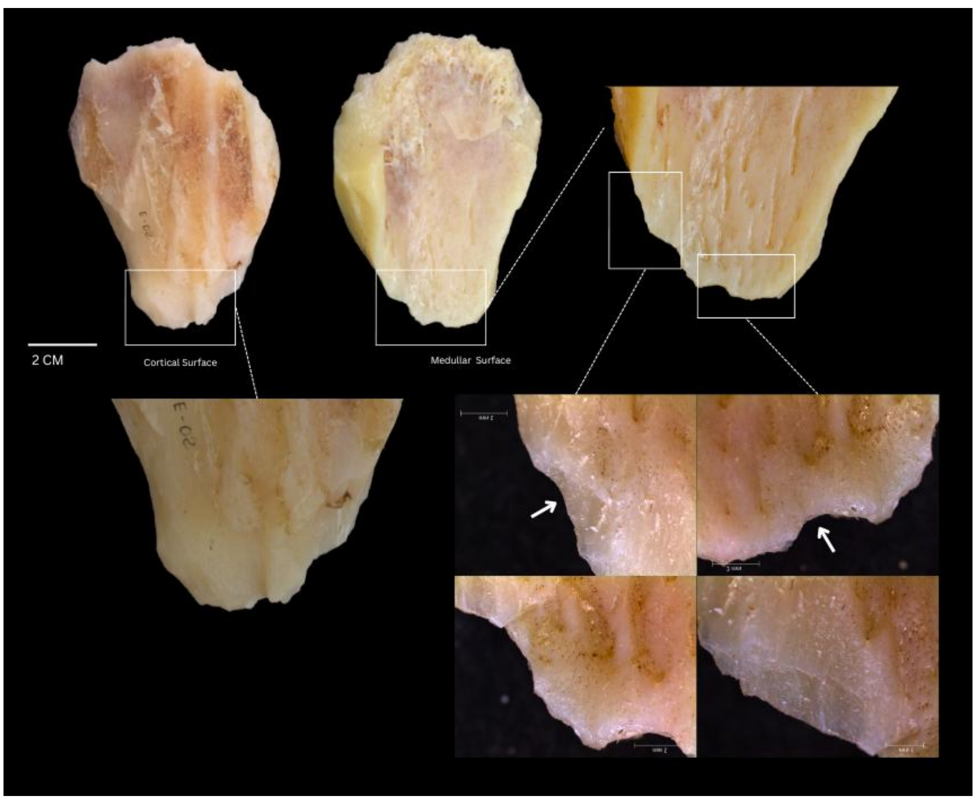


Figure 57: Experimental retouched tool (E-02). The active edge is highlighted within the white squares, and the impact points are indicated by the white arrows.

Figure 58: Experimental retouched tool (E-03).

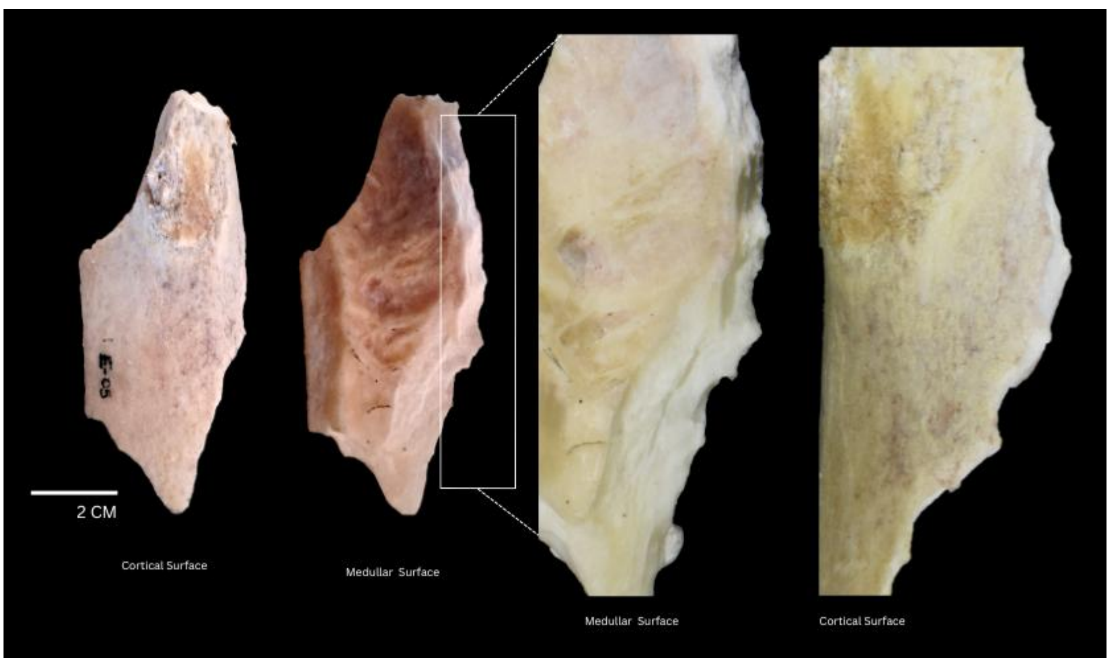


Figure 59: Experimental retouched (denticulated) tool (E-04).

Figure 60: Experimental retouched tool (E-05).

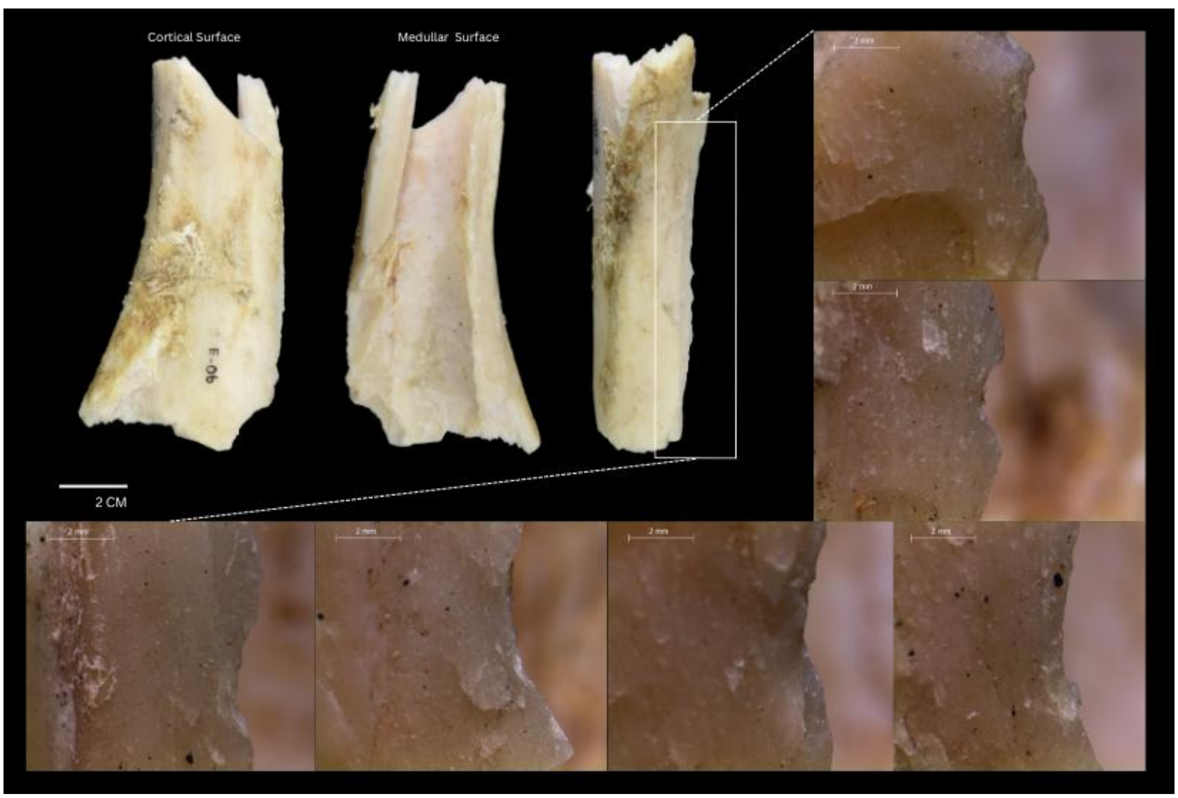


Figure 61: Experimental retouched tool (E-06). Cracks and microcracks are visible, that are developed from the percussion point. They do not form a systematic homogenous pattern, depending on the states of the material and percussion gesture.

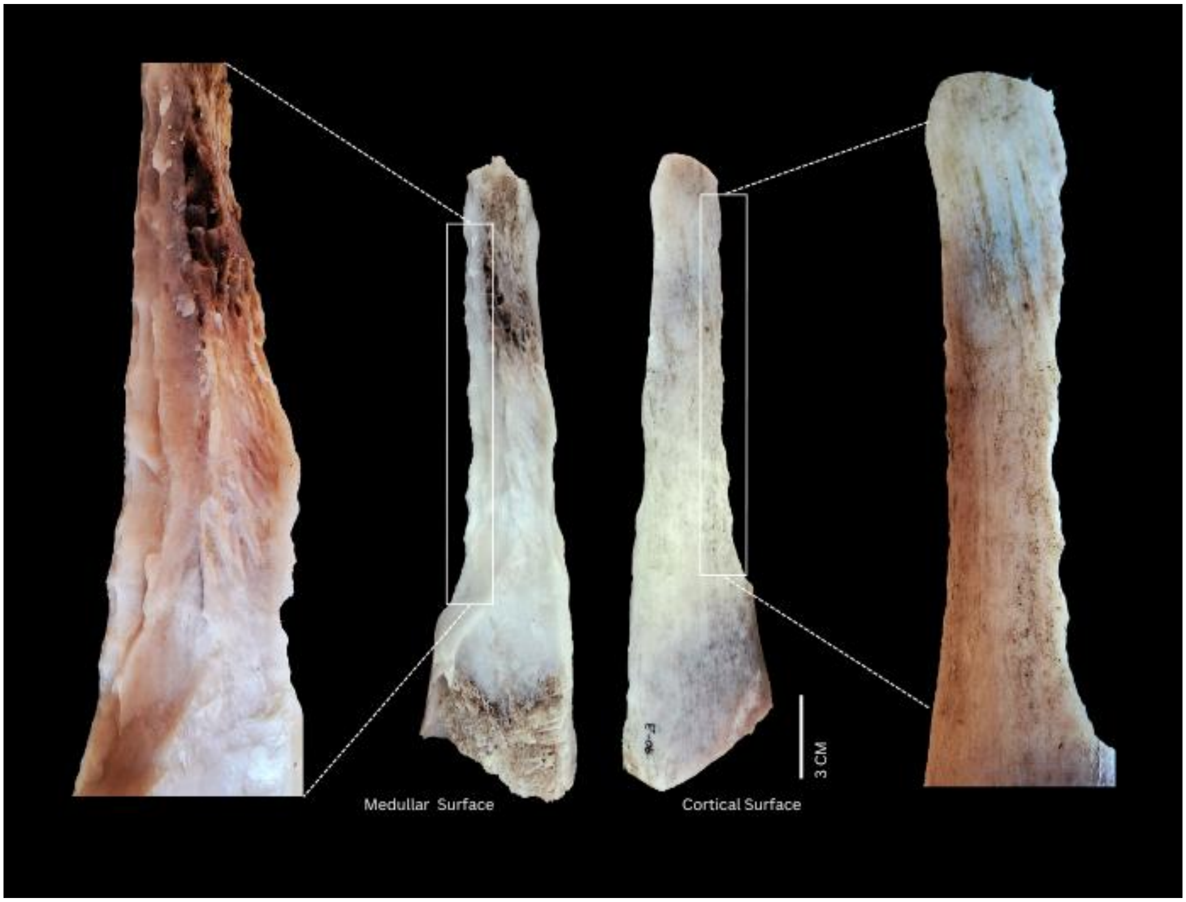


Figure 62: Experimental retouched tool (E-07).

Based on the archaeological and experimental materials analysed in this study, certain characteristics have been observed that confirm their functionality as tools.

a. The presence of active edges on these tools indicates that the surface features cannot be solely explained by natural taphonomic processes (such as carnivore gnawing, rodent activity, trampling, or sediment pressure) or anthropic modifications resulting from green bone breakage for marrow extraction.
b. At a microscopic level, distinct narrow striations are observed solely along the active edge of the bone, while the rest of the surface lacks these features. These striations are oriented parallel or subparallel to the bone's main axis and become less frequent when further away from the active edge.
c. In archaeological materials, the specific areas where these modifications are found display a uniform colour and patina that closely matches the surrounding specimens. This similarity indicates that these modifications are unlikely to be the result of excavation or preservation-related damage.

The methodology of technological analysis explored in this study represents an initial framework for systematically describing the technical features observed in knapped bone tools. An analytical approach is proposed for each tool, placing it within its operational context without relying on typological classifications, which can often be dubious, particularly in cases involving minimally modified bone artefacts, as demonstrated in this study. Furthermore, adapting a lithic industry analysis system to bone artefacts allows for comparative analysis, both synchronically and diachronically, among artefact assemblages made from different raw materials at archaeological sites.

This research integrates terminology and analytical criteria from taphonomic and lithic technological studies, facilitating future comparisons among tool assemblages manufactured from diverse raw materials. Consequently, bone artefacts are examined comprehensively, considering their distinctive characteristics and their place within the operational sequence. The acknowledgment is that this novel interdisciplinary approach to studying bone tools assist in identifying unmodified or minimally modified bone tools within archaeological contexts and in mitigating some of the equifinality challenges encountered in assemblages containing pseudo-tools.

Chapter 7
DISCUSSION

In this chapter, the results are synthesised and analysed in relation to the research objectives outlined in Chapter 1 of this dissertation. Key patterns, trends, and relationships within the data are thoroughly examined, providing insights into the broader implications and significance of the study's outcomes. Additionally, this chapter proposes directions for future investigation, and highlights the practical and theoretical contributions of the study to the field. By exploring these aspects, the discussion and conclusion chapters seeks to provide a contextual framework for the results and findings presented in chapter 6 within a specific Middle Palaeolithic technocomplex.

7.1 Recap of what we already know

The discussion of the earliest use or manufacture of bone tools remains a subject of continual debate among scholars investigating early human culture and the development of modern cognition. This discourse revolves around the significance of bone tools in evaluating hominid cognitive capacities and the criteria necessary for definitively identifying bones as tools that were potentially used or minimally modified. This includes bones that might be found in association with early hominid sites or have been documented as such in previous studies (See chapter 2).

Numerous bone, antler, and ivory tools that are purportedly used or modified have been reported from a wide range of Lower (Breuil, 1932, 1938; Breuil & Barral, 1955; Dart, 1957; Bonifay, 1974; Cahen *et al*., 1979; Biddittu & Segre, 1982; Howell & Freeman, 1983; Mania & Weber, 1986; Aguirre, 1986; Justus, 1989; Dobosi, 1990) and Middle Palaeolithic sites in Africa and Europe (Kitching, 1963; Debenath & Duport, 1971; Freeman, 1978, 1983; Vincent, 1988; Stepanchuk, 1993; Gaudzinsky, 1998, 1999). However, the majority of these early research have been published without undergoing substantial microscopic analyses of the bone surfaces to document potential traces of manufacture and use, and they have been studied in isolation from their taphonomic contexts (d'Errico & Blackwell, 2007).

Identifying manufacturing and use traces on bone tools can be challenging and requires an advanced skill set in taphonomy and understanding the functional use of tools, primarily due to the complex interplay between natural and anthropogenic factors influencing bone modifications. Various natural processes occurring during an animal's life or after its death can create pseudo-tools that resemble human-made objects. These processes include the formation of surface features due to vascular grooves (Shipman & Rose, 1984; d'Errico & Villa, 1997), wear on teeth (Gautier, 1986), breakage and wear of deer antlers (Olsen, 1989) and elephant tusk tips (Haynes, 1991; Villa & d'Errico, 1998), gnawing or digestion by carnivores, rodents, or herbivores (Pei, 1938; Sutcliffe, 1973, 1977; Binford, 1981; Villa & Bartram, 1996; d'Errico & Villa, 1997), fractures caused by hominids or carnivores for marrow extraction (Bunn, 1981, 1982; Gifford-Gonzalez, 1989), trampling (Haynes, 1988), root etching (Binford, 1981), weathering (Brain, 1967), and the effects of different sedimentary environments (Brain, 1981; Lyman, 1994). Often, bones that have been chewed by carnivores can bear a resemblance to knapped bone tools and have occasionally been misidentified as such.

According to many other researchers (Bonnichsen & Sorg, eds., 1989; Shipman, 1988; Shipman & Rose, 1988), distinguishing between pseudo-tools and genuine tools requires an interdisciplinary approach. This involves conducting taphonomic analyses of associated fossil assemblages, microscopic examinations of potential manufacturing and use traces, and experimental replication of the purported tools. By employing this methodology, theories such as Dart's (1957) proposal of an early hominid '*Osteodontokeratic'* culture have been vigorously contested and largely disproven (Klein, 1975; Shipman & Phillips, 1976; Brain, 1981; Maguire *et al.* 1980).

One of the influential taphonomic studies in this area is Binford's (1981:44–46). Binford contributed to the discussion on bone retouchers by categorising Palaeolithic examples as pseudotools. He demonstrated this by highlighting modern compressor pitting and scoring on compact bones (Binford, 1981: figs. 3.03–3.05). Binford argued that retouchers and compressors found at Palaeolithic sites, as depicted by Martin (1906, 1907a, 1923), Movius (1953), Bordes (1961b), Semenov (1964), were naturally formed due to carnivore chewing. Binford then applied his assessment to a collection of Mousterian retouchers (approximately 134) from Combe Grenal (France), interpreting them as pseudo tools displaying pitting and scoring from carnivore teeth. Binford provided an illustration from Combe Grenal (Binford 1981: fig. 4.41) and referenced other examples (previously illustrated by Martin (1907a), demonstrating striations caused by periosteum removal with additional marks that he identified as pitting from carnivore teeth. These instances serve to exemplify Binford's concept of pseudo tools in relation to retouchers. Lately, this disagreement is widely call upon '*Binford Syndrome*'.

Overall, our current understanding indicates that despite previous research efforts in the field of bone industry, a collective effort is required to fully comprehend the manufacturing processes, functions, and uses of bone tools within their archaeological contexts.

However, according to Rosell *et al.* (2011), not all bone tools are indicative of modern human behaviour. Bone tools encompass various types from a technological perspective:

a) Intentionally polished bones,
b) Bones knapped through direct percussion (with retouched edges or flakes), and

c) Unmodified bones used for specific purposes.

Among these, only intentionally polished bones are associated with modern human behaviour (Soressi *et al.* 2013), as the act of polishing represents a crucial advancement in the manufacturing and use of bone artefacts. The practice of polishing bone tools originated in Africa during the MSA and became more prevalent during the Upper Palaeolithic.

The second category of modified bones, shaped by direct percussion, represents a more ancient practice and such bone artefacts are relatively common in archaeological discoveries. In recent decades, new Lower Palaeolithic sites featuring shaped bone tools have been identified in Europe. Examples include Castel di Guido (Radmilli & Boschian 1996), Fontana Ranuccio (Biddittu & Celletti 2001), and Polledrara (Anzidei 2001) in Italy, Bilzingsleben (Mania & Mania 2005) and Schöningen (Julien *et al.* 2015) in Germany, and Vertesszöllös in Hungary (Dobosi 2001), among others. These sites frequently yield artefacts manufactured from proboscidean bones, often comprising large tools associated with Technological Mode 2 or Acheulean technology. Some researchers posit that the use of bones at these sites was driven by a scarcity of suitable lithic raw materials in the vicinity (Anzidei 2001; Dobosi 2001; Gaudzinski *et al.* 2005). Recent studies focusing on Neanderthals from various sites such as Chagyrskaya cave (Baumann *et al.* 2020), Denisova cave (Baumann et al. 2017, 2018; Kozlikin et al. 2020; Kolobova et al. 2020), Chez-Pinaud (Baumann *et al.* 2023), Abri Lartet (Baumann *et al.* 2022), Abric Romaní (Mateo-Lomba *et al.* 2024) and Dordogne-Charante (Baumann & Maury 2023) have revealed that Neanderthals possessed cognitive abilities enabling them to utilize bones as an alternative raw material to lithic technology.

The third category of bone tools comprises unmodified bones, which can also encompass bones that show evidence of modification through use (e.g., bone hammers). Typically, these bones are long and may be whole or fragmented, employed to strike or press lithic elements to create flakes or shape the edges of stone flakes. The interaction between these bone tools and harder materials often results in distinctive markings on the bone shaft, resembling percussion pits (Pickering & Egeland 2006; among others). These pits are frequently accompanied by clustered striae, caused by the slipping of stone against bone during impact events. However, isolated marks resembling chop marks can also be observed. Crop marks are typically short, deep, and have an oblique section, resulting from blows with a blade-cutting instrument that produces isolated, deep cuts without internal microstriations (Armand & Delagnes 1998; Giacobini & Malerba 1998; d'Errico & Henshilwood 2007).

While bone hammers are noted in the Lower Palaeolithic context of Boxgrove, England (Parfitt & Roberts 1999; Parfitt & Bello 2024), their use is predominantly associated with Middle Palaeolithic or Mode 3 contexts, such as the Middle Pleistocene sites in France like Orgnac 3 (MIS 8; (Moncel *et al.* 2005), Biache-

Saint-Vaast (MIS 7; (Auguste 1992), and Lazaret Cave (MIS 6; (Valensi 1996). By the Upper Pleistocene, these bone tools become more prevalent, as evidenced by sites such as Peña Miel, Abric Romaní, Prado Vargas Cave, and Axlor in Spain (Barandiarán 1987; Aïmene 1998; Navazo *et al.* 2005; Mozota Holgueras 2009b), Riparo Tagliente and Riparo di Fumane in Italy (Giacobini & Malerba 1998; Jéquier *et al.* 2012, 2013, 2018; Romandini *et al.* 2015), and Combe Grenal, Artenac, and La Quina in France (Chase 1990a; Armand. D & Delagnes 1998; Verna & d'Errico 2011), among others.

Recently, additional categories of unmodified tools have emerged, including beveled tools (Baumann *et al.* 2023), unworked intermediate tools (Tartar 2012b), and *pièce esquillée* (d'Errico *et al.* 2012b). These tools have undergone multidisciplinary studies focusing on their archaeozoological, taphonomic, technological, and functional characteristics. From a functional perspective, the distinctions among these tools become more apparent.

7.2 Zooming into grotta de Nadale

Grotta de Nadale represents a single layered Quina Mousterian referential site in Northeastern Italy, during MIS 3 (late middle Palaeolithic). The dating obtained from the large herbivore tooth using the U-Thorium dating method suggests a minimum age of 70.2 ± 1.0 ky BP. The stratigraphic integrity of the site is well-established, with minimal reported disturbance to the stratigraphy (Jéquier *et al.* 2015). The presence of giant deer, red deer, and aurochs confirms the existence of an open plain environment within a generally cold temperate climate. The taphonomic conditions indicate excellent preservation of the bones, with some natural alterations such as vermiculation, manganese oxide staining, and concretions (Livraghi 2015; Martellotta *et al.* 2021; Livraghi *et al.* 2021) . The remains are generally well-preserved, and their surfaces exhibit distinct anthropic marks and corrosion pits. Occasional evidence of carnivore gnawing and rodent activity is also observed, albeit to a lesser degree. Existing pollen records from the region suggest that this would have indeed been a cold, dry period (Vidal-Matutano *et al.* 2022), however these lake archives remain detached from the archaeological assemblages themselves (Pini *et al.* 2009, 2010). Zooarchaeological analysis of small mammals from the site itself provide further environmental indicators (López-García *et al.* 2018), while an abundance of open grassland large-mammal species *Bison priscus* (steppe bison) and *Megaloceros giganteus* (giant deer) in Unit 7 provide further indications of dry ecosystems (Livraghi *et al.* 2021). However, these records face taphonomic issues (e.g., the small mammals may have been accumulated by raptors) and the ecological and climatic tolerances of some larger species in the past remain difficult to determine (Andrews 2006; López-García *et al.* 2018).

The lithic techno-complex in found in the site differs notably from the Mousterian industry of neighboring regions due to its distinct technological and typological attributes, particularly evident in core reduction methods and the characteristics of produced blanks and retouched tools. The reduction strategy observed at grotta de Nadale, featuring scrapers and tools with invasive retouch (Jéquier *et al.* 2015; Delpiano *et al.* 2022), shows similarities to Quina assemblages identified in Italy and southwestern France (Bourguignon 1997). Given the absence of suitable local lithic resources, chert was sourced from areas spanning the eastern Berici Hills, western Euganean Hills, and central-western Lessini, situated at distances ranging from 20 to 80 kilometres from the cave (Livraghi *et al* 2015, 2021).

At the site, the practice of using bone blanks to retouch lithic artefacts is well-documented. Bones from hunted animals served as an alternative raw material, which Neanderthals adeptly exploited for this purpose (Martellotta *et al.* 2021). In addition to Quina scrapers, there has been a suggestion of a correlation between bone retouchers and denticulate tools (Rosell *et al.* 2011). Within the definition of the Quina complex, the utilisation of animal resources—both for food and technological requirements—is closely intertwined with human mobility and subsistence strategies (Castel *et al.* 2017; Costamagno *et al.* 2019).

Table 43: Reports of knapped bone tools from pre-anatomically modern human contexts in Eurasia (modified after Baumann *et al* (2023).

Locality	Site	Industry	Dates	Reference
France	Combe-Grenal	Mousterian Levallois Denticulate	MIS 3 (39-38 ky BP)	(Bordes 1961b; Vincent 1993; Tartar & Costamagno 2016)
	Jonzac	Quina	MIS 4 (72 ky BP)	(Richter *et al.* 2013; Rendu *et al.* 2020)
	Vaufrey	Mousterian Levallois	MIS 4 (74 ky BP)	(Vincent 1993; Tartar & Costamagno 2016)
	Pié-Lombard	Levallois	MIS 5 (70 ky BP)	(Texier 1974b; Texier *et al.* 2011)
	Rigabe	Levallois	MIS 3-5	(Defleur 1988; Brugal *et al.* 2020)
	La Ferrassie	Mousterian		(Bordes 1961b)
	Bois-Roche	Mousterian		(Vincent 1993)
	Baume de Gigny	Mousterian		(Vuillemey 1993)
Italy	Fumane	Levallois	MIS 3 (42 ky BP)	(Peresani *et al.* 2013; Romandini *et al.* 2015)
	Poggeti Vecchi	Mousterian	MIS 6-7 (171 ky BP)	(Aranguren *et al.* 2019)
	Casal de'Pazzi	Protopontinian	MIS 7 (270-250 ky BP)	(Anzidei & Gioia 1992; Marra *et al.* 2018; Villa *et al.* 2021)
	La Polledrara	Acheulean (without bifaces	MIS 9 (324 ky BP)	(Santucci *et al.* 2016; Villa *et al.* 2021)
	Lademagne	Acheulean	MIS 10-11 (405-389 ky BP)	(Pereira *et al.* 2018; Villa *et al.* 2021)

	Castel di Guido	Acheulean	MIS 11 (395 ky BP)	(Boschian & Saccà 2015; Villa *et al.* 2021)
	Fontana Ranuccio	Acheulean	MIS 11 (407 ky BP)	(Biddittu & Serge 1982; Pereira *et al.* 2018; Villa *et al.* 2021)
	Malagrotta	Acheulean (without bifaces)	MIS 11 (451-378 ky BP)	(Marra & Gatta 2019; Villa *et al.* 2021)
	Pontecorvos	Acheulean		(Biddittu & Serge 1982; Villa *et al.* 2021)
Germany	Rhede	Micoquian (Keilmesser)	MIS 5 (70 ky BP)	(Tromnau 1983; Baales & Stapel 2015)
	Sirgenstein	Mousterian		(Hahn 1976; Ono 2006)
Belgium	Trou Magrite	Mousterian	MIS 3	(Jimenez *et al.* 2016)
Spain	Axlor	Quina	MIS 3 (>47 ky BP)	(Baldeón 1993; Mozota Holdueras 2012)
	Peña Miel	Quina	MIS 3 (+/-50 ky BP)	(Barandiarán 1987; Montes *et al.* 2001)
	Abric Romaní	Denticulate	MIS 4-3 (61-39 ky BP)	(Carbonel *et al.* 1994; Tartar & Costamagno 2016)
	Gran Dolina	Mousterian	MIS 9 (372-244 ky BP)	(Rosell *et al.* 2011)
	Bolomor	Denticulate	MIS 9 (350 ky BP)	(Rosell *et al.* 2015)
Portugal	Nova de Columbeira	Mousterian	87 ky BP	(Zilhão *et al.* 2011)
Czech Republic	Kůlna	Micoquian Taubachian	MIS 3 (125-45 ky BP)	(Vincent 1993)
		Levallois		
Russia	Denisova	Levallois	MIS 5 (105 ky BP)	(Baumann *et al.* 2018; Jacobs *et al.* 2019; Kozlikin *et al.* 2020b)
	Chagyrskaya	Micoquian	MIS 4-3 (60 – 50 ky BP)	(Baumann *et al.* 2020, 2023)

7.3 Points of discussion

7.3.1 Provenance of blanks: using available sources or by choice?

7.3.1.1 Faunal spectrum

The evaluation of zooarchaeological profile chosen to procure materials for toolmaking among Neanderthals of grotta de Nadale is a crucial matter, closely linked to their subsistence strategies and mobility patterns. The collection of over 300 retouchers from de Nadale, primarily consists of bones from large cervids such as *Megaloceros giganteus* and *Cervus elaphus*, as well as bones from large bovids including Bos/Bison and *Bison priscus* (Martellotta *et al*. 2021, Livraghi *et al.* 2019: table 1). As suggested by the authors, the specific preference for certain species in manufacturing retouchers may be influenced by the availability of resources or guided by specific technological considerations.

In this study, a similar pattern emerges. Across both hypotheses, the majority of identifiable specimens are attributed to *Megaloceros giganteus* (13.1%), *Cervus elaphus* (17.2%), and *Bos/Bison* (14%). The portion of indeterminate ungulates accounts for 32% of the entire assemblage, with large-sized ungulates comprising the majority (32%), followed by medium-sized ungulates at 21% (figure 63).

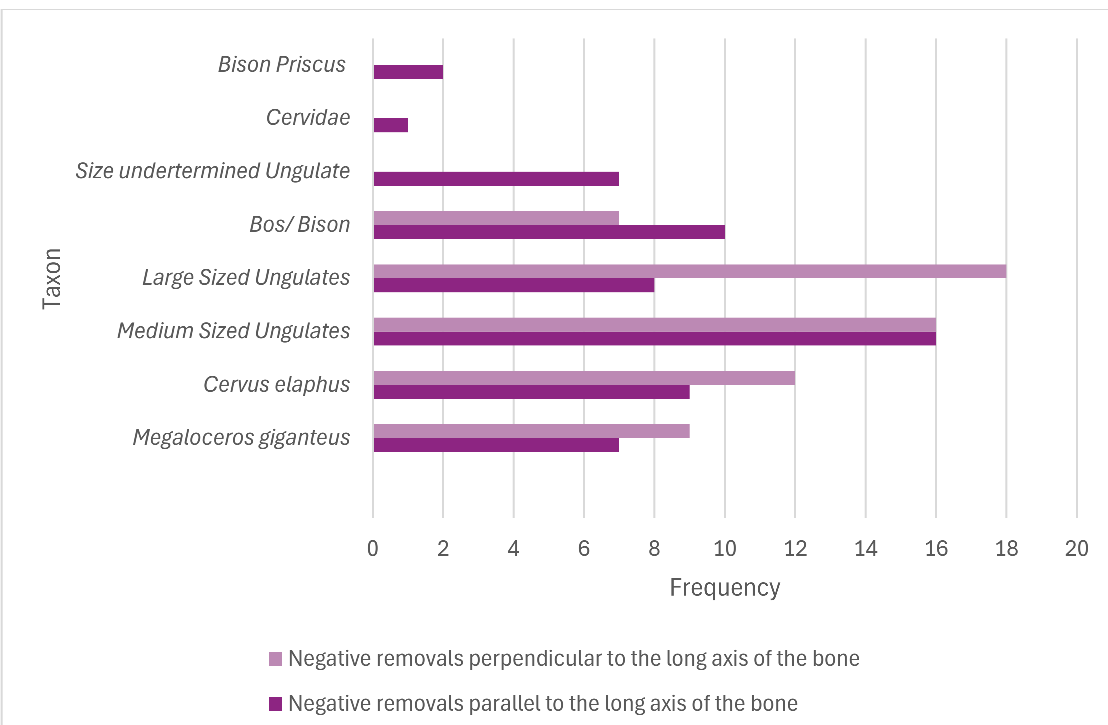


Figure 63: Overall presentation of animal taxa for the studied assemblage from grotta de Nadale

Table 54: Overall presentation of animal taxa for the studied assemblage from grotta de Nadale

Taxon	***Negative removals parallel to the long axis of the bone***	***Negative removals perpendicular to the long axis of the bone***
Megaloceros giganteus	7	9
Cervus elaphus	9	12
Medium Sized Ungulates	16	16
Large Sized Ungulates	8	18
Bos/ Bison	10	7
Size undetermined Ungulate	7	
Cervidae	1	
Bison Priscus	2	
TOTAL	60	62

Therefore, given the correspondence between the species represented in these specific technological assemblages and the broader faunal assemblage at grotta de Nadale, it can be posited that the selection of species for retoucher production was influenced by the availability of environmental resources. Similar pattern has emerged from the abundance of retouchers discovered within the cave (Martellotta *et al.* 2021).

7.3.1.2 Anatomical elements

The selection of limb bones for manufacturing bone tools is an extremely widespread pattern. Grotta de Nadale fits in this model in that almost all retouchers are obtained from long bones; among the most selected elements, tibias are the most represented, followed by radius, femurs, metacarpals and metatarsals. Humeri, on the contrary, are extremely rare. Same pattern is observed from the retouchers from the cave (Martellotta *et al.* 2021: Table 3; Figure 3, 11). Diaphysis is almost the only bone portions used as tools. The lack of this skeletal element could be ascribed to several factors: the high fragmentation rate in the deposit (Livraghi *et al*. 2019), the use of epiphyses as fuel (Costamagno *et al.* 2005)—since this assemblage contains a high number of burned and calcinated bones—or the fact that epiphyses may possess less of the technological features suitable for tool manufacturing as diaphysis do.

In this study, the pattern appears reversed compared to retouchers: the tibia and humerus are the most commonly used bones, while the radius is extremely rare (figure 64). The tibia, a long and robust bone, is well-suited for heavy-duty tasks due to its balance of length, strength, and thickness. This makes it ideal for providing a solid grip and a durable edge for percussion work. The humerus, also a robust bone, has more irregularities because of its articulation at the shoulder, but it offers a more substantial, rounded handle, which may be preferred for its ergonomic grip in certain tasks. In contrast, the radius, while less robust than the tibia, is relatively straight and often has a good, flat surface, which could be suitable for retouching purposes. However, it may not be ideal as an intermediary tool and often lacks the necessary angles for effective edge retouching.

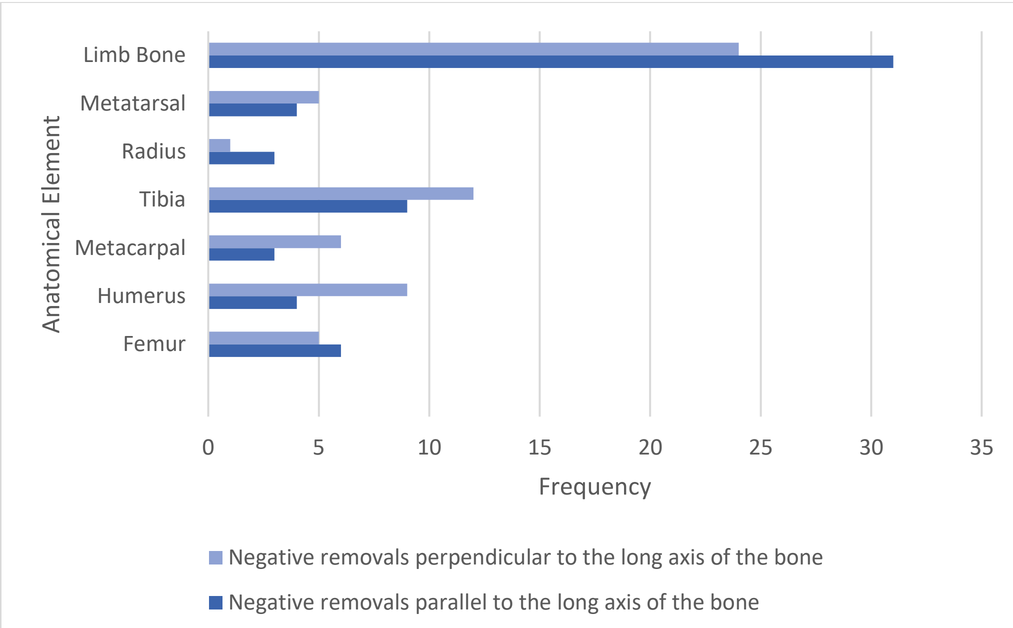


Figure 64: Overall presentation of anatomical element for the studied assemblage from grotta de Nadale

Table 65: Overall presentation of anatomical element for the studied assemblage from grotta de Nadale

Anatomical Element	Negative removals parallel to the long axis to the bone	Negative removals perpendicular to the long axis to the bone
Femur	6	5
Humerus	4	9
Metacarpal	3	6
Tibia	9	12
Radius	3	1
Metatarsal	4	5
Limb Bone	31	24
TOTAL	60	62

Examining the specific skeletal elements chosen for retouching holds significance for several reasons. Firstly, it aids in understanding the strategies Neanderthals employed for carcass exploitation, as retouchers typically originate from bones broken during subsistence activities. Secondly, the selection of precise anatomical elements, guided by morphological criteria essential for retouching tasks, suggests a technological purpose behind their choice. The observed bias in frequency between appendicular and axial elements is not attributed to post-depositional processes but rather indicates deliberate selection by human groups, who favoured the introduction of leg quarters into the site (Livraghi *et al.* 2019).

Hypothesis 1: Negative removals perpendicular to the long axis of the bone (i.e., Intermediate tools)

Drawing upon the findings presented in chapter 6 of this dissertation, this category of bone tools comprises long diaphyseal fragments likely a byproduct from marrow extraction, and axial damage observed: being in these cases, traces of manufacture. What is particularly noteworthy about these pieces is the consistent pattern of blunting and crushing observed on the distal end, along with chips and negative removals evident on the proximal end. These features are distinct from typical bone opening methods for marrow extraction, such as green bone fractures or dry bone fractures. These are essentially fragments of long bones resulting from diaphysis fracture via direct percussion. These tools are unworked and are identifiable solely by the percussion marks present at their ends. When studying these pieces, it is crucial to analyse not only their morphological characteristics but also to conduct taphonomic analysis and describe the markings or features observed on the pieces, distinguishing between anthropic and non-anthropic origins. This approach aids in taphonomic analysis of their archaeological context, reducing the risk of mistaking them for pseudo-tools produced by non-anthropic agents. It is crucial to note that, however, while carnivore pseudo-retouch can occur randomly anywhere on the bone surface, the removal flakes observed on intermediate tools are exclusively found at their ends and are consistently associated with crushing resulting from use in indirect percussion. This distinction underscores the deliberate and systematic nature of the modifications observed on these tools compared to natural or carnivore-induced markings on bones. Conversely, carnivore pseudo-retouch is often characterised by accompanying teeth marks, claw marks, or chemical alterations from gastric juices, none of which are observed when rigorously examining the assemblage. This absence of typical carnivore-related features reinforces the distinction between deliberate tool modifications and natural carnivore interactions on bones.

Through careful analysis, with a focus on the archaeological context and taphonomic traces present on the bone surface, pieces exhibiting negative removals perpendicular to the long axis of the bone (n=60) from the grotta de Nadale are revealing themselves to be part of an assemblage consisting of intermediate tools (*i.e.,* unmodified intermediate tools). Moreover, these tools, identified as diaphyseal fragments from food processing, share similarities with many unused bone fragments found within the rest of the faunal assemblage. Therefore, the hypothesis that these intermediate tools were intentionally produced as such appears unsupported (Tartar 2012b).

The choice of blanks for these tools appears to have been made based on specific preferences:

a) *Size:* There was a preference for bones from large ungulates, suggesting that Neanderthals selected bones from larger animals, possibly due to the abundance of marrow and resources available in such bones guaranteeing long, broad and solid tools.
b) *Anatomical element:* Neanderthals favoured limb bones with regular diaphysis, which are the shaft portions of long bones. This preference implies a selection of bones with uniform and predictable shapes, which may have been more suitable for the tool's functionality.
c) *Profile:* The selected bones exhibit a 'rectilinear' profile, meaning they have straight or linear features. This preference for bones with such profiles suggests that Neanderthals sought bones that were structurally suitable for specific tool-making techniques, such as shaping or modification into functional implements.

Overall, the deliberate selection of large bones with regular diaphysis and a rectilinear profile indicates a degree of strategic decision-making by Neanderthals in choosing raw materials for tool production, potentially reflecting their understanding of bone properties and suitability for manufacturing tools for various purposes. Therefore, the dimensions of these tools vary, with demonstrated variability in both length and width that does not adhere to strict or consistent measurements. These characteristics are consistent with the assemblage of unmodified intermediate tools found in Abri Castanet, the Grotte des Hyènes, and Gatzarria in early Aurignacian levels, as described by Tartar (2012). It therefore seems that the unmodified intermediate tool is to be related to the *Pièces esquillées* (d'Errico *et al.* 2012b: figure 9) as proposed from the Sibudu Cave MSA (South Africa). Related to the present assemblage of study, the negative removals, although they are not necessarily found on both the cortical and medullary surfaces, could therefore suggest that the pieces in the first hypothesis were used as '*Pièces esquillées*'. Furthermore, Baumann *et al.* (2023) suggests that the absence of a striking surface does not necessarily indicate that a hammer has not been used. Therefore, the interpretation that the grotta de Nadale pieces may resemble wedge- or chisel-type tools described by Holgueras (2012) is notional. Furthermore, the suggestion that these pieces might have been used in a '*Pièces esquillées'* form remains a hypothesis that requires substantiation. To assess this hypothesis, it is essential to conduct a comparative analysis with an experimental collection of dwarfed tools employed for various tasks. Such experimental investigations would provide crucial insights into the validity of this comparison and aid in interpreting the archaeological findings more accurately. This underscores the necessity of empirical research in archaeology to substantiate or challenge hypotheses regarding suspected bone tools.

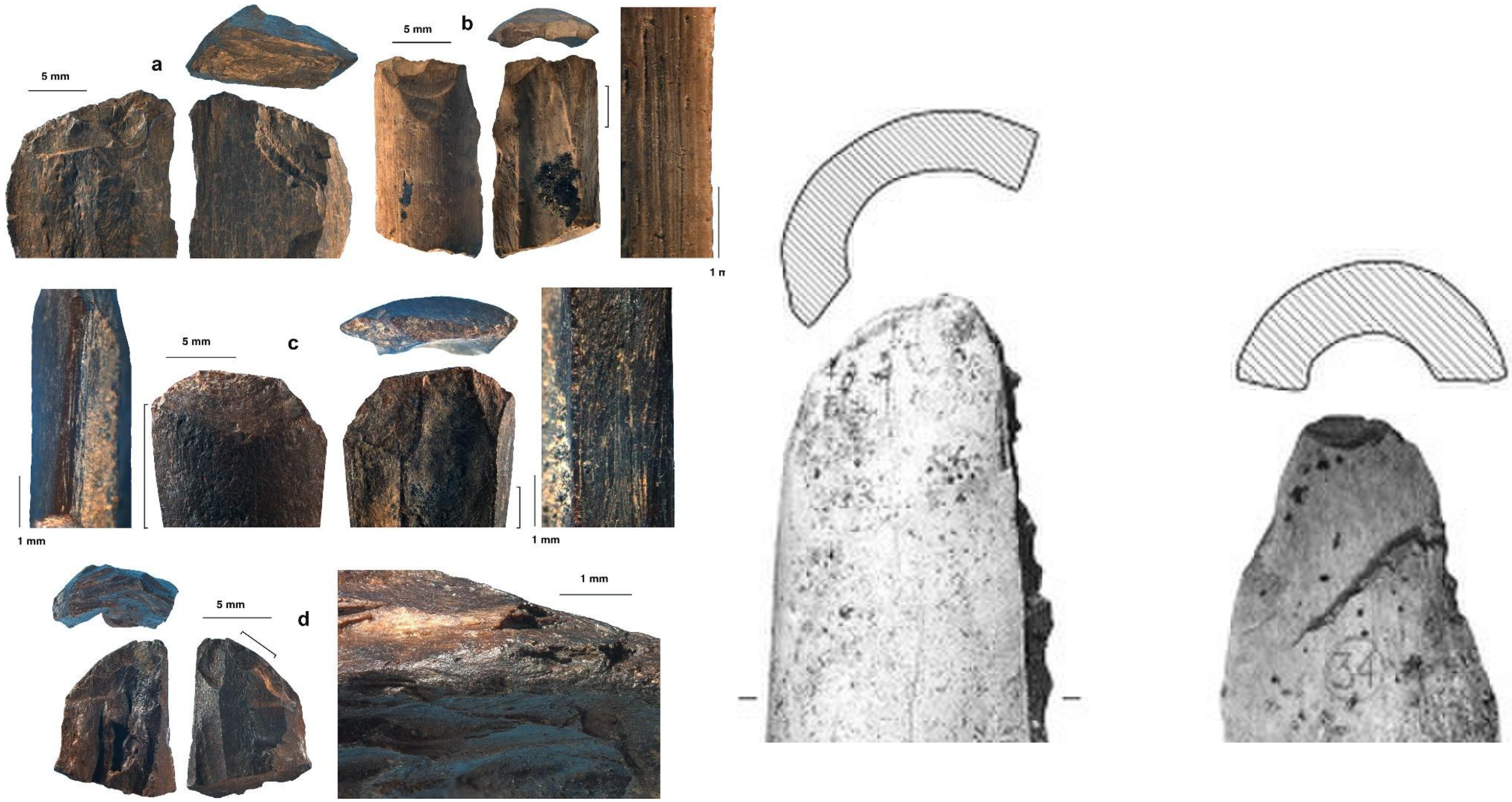


Figure 65: (Left) ‘*Pièces esquillées’* from Sibudu cave, South Africa. After (d’Errico *et al.* 2012b). (Right) Examples of unworked intermediate bone tools from Early Aurignacian assemblages after (Tartar 2012b)

Nevertheless, alternative explanations for the presence of negative removals at the ends, are also conceivable. It is plausible that certain instances of bone fracturing aimed at extracting marrow resulted in 'failed attempts,' whereby repeated strikes with a tool on the bone caused the presence of negative removals (Tartar, pers. comm). To investigate this hypothesis, experimental observation of fractured material, especially at impact points, would be essential to document and measure the potential formation of negative removals.

It is well established that how natural processes, rather than human actions, can create negative removals at the extremities of bones. These processes include instances such as falling boulders or fractures occurring in an animal's skeleton followed by its demise. Lyman (1984) suggests that fractures resulting from abrupt falls or animal projections can occasionally generate negative removals at the extremities of a bone. However, the specimens presented by Lyman exhibit only one negative at their extremity, whereas bones from grotta de Nadale are witnessing up to 5 (N°891, CN 3482) to 6 (CN3874) negative removals per extremity. Nonetheless, certain pieces (CN 2452, N°565, N°406, N°512; refer to Table 5 in Chapter 6 for more details) exhibit only one removal negative, often associated with crushing, blunting, or chipping, as detailed by Tartar (2012). However, there remains a limited understanding of the negative removals forming following fractures in an animal's skeleton. It is proposed that a comprehensive study aimed at elucidating this phenomenon, conducted at slaughter sites where hunted animals have fallen into voids, could shed light on the frequency of such negative removals.

The impact of falling boulders on bones can result in fractures that may exhibit features resembling percussion notches, often accompanied by a counter-bulb (Fisher, 1995: 45). However, these characteristics are markedly different from the negative removals observed in the analysed pieces under hypothesis 1.

Therefore, the group of pieces described in hypothesis 1 proposed here, are compatible with the definitions of 'unmodified intermediate tools', *'pièces esquillées'*, or 'beveled tools' based on the following characteristics:

a) Negative removals, or chips of the proximal end and striations aligned along the tool's main axis,
b) Glossing, compactness, or blunting observed at the distal end.

These use-wear traces are reported to be prevalent in the bone assemblage from grotta de Nadale.

Hypothesis 2: Negative removals parallel to the long axis of the bone (i.e., Retouched tools)

The 62 pieces identified under hypothesis 2, characterised by continuous edge negative removals, may suggest tools shaped through percussion activities. These pieces could be comparable to those described in following published literature (Rosell *et al.* 2011: fig. 2; Romandini *et al.* 2015: fig. 3,4; Kozlikin *et al.* 2020b: fig. 2,7; Baumann *et al.* 2020: fig. 8, 2023: fig. 10.11,12) (also see Chapter 3). The negative removals observed could therefore represent manufacturing marks. However, the pieces within this group exhibit notable variation unlike the negative removals observed on pieces from hypothesis 1 (refer to table 7,8 in Chapter 6 for further details and morphometric characteristics of each specimen).

The recognition of intentional bone retouching is typically considered after excluding other potential causes for removals (Vincent 1993). Greater confidence in this diagnosis is achieved through the archaeological context (Inizan *et al.* 1995). At grotta de Nadale, the absence of carnivore consumption traces (such as chewing, grooves, pits, punctures, and digestion blunts; (Sutcliffe 1973b; Haynes 1983; Campmas & Beauval 2008; Fourvel 2012) are rare (Jéquier *et al.* 2015; Martellotta *et al.* 2021; Livraghi *et al.* 2021; Vidal-Matutano *et al.* 2022), therefor eliminates the primary source of confusion regarding the origin of the negative removals and notches. The likelihood that the bone blanks were modified by humans for technical purposes is reinforced by their function as tools, primarily as retouchers (Jéquier *et al.* 2018; Martellotta *et al.* 2021). Among the technical causes, bone fracturing due to percussion during butchery processes can also result in removals (on the medullary or cortical side). In such cases, these removals are associated with the adjacent fracture and sometimes show traces of the anvil's counter-strike on the opposite face, all stemming from a single event—typically a forceful blow delivered perpendicular to the bone (Capaldo & Blumenschine 1994; Pickering & Egeland 2006).

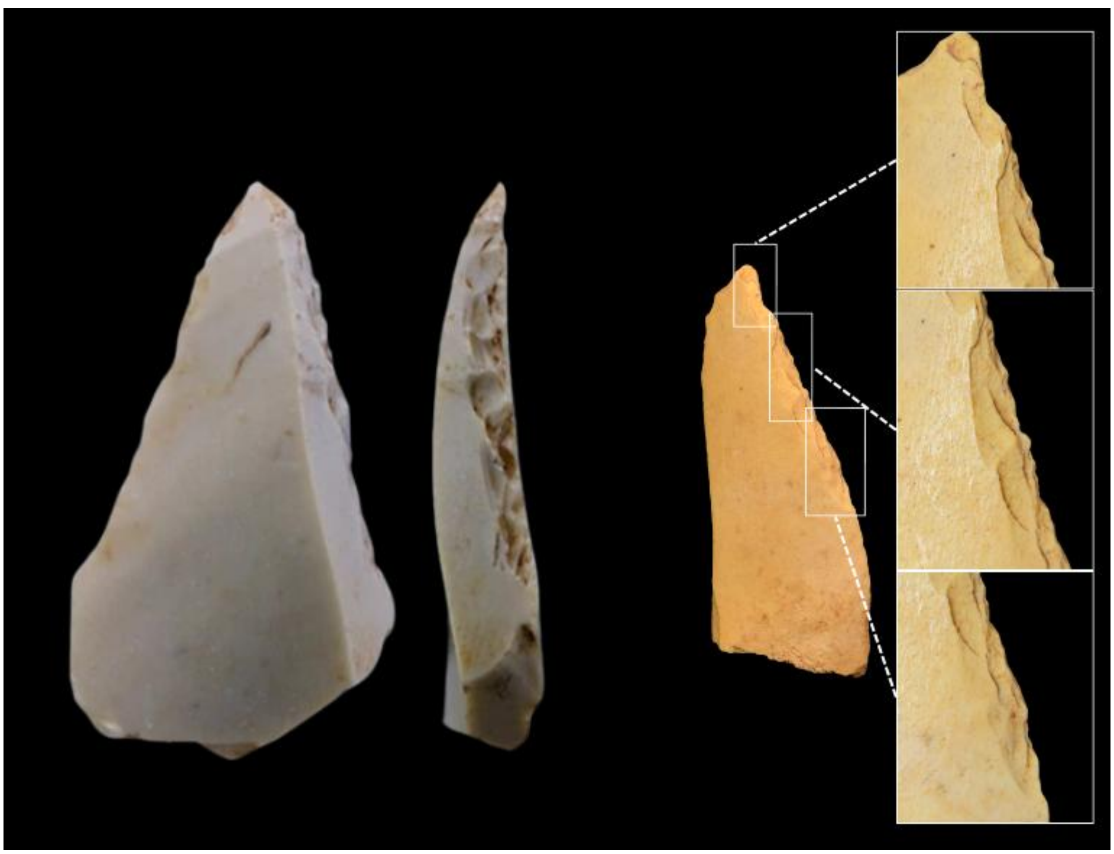
While literature on intentional bone knapping is limited, certain positive indicators can still aid in identification. Knowledge from lithic knapping can offer insights that are partly applicable to bone, given its behaviour resembling conchoidal fracture materials. Bone, however, being fibrous, exhibits mechanical properties that vary with stress direction, resulting in a more complex response to knapping compared to flint, owing to its anisotropic structure. Nonetheless, consistent patterns and characteristics can be observed, supporting similar analytical approaches. The organisation of removals serves as the primary criterion for identifying intentional knapping (Lyman 1984; Vincent 1989; Inizan *et al.* 1995).

Based on lithic knapping morphologies, several categories (non-exhaustive) can be identified or classified[59].

[59] In this context, "non-exhaustive" indicates that the list of categories is not intended to cover every possible type or variation of lithic knapping morphologies but rather presents a selection or representative examples. Additional

Table 76: Categories (non-exhaustive) based on morphologies observed

Category	Specimens
Retouched points	CN 3304, N°1133, CN 1074, N°891, CN 3588, CN 2352, N°1155, CN 3586, N°365, CN 3545
Flakes with marginal retouch	CN 3488, N°161, CN 468, N°366, N°217, CN 4801, CN 3177, CN 903, CN 3550, CN 3172, CN 2330, CN 1075, N°23, N°2, CN 3489
Simple lateral retouch	N°750, N° 191, N°512, N° 251, CN 4718, CN 4059, CN 4135, CN 3618, CN 2371
Denticulated (scrapers)	CN 3577, CN 4162, CN 4815, CN 5026, CN 3496, CN 4778, CN 4048, CN 4848
Marginal end scrapers	CN 4071, N°251, N°198, CN 4240, CN 3126, CN 3551, CN 4359
Notches	CN 4238-1, CN 2472, N°406, N°1175, CN 99



categories beyond those identified may exist, but the list provided offers a meaningful framework for classification based on available observations and knowledge.

Figure 66: (Left) Retouched lithic tool (adopted from Delpiano *et al,* 2022) and (Right) bone tool (N° 2) from grotta de Nadale, showcasing identical morphological stepped and scaled retouching. Not on the scale.

7.4 Quina- Mousterian lithic complexes at grotta de Nadale

Grotta de Nadale layer 7 is the first documented example of Quina Mousterian on the Berici Hills, dated to MIS 4. It is characterised by a high retouching rate of flakes, wide platforms, orthogonal secant surfaces, asymmetrical triangular section, and cortical backs. Grotta de Nadale is different from the 'classic' Quina complexes of South-Western France in that it uses surface-oriented reduction systems and diverse core-knapping techniques, and produces a wide set of diverse objectives, going beyond the classical Quina toolset. Some features of the de Nadale assemblage concur to identify it as atypical Quina Mousterian. Differences and local adaptations could have characterised the emergence and spread of Quina concept during the last glacial cycle (Delpiano *et al.* 2022).

At de Nadale, core reduction procedures share similarities with the Quina knapping method (Bourguignon 1996, 1997), such as construction on two or more adjacent surfaces, one of which is strongly inclined. One surface is peripherally and deeply exploited while the other surface is rarely exploited on the entire periphery. The ramification cycle is also present, with long-lived blanks being considered both cores and tools. Multidirectional cores pivot on the frequent displacement of the striking platform, and intentional fractures create new striking platforms (Delpiano *et al.* 2022).

In the Quina assemblages, the focus is on producing thick and short flakes, which is also seen in non-Quina systems like Clactonian/SSDA and Tares débitage, as well as discoid technology (Turq 1992; Forestier 1993; Bourguignon 1996, 1997, 2001; Geneste & Plisson 1996; Hiscock *et al.* 2009). However, de Nadale also produced a wider range of blanks, including thin flakes and bladelets. Different stages of production and knapping techniques contributed to this diversity. The reduction and thinning of large flakes and tool cores played a role in obtaining a variety of blanks. Cores on flakes were present but comparably few, and most of them were not retouched. The use of blanks as tools and cores, alternating and replacing modalities, was common at de Nadale. Quina and demi-Quina scrapers were particularly versatile, serving as both tools and cores. Other reduction systems, such as Levallois and Discoid, were also present, sometimes coexisting with the Quina method. The Levallois system, although less common in western European Quina assemblages, was more prevalent in the Eastern Charentian. While there may be some intrusive features of Levallois sequences at de Nadale, it is clear that the site exhibits a diverse range of reduction systems.

The objectives of the Quina technological systems were focused on the production of retouched tools, particularly scrapers. The majority of the artefacts that underwent further working were those with a high retouching potential. Less than half of the artefacts in the entire reduction sequence were retouched, but when excluding certain flakes and thin pieces, the retouch ratio increased to about 2/3 of the available blanks. The Quina and demi-Quina scrapers were the most common types of tools, with a preference for long-life curated tools that underwent multiple stages of retouch and resharpening. The functionality of these scrapers varied, with different purposes identified, including heavy-duty tasks such as butchering, hide working, and processing of materials like wood and vegetal matter. The Quina retouch allowed for the adjustment of the edge angle, bevel, and shape, modulating the effectiveness of the scrapers for different functions. The Quina and demi-Quina scrapers also served as a matrix for producing flakes with different functionality. Overall, the Quina technological systems demonstrated a dualism between high potential and low potential products, with a focus on maximising productive and functional efficiency.

The Quina assemblages in south-western France are characterised by high rates of retouched tools and the presence of the eponymous scraper. These assemblages are associated with high mobility and organised subsistence strategies, with reindeer being the preferred prey (Mellars 1965; Rolland 1981; Delagnes & Rendu 2011b; Rios-Garaizar & Garcia-Moreno 2015). Local lithic resources were primarily used, but non-local materials were utilised during periods of climate turbulency (Jaubert *et al.* 2001; Turq *et al.* 2017). The grotta de Nadale in Italy was occupied during the cold season, with limited periods of occupation during the good season (Livraghi *et al.* 2022). The site was characterised by the selective introduction of rich body parts of hunted game and the fragmentation of bones (Terlato *et al.* 2019b; Livraghi *et al.* 2021). The lithic assemblage at grotta de Nadale showed extreme reduction of cores and high rates of blanks transformed into tools, indicating intense territorial mobility (Delpiano *et al.* 2022).

7.5 Ecological implications

Why so ubiquitous?

Considering the absence of suitable lithic raw materials near the site, chert was procured from areas ranging between the eastern Berici hills, the western Euganean hills, and the central western Lessini (located 20-80 km away from de Nadale) (Livraghi *et al.* 2021). Moreover, given the extensive exploitation of lithic cores discovered at de Nadale (Delpiano *et al.* 2022; Delpiano, pers. comm), bones emerged as the subsequent raw material option and were knapped in a manner akin to stone to manufacture tools. This likely occurred during a period when stone resources were becoming scarce, necessitating the use of bones to meet essential technological requirements. These tools are thus the product of a neanderthals response to local needs as well as proof that the technological properties and whereabouts of bones, are known and familiar to them.

Therefore, these tools exemplify how Neanderthals adapted to local conditions and challenges by utilising bones as a technological resource. The exploitation of bones implies that Neanderthals possessed knowledge of the technological properties and characteristics of bones, indicating their proficiency in working with diverse raw materials present in their environment. This adaptation underscores the resilience, resourcefulness, and technological prowess of Neanderthals, demonstrating their capacity to innovate and manufacture tools using materials beyond conventional stone resources. It highlights the sophisticated knowledge and skills of Neanderthals in exploiting diverse resources to address their needs within varying environmental contexts.

In conclusion, the use of bones as a technological resource not only reflects the adaptability and innovation of Neanderthals but also highlights their sustainable approach to using available resources. By effectively repurposing bones, Neanderthals demonstrated a sophisticated understanding of their environment and an ability to maximise the utility of the materials at hand. This practice of using locally available resources underscores their resourcefulness and resilience, ensuring that nothing went to waste. On the other hand, their ability to manipulate various materials, including bones, for toolmaking demonstrates a complex understanding of their environment and a high degree of cognitive and cultural development. Such adaptability was crucial for their survival and success in a range of habitats, illustrating that Neanderthals were not just surviving but thriving in diverse and challenging environments. Their technological ingenuity, as evidenced by their use of bones, places them firmly within the lineage of intelligent and resourceful ancestors.

CONCLUSION

Our ancestors have been using bone for interacting with their surrounding environments for at least two million years (Brain & Shipman 1993b; d'Errico *et al.* 2001; Backwell & d'Errico 2001b, 2008; Stammers *et al.* 2018; Hanon *et al.* 2021). Researchers have been diligent in collectively analysing zooarchaeological and taphonomical contexts to arrive at plausible conclusions regarding pre-AMH bone tool manufacture and use.

As demonstrated in previous chapters, evaluating the role of bone tools within the technical systems of the Lower and Middle Palaeolithic periods remains challenging. Advances in methods for studying bone assemblages from the late twentieth century into the early twenty-first century have significantly influenced our understanding of these tools. The increased accessibility to advanced technical resources, particularly high-magnification microscopy, along with the expansion of taphonomy, which aims to identify all factors impacting a bone assemblage, has transformed our perception of these ancient tools. These developments have also challenged and revised theories that were widely accepted throughout the twentieth century.

In one aspect, there are numerous natural agents that produce pseudo-tools, and determining their impact requires thorough material analysis. This analysis typically involves creating experimental replicas (to replicate natural phenomena on bone material) and conducting trace studies. On the other hand, there are established tools, primarily made of bone, whose identification has been validated through an interdisciplinary approach. However, the manufacturing and use marks revealed are often subtle; indeed, it is likely that many tools have gone unrecognised within bone assemblages. This difficulty in assessing the proportion of bone tools persists in the Lower and Middle Palaeolithic periods. Furthermore, it cannot be discounted that discreet manufacturing processes persisted into the Upper Palaeolithic and similarly went unnoticed within the broader 'technological' context.

In the case of grotta de Nadale, as outlined earlier, present analysis was concerned describing intentions behind negative removals based on their location of the bone. Therefore, the study has formulated couple of hypotheses regarding the origin of the observed manufacture and use wear traces. While natural taphonomic agents could account for some of these marks, the possibility remains that certain marks are indeed indicative of manufacturing or use activities. Among the studied assemblage, the study has identified potential tools identified as '*Intermediate tools*', tools manufactured through percussion '*retouched edges'*.

However, while these interpretations are compelling, they require more rigorous traceological analysis. Due to the limitations posed by the available time and resources for this study, relying on macroscopic and microscopic descriptions, supported by an experimental phase, provides a solid foundation for the conclusions outlined in the chapter 6 and 7. Moreover, this material description and taphonomic study of Grotta de Nadale suggest the potential existence of a more diverse bone tool assemblage beyond retouchers.

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Grotta de Nadale stands as a singularly important Quina Mousterian site in northern Italy, characterised by its unique, single-layered stratigraphy. As Binford (1969) aptly noted, archaeologists should avoid making broad generalisations from a global perspective, as each archaeological assemblage is shaped by a constellation of factors—its specific chronology, environmental conditions, climatic oscillations and regional geology. This study intentionally refrains from placing the distinct bone tool assemblage from grotta de Nadale within a broader regional or chronological framework, hence reducing the risk of oversimplifying complex behaviours or overlooking the diversity among different Neanderthals in Europe. Instead, this dissertation's aim was achieved by introducing this unique assemblage for the first time, undertaking a meticulous taphonomic study firmly rooted in its archaeological context. By doing so, it preserves the integrity of the findings and invites further advanced analysis, ensuring that future research can build upon a solid foundation. The approach this present study has taken so far, ensured that future research can engage with the findings in a way that respects the uniqueness of the assemblage, potentially leading to more accurate, technologically advanced and contextual interpretations of Neanderthal behaviour and technology, unique to northern Italy.

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Supplementary Information related to this thesis can be found at:

https://unifeit-my.sharepoint.com/:f:/g/personal/k_theppamudiyanselag_edu_unife_it/Ek4ylSbX-vpPhHjur4udFxkBF0sg7xeEf5VNyJ8mah1UtQ?e=8vgYjl

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Appendix 1
TERMINOLOGY

Terminology	Description	Notes
Bone materials	Soft material used by ancient human to manufacture tools and other objects since Palaeolithic (Choyke & Bartosiewicz 2001; Luik *et al.* 2005; Gates St-Pierre & Walker 2007; Legrand-Pineau *et al.* 2010). Includes all the hard parts of the animal skeleton: not only bones, tooth, antlers, but also eggshells, mollusc shells and turtle shells as well (Elizabeth & Elizabeth 1999; Bartosiewicz 2008; O'Connor *et al.* 2015; Costamagno *et al.* 2019). Bone materials include only skeletal elements with bone tissue *i.e.,* bone and teeth (including ivory of Proboscideans) and antlers (Müller & Reiche 2011).	
Bone tool	An implement used to accomplish a task or modify or create an item (Backwell & d'Errico 2014) Any intentional transformation leading to production.' Shaping refers to 'the deliberate act of forming a medium, which includes the general configuration and arrangement of features (such as perforations and barbs) (Averbouh 2000; Goutas *et al.* 2018).	
Finishing of a bone material	The addition of elements that no longer alter the general shape of the blank (Provenzano 2004).	
Negative Removal	Which considered of a detachment surface more or less concave; it can present a series of scars[60], contiguous removals with sharp leading edges or, when arising from a conchoidal fracture, counter-bulb[61] and ripples.	
Fracture Face	It is constituted in entirely a fracture, by a line and two faces, after detachment, the fractured area has a single face.	
Groove (*le sillon*)	Corresponds to a deep hollow line, made up of a bottom, two surfaces and two edges.	
Striations (*les stries*)	Generally grouped in clusters, they have the appearance of fine striped, parallel, and integral with each other, separated by protruding edges. The striations are straight or circular depending on the direction of the movement applied. It is organised into more or less rough, flat, and smooth areas depending on the applied techniques.	
Finished Object	The final culmination of all technological operations and all the phases that have been implemented to get a 'ready-to-use object'; the blank is 'the intermediate element between the support and the finished object, the appearance of which depends on the progress of the shaping and finishing operations (Averbouh 2000).	
Waste blanks (or manufacturing waste)	Whose production, concomitant with an operation, is not sought'; a distinction is made between manufacturing waste, which can 'come from all the operations of the technical chain, but generally related to debitage, shaping and retouching' (Averbouh 2000).	
Polished	The sign of manufacture (polishing technique) or use, polish belongs to the group of striations, it takes the form of streaks of very narrow width, resulting 'from the presence of fine abrasive particles between the surfaces in contact' (Tartar 2003: 8, 2012b) – contact between the bone material and the tool in action (manufacture), or between the bone material and the worked material (use). Their 'curved course corresponds to the direction of movement, imprinted in the bone material or on the tool that works it (Giacobini & Patau-Mathis 2002: 22).	
Crushing	Stigma of use, in the case of surface crushed transverse to the axis of the bone fibres, the crushing takes the form, under the effect of repeated pressure, of a surface faceting, the manipulation or the violence of the pressure leading to a separation of the bone fibres which then withdraw into themselves (Tartar 2009: 163).	
Blunting	Stigma of use which corresponds to a deformation of the morphology of the end of the tool in bone material, caused by its wear at the contact with a worked material (Tartar 2003, 2009, 2012b).	

[60] Scarring (Inizan *et al.* 1995: 146)

[61] Counter-bulb: recessed (or negative) impression of a bulb*, i.e.,* more of less marked conchoidal fracture which developed on the underside of the flake from the point of percussion or pressure (Inizan *et al.* 1995: 136).

Luster (gloss)	Stigma of use, results from a change in the appearance of surface that becomes shiny as a result of exchange particles of matter between the tool (i.e., the bone material) and the worked material (Tartar 2003: 8).	
Scarring or Chipping	An alteration of an edge that takes the form of very small negative removals which either can be a result from use or post depositional event (Vincent 1993).	
Direct percussion	By the explosion of the material by means of a shock sharp'; notch obtained in diffuse thrown percussion, 'shatters' and divides the block in two or several fragments. The hammer used is often heavy, dense and has a surface active more or less convex (e.g., pebble).	Defining Feature: Fracture Surface
Indirect percussion	By exploring the material by means of a percussion launched with intermediate, divides the block in its longitudinal axis. It is realised using an intermediate tool (acting as a corner with a beveled active part) and a variable-weight striker (pebble or striker with a handle).	
Pressure flaking	Aims at the explore of the material by a continuous and pressing impact applied by forcing, in order to detach a fragment from the worked block, is usually done by bare hand although it can sometimes be associated with a wedging device (Averbouh 2000).	
Knapping techniques	The percussion launched in order to detach shards from the block of raw material 1. Removals by direct percussion 2. Removals by indirect percussion *3.* Removals by direct diffuse percussion (*l'enlèvement en percussion lancée diffuse directe) (Averbouh 2000).*	Defining Feature: Negative Removal
Wear techniques	Applying pressure to the material being worked, with the goal of removing particles.	
Surface wear techniques	Abrading or polishing the surface of the material through scratching or rubbing, typically covering a significant area.	
Scraping	Proceeding to eliminate fine shavings by scraping aims to regularise the surface or reduce the thickness of a part. Achieved by repetitively moving the tool unidirectionally in the longitudinal axis of the bone fibres, using an active part that has a deliberately sharp edge and extends to a flat range below it.	Defining Feature: Presence of striations.
Abrasion	Abrasion of a surface through friction, leading to the removal of particles of matter and regularising or reducing thickness. Accomplished by rotating or moving back and forth while applying variable pressure depending on the level of desired abrasion using a grinding wheel.	
Perforation	Involves piercing the material with a rotating movement, gradually cutting deeper into it. This can be achieved via a hand-held lithic or metal drill or a bow drill (Giacobini & Patou-Mathis 2002: 22)[62].	
Bone Industry *(l'industrie en matières osseuses)*	Covers all products and by-products involved in the technical chain of bone material transformation, including waste and equipment related to bone materials. A bone industry involves repetitive technical gestures that lead to the production of parts with virtually identical shapes (Patou-Mathis 1999: 50).	
Bone material equipment *(l'équipement en matières osseuses)*	Includes both unaltered objects designed with dimensions suitable for their intended use and all finished objects made through transformation of bone materials	
chaînes opératoires	Life cycle of an object, particularly used to define lithic tools	
Bone tool	Encompasses all objects made from bone, including both finished (transformed) and raw, unshaped materials. The definition of a 'tool' itself is imprecise, but these objects are presumed to have been used for domestic purposes (Averbouh 2000).	

[62] The edges of the perforation exhibit visible traces. '*The bone displays fine concentric striations caused by the instrument's contact, interrupted twice at points where the instrument ceased its 'scraping' motion at the end of its last half-rotation movement. If the suspension link remains in contact for an extended period, it can erase the perforation-produced striations via a 'polishing' action.*'

<table>
<tr><td>Bone objects</td><td colspan="2">Designed for mobility, decoration, or musical purposes fall outside the category of bone tools (Averbouh 2000).</td></tr>
<tr><td>Formal tools</td><td>Created through a potentially complicated process involving the transformation of bone material</td><td rowspan="2">Johnson et al (2000)[63]</td></tr>
<tr><td>Informal tools</td><td>Objects that have undergone minimal transformation or have not been transformed at all, making it difficult to distinguish them from unmodified materials without a meticulous inspection.</td></tr>
<tr><td>Unshaped tools</td><td colspan="2">These tools consist of whole bones or bone fragments used without any prior shaping. They are identified by the presence of use-wear marks on their surface. Although they may have undergone minor modifications, such as periosteum scraping, their original morphology remains unchanged, and the bone tissue is not significantly affected. The recognition of these objects as tools is based on their use, allowing them to be retrospectively classified as tools (Vincent 1993)</td></tr>
<tr><td>Tools shaped by percussion</td><td colspan="2">Includes tools that are shaped using knapping techniques, often involving multiple removals that impact one or more edges of the tool, similar to lithic retouching. This process can be referred to as shaping by percussion.</td></tr>
<tr><td>Tools shaped by wear techniques</td><td colspan="2">Tools that have undergone wear techniques either on the surface or in depth or have been shaped accordingly through wear processes.</td></tr>
<tr><td>Active part of a tool</td><td colspan="2">Involves three components: the distal part (recognised as the functional end), the proximal part (typically located opposite the distal part and nearest to the body or hand, often serving as a gripping or pressing zone, according to Averbouh 2000: 177), and the mesial part, the intermediate position between the distal and proximal parts.</td></tr>
<tr><td>Medullar Surface</td><td colspan="2">The internal surface of the bone</td></tr>
<tr><td>Cortical Surface</td><td colspan="2">The external surface of the bone</td></tr>
<tr><td>Retoucher</td><td colspan="2">Tool/ tool support

Manufacture: more often fragmented bone (distal end of humerus of Bovinae and Equidae, fragments of ribs and diaphysis of long bones of large mammals) (Patou-Mathis 2002).

Raw material acquisition: Could have been knapped to a desired size (e.g., Valensi 1996) or collected from food waste (e.g., Armand & Delagnes 1998).

Characteristics: an external surface, commonly referred to as the cortex, marked by ‘impressions that correspond to crushing, tearing, and striations’ (Campmas, 2012: 196).

According to experimental data, the retoucher is employed to retouch (via percussion) lithic material (Averbouh 2000: 198; see especially Tartar 2002, as well as Vincent 1993, Armand & Delagnes 1998, Mallye et al. 2012).</td></tr>
<tr><td>compressor[64]</td><td colspan="2">An alternative term for retoucher (as described by Martin 1906),</td></tr>
<tr><td>An intermediate tool[65]</td><td colspan="2">An object used in processing activities, interposed between the material being worked (on which the active part of the tool is applied) and a percussor (which strikes the proximal part of the tool) (Tartar 2009, 2012).</td></tr>
</table>

[63] To identify a bone fragment as a tool, evidence of anthropogenic (human-made) fractures and recent use traces are required. ‘*Utilisation flaking, polishing, striations, and edge-rounding are considered diagnostic characters. They are defined based on their limited distribution on an element and their differentiation from damage caused by carnivores or other natural agencies’* (Johnson *et al* 2000: 468).

[64] Description of the use of the ‘compressor’ by the Neanderthals of La Quina (Charente), according to Martin (1923: 55): *‘It is clear that the Neanderthal possessed the knowledge that pressure on the edge of the cutting edge made from [flint], compressing the base on a hard surface, would result in the detachment of closely-spaced flakes, thus allowing the recovery of a fresh cutting edge.’* This study utilised compressors, with bone being the most commonly used material found, though a few were made of hard materials like the cortex of a nucleus. It was necessary for the compressor to be active and the flint to be passive.

[65] As defined by Tartar, the unworked intermediate tool is made of bone, usually a diaphysis fragment collected from food remains, chosen for its morphometric characteristics (usually fragments of long bones from large mammals - long, wide, and thick enough to withstand impact). *‘For the most part, these tools have required minimal technical investment. The majority of them did not require any manufacturing’* (Tartar 2009: 165). The distal part displays a roughly convex contour and a ‘naturally beveled’ profile.

	It is possible to identify a bone fragment that has been used as an intermediate tool through its use wear traces, which are characterised by bluntness, crushing, and the presence of negative removals - also known as 'negative flakes (*négatifs d'éclats*)' by the author: I. Blunting is limited to the distal end of the tool and is observable both on the edge and its surrounding area II. Crushing, on the other hand, can be observed on both the proximal and distal ends III. Negative removals can also appear on both ends; they 'result from the detachment of splinters (or chips) caused by a pressure with the striker or the material being worked. It is possible to distinguish between two sizes of splinters. The smaller negatives (or chips) have little impact on the morphology of the extremities, unlike the negative removals, which sometimes modify them significantly' (Tartar 2012: 167).
Scraper	A bone fragment of any shape, which displays a series of continuous removals on one or more edges, on the cortical and/or medullary surface.
End scraper	A bony fragment, with one end – often shaped convexly and forming the tool's distal part – featuring a series of removals resembling a 'scraper edge' (see d'Errico and Henshilwood, 2007).
Biface	An object made of bone shaped on both sides through total or invasive percussion retouch' (Averbouh 2000: 190). Most bifaces have been manufactured on very large bone fragments (usually remains of Proboscideans) (Vincent 1993).
lissoirs	A 'mainly flat and elongated bone object, featuring a distal end of varied shapes (ogival, convex or triangular), possessing a smooth front (or active front) whose orientation in relation to the longitudinal axis of the part discerns it as a corner or an axis. This section of use, or the actively used portion, is frequently identified by its sheen, facets, and streaks' (Averbouh 2000: 194). Predominantly created from a particular type of bone blank - the half-rib (Tartar 2009).
Beveled object	A simple bone or antler tool, either whole or cut, with a distal section that has been crafted into a unifacial or bifacial bevel. '*Beveled objects were identified in early deposits and named after their function, in comparison to existing ethnographic or modern tools. Initially, they were mostly referred to as wedges or chisels based on their supposed functions, but these functional hypotheses have been disregarded in favour of a more detailed morphological analysis. As a result, the object is now commonly referred to as a beveled object, which is a more neutral name* (Provenzano 1998: 5) [66].

As for the proximal section, the strikes of the percussion tool having gradually compressed and flattened the bone fibres, it is 'flat and perpendicular to the axis of elongation of the pieces.

[66] See also Binford (1978).

A p p e n d i x   2

Taphonomical Framework

Responsible Agent		Marks Observable	Characteristics
Animals	Carnivores (Binford 1981)	Bone fracturing and digestion	Tooth notches refer to 'notches found at the edge of the diaphysis of the bone (resulting from scraping off the bone tissue), which correspond to the fracturing of the bone for extracting the marrow' (Costamagno 1999). Confusion: Traces from direct percussion or as a result of manufacturing processes; retouching (Binford 1981[67]; Villa & Bartram 1996) Distinguished by: Percussion activities- a certain angulation of the striking plane in order to release the retouch and carnivore activities- show an anarchic distribution and extent, irregular arrangement, never overlap (Vincent, 1993: 85-86). Tooth notches are normally associated with evident changes caused by carnivores, which eliminates ambiguity about their origin (Fisher 1995). The negative removals were more numerous, wider, and formed a sharper angle with the cortical face of the bone than the tooth notches (Capaldo & Blumenschine 1994).
		Gastric Juice	Surface dissolution, scaling, polishing, perforation (d'Errico & Villa, 1997) Confusion: The polish may seem to show signs of manufacturing or use. Distinguished by: Upon closer examination, absence of striations and traces of dissolution on the surface (Fisher, 1995).
	Rodents	Gnawing marks	Two parallel grooves found in a linear series. The length and depth of these grooves depend on the size of the rodent[68]. These marks closely resemble those left by wear techniques but are distinguishable due to their symmetrical pairs of incisor marks.
	Herbivores	Bone and antler chewing (Sutcliffe 1973)	Misinterpreted as human-manufactured items; polished and/or fractured specimens with polished and/or fractured ends (showing 'negative removals' or 'fracture surfaces') (Oslen 1989) Solution: microscopy and reference comparisons are necessary to determine the origin of the marks.
	Proboscidean tusks	Ivory Cuts	Confusion: Formed wear marks like polishing, abrasion, and striations, they might get confused for use wear

[67] '*For someone accustomed to work in lithics, an encounter with a chipped-back bone produced by animals will almost always convince the observer that he is seeing the work of man'* Binford (1981, 54).

[68] '*a consistent sequence of small, delicate cuts generally running perpendicular to the bone's long axis'* (Giacobini and Patou-Mathis, 2002: 21).

			tracesor traces left by surface-wear techniques (Villa and d'Errico, 2001). Solution: Microscopic examination along with comparative references (Villa and d'Errico, 2001).
Trampling (Behrensmeyer *et al*. 1986)	Humans/ Animals	Striations	Confusion: Cut marks or signs of manufacturing or use; Blunting (Brain 1967) Distinguished by: Striations may lack orientation Solution: High magnification, and the use of comparative reference collection.
	Cave bears	Dry Loading (*Le charriage à sec)* (Koby 1930)	Abrasion and polishing (Giacobini and Patou-Mathis 2002: 22). Bones modified in this way have been mistaken for tools, *i.e.,* smooth-ended tools.
Non-biological Agents	Weathering		In the case of long bones, fractures can create rods that may be mistaken for the result of debitage (Vincent 1993).
	Sedimentary, wind and water abrasion	blunt and polished edge	Fluvial abrasion typically results in a uniform polish on the entire bone surface, whereas use-wear polish is confined to specific areas (Shipman & Jennie 1983; Lyman 2014). Wind abrasion: Only affects surfaces exposed to the wind but need a significant amount of time. (Shipman & Rose 1988, cited in Lyman, 1994).
	Rock Outcrops	Manufacture traces	They may resemble human-induced modifications, such as cut marks, scrape marks, hammerstone-induced conchoidal flake scars, and chop marks (Fisher 1995: 45). Also, in large mammal bones (i.e., mammoths) (Karr 2015).
Man		Percussion impact notches (Binford 1981), Impact notches (Blumenschine 1988), and Percussion notches (Capaldo & Blumenschine 1994).	Percussion notches typically form on the medullary surface of bones (Capaldo & Blumenschine 1994). Negative removals are wider than they are long Fisher 1995:21) Solution: It is a matter of identifying the frequency of removals, their location (cortical or medullary), their extent (smaller negatives like wider-than-long percussion notches that do not reach the bone fragment's edge, or invasive removals), their distribution pattern (adjacent or isolated negatives), and the occurrence of series of negatives (overlaps), to grasp the intention behind the negative removals (Vettese *et al* 2020).

Timeline of the Research

	Month / Task	2023									October 2023– February 2024	2024						
		January	February	March	April	May	June	July	August	September		March	April	May	June	July	August	September
1	Initiation Discussions with the Supervisor	■																
2	Preliminary Material Analysis		■	■	■	■	■											
3	Literature Survey		■	■	■	■	■											
4	Methodology Construction						■											
5	Analysis/ Documentation							■	■	■		■	■					
6	Experimental Phase of the Study								■									
7	Analysis							■	■	■		■	■	■	■			
8	Writing the thesis						■	■	■	■		■	■	■	■	■		
9	Proofreading, revisions												■	■	■	■	■	
10	Thesis Submission																	■