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A PLACE OF THE ACHEULEAN BIFACES DURING THE LOWER TO MIDDLE PALEOLITHIC TRANSITION; A CASE OF GUADO SAN NICOLA, CENTRAL ITALY

Master's Dissertation

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by

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Master's/Licentiate Degree

in

Prehistoric Archaeology and Rock Art

Instituto Politécnico de Tomar

DECLARATION

I declare that this dissertation is the result of personal and independent research, its content is original, and all sources consulted are duly recorded in my text, in the notes and the bibliography.

I further declare that any other institution has not accepted this dissertation, nor is it being submitted for any degree or guarantee of a degree beyond the one it concerns.

The candidate

F.kisena

I declare that, as far as I was able to verify, this dissertation is the result of a personal and independent investigation of the application.

The advisor

I declare that, as far as I was able to verify, this dissertation is the result of a personal and independent investigation of the application.

The co-advisor

DEDICATION

I dedicate this work to myself as a sign and a reminder of persevering in this wonderful career journey that is about to start.

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ABSTRACT

The Acheulean Palaeolithic period is a long-lasted cultural period in human prehistory and history. It persevered for almost 1.5 Ma, demonstrating a crucial timing of human evolution and development in prehistory. Unequivocally, it was the period of diversification of aspects of humanity, i.e., geography, technology, socio-economic, etcetera, and morphological configuration of major prehistoric human groups, i.e., *Homo erectus*, Anatomically Modern Humans and *Homo neanderthalensis*. The Acheulean has appeared all over the Old World and was distinctively characterized technologically, chronologically, and in occurrence. European Acheulean mainly appeared during the late period, characterized by assemblages with bifaces and, on the other hand, small to medium-sized flakes without bifaces.

Most assemblages with the Late Acheulean bifaces in Europe have been tentatively characterized to have standard features, and some have cooccurred with the advanced succeeding lithic industry. The Guado San Nicola archaeological site in South-central Italy is among the well-known palaeolithic sites in Europe, presenting lithic technological shifts from Lower Palaeolithic to Middle Palaeolithic. This work is dedicated to investigating the association of Acheulean bifaces during transitional periods in terms of functional, technology and site formation factors on an assemblage scale.

Through use-wear analysis methodologies, Low and High-Powered approaches, this work has managed to identify a significant hominid activity associated with bifaces at Guado San Nicola to be carcasses processing. Nonetheless, given the small sample size analyzed for this research, the results are immensely supported by comparative analysis from related studies and previously reported analysis results of the same assemblage, such as zooarchaeological, paleontological, geological and archaeological results. Technologically and morphologically, the bifaces assemblage at Guado San Nicola presents major common traits of such aspects in the European Late Acheulean bifaces.

Keywords

- Acheulean
- Bifaces
- Guado San Nicola
- Use-wear analysis
- The Lower to Middle Palaeolithic transition

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LIST OF ABBREVIATIONS

AFM	Atomic Force Microscopy
Fig	Figure
GSN	Guado San Nicola
Kya	Kilo (thousand) years ago
LSCM	Laser Scanning Confocal Microscopy
Ma	Mega-annum (Million years)
Mya	Million years ago
S. U	Stratigraphic Unit
S.S.D.A	*système par surface de débitage alternée*
SEM	Scanning electron microscopy

INTRODUCTION

Prehistoric population has been proven to cover most part of Old world, since the previous century there have been many discoveries of evidence to define and reconstruct prehistoric human culture and hence distribution and environmental adaptations. The remnants of lithic artifacts are the most prominent evidence for archaeologists to define prehistoric culture, human behaviour and evolution. Palaeolithic culture represents a more complex capabilities of hominids interaction, environmental adaptation, and cognitive evolution. This work intent to contribute on the association of Acheulean lithic industry with specific techno-morphological category (bifaces) during transitional period between the Lower to Middle Palaeolithic period in Europe. The term "bifaces" herein refer to a specific tools type evolved during the Lower Palaeolithic as described in (Leakey, 1971). Although not all the tools were bifacially made, the term had evolved later when other researchers prefer to describe the tools category as Large Cutting Tools (LCTs) e.g., (de la Torre, 2016; Kuman, 2014). Still the term presented a specific surmised activity 'cutting', the term Heavy Duty Tools (HDTs) was then preferred (Lambert-Lauriston, 2015). Other researchers have interpreted and justified the tools as symbolic social representation for sexual selection (Kohn & Mithen, 1999). In this work the term bifaces will be exclusively adopted to represent functional terms such as picks and handaxes. With a case of Guado San Nicola archaeological site in central Italy, this study has the following intended goals.

i. To identify major technical features of bifacial tools production at Guado San Nicola archaeological site during the Lower to Middle Paleolithic transition;
ii. To assess the main functions of the bifaces at Guado San Nicola archaeological site during the Lower to Middle Paleolithic transition; and
iii. To determine the site formation processes affected the Acheulean assemblage at Guado San Nicola archaeological site.

To attain these objectives this work employed several methodological attempts to sustain the reliability of final interpretation. Despite practical research approaches, the review from previous reported interpretations have contributed significantly on the achievement of set objectives. Major characterization and analysis of Guado San Nicola's assemblage has already comparatively performed and reported in several aspects such as, geological and chronological characterization (Pereira et al., 2016), paleontological, zooarchaeological and archaeological interpretations (Berruti, 2017; Berruti et al., 2020; Muttillo et al., 2014; Peretto et al., 2016). Comparative archaeological placement is also achieved especially by considering cultural, chronological and technological determination of lithic artifacts (Arnaud et al., 2017; M. H. Moncel et al., 2018; M. H. Moncel, Ashton, et al., 2020; Muttillo et al., 2021).

Research approaches in this work involves the fundamental lithic use-wear studies methodologies as previously emphasized for Low-powered approach (Tringham et al., 1974) and High-powered approach (Keeley, 1980). Use wear analysis on Guado San Nicola's lithic assemblage was previously performed only on Levallois and *façonnage* flakes (Berruti, 2017; Berruti et al., 2020). The study of bifacial Acheulean artifacts has not yet been performed hence this work is substantially intended to investigate the functional and post depositional modifications on bifacially made lithic artifacts at Guado San Nicola.

1. THE ACHEULEAN CONTEXT

1.1 Before the Acheulean

The earliest known lithic industries are Lomekwian and Oldowan, both attributed to the earliest technologies of lithic production dated to 3.3 Mya and 2.6 Mya, respectively. Currently, the oldest industry is Lomekwian, found in the site of Lomekwi 3 in West Turkana, Kenya. The industry is predominantly composed of massive cores (unifacially exploited) and flakes (Fig. 1.1), possibly associated with the australopithecine '*Kenyanthropus platyops*' (Harmand et al., 2015). Oldowan type industry dominated the lower Palaeolithic as early as 2.6 Mya - 1.6 Mya, and it spread all around the old world (Barsky & Cauche, 2009; Braun et al., 2019; Le Tensorer et al., 2015; Parés et al., 2006; Semaw et al., 2003; Stollhofen et al., 2021). Unlike the preceding lithic industry, the Oldowan represents more varied and advanced technological implications and comprehensive variation of lithic artifacts composition (Fig. 1.2) (Braun et al., 2019; Cueva-Temprana et al., 2022; de la Torre & Mora, 2018; Delagnes & Roche, 2005; Kuman et al., 2018; Leakey, 1971; Roche et al., 2018). Major tools defining the classic Oldowan comprises a variation of flakes (sometimes retouched), choppers, scrapers, discoidal and polyhedral cores, manuports, spheroids and sub spheroids (de la Torre & Mora, 2018; Leakey, 1971; Titton et al., 2020). The earliest occurrence documented from eastern Africa, North Africa, as well as South Africa, such as Ledi-Geraru, Gona and Hadar in Ethiopia, around 2.6 Mya (Braun et al., 2019; Campisano, 2012; Semaw, 2000), Ain Boucherit in Algeria, 2.4 Mya (Duval et al., 2021; Sahnouni et al., 2018), Western Turkana in Kenya, 2.34 Mya (Delagnes & Roche, 2005; Roche et al., 1999), in South Africa at Swartkrans and Sterkfontein around 2.2 Mya (Caruana & Stratford, 2019; Clark, 1994; Kuman, 2007; Kuman et al., 2018; Kuman & Clarke, 2000). However, the collection from Olduvai Gorge, recently dated to 2 Mya, has been considered a fundamental classic Oldowan (Diez-Martín et al., 2022; Gabel & Leakey, 1973; Mercader et al., 2021, 2022; Proffitt, 2018; Stollhofen et al., 2021). The site of Olduvai Gorge is vital from the standpoint of Archaeology because it records the cultural change from the occurrence, development, and disappearance of the Oldowan and the appearance of the Acheulean lithic technologies (de la Torre & Mora, 2018; Leakey, 1971; Uno et al., 2018). Therefore, it is considered exceptional to be the only site in the world filmed and well preserved Oldowan-Acheulean transition (de la Torre, 2016; de la Torre & Mora, 2018; Diez-Martín et al., 2022; Fujioka et al., 2022; Leakey, 1971). The earliest Oldowan industry assemblage in Asia was found in the India sub-continent from the Siwaliks (Punjab) in Northwest India dated at 2.6 Mya (Cauche et al., 2021; Dambricourt Malassé et al., 2016; Gaillard et al., 2016) and southern China, that of Longgupo and Renzidong dating to 2.4-2.2 Mya (De Weyer, 2019; Han et al., 2017). The earliest evidence of Oldowan type industry in Europe spanning between 1.5 Mya to 1.2 Mya found in Italy and Spain. The earliest record was found in the site of Pirro Nord 1.5 Mya, southern Italy (Arzarello et al., 2007, 2015; Arzarello & Moncel, 2021; Cauche, 2022), and in Spain around 1.4 Mya to 1.2 Mya in Orce region (Barranco Leon and Fuente Nueva 3 and Baza basin) and Sima del Elefante (Cauche, 2022; De Weyer, 2019; Huguet et al., 2017; Moyano et al., 2010; Parés et al., 2006; Scott & Gibert, 2009; Titton et al., 2020).

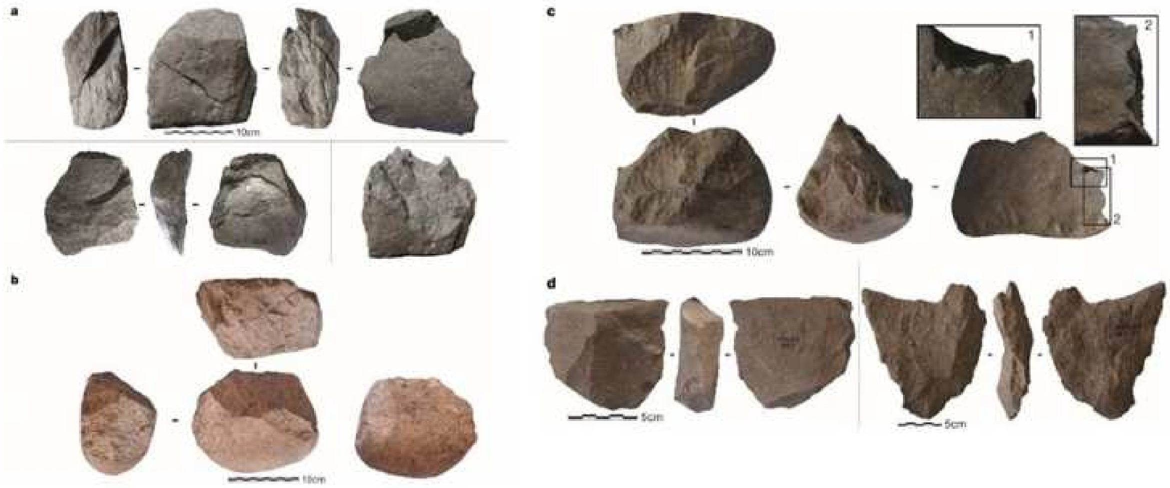


Figure 1.1. Lomekwian Artifacts; a. Cores and refitting surface flake; b. Unifacial core, bipolar technique c. Unifacial core, passive hammer technique d. Flakes. Adapted after (Harmand et al., 2015)

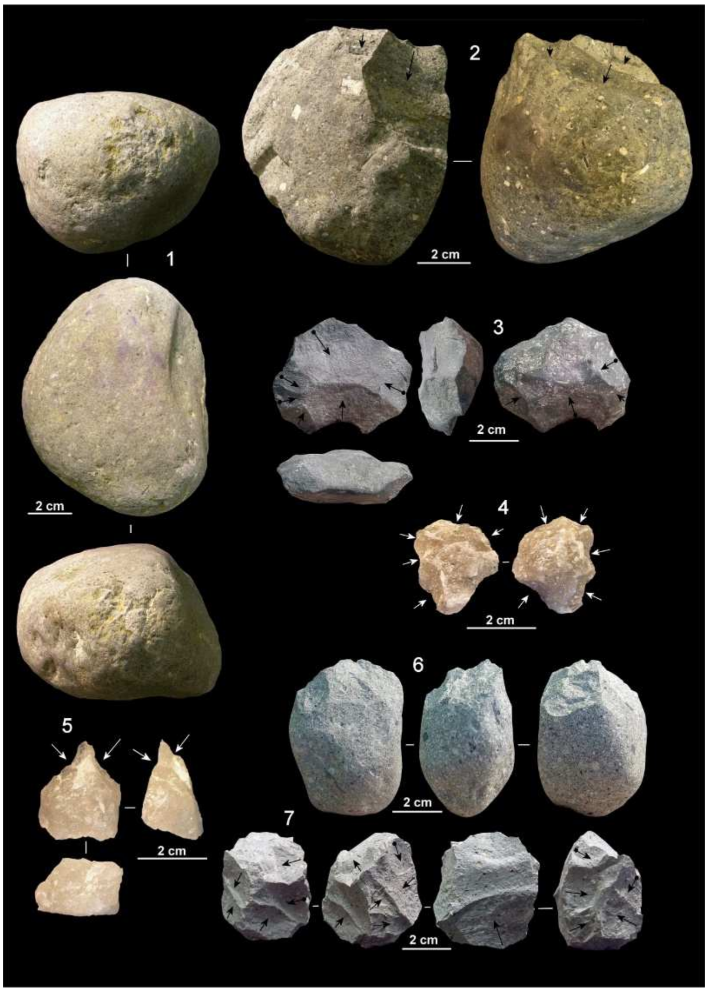


Figure 1.2. Oldowan type artifacts from Olduvai Gorge; 1. Basalt hammerstone; 2. Bifacial chopper in phonolite; 3. Bifacial centripetal core in basalt; 4. Quartzite denticulate; 5. Borer on quartzite; 6. Bifacial chopper on phonolite; 7. Phonolite multifacial/multipolar core in a final stage of exploitation. Adapted after Diez-Martín et al., (2022).

Generally, these current known earliest technological inventions of the lithic industries during the late Pliocene and early Pleistocene represent significant advances in early human cognitive ability and adaptive behaviour (de la Torre, 2016; Harmand et al., 2015; Key et al., 2021). These technologies demonstrate a gradual technological advancement where each is technically more demanding than its immediate predecessor (Braun et al., 2019; Roche et al., 1999). Therefore, account for a considerable proportion of existing knowledge on earliest hominin behaviour and evolution (Key et al., 2021).

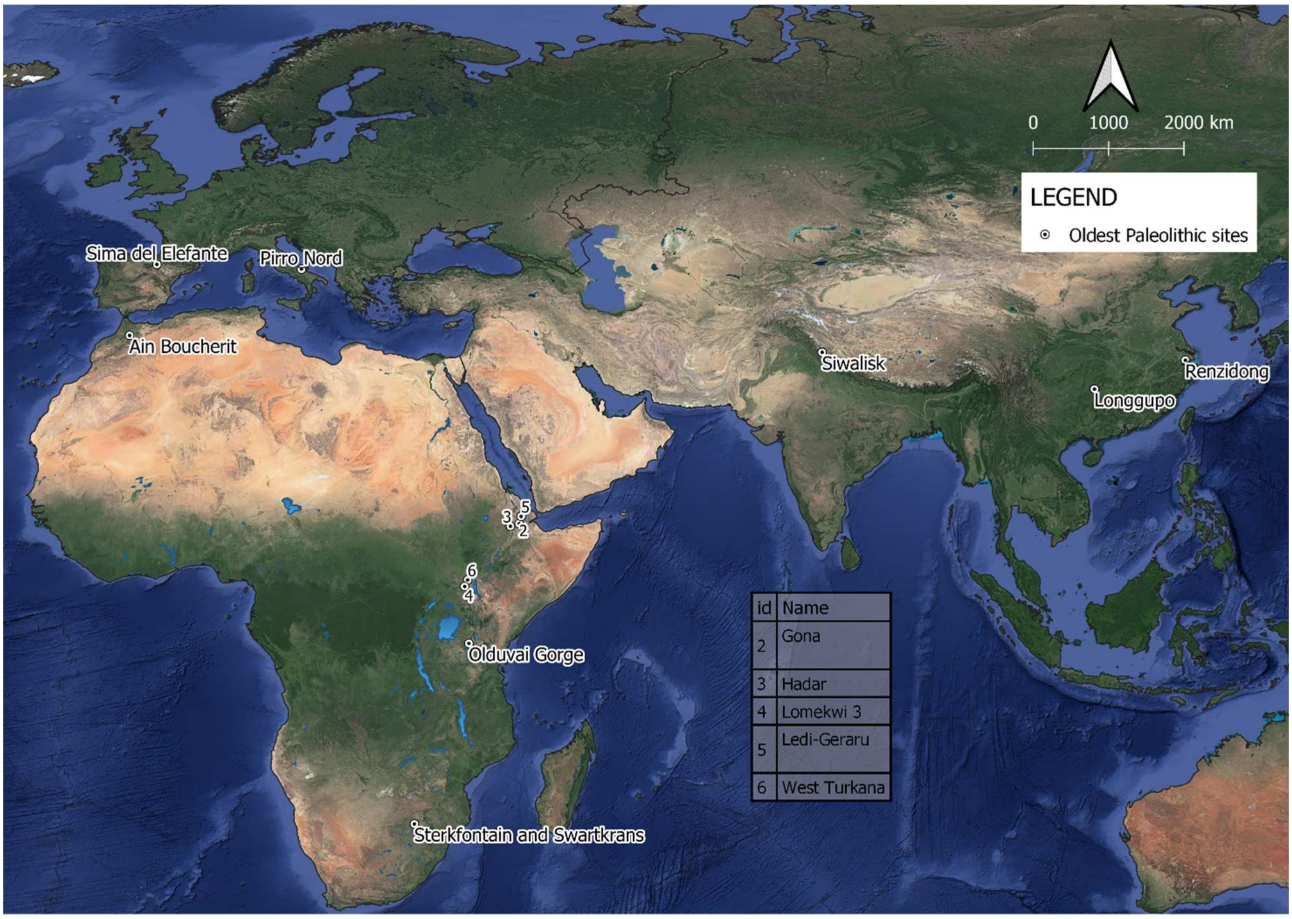


Figure 1. 3. A map representing the global distribution of the earliest lithic Industries as mentioned in this work.

1.2 The Acheulean

The Acheulean techno complex is a stone tools industry that spread throughout most old-world, including Africa, Asia, and Europe (de la Torre, 2016; Kuman, 2014; Toth & Schick, 2019). It was firstly recognized in western Europe in the late 19th century in the fluvial terrace of the Somme River near Amiens, France (Gaudry, 1861; Rigollot, 1954). Prehistorian Gabriel de Mortillet named the Acheulean industry after the site of Saint Acheul (France) in his attempt to define Palaeolithic cultures and periods based on tool types (de la Torre, 2016; de Mortillet, 1873). The industry was primarily characterized merely by the presence of bifacial tools (e.g., handaxes) (Lambert-Lauriston, 2015). The discovery of Acheulean in other parts of the world especially Africa sparked the debate over what a typical Acheulean assemblage should contain.

It is now accepted that an Acheulean assemblage can generally contain large flakes, bifacial tools variation with cores of different types worked by hard hammer (Clark, 1994; Diez-Martín et al., 2015; Lambert-Lauriston, 2015; Leakey, 1971). However, further discoveries identified many other assemblages without bifaces corresponding to geographical and chronological contexts with the Acheulean localities bearing bifacial assemblages (de la Torre, 2016; Toth & Schick, 2019). The Acheulean assemblages without large bifacial tools have been reported from African and European Acheulean contexts and sometimes has been described to represent a specific cultural group (Arnaud et al., 2017; de la Torre, 2016; Grifoni & Tozzi, 2006; Lepre et al., 2011; Muttillo et al., 2021; Policarpo et al., 2018; Uribelarrea et al., 2017). The setting of Acheulean global distribution is still highly debatable, while the earliest known occurrence is based on Eastern African assemblage from Kokiselei in western Turkana region (northern Kenya), dated to 1.76 Mya (Arroyo et al., 2020; Kuman, 2014; Lepre et al., 2011; Toth & Schick, 2019). Around the same period, the Acheulean appeared beyond the African continent in Ubeidiya (Israel) dated to 1.4 Mya (Bar-Yosef, 1994) and India sub-continent dated to 1.5 Mya (Pappu et al., 2011).

1.3 The Acheulean in Europe

Current knowledge about European Acheulean has placed the oldest known occurrence at Barranc de la Boella (la Canonja, Southern Spain), dated to ca. 1 Mya (Ashton & Davis, 2021; de la Torre, 2016; Kuman, 2014; M.-H. Moncel et al., 2020; Ravon et al., 2022; Vallverdú et al., 2014), which has been documented as showing morphological similarities to Early Acheulian sites in Africa and the Levant (Sharon & Barsky, 2016). Predominantly, raw materials are chert and schist, although many others were also observed, including granite, sandstone, quartz, and quartzite, all locally available(Vallverdú et al., 2014). Technological investigation of Barranc de la Boella lithic assemblage attributed the site to Early Acheulean technology characterized by few large bifaces and small to medium-sized flakes. The assemblage is mainly represented by a split cobble technique, a defining feature of Early Acheulean in Africa (M.-H. Moncel et al., 2020; Vallverdú et al., 2014). The site represents an early attempt of bifacial shaping, perhaps the local inception of bifacial tools. Large flakes and partial bifacial (M. H. Moncel et al., 2018; M. H. Moncel, Santagata, et al., 2020) shaping are sporadic in Europe and seem implausible to represent the Oldowan-Acheulean transition (M. H. Moncel et al., 2018; M. H. Moncel, Santagata, et al., 2020). Notwithstanding, the presence of other several sites in Europe relatively around the same chronology of 1 Mya recognized with a typical Oldowan type assemblage, e.g., Vallonnet cave, Bois-de-Riquet and Pont-de-Lavaud in France, Untermassfeld in central Germany and Ca' Belvedere di (Monte Poggiolo) in Italy (Cauche, 2022), the Oldowan-Acheulean transitional attributes have not been reported. Therefore, Barranc de la Boella's assemblage could essentially represent the arrival of a non-local hominin group and technology (M. H. Moncel, Santagata, et al., 2020), although such interpretations concerning the advent of Early Acheulean in Europe are still highly debatable (Arnaud et al., 2017; Arzarello & Moncel, 2021; Ashton & Davis, 2021; Grimaldi et al., 2020; Hardy et al., 2018; Zanolli et al., 2018). Further evidence has shown the appearance of the Acheulean in other parts of the continent starting from ca 0.7 Mya (Hardy et al., 2018; M.-H. Moncel et al., 2020; Voinchet et al., 2015), with minimal exceptions before that chronological boundary.

At Cueva Negra del Estrecho del Río Quípar and Gran Dolina TD6 in Spain, the Acheulean assemblage has been reported dating ca 0.9 Mya and 0.8 Mya, respectively (Gallotti & Peretto, 2015; Hardy et al., 2018; Scott & Gibert, 2009; Walker et al., 2020). At the site of Bois-de-Riquet (Lézignan-la-Cèbe, France), a typical Oldowan type industry was reported from an archaeological unit dated ca 1 Mya. This seems to establish the Oldowan-Acheulean transition between 1 Ma and 0.9 Ma in this region. The assemblage is only composed by flakes, cores and manuports (Bourguignon, Barsky, et al., 2016; Bourguignon, Crochet, et al., 2016; Cauche, 2022). Another archaeological unit harbouring the Acheulean industry artifacts has been interpreted as a secondary depositional context, altered by mudflow, dated at 0.8 Mya(Bourguignon, Barsky, et al., 2016; M.-H. Moncel et al., 2020; Vialet, 2018). The assemblage represents an association of two technologies (knapping and shaping) in a single matrix (Bourguignon, Barsky, et al., 2016; Brenet et al., 2010), which is also characterizing the Early Acheulean contexts in Europe (Brenet et al., 2010; 85) Nevertheless, regarding the Bois-de-Riquet lithic assemblage, the available data thus far is still insufficient to generally surmise the technological and chronological relationship between Oldowan type and Acheulean industries. Despite early occurrences, the Acheulean in Europe became widespread only at ca. 0.5 Mya (Ashton & Davis, 2021; Gallotti & Peretto, 2015; Hardy et al., 2018; Kuman, 2014; Lefèvre et al., 2010; Sharon & Barsky, 2016). In general, most European Acheulean assemblages are attributed to the Late Acheulean, i.e., 0.6 Mya – 0.3 Mya (Clark, 1994; Kuman, 2014) and characterized by the assemblages with and without bifaces (Arnaud et al., 2017; Muttillo et al., 2021; Sharon & Barsky, 2016). Some authors argue that the occurrence of bifacial tools may not affirm the presence of distinct cultural or technological contexts rather than reflecting other functional usages (Ceruleo et al., 2015). Nevertheless, Ashton & Davis (2021) proposes a cultural mosaic model to justify the widespread Acheulean assemblage's variations in Europe. The Acheulean assemblage inconsistencies in Europe may reflect specific groups of hominids who persisted in particular geographic areas and developed distinctive cultural traditions (Ashton & Davis, 2021). Besides, typically this period is considered essential for the shifting of hominin adaptation in Europe and the evolution of Neanderthal lineage (M. H. Moncel et al., 2012). The complete Neanderthal morphological dental pattern was preconfigured at least ca 0.45 Mya, but different hominin groups other than the Neanderthal lineage associates may have existed in Europe around the same period (Grimaldi et al., 2020; Hardy et al., 2018; Zanolli et al., 2018). Therefore, a broad understanding of prehistoric hominins' behavioural variation and adaptation at this temporal range is crucial to correlate cultural and technological convergence in evolutionary traits.

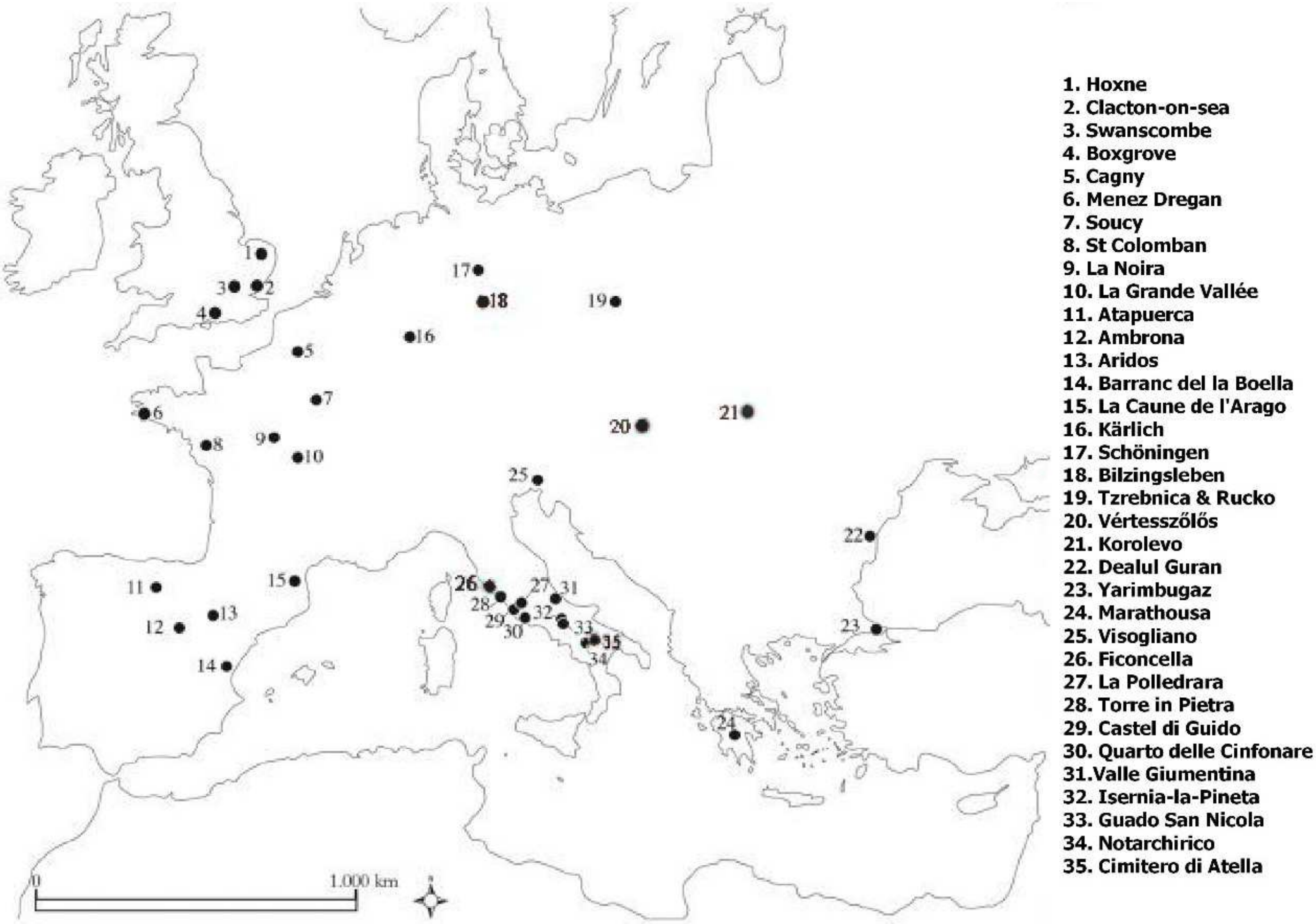


Figure 1.4. A map of the main Acheulean sites in Europe between 0.7 Mya and 0.3 Mya, adapted after Rocca et al. (2016).

1.4 The Acheulean in Italy

The current known earliest Acheulean assemblage in Italy comes from the Southern Italy. With the sites of Cimitero di Atella, Loreto, Isernia la Pineta and Notarchirico, 0.7-0.6 Mya (Lefèvre et al., 2010; M. H. Moncel, Ashton, et al., 2020; M. H. Moncel, Santagata, et al., 2020; Muttillo et al., 2021; Peretto, 2006; Piperno et al., 1998; Sharon & Barsky, 2016), Notarchirico locality has yielded a well-stratified collection which has been well studied and considered the oldest in the region (Lefèvre et al., 2010; M. H. Moncel, Santagata, et al., 2020; Muttillo et al., 2021;

Sharon & Barsky, 2016). The assemblage is characterized by large cutting tools and pebble tools (both unifacially or bifacially made), cores, flakes, cobbles, and nodules of chert (M. H. Moncel, Santagata, et al., 2020). In Cimitero di Atella the assemblage is still under study. However, it could be surmised that the site has yielded a more complex and varied Acheulean assemblage in different archaeological layers (Muttillo et al., 2021), while in Loreto, the investigation of lithic assemblage confirmed the rarity and poorly presented bifacial tools. Therefore, the assemblage is essentially attributed to the Acheulean without bifaces (Muttillo et al., 2021). Another site with the same chronology is the Isernia la Pineta. The site has yielded Acheulean lithic industry without bifaces but with the particular feature of small-sized flakes and large chopping tools made on flint and limestone, respectively (Peretto, 2006; Sharon & Barsky, 2016). Primarily this assemblage was attributed to Mode 1 technology by early studies (Peretto, 2006). However, the site was eventually recognized with the Acheulean features after identifying mainly discoid knapping strategies for optimum production of medium-sized flakes, specifically transformed into small tools (Gallotti & Peretto, 2015). In Italian peninsular, the late Acheulean assemblages are usually characterized with few bifacial tools, e.g., Fontana Ranuccio (Ascenzi & Serge, 1996; Grimaldi et al., 2020), Guado San Nicola (Muttillo et al., 2014; Peretto et al., 2016), Scornetta (Bologna) (Bisi et al., 1989), and Monte Conerno (Broglio et al., 2005), or without bifacial tools, e.g., Ficoncella (Aureli et al., 2016; Muttillo et al., 2021), Valle Giumentina (Muttillo et al., 2021), while essentially devoid the presence of cleavers unlike early occurrences in Europe ca 0.7 Mya, e.g., Notachirico (Italy) and La Noira (France) (M.-H. Moncel et al., 2020; M. H. Moncel et al., 2018, 2019). These factors are generally considered basic features for the emergence of Late Acheulean industries in western Europe (Sharon & Barsky, 2016). The lack of bifaces in some assemblage being a common factor, European Acheulean has previously often been categorized as Tayacian or Clactonian (Arnaud et al., 2017; Grifoni & Tozzi, 2006; Muttillo et al., 2021). However, the variability of bifacially made artifacts is high both within and between the sites during European Late Acheulean but still lacks clear functional explanations. Recent research highlighted several modification differences, including general management of bifacial volume, a plano-convex cross-section with unifacial retouch on the convex face with a distinct functional edge, for example, in Italy; Fontana Ranuccio (0.46 Mya), Torre in Pietra (0.43 Mya) and Guado San Nicola (0.4 Mya) (M. H. Moncel et al., 2018: 50). Extensive morphological and shaping variability of bifacial tools in some sites and some areas could result from the cutting-edge resharpening for multifunctional tools (M. H. Moncel et al., 2018). The European Acheulean dating to a late period and co-occurrence with the succeeding industry of more advanced lithic production technology undoubtedly attributes the context to the transitional period between Lower to Middle Palaeolithic. Several sites around Europe attest to this i.e., Cagny-la-Garenne 0.43 Mya and Orgnac3 0.37 Mya (France), Fontana Ranuccio 0.46 Mya and Guado San Nicola 0.4 Mya (Italy), Purfleet 0.32 Mya (UK) (Ceruleo et al., 2015; M. H. Moncel, Ashton, et al., 2020; Peretto et al., 2016). The Acheulean site of Guado San Nicola in central Italy represents well-developed Acheulean bifaces and have also been reported with the earliest Levallois technology in Europe (Arnaud et al., 2017; Berruti et al., 2020; M. H. Moncel, Ashton, et al., 2020; Peretto et al., 2016).

2. DESCRIPTION OF THE SITE

2. 1 Geomorphology and Location of the Site

Guado San Nicola (GSN) is a prehistoric site located approximately 2 km northwest of the village of Monteroduni (Molise, Isernia central Italy) that saves for substantial middle Pleistocene deposits (Fig. 2.1a). The site was discovered in 2005 during the investigation of the nearby Acheulean site of Colle delle Api, located 100 m away southeast (Berruti et al., 2020; Peretto et al., 2016). The site is located on the left bank of the river Volturno around 30 m above the current alluvial plain. It is bounded to the North and South, respectively, by the Lorda stream, a tributary of the Volturno river, and a small valley. This valley originated on a spring rising from the distal part of a flood plain. The Volturno valley is surrounded from the North by the Venafro and Mainarde mounts and to the South by the Matese Massif (Pereira et al., 2016; Peretto et al., 2016).

Guado San Nicola has been subjected to an intensive systematic investigation since 2008. The excavation of an area of 98 m^2 has revealed a stratigraphic sequence of more than two meters thick, in which several archaeological levels were recognized (Pereira et al., 2016; Peretto et al., 2016). The site is considered among the prolific localities in Europe with the earliest evidence of Levallois lithic production method, thus representing technological shifting from the Acheulean lithic industry to the Middle Palaeolithic (Arnaud et al., 2017; Berruti, 2017; Berruti et al., 2020; M. H. Moncel et al., 2018; M. H. Moncel, Ashton, et al., 2020; Peretto et al., 2016) The site has yielded various prehistoric remains, including an assortment of fauna and lithic materials. A poor state of preservation generally characterizes fauna assemblage, while lithic assemblage attests to diverse and more complex technological and typological characterization (Arnaud et al., 2017; Berruti, 2017; Berruti et al., 2020; Muttillo et al., 2014; Peretto et al., 2016).

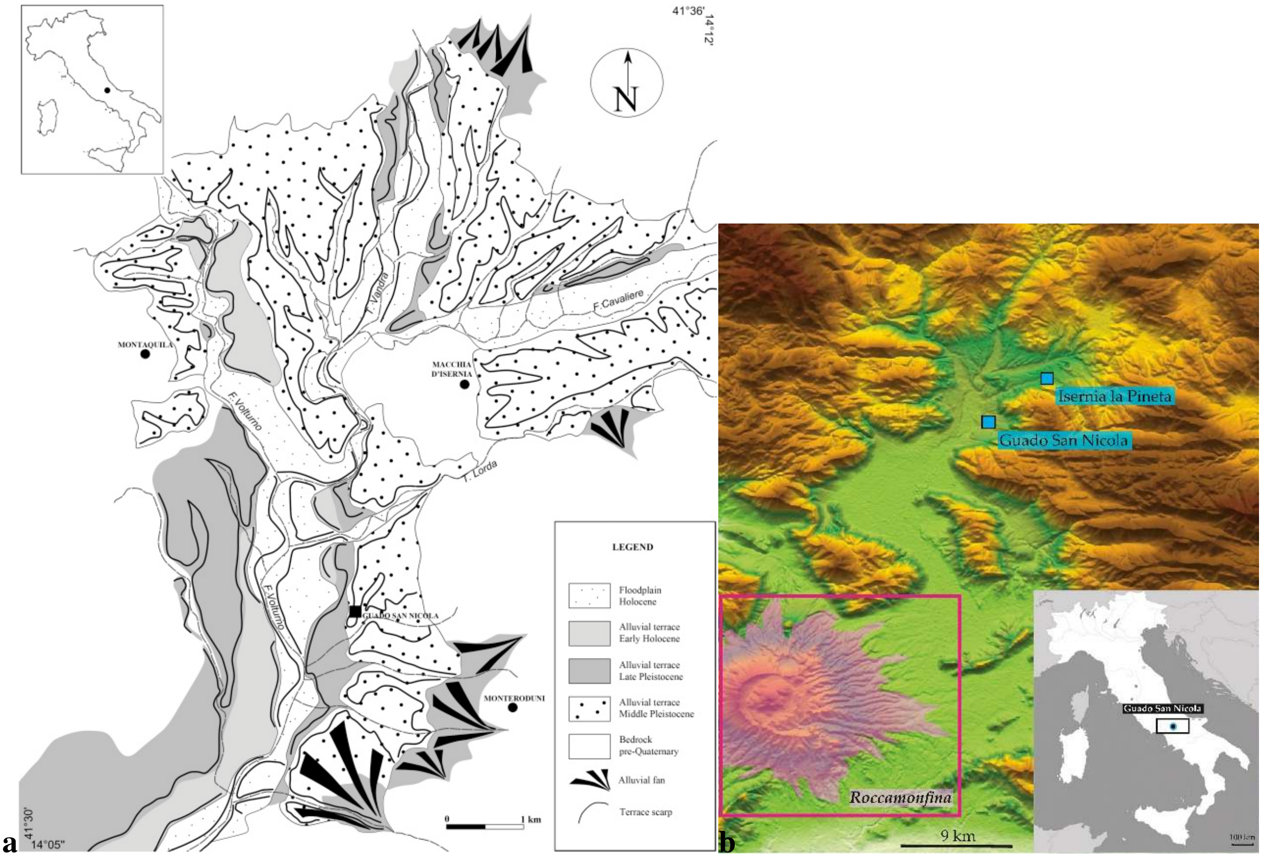


Figure2.1. a. Geomorphological map showing a location of Guado San Nicola and the surroundings, adapted after Peretto et al. (2016), b. Schematic geographical map of the Isernia basin, showing the Guado San Nicola and Isernia la Pineta sites location, adapted after Pereira et al. (2016).

2.2 Stratigraphy

The Guado San Nicola stratigraphy represents the first cycle of Quaternary deposition in the Monteroduni area, consisting of polygenic gravelly, silty, and clayey deposits that contained interstratified tephra layers (Berruti, 2017; Berruti et al., 2020; Pereira et al., 2016; Peretto et al., 2016) Geological and geomorphological analysis positioned the Guado San Nicola site within the oldest Middle Pleistocene Volturno fossil terrace identified in the valley (Fig.2.1a)

(Pereira et al., 2016; Peretto et al., 2016). The terrace corresponds to the main filling of the nearby Isernia basin (Fig. 2.1b) (Peretto et al., 2016) . The Stratigraphic sequence of Guado San Nicola has been identified and well described from the excavated area of 98 m^2.

The area preserves a depositional sequence of 2 m thick. The succession has yielded four Archaeological layers in stratigraphic units (S.U.) A*B, B, B*C, and C (Berruti, 2017; Berruti et al., 2020; Pereira et al., 2016; Peretto et al., 2016), and two sterile layers in S.U. D and E (Pereira et al., 2016).

S.U. A*B is a shallow layer of alluvial deposits characterized by darker gravelly silt. S.U. B is composed of sands, gravels, pebbles with volcanic elements, and it has been interpreted as the result of surface runoff. S.U. B*C has shallowly appeared while having yielded a well-preserved archaeological paleosurface ca 15cm thick. S.U. C is composed of fluvial gravelly sand, and many volcanic materials especially pumices of good quality. The S.U. D and S.U. E predominantly comprises fluvial sandy clay and fluvial coarse gravels (Fig. 2.2) (Pereira et al., 2016; Peretto et al., 2016). The top of the stratigraphic sequence, corresponding to the top of the alluvial terrace, is weathered by a deep, leached, rubified relict paleosoil (Argillisoil), characterized by a succession of decarbonated and argillic horizons, with strongly corroded flint and limestone clasts (Berruti, 2017; Peretto et al., 2016). The layer has been covered by gravel slope deposit containing sand particles, tiny pumices, and clays, crossing after the underlying stratigraphic deposition of volcanic tuff (S.U. Tufi), an in situ volcanic fallout directly deposited in the Lorda River. This unit's base (variable thickness) is white, while the superior part is darker, with a red color, but its composition is homogeneous(Pereira et al., 2016) . S.U. A is characterized by sandy clay and rich volcanic minerals (Berruti, 2017; Pereira et al., 2016), which are attributed to the outcomes of the earth movement (Pereira et al., 2016; Peretto et al., 2016). In general, the coarse fluvial sediment in the base of the entire succession indicates a braided channel's path in rapid aggradation during a cold and arid period, while the top indicates meandering paths; therefore, the beginning of a marked climatic improvement and a distinctive floodplain environment is attributable to the Volturno river's ancient course (Pereira et al., 2016).

2.3 Chronology

The chronological examination of Guado San Nicola's stratigraphic deposition employed two approaches of Geochronological analysis of Argon-argon ($^{40}Ar/^{39}Ar$) and Electron Spin Resonance and Uranium-series (ESR/U-series). The $^{40}Ar/^{39}Ar$ dated samples were retrieved directly from the S.U. Tuff, S.U. A, S.U. C and S.U. E while the ESR/U-series samples were selected from the remains of horse and rhinoceros from the S.U. B (3 teeth), S.U. B*C (1 tooth), and S.U. C (2 teeth) (Fig. 2.2) (Berruti, 2017; Pereira et al., 2016).

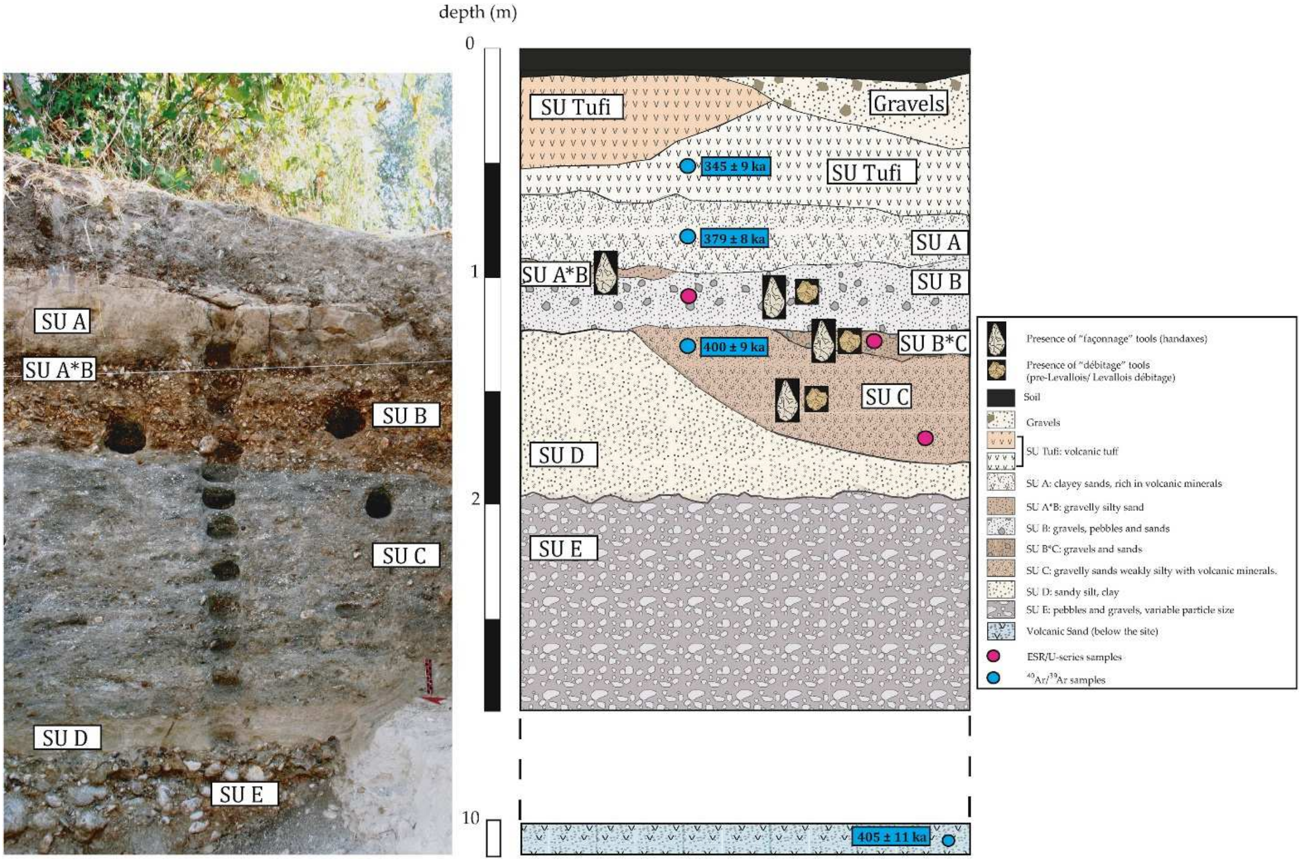


Figure 2.2. A Photo and schematic stratigraphy of Guado San Nicola showing the stratigraphic units and the sampling positions for the 40Ar/39Ar and ESR/U-series methods and the archaeological deposits, adapted after Pereira et al. (2016)

A single crystal $^{40}Ar/^{39}Ar$ dating on sanidines extracted from the pumices in corresponding units provided a deposition age of 0.345 ± 9 Mya, 0.379 ± 8 Mya, and 0.4 ± 9 Mya for S.U. Tuff, S.U. A and S.U. C (Fig. 2.2), respectively (Berruti, 2017; Pereira et al., 2016; Peretto et al., 2016) . However, the Electron Spin Resonance and Uranium-series (ESR/U-series) method was applied on six teeth of horse and rhinoceros from the S.U. B, B*C, and C allowed estimating an average age of 0.364 ± 39 Mya (Pereira et al., 2016; Peretto et al., 2016). This age has been interpreted as a minimum age for the deposition of the S.U. B as the exact age cannot be determined because of frequent U-leaching evidence in the teeth(Pereira et al., 2016). The results subsequently put the archaeological layers (S.U. A*B, B, B*C, and C) between 0.4 ± 9 Mya (M.I.S. 11) and 0.345 ± 9 Mya (M.I.S. 10), which is a transitional period between Lower to Middle Palaeolithic (Arnaud et al., 2017; Berruti, 2017; Berruti et al., 2020; M. H. Moncel, Ashton, et al., 2020; Pereira et al., 2016; Peretto et al., 2016);The sterile layer S.U. E dated by $^{40}Ar/^{39}Ar$ dating method rests this unit to 0.405 ± 11 Mya, the dating estimated for both sterile compositions, i.e., S.U. D and S.U. E (Fig. 2.2) (Pereira et al., 2016).

2.4 Fauna assemblage

The occurrence and distribution of fauna at Guado San Nicola have been recorded from all identified archaeological stratigraphic units A*B, B, B*C, and C. The assemblage comprises the remains of *Cervus elaphus acoronatus,* Cervidae*, Equus ferus ssp*., *Palaeoloxodon sp., Bos primigenius*, *and Stephanorhinus kirchbergensis*, *Ursus sp.*, *Dama sp.*, while Megacerini sp. are very rare (Table 2.1) (Peretto et al., 2016). The reconstruction of fauna sequence variation was nonviable due to the rarity of identified specimens according to a specific stratigraphic correlation (Peretto et al., 2016; B. Sala et al., 2014). The faunal composition suggests the occurrence of a paleoenvironment constituted by woodland and shrub areas, occupied mainly by cervids, and open grassland, populated by elephants, aurochs and horses; that should refer to one or more temperate or warm temperate phases, due to the presence of Merk's rhinoceros and aurochs, together with the absence of cold indicators. The presence of *Cervus elaphus acoronatus*, typical of the Galerian mammal age, and horse with relatively large body size, allows attribution to the Fontana Ranuccio faunal unit (Peretto et al., 2016; B. Sala et al., 2014), confirming the assignment of the site to the latest part of M.I.S. 11, despite being located on the southern margins of the geographical distribution of *Equus ferus* populations (Berruti et al., 2020; Peretto et al., 2016; B. Sala et al., 2014)

Recovered specimen	S.U. A*B	S.U. B	S.U. B*C	S.U. C
Antler fragments	-	23	24	260
Bos primigenius	-	8	3	6
Cervidae	1	6	2	9
Cervus elaphus acoronatus	-	7	5	20
Dama sp.	-	-	1	1
Equus ferus ssp.	-	32	12	3
Megacerine	-	-	1	2
Palaeoloxodon sp.	-	6	5	30
Stephanorhinus kirchbergensis	2	7	3	4
Ungulate	-	10	6	4
Ursus sp.	-	-	1	-
Unidentified	16	175	82	475
Total identified specimen	**3**	**66**	**33**	**75**
Total	19	274	145	814

Table 2.1. Guado San Nocola; Faunal composition grouped by stratigraphic unit. In the S.U. C elephant is overestimated due to fragments of tusk and dental plates (Berruti et al., 2020; Peretto et al., 2016; B. Sala et al., 2014).

2.4.1 Fauna Taphonomy

Faunal remains recovered from S.U. B, B*C, and C seem relatively well preserved at a macroscopic level, although 30% of the remains are missing superficial cover due to exfoliation. Well-preserved specimens present an overall fair degree of preservation at a microscopic level, although all the surfaces are extensively impregnated with manganese oxides. Weathering cracks and micro-cracks have affected the bone thickness and the assemblage to an advanced degree, and they seem to originate from pre-depositional factors such as temperature and humidity variations and exposure to meteoric agents. Exfoliations and erosions are mostly slight in S.U. C and B*C, while they appeared marked and spread in the S.U. B. An intense and widespread root activity was documented in the later stratigraphic units. The rounding edges are more documented in the S.U. C materials, while rarely are the traces of carnivore and rodent gnawing (Muttillo et al., 2014).

2.4.2 Zooarchaeology

Butchering activity has been recognized by identifying cut marks on the few remains of horses and rhinoceros. Although the low frequency of determined remains, the cutmarks were recognized on elements identified anatomically and taxonomically, thus allowing attribution to different stages of butchering (Berruti et al., 2020; Muttillo et al., 2014; Peretto et al., 2016). Recognized traces, including linear attributable to stripping have been found on a metacarpal IV of a horse (*Equus ferus*) from S.U. B (Fig. 2.3), the traces of disarticulation were found on a large ungulate vertebra aimed at splitting the vertebral column into several parts and on the coxals of horse (S.U. B*C) and rhinoceros (S.U. B) (Fig. 2.4) to detach the femoral head from the acetabulum.

Figure 2.3. *Equus ferus:* A. Right fourth metacarpal bone with cut marks (B, C), modified after Peretto et al. (2016).

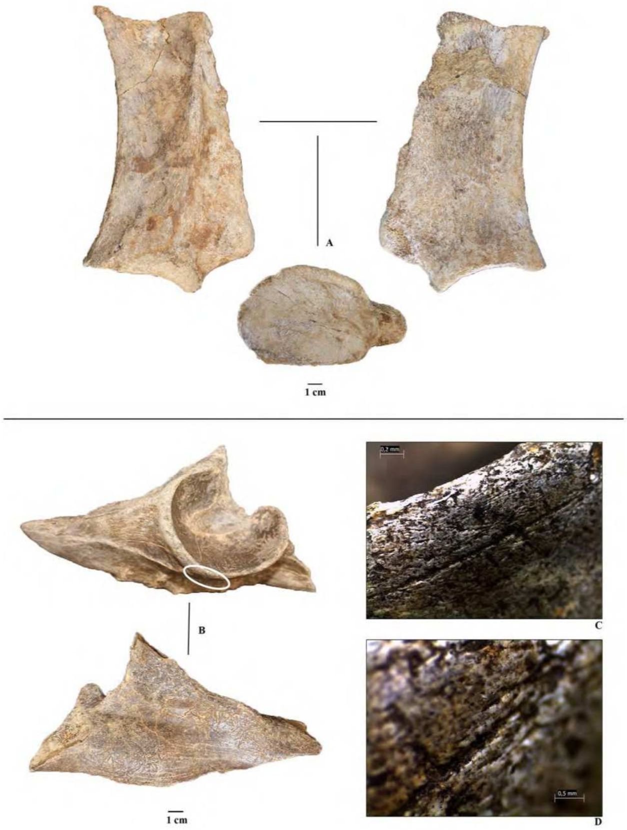


Figure 2.4. *Stephanorhinus kirchbergensis*. A. Articular portion right shoulder; B. Fragment of the left coxal, which presents on the edge of the acetabulum linear traces (C, D) adapted after Muttillo et al. (2014).

Linear traces were observed in positions compatible with the recovery of the flesh mass on fragments of tibia and humerus diaphysis, which have preserved the micromorphological characteristics observable in stereo miscopy (Muttillo et al., 2014). Four antlers of *Cervus elaphus acoronatus* coming from S.U. C exhibits traces that appear as linear and irregular notches, which profoundly affects the surface (Fig. 2.5). These grooves have only been found on these four specimens, the abundance of deer antlers from the S.U. C (Table.1) and the presence of such peculiar marks seems to reflect an interest in their collection and possible use as hammers for the knapping of lithic material (Berruti et al., 2020; Muttillo et al., 2014; Peretto et al., 2016; B. Sala et al., 2014).

Figure 2.5. *Cervus elaphus acoronatus*; A. basal portion of a shed antler with broken brow and bez tines; B. The antler's retained surface with visible sub-parallel notches (C, D) produced by percussion, adapted after Peretto et al. (2016).

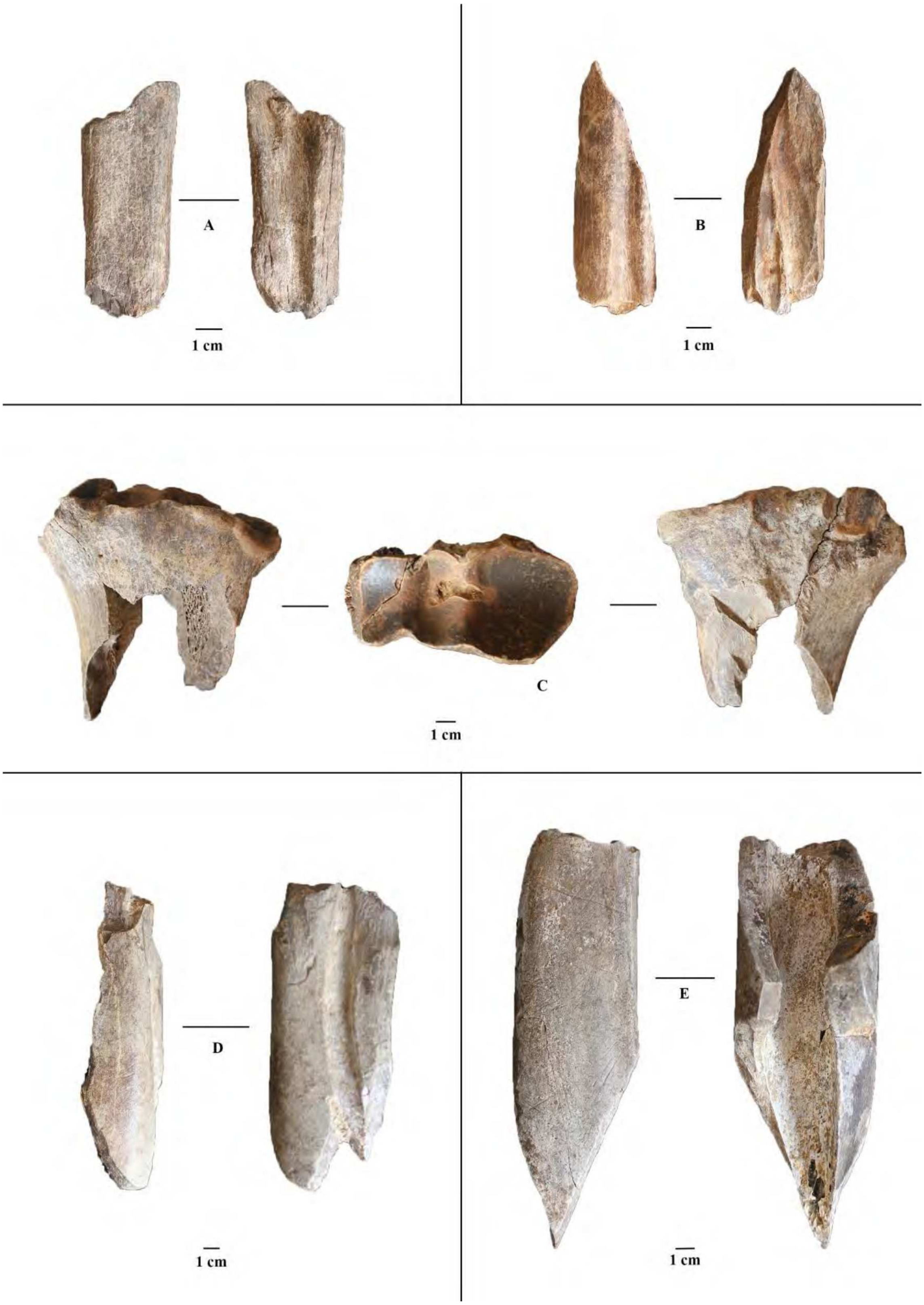


Figure 2.6. Ungulate; A-B. Fragments of metapods showing fracture and percussion grooves; C. Proximal part of the right radius of aurochs showing a fracture of anthropogenic origin; D. diaphysis part of left radius ulna of aurochs with breakage impact; E. a part of the large ungulate tibia with a fracture of anthropogenic origin and numerous trampling streaks on the cortical surface, adapted after Muttillo et al. (2014).

The fauna assemblage recovered from the S.U. C is constituted mainly by fragments of the diaphysis, which present mainly a fragmentation due to post-depositional factors of an edaphic nature (Muttillo et al., 2014; Peretto et al., 2016; B. Sala et al., 2014), but often overlaps with a fracturing attributable to anthropic activity aimed at recovering the marrow (Fig 2.6). Nevertheless, the low quantity of identified remains and the lousy bone preservation prevents the reconstruction of prey exploitation modalities (Muttillo et al., 2014; Peretto et al., 2016; B. Sala et al., 2014).

Alteration traces				**Fracture traces**				**Anthropic traces**			
Type	**B**	**B*C**	**C**	**Type**	**B**	**B*C**	**C**	**Type**	**B**	**B*C**	**C**
Oxides Fe	90	84	107	Flexion	-	-	14	Streaks	1	3	1
Oxides Mn	212	121	448	Transversal	1	6	72	Linear	8	7	5
Weathering	67	61	398	Longitudinal	3	10	39	Notches	-	-	5
Exfoliations	9	17	116	Serrated	2	-	22	Fractures	43	28	37
Erosions	51	14	226	Spiral	3	-	14	Grooves	9	7	11
Concretions	14	7	192	Step	13	5	78	Detachments	-	9	21
Post fractures	74	60	491	A.V.	1	1	10	Percussion	-	1	5
Inclination	14	29	378								
Roots	78	14	76								
Gnawing C	-	2	5								
Gnawing R	-	-	1								

Table 2.2. Guado San Nicola. The faunal alteration, fracture types, and anthropic traces identified from fauna assemblage relatively to stratigraphic units B, B*C and C, after (Muttillo et al., 2014).

2.5 Lithic assemblage

Guado San Nicola's lithic artifacts are primarily made of flint and limestone in a few cases. The limestone assemblage predominantly comprises unworked material, thus inhibiting the reconstruction of reduction sequences (Berruti et al., 2020; Muttillo et al., 2014; Pereira et al., 2016; Peretto et al., 2016). The characterization of lithic artifacts focuses exclusively on the flint lithic assemblage. Lithic materials 4,168 elements were recovered from excavations between 2008-2012 (Table 2.3). The analysis of the lithic industry at Guado San Nicola is based on technology, typology, raw materials variation, and preservation status. The lithic assemblage is characterized by bifacial shaping (*façonnage)* and *debitage*, using different methods that ensure extensive exploitation of raw materials (Arnaud et al., 2017; Berruti et al., 2020; M. H. Moncel et al., 2018; M. H. Moncel, Ashton, et al., 2020; Pereira et al., 2016; Peretto et al., 2016). Secondary modifications are rarely observed, retouched tools are rare, and primarily flakes resulted from opportunistic debitage, although the progressive increase was noted with greater diversification and standardization of retouching characters (Table. 2.4) (Arnaud et al., 2017; Peretto et al., 2016).

Findings	**S.U. A*B**	**S.U. B**	**S.U. B*C**	**S.U. C**	**Total**
Cores	7	167	49	67	290
Flakes	92	1521	468	876	2957
Retouched flakes	2	116	13	58	189
Retouched blanks	1	23	3	13	40
Handaxes	2	85	13	43	143
Debris	2	42	42	156	242
Unworked materials	1	35	16	126	178
Indeterminable fragments	0	29	22	78	129
Total analyzed materials	**107**	**2018**	**626**	**1417**	**4168**

Table 2.3. Guado San Nicola. The composition of flint lithic assemblage by stratigraphic unit. The term“debris” hereafter refers to “any shapeless fragment which cannot be identified”(Inizan et al., 1999, p. 34) adapted after Peretto et al. (2016).

2.5.1 Raw materials and Taphonomy

The predominant raw materials are various types of flint, but limestone and jasper are barely presented throughout the stratigraphic sequence. Flint types were categorized according to their texture, granulometry, and color. Four main categories have been identified when the most exploited type is aphanitic flint followed by micro and macro-brecciated flint relatively highly presented in the lower (S.U. C and B*C) and upper (S.U. B and A*B) stratigraphic units, respectively. The exploitation of silicified limestone is hardly observed in all stratigraphic units

(Muttillo et al., 2014; Peretto et al., 2016). The sources of raw materials are nearly allocated considering the reported outcrops in the high Volturno Valley (Brancaccio et al., 2000; Muttillo et al., 2014; Peretto et al., 2016). Raw materials were secondarily collected as slabs within the clast deposits and the most common documented flint blocks were structured with a roughly parallelepiped shape, partially covered by the cortex, poorly preserved, and dimensions between 5 and 15 cm (Peretto et al., 2016). Raw materials difference does not seem to affect the technical capabilities of the flint artisans, although influenced the debitage reduction sequence by emphasizing length over core management while independent technical components were observed in bifacial shaping. The rate of raw materials preference is relatively consistent and similar for both debitage production and bifacial shaping (Muttillo et al., 2014; Peretto et al., 2016). The knapping accidents recorded are generally referred to as cracks contemporary to the debitage (simple breaks, Siret fractures, languette fractures), but there are also characteristics related to the use of the artifact (Muttillo et al., 2014). The physical state of the artifacts is mainly altered, both in mechanical terms (fluctuation, pseudo-retouch) and chemical-physical (different types of surface patina) (Muttillo et al., 2014; Peretto et al., 2016). The causes of fragmentation can also be found in post-depositional phenomena (transport, trampling, etc.) (Peretto et al., 2016). In the recent lithic taphonomic interpretation, (Berruti et al., 2020) reported that similar post-depositional alterations must have been affected the entire stratigraphic sequence in different degrees. Regarding the three considered stratigraphic units S.U. C, S.U. B and S.U. B*C all suffered the same alteration processes accordingly (Berruti et al., 2020). The investigation of the lithic post-depositional traces has shown the impacts related to a strong transport phenomenon, supporting the geological analysis and fauna taphonomic study (Berruti et al., 2020; Muttillo et al., 2014; Pereira et al., 2016; Peretto et al., 2016).

2.5.2Technology and typology

Technologically, the assemblage is one of the rare Italian findings that present distinctive features of the Lower to Middle Palaeolithic transitional period and represents the earliest advent of Levallois lithic production in Europe (Arnaud et al., 2017; Berruti, 2017; Berruti et al., 2020; M. H. Moncel et al., 2018; M. H. Moncel, Ashton, et al., 2020; Muttillo et al., 2014; Peretto et al., 2016).

2.5.2.1 The Acheulean bifacial tools (Bifaces)

In the production of the Acheulean bifaces at GSN, the bifacial shaping was adopted primarily from the choice of flattened flint slabs, characterized by two surfaces parallel and opposite cortical surfaces with a relatively reduced thickness which allows limiting the first phase of the shaping of two symmetrical surfaces (Muttillo et al., 2014). The bifaces are generally featured by a bifacial and bilateral asymmetry or only partial symmetry, while the bifacial and bilateral equilibrium is rarely presented (Peretto et al., 2016). Consequently, the primary choice of flattened flint slabs intends to minimize technical investment and often preserve the base entirely corticated. The technical investment is instead concentrated in the working of the tip and distal edges that seem to represent the actual functional part of the instrument (Muttillo et al., 2014; Peretto et al., 2016).

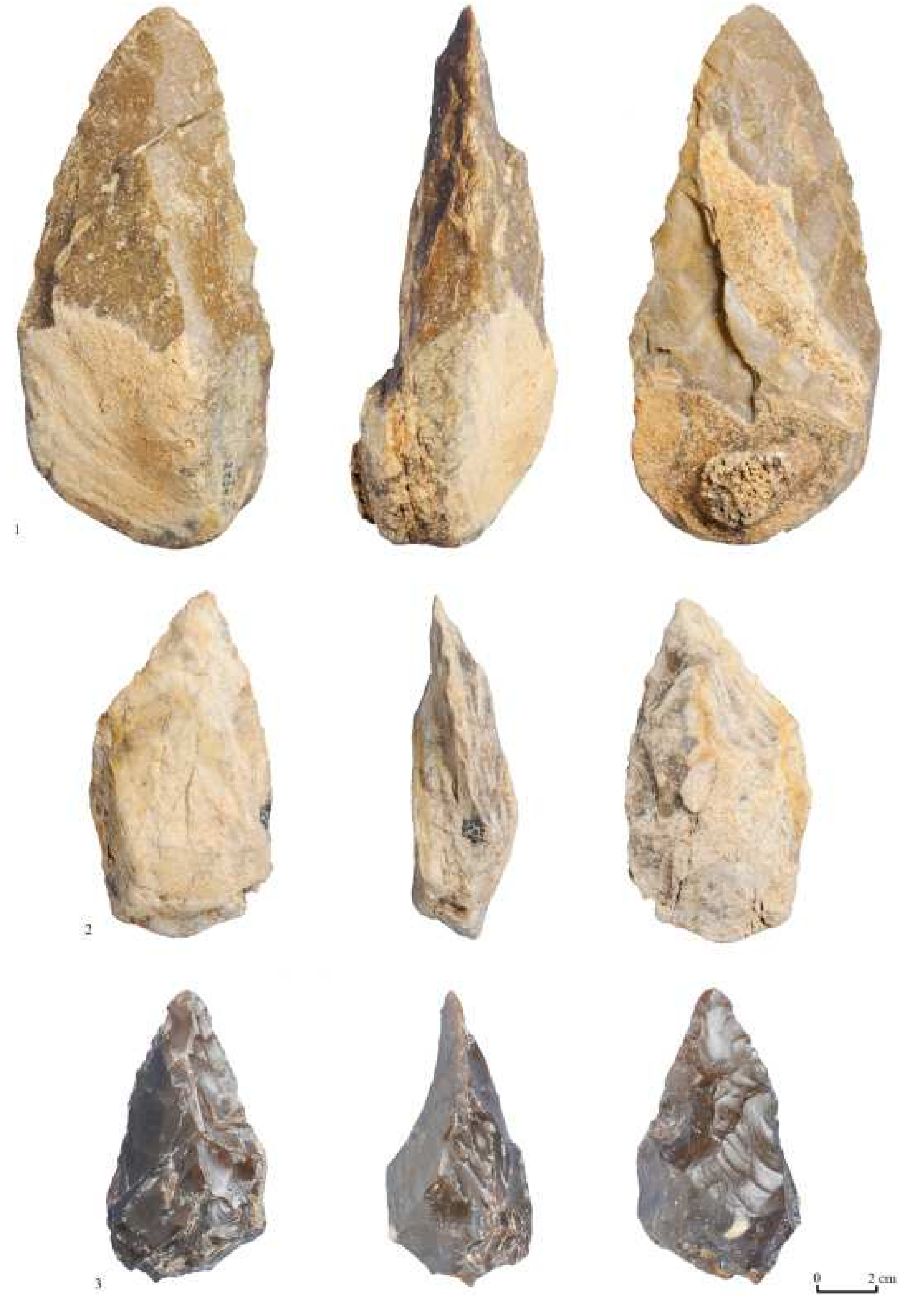


Figure 2.7. Guado San Nicola; Flint made bifaces; 1, 2. S.U. B; 3. S.U. C, adapted after Peretto et al. (2016)

The bifaces are characterized by highly morphological and dimensional differences that deter a possibility of precise systematization (Fig. 2.7) (Muttillo et al., 2014). The variation is relatively high between pointed and oval morphologies and became evident in the S.U. B, where the pointed ones predominated (Muttillo et al., 2014; Peretto et al., 2016), characterized by a considerable thickness and deep and invasive detachments on the edges maintaining definite tips (Muttillo et al., 2014).

	S.U. B	**S.U. B*C**	**S.U. C**
Bifaces	86	13	43
Façonnage flakes	40	38	40

Table 2.4. Guado San Nicola. The number of bifaces and bifacial shaping flakes per stratigraphic unit adapted after Berruti et al. (2020).

The edges are sinusoidal or slightly sinusoidal likely straight or sub-straight at the tips, which are generally affected by the retouching. The operational chain appears fragmented in the archaeological record. Only edges modifications are well represented while other phases are underrepresented (Table. 4) (Muttillo et al., 2014). The use of the soft organic hammer, particularly in the last phases of shaping, makes it possible to obtain thin invasive flakes with an optimal state of preservation and, in some cases, were used as tools (Berruti et al., 2020; M. H. Moncel, Ashton, et al., 2020; Muttillo et al., 2014; Peretto et al., 2016).

2.5.2.2 Debitage Production

Core reduction (*Debitage*) is frequently presented throughout the stratigraphic sequence at GSN featured by the presence of different knapping methods (Table. 2.5): S.S.D.A. method (*Systeme par Surface de Debitage Alterne*) (Forestier, 1993), discoid *debitage sensu stricto* (Boëda, 1993), discoid debitage *sensu lato* (Mourre, 2003) and Levallois method (Boëda, 1993, 1994). All debitage production methods involve the maximum intensity of raw materials exploitation, the evidence of integrated technical scheme is observed in the assemblage and seems to influence the high productivity of debitage production lithic artifacts. The cores were typically comprehensively utilized while was only hastily ignored in case of fracture incidence or knapping accident, which may require an advanced technical venture (Arnaud et al., 2017; Berruti et al., 2020; M. H. Moncel, Ashton, et al., 2020; Peretto et al., 2016).

Core types	**S.U. A*B**	**S.U. B**	**S.U. B*C**	**S.U. C**
S.S.D.A	5	103	26	40
Discoid (*sensu lato*)	2	38	15	17
Discoid (*sensu stricto*)	-	12	3	7
Levallois	-	14	5	3
Total	**7**	**167**	**49**	**67**
Retouched tool types				
Sidescrapers	1	41	7	29
Denticulates	1	62	7	26
Notches	1	25	1	9
Endscrapers	-	6	-	2
Tayac points	-	1	-	1
Flakes abruptly retouched	-	3	-	1
Total	**3**	**138**	**15**	**68**

Table 2.5. Guado San Nicola. Frequency of cores representing different knapping methods and the number ofretouched arifacts according to stratigraphic units, modified after Perreto et al. (2016).

2.5.2.2.1 S.S.D.A. method

The S.S.D.A. method generally involves using multiple striking platforms gradually created with the advance of core reduction through unidirectional exploitation. Each surface detaches two or more flakes where the negatives serve as striking platforms for further detachments. The whole knapping process is random, thus resulting in the lack of characteristic flakes. The morphology of the initial block, the debitage's organization, and the reduction sequence's length have highly influenced the flakes morphology showing an extreme variety. A flat butt characterizes these flakes, and the flake scars on the dorsal face are mostly orthogonal and barely unipolar. However, occasional shorter reduction sequences were observed when the flint is fissured or broken where the products correspond to flakes of small size, generally quadrangular, in some cases hinged, due to the presence of fissures in the raw material, preferably noted the aphanitic and brecciated types of flint (Peretto et al., 2016).

2.5.2.2.2 Discoid method

The discoid method at Guado San Nicola involves the knapping components of debitage and cores; Discoid debitage method (*sensu lato*) (Mourre, 2003) is characterized by the exploitation of a unique peripheral platform that separates two convex surfaces, generally asymmetric, through the detachment of short and slightly invasive flakes conducted in a centripetal direction. The discoid core *(sensu strict)* (Boëda, 1993) is featured by two opposite convex asymmetric surfaces, both utilized as flakes removal surface and striking platform alternatively. The flake's detachment planes are mostly subparallel and secant for the debitage and core method, respectively, to the intersection of the two core surfaces. Discoid debitage products lack the characteristic of self-maintenance of the convexities. It shows some variability in thickness, surfaces utilization, the morphology of the section, and the symmetry or asymmetry of the surfaces. At the same time, the discoid core products are relatively scarce, even though some cores with characteristics intermediate between the discoid and S.S.D.A method was observed as evidence of applying an opportunistic scheme, especially in the final stage of reduction (Berruti, 2017; Muttillo et al., 2014; Peretto et al., 2016).

2.5.2.2.3 Levallois method

Levallois method is represented throughout, although it is rarely applied in the S.U. C but becomes more frequent upward in the stratigraphic sequence and shows a diversified morphological and technological criterion. The method offers a comprehensive representation of different stages of reduction processes such as preparation, management, maintenance of flaking platforms, and convexities (Peretto et al., 2016). The centripetal method was commonly used but also unipolar and lineal, usually associated with the final products. The unipolar model generates long and wide products while applying the lineal method at the end of the production to obtain the support of a predetermined shape that occupies most of the available surface. The phases of preparation of the plane of percussion and the lateral and distal convexities, readable from the cores, appear more accurate in the upper levels than the levels below (Muttillo et al., 2014), indicates the ability to prepare and re-prepare cores aimed at the production of predetermined flakes even if they are equally underrepresented (Peretto et al., 2016). The butts are smooth, dihedral, and rarely faceted; the organization of the negative flake scars is orthogonal, centripetal, and rarely convergent and unipolar (Muttillo et al., 2014). Compared to the lower unit S.U C, the Levallois method is significantly improved in the S.U. B*C and B, where the aim of obtaining products with a predetermined shape becomes more evident. All types of flint have been used in this method, even though most are aphanitic without cracks (Muttillo et al., 2014; Peretto et al., 2016).

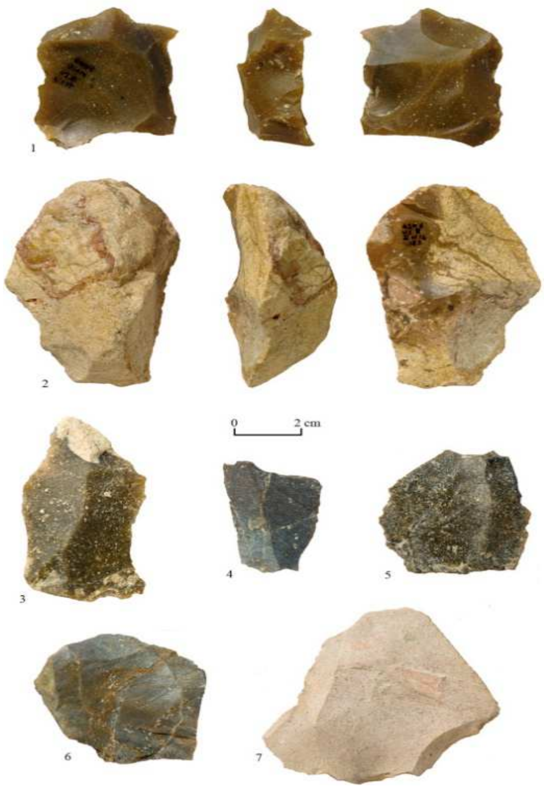


Figure 2.8. Guado San Nicola; Levallois method; 1. preferential core (S.U. B); 2. recurrent core (S.U. B); 3, 4. recurrent unipolar flakes (S.U. B, S.U. C); 5–7. preferential flakes (5; S.U. C, 6-7; S.U. B*C), adapted after Peretto et al. (2016).

2.5.3 Previous Lithic use-wear analysis

The recent lithic analysis study concerning this assemblage was recently published by (Berruti et al., 2020). The research primarily focused on understanding the functional relationships between the Levallois flakes and bifaces shaping (*façonnage*) flakes while also determining the post-depositional alterations on the respective lithic artifacts. The functional analysis results showed equifinality of uses in both lithic artifact types. The outcomes concluded that despite the distinctive production techniques, all considered lithic samples were primarily aimed at certain activities related to animal carcasses processing, including butchering, hide, soft animal tissue, and fresh bone working, while vegetal material working is minimal observed (Berruti, 2017; Berruti et al., 2020). The microscopic analysis for post-depositional traces was able to identify the polishing of the surfaces and rounding of the edges and ridges, which relate to the transport of the lithic assemblage in the sediment, edge crumbling due to the same phenomenon or trampling, white patina attesting alkaline and wet conditions, Fe-Mn patina which could be the result of bacterial decomposition or delivered from dissolved moisture in the surrounding limestone rock (Berruti, 2017; Berruti et al., 2020).

3. USE WEAR ANALYSIS METHODS (HISTORY AND DEVELOPMENT)

3. 1 Early Periods

The background of the use-wear analysis goes back to the 1830's beginning with the work of Sven Nilsson, a Swedish zooarchaeologist. One of his studies, entitled *The Primitive Inhabitants of the Scandinavian North,* "made considerable use of ethnographic analogy to determine the probable uses of tools from the past" (Olausson, 1980: 48). Nilsson (1838: 49) stated that "through carefully examining how tools were worn, one can often with certainty conclude how they were used (Olasusson's 1980 translation). Initially, a comparison attempt was made between ethnographical tools and archaeological tools to understand archaeological tools' functions by identifying wear traces produced by different specific activities (Lambert-Lauriston, 2015). It was not until John Evans (1872) publication of *The Ancient Stone Implements: Weapons and Ornaments of Great Britain*, although Evans did not use a comparative approach (Evans 1881; Olausson 1989: 48) his work was regarded as a seminal piece by some authors (e.g., Spurrell, 1892: 66; Tringham et al., 1974: 172) as he described and sketched in detail flaking techniques and wear patterns that he believed were related to use (e.g., edge damage, polish, and striae) (Berruti & Daffara, 2014; J. Evans, 1872, 1881; Lambert-Lauriston, 2015; Marreiros, Mazzucco, Gibaja, & Nuno Bicho, 2015; Spurrell, 1892; Tringham et al., 1974). The incorporation of experimental archaeology in the discipline was initially marked in Sehested (1884) *Practical Experiments: Archaeological Studies*. He used different methods of polishing and grinding with different abrasives to reproduce striations he observed on archaeological axes and proved that flint axes were useful tools (Paardekooper, 2013). Also, John Spurrell, (1884) made experimentation to distinguish between flakes that occurred from knapping and those that detached during use. Spurrell, (1892) experimentally attempted reproducing the "sickle polish" by working on different materials (e.g., ripe straw, bone, horn, and wood) and found that the traces produced when sawing ripe straw was comparable to the sickle polish seen on the archaeological specimens (Berruti & Daffara, 2014; Lambert-Lauriston, 2015; Marreiros et al., 2015; Spurrell, 1892: 58; Unger-Hamilton, 1984).

3.2 Early 1900's

This period of discipline development began around the turn of the 20th century (Lambert-Law de Lauriston 2015), with the publication of Ludwig Pfeiffer, (1912), *Stone Age Technology and Its Relationship to The Present*: A *History of Contributions to The Work* (Original in Germany). He mainly focused on replicative experimentations. However, he marked the initial attempt of macroscopic use-wear by comparing the wear traces of the archaeological and ethnographical collected pieces (Lambert-Lauriston, 2015; Marreiros, Mazzucco, Gibaja, & Nuno Bicho, 2015; Pfeiffer, 1912; Tringham et al., 1974). The following multiple works published in 1914 was focused on the possible natural cause of edge damage and the hafting and use of axes. Moir (1914) and Warren (1914),both through experimental archaeology, replicated the possible natural ways that the traces found on eoliths (in England) could have been made. Even though Warren had demonstrated that natural forces could have caused the wear features, particularly striations observed in eoliths, he remained open to the possibility that there were factors at work that he could not identify or quantify. Moir and Warren both had similar conclusions (Olausson 1989: 49) and provided for the first time in the discipline the photomicrographs of the experimental and archaeological traces they observed. Quente, (1914) experimented with hoeing and ploughing and compared the traces to the archaeological pieces through magnification and marked the earliest recorded uses of magnification in use-wear studies (Olausson 1989; Lambert-Law de Lauriston 2015). Vayson de Pradenne (1922) was one of the first archaeologists to suggest that shape does not equal function when he stated that "identity of the shape need not mean identity of use" (Vayson de Pradenne 1922: 34). He further stated that, based on morphology, an "hache néolithique" and an Eskimo scraper would have been put to the same use (Vayson de Pradenne 1922: 36). Therefore, he was essentially concerned with incorporating ethnographic analogy in use-wear studies since ethnographic data alone could lead to misinterpretation (Lambert-Law de Lauriston 2015). Cecil Curwen (1930; 1935) made experimentations to distinguish between the traces that were produced from cutting different materials (e.g., wood, dry bones and corn stalks) (Curwen, 1930: 184). New experimental data set involved the flint tool worked on wood, bone and straw were published confronting the previous results (Curwen 1935). Curwen stated, "These experiments, though far from being exhaustive, do surely support the view that the polish on the flint blades is not merely the result of hard usage, but is conditioned by the nature of the material cut" (Curwen 1935: 65). Several decades later, the high-power use-wear analysis approach was achieved to distinctively identify polishes reflecting different worked materials (Berruti & Daffara, 2014; Keeley, 1980; Keeley & Newcomer, 1977; Keeley & Toth, 1981; Lambert-Lauriston, 2015; Marreiros, Mazzucco, Gibaja, & Nuno Bicho, 2015).

3.3 After 1950

This period of use-wear analysis began with Sergei Semenov (1957), a work published in the U.S.S.R. and translated into English in 1964) (Álvarez-Fernández et al., 2020; Berruti & Daffara, 2014; Lambert-Lauriston, 2015; Murray, 2017; Semenov, 1957, 1964; Tringham et al., 1974). New methods were introduced and based on experimental observations, use-wear analysis became a vital proxy to identify and classify wear traces that allow functional interpretations (Álvarez-Fernández et al., 2020; Marreiros, Mazzucco, Gibaja, & Nuno Bicho, 2015). Semenov describes how tool morphology in conjunction with microscopic observations of edge damage, striae, fractures and polish could determine the function of an artifact (e.g., cut, saw, or scrape) and the materials worked (e.g., hide, bone, or wood) (Lambert-Lauriston, 2015). Semenov employed the use of stereoscopic microscopy with magnification 180 x, but also the higher magnifications >300 x (metallographic) for more detailed examination and photographs for monitoring his observations (Keeley, 1974; Semenov, 1964, 1970).

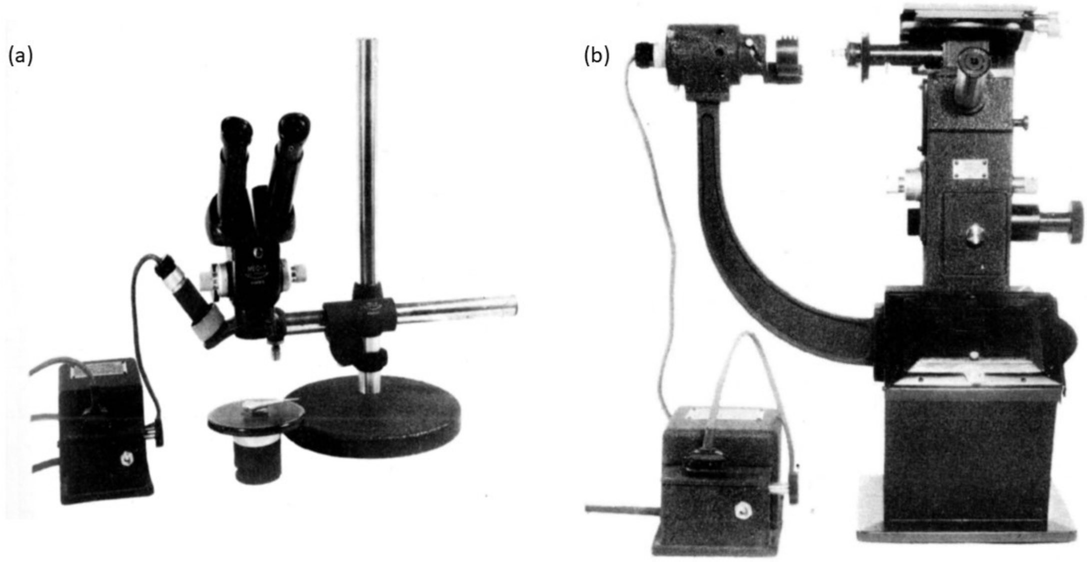


Figure 3.1. (a) Binocular microscope (stereoscope) MBS-1 attached to clamp stand and lamp, with transformer and object on ball-jointed rest; (b) Metallographic microscope MIM-6 with camera, lamp and transformer, adapted after (Semenov, 1964).

Semenov's work sparked an ever-increasing interest in micro-wear studies that continues today (Álvarez-Fernández et al., 2020; Bello-Alonso et al., 2020; Berruti & Arzarello, 2020; Berruti & Daffara, 2014; Diamond, 1979; Kamminga, 1979; Keeley, 1974; Lemorini et al., 2014; Marreiros et al., 2020; Marreiros, Mazzucco, Gibaja, & Nuno Bicho, 2015; Martín-Viveros et al., 2020; G. H. Odell, 1975, 1981; Pedergnana & Ollé, 2017; Shea, 1993; Tringham et al., 1974). Semenov was acknowledged as the first archaeologist conducted experiments according to a strict methodological framework, allows classifying and coding the use-wear traces identifying the hardness of the processed material, the direction of the gesture and recording as many variables as possible studying tools functions (e.g., time used, worked material, and strokes per minute) (Berruti & Daffara, 2014; Lambert-Lauriston, 2015; Tringham et al., 1974).

Three major wear types were distinguished by Semeonov: polishing (very fine abrasion), coarse abrasion (in the form of grinding and striations), and "rasping" or chipping of the edge (which is also visible macroscopically) (Tringham et al., 1974). While the recognition of microflaking as indication of tool use were essentially disregarded for what argued as it was difficulty distinguishing the traces from the tool use and deliberate secondary retouch (Keeley, 1974; Keller, 1966; Semenov, 1964; Tringham et al., 1974). Shortcomings regarding his work were highlighted, and the most striking was his experimental tools to be machine manufactured metal instruments made to his specifications (Lambert-Lauriston, 2015). Although he mentioned the hurdles that can confuse the wear interpretation from use and natural causes including, natural abrasion through the agencies of wind and water, patination and weathering changes (Keeley, 1974; Semenov, 1964). In Semenov's work, the wear traces were linked to hypothesized functions of particular tools and still lacked consideration of other possible factors (e.g., post-depositional alterations, weathering, trampling) (Keeley, 1974; Lambert-Lauriston, 2015; G. H. Odell, 1975). Early research involving use-wear analysis emphasized the low-powered method (Kamminga, 1982; G. H. Odell, 1981; Tringham et al., 1974), sometimes known as the "Tringham approach" because of Tringham et al.'s (1974) systematic study on the formation of edge damage from tool use. This approach is typically conducted using a stereoscope with magnifications between 25x and 100x (Grace, 1996a; Murray, 2017). Lawrence Keeley (1980), *Experimental Determination of Stone Tool Uses: a Microwear Analysis*, utilized high powered microscopy to investigate use-wear traces, which allows the identification of micro-traces on the edges of the tools (micro-polish). By using binocular incident-light lab microscope (WILD M20) 400 x over stereomicroscope (WILD M5) 50 x – 200 x, he showed that these micro-traces have different morphologies depending on the processed material, allowing a univocal identification (Berruti & Daffara, 2014; Keeley, 1980; Keeley & Newcomer, 1977; Marreiros, Mazzucco, Gibaja, & Nuno Bicho, 2015; Vaughan, 1985). Due to his contribution, a high-powered approach to microwear analysis is sometimes called the “Keeley approach” or “high-powered approach" (Berruti & Daffara, 2014; Lambert-Lauriston, 2015; Marreiros, Mazzucco, Gibaja, & Nuno Bicho, 2015; Murray, 2017). The high-powered approach has been adopted by many researchers and is one of the standard approaches in use-wear analysis (Fullagar et al., 1992; Jensen, 1988; Keeley & Toth, 1981; Marreiros, Mazzucco, Gibaja, & Nuno Bicho, 2015; Rots, 2005). Currently, the integrated approach between these two use-wear investigation approaches (low and high powered) is considered prominent (Berruti & Daffara, 2014; Lemorini, 2000; Moss, 1983; Plisson, 1983; Vaughan, 1985; Ziggiotti, 2007). The effectiveness of both approaches (Low-powered approach and High-powered approach) has been constantly tested to compare and prove the accuracy of results through the blind testing (Chan et al., 2020; A. A. Evans, 2014; Keeley & Newcomer, 1977; Lambert-Lauriston, 2015; Law-De-Lauriston, 2014; M. Newcomer et al., 1986; M. H. Newcomer & Keeley, 1979; G. Odell & Odell-Vereecken, 1980; Rots & Van Peer, 2006).

3.4 Low-powered approach

Low-powered approach was a steppingstone to the current state of the discipline, systematically introduced by (Semenov, 1957, 1964). Further, the approach was standardized and pioneered by the works of (G. H. Odell, 1975; Tringham et al., 1974). This approach is a lithic analytic method in use-wear analysis that is primarily concerned with the study of utilization damages, which are observable with stereoscopic microscopes (stereoscope) at relatively low magnification (6 x to 200 x) (Grace, 1996b; Keeley & Newcomer, 1977; Lambert-Lauriston, 2015). Stereoscopes are usually rigid, where the two objective lenses are attached to a platform upon which the object being viewed is placed. A three-dimensional view of the object under observation is provided with external reflective light and merging visions from double lenses, which supports the interpretation of the microtopography of the object (Lambert-Lauriston, 2015; Murray, 2017). Low-powered use-wear studies focus on analysing traces of edge damage such as micro flaking, rounding (Grace, 1996b; Keller, 1966; Murray, 2017) and striation and polishes (G. H. Odell & Odell-Vereecken, 1980a). For the effectiveness of this approach, the analyst should consider all types of wear traces (e.g., scarring, rounding, crushing, polish) while analysing the function of the tool instead of focusing only on a specific wear type for interpretation (Law-De-Lauriston, 2014; G. H. Odell, 1981). The extensive limitation of this approach is the failure to precisely determine the specific type of worked materials (G. H. Odell, 1981, 1990; G. H. Odell & Odell-Vereecken, 1980a; Tringham et al., 1974). The application of this approach is more reliable in terms of timesaving for several reasons. The interpretation of the tool functions is relatively fast compared to other approaches (Shea, 1987). The analyst can observe different types of wear traces on the surface of a tool at once while it allows the easy control of light reflection and magnification changes (Law-De-Lauriston, 2014; G. H. Odell & Odell-Vereecken, 1980b). Therefore, it makes the analysis of a large sample size more affordable (Law-De-Lauriston, 2014; G. H. Odell, 1990, 2006). This approach does not necessarily require cleaning the materials prior to analysis (Law-De-Lauriston, 2014). Rots (2005) explained that “Artifact stabilisation under the Low-power microscope is not necessary. The direct association of terminations, striae, rounding, polish, etc. can be appreciated in context with the topographical and morphological characteristics of the tool”(Rots, 2005).

3.5 High-powered approach

High-powered approach of use-wear analysis is defined from its greater magnification at least beyond 200 x. The approach was standardized by the work of (Keeley, 1980) and further adapted as the standard approach to functional analysis in Palaeolithic archaeology (Marreiros, Mazzucco, Gibaja, & Nuno Bicho, 2015). This approach is conducted with compound microscopes such as a metallurgical microscope (Lambert-Lauriston, 2015; Law-De-Lauriston, 2014; Murray, 2017). These microscopes operate with one optical path divided at the eyepiece to provide each eye with the same two-dimensional image. They can reach magnifications up to and sometimes greater than 1000x. However, for this approach of use-wear analysis, the observation magnification is usually 200-400 x (Lambert-Lauriston, 2015; Law-De-Lauriston, 2014; Murray, 2017). The large observable degree of surface variation under the magnifications mentioned above enables the interpretation of polishes responsive to specific contact materials (Law-De-Lauriston, 2014). The major significance of this approach is that it allows the analyst to precisely identify and classify micro-traces (polishes and striations) made by the specific worked material and activities (Keeley & Newcomer, 1977; Lambert-Lauriston, 2015; Marreiros, Mazzucco, Gibaja, & Nuno Bicho, 2015; Murray, 2017). Keeley & Newcomer (1977) emphasized holistic consideration of all wear patterns (e.g., striae, edge damage, or fractures) when interpreting the tool function while highlighting that polish is the most diagnostic use trace when using the high-power method. Nevertheless, many researchers on this approach kept their focus on polishes as a primary indicator of tools functions, e.g. (Diamond, 1979; Kamminga, 1979; Keeley & Toth, 1981; Meeks et al., 1982; Ollé & Vergès, 2008; I. L. Sala, 1996; Unger-Hamilton, 1984). A high-powered approach allows the determination of the used edge of a tool, specific worked materials and tool motion with a high degree of accuracy. But also, it can help to distinguish the impacts of tools manufacture, use, secondary modification (Rots, 2003) and post-deposition alterations (Burroni et al., 2002). This approach imposes the limitation of being time-consuming since it takes longer to analyse a part of one sample and the operation of the microscope is more complex. Therefore, this approach is undoubtedly limited to the small sample size analysis.

3.6 Other use-wear analysis approaches

For the modern period of use-wear analysis, researchers have rapidly invented new approaches to quantify the use-wear investigations and confront newly established supplementary approaches (Berruti & Daffara, 2014; Marreiros, Mazzucco, Gibaja, & Bicho, 2015; Murray, 2017). Other methods that have been developed include the “Ultra High-Power Approach”

(Kamminga, 1979) using scanning electron microscopes and atomic force microscopes (Kimball et al., 1995), the profilometry (Beyries, 1988), the analysis of residues (Fullagar & Gaudey, 1994), image-processing technique (Grace et al., 1985).

3.6.1 Image-based approach

In attempts to rectify some hurdles of use-wear analysis approaches during the new wave of modern era, early studies employed image-processing techniques for observing micro-polishes produced by different worked material (González-Urquijo & Ibáñez-Estévez, 2003; Grace, 1989; Grace et al., 1985; Murray, 2017; M. Newcomer et al., 1986). The methodology and conclusions produced by the authors (Grace, 1989; Grace et al., 1985; M. H. Newcomer et al., 1988) were refuted (Bamforth, 1988; Hurcombe, 1988; Moss, 1987). Later the new methods have shown that polishes are distinguishable from one another (González-Urquijo & Ibáñez-Estévez, 2003; Kimball et al., 1995; Stemp & Stemp, 2001); thus, the previous methodology was disregarded. Vergès & Morales (2014) used image-based techniques to create better documentation of Scanning Electron Microscopy (SEM) use-wear photographs, while, Bird et al (2007) improved the method by creating a multi-faceted approach using imagery, Geographic Information Systems (GIS), and statistics. Rather than focusing on quantifying micro-polishes, the authors intended to measure and assess macroscopic "edge damage" distribution; therefore, this approach can be done with the naked eye or a simple stereoscope rather than using high powered microscopy. An early example of looking at edge damage distributions was by Shea (1993) in his analysis of impact fractures in Levantine Mousterian points. Bird's et al (2007) methodology was later expanded and has been consistently refined over the past few years (B. Schoville & Brown, 2010; B. J. Schoville, 2010, 2014; B. J. Schoville et al., 2016; Wilkins et al., 2012; Wilkins & Schoville, 2016). The distinction between Schoville's methodology and that of Bird includes using an experimental dataset (B. Schoville & Brown, 2010; B. J. Schoville et al., 2016; Wilkins & Schoville, 2016), the increased attention to post depositional modification processes (B. J. Schoville, 2014), and the visual representation of the statistical results. However, the method has been criticized by Rots & Plisson (2014) for insufficient evidence on individual tools to determine the function and various misinterpretations of the use-wear signatures (Murray, 2017; Rots & Plisson, 2014; Wilkins et al., 2012, 2015).

3.6.2 Surface Metrology

Technological advancements and integrated research designs influenced the development of more sophisticated approaches of use-wear analysis in the modern era, where the quantification of use-wear analysis has been aided by studies utilizing surface metrology. Surface metrology is the measurement and characterization of an object's micro-topography, usually with the aid of scanning or laser microscopy (Murray, 2017). Different models have been developed and successfully managed to describe the rough surfaces from an archaeological point of view, such as those developed by Brown & Savary (1991), Chauvy et al. (1998), Majumdar & Tien (1990), and Malinverno (1990). In recent times the increase of new approaches is substantially contributed to the expansion of the field and the invention of new methods (Murray, 2017; Stemp & Stemp, 2001).

3.6.2.1 UBM Laser profilometry

UBM Laser profilometry was developed and first used by Stemp & Stemp (2001) to quantify use-wear analysis of experimental collection (Murray, 2017). The approach involves the laser profilometer measurements and fractal geometry, specifically a length-scale fractal analysis quantifying the surface micro-topography on various scales (Avdelidis et al., 2007; Stemp, 2014; Stemp et al., 2009). The method accurately documented various stages of polish formation in lithic tools (Ibáñez & Mazzucco, 2021; Stemp, 2014; Stemp & Stemp, 2001, 2003).

3.6.2.2 Interferometry

In investigating microwear traces on the flint blades of threshing sledges, Anderson et al. (2006) used the interferometer microscope to study the topography of the lithic tools. The vertical-scanning interferometer was used to obtain a section of light showing the surface topography of the lithic objects and scan the surface at varying heights. The process eventually, through an algorithm in the standard height, converts the observed light intensities (Anderson et al., 2006: 1565) in 3D presentation (Anderson et al., 2006; Murray, 2017).

3.6.2.3 Atomic Force Microscopy (AFM)

The method was first developed and applied by Kimball et al. (1995) as a supplementary approach after high-powered microscopy to identify micro-wear in lithic tools (Kimball et al., 1995; Murray, 2017). (AFM) uses the atomic forces between two materials to digitally map a 3D surface with one nanometre resolution (Kimball et al., 1995:10). The AFM requires the sample to be moved through piezoelectric ceramics, which physically expands or contracts the material when voltage is applied. The voltages are then monitored, and the digital map of the surface or microtopography is created. The maps can then be analysed for grain size, height profiles, and surface roughness. Surface roughness can effectively portray use-wear traces in lithic artifacts (Faulks et al., 2011; Kimball et al., 1995; Murray, 2017).

3.6.2.4 Laser-Scanning Confocal Microscopy (LSCM)

Evans & Donahue (2008) developed the laser-scanning confocal microscopy approach. The LSCM approach combines the traits of surface metrology, atomic force microscopy and laser profilometry with the high magnification and depth of field offered by an SEM. Initially, the Olympus LEXT 3100 laser scanning confocal microscope (LSCM), which is typically utilized for metrology, was used (A. A. Evans & Donahue, 2008; Murray, 2017). The microscope creates an image through the reflected light from a discrete focal plane (A. A. Evans & Donahue, 2008: 2225). LSCM has been used extensively in lithic assemblages use-wear research and proved to provide good results (Álvarez-Fernández et al., 2020; A. A. Evans et al., 2014; A. A. Evans & Donahue, 2008; A. A. Evans & Macdonald, 2011; Galland et al., 2020; Ibáñez & Mazzucco, 2021; Key et al., 2015; Macdonald et al., 2018; Macdonald & Evans, 2014; Stemp et al., 2018, 2015). Evans & Macdonald (2011) did a comparative experiment to assess the effectiveness of the method when a new approach was defined 'focus variation microscopy' and further experimentally refined by Macdonald (2014) (Álvarez-Fernández et al., 2020; Murray, 2017).

3.6.3 Residual analysis

The idea of the residual analysis approach paved its initial recognition after Schleiden (1849) reported that the optical properties of starch grains could be utilized to identify the grains to the species level (Lambert-Lauriston, 2015). However, it was not until the following century that knowledge was brought into archaeology (e.g., Briuer, 1976; von Stokar, 1938). Residue analysis is primarily concerned with different organic, and inorganic remains that may be termed residues (e.g., phytoliths, blood, starch grains, wood, hair, pollen, and even soil) (Fullagar & Matheson, 2013; Haslam, 2006; Lambert-Lauriston, 2015; Marreiros, Mazzucco, Gibaja, & Bicho, 2015; Murray, 2017). (Grace, 1989: 5) describes residue analysis as the study of deposits on lithic technology that may or may not be related to use (Murray, 2017). Therefore, the spatial relationship between use-wear signatures (e.g., microfractures, cracks, and micro-striations, or stuck) and residues must be linked (Haslam, 2006; Langejans, 2010; Marreiros, Mazzucco, Gibaja, & Bicho, 2015; Murray, 2017; Wadley et al., 2004; Wadley & Lombard, 2007). Thus far, this approach has managed to retrieve many indications of worked materials in lithic artifacts such as blood and muscular tissue (Gernaey et al., 2001; Gurfinkel & Franklin, 1988; Kooyman et al., 1992; Loy, 1983; Loy & Hardy, 1992; Nowell et al., 2016;

Tuross et al., 1996; Walton, 2022), amid (Barton, 2007, 2009; Lu, 2003; Marreiros, Mazzucco, Gibaja, & Bicho, 2015), animal products such as meat, feather, bone, scales, barbules, fish scales and collagen or hair fibers (Hardy & Moncel, 2011; Jans et al., 2004; Marreiros, Mazzucco, Gibaja, & Bicho, 2015; Walton, 2022), lipids and fat acids (Copley et al., 2001; Evershed, 2008; Evershed et al., 2002), plant remains and microfossils (phytoliths, pollens, etc.), and pigments (Blanchette, 2000; Hardy & Garufi, 1998; Jahren et al., 1997; Kealhofer et al., 1999; Mercader et al., 2019, 2021, 2022; Rots et al., 2015; Zucol et al., 2022)

4. EXPERIMENTAL ARCHAEOLOGY

Experimental Archaeology is a research method used by archaeologists to investigate and interpret archaeological data (Armenio, 2019; Astruc et al., 2003; Cattani, 2016; Coles, 2009; Flores, 2012; Marreiros et al., 2020; Outram, 2008; Rademakers et al., 2021; Reynolds, 1999). Experimental archaeology refers to the part of archaeological science that involves testing theories and hypotheses through actualistic studies and interpretation reflecting the ancient phenomenon (Armenio, 2019; Coles, 1979; Lin et al., 2018; Marreiros et al., 2020; Outram, 2008). Reynolds (1999) proposed the term hypothesis instead of interpretation in experimental activities. "Rather than use the term 'interpretation', which implies full comprehension, the term 'hypothesis' is substituted. The hypothesis implies a deduced or reasoned conclusion that can be further subjected to a test or trial to confirm or deny that conclusion. The testing method is called an experiment" (Reynolds, 1999: 387). Therefore, Experimental Archaeology aims to imitate past phenomena to verify the hypothesis of interpretations and acquire more excellent knowledge in Archaeology (Armenio, 2019; Cattani, 2016; Lin et al., 2018; Marreiros et al., 2020; Outram, 2008). Based on practical experimental observations and comparative implications, reasonable interpretations of the archaeological record can be inferred (Gaudzinski-Windheuser et al., 2018; Marreiros et al., 2020).

Lithic use-wear studies have been regarded as prominent functional analyses in archaeology and the direct research approach to interpreting past human behaviour and prehistoric technology (Marreiros et al., 2020; Semenov, 1964; Shea, 2011). Experimental Archaeology is the essential procedural approach in archaeology to investigating lithic use-wear traces since it offers insights into the initial recognition of definite traces produced by various anthropogenic activities and natural factors (Murray, 2017). In the studies of lithic use-wear traces, the use of Experimental Archaeology began in the early period of the discipline, e.g. (F. Sehested & Bernhard, 1884; Spurrell, 1884, 1892). However, the standard procedures for

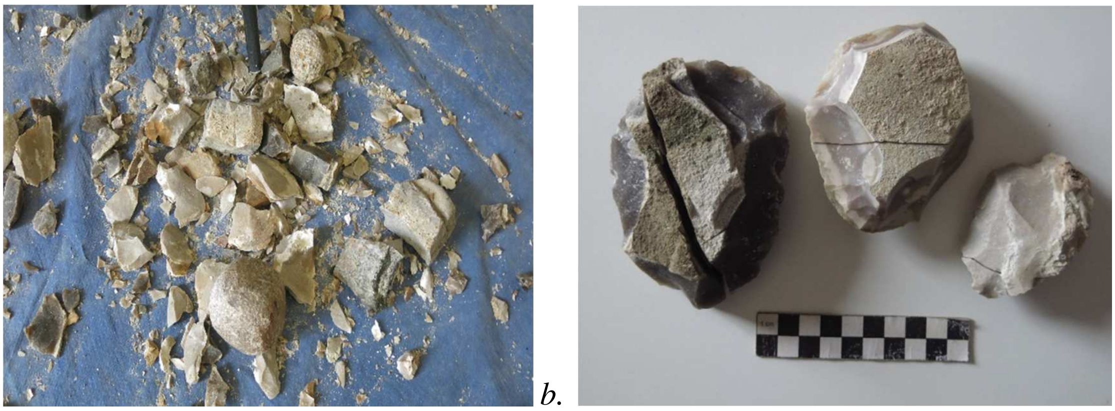
Experimental Archaeology in lithic use-wear investigations were initially characterized by (Semenov, 1957, 1964) and further well clarified regarding the Low-powered approach (G. H. Odell, 1975; Tringham et al., 1974) and the high-powered approach and the integrated method (L. Keeley, 1976; L. H. Keeley & Newcomer, 1977; Lawrence H Keeley, 1980). For this work, the experimental design and protocols will follow the integration of essential set critique standards of early fundamental works (Keeley, 1980; Keeley & Newcomer, 1977; G. H. Odell, 1975; Tringham et al., 1974).

4.1 Experimental Design

Experimental Archaeology in this work is intended to determine the function of replicated lithic tools by assessing the specific imprints left in the lithic tools after a particular activity on different worked materials. The guiding hypothesis is inferred from Guado San Nicola's archaeological context, former assemblage's functional study and bifaces functional interpretations from other studies. Carcasses processing activities are prevalent in Guado San Nicola's assemblage, as shown by faunal composition and zooarchaeological study (Muttillo et al., 2014; Peretto et al., 2016) and previous use-wear analysis of Levallois flakes and *façonnage* flakes (Berruti, 2017; Berruti et al., 2020). The evidence of plants processing is underrepresented in a previous use-wear study at Guado San Nicola (Berruti et al., 2020). Other bifaces functional studies have shown the tools to be useful in various ways and activities such as woodworking, digging and bone working (É. Claud et al., 2015; Keeley, 1980; Murray, 2017; Viallet, 2016a, 2016b).

4.2 Experimental preparation

Experimental tools were made (n=13) bifaces of flint from the Isernia Basin, like the predominant raw materials used for archaeological assemblage. The knapping technique is basically a hard hammer, while the final stages of bifacial shaping use a soft organic hammer. Generally, two significant independent variables were considered during the production of the tools, raw materials consideration, and the general morphology of the tools. The quality of raw materials for experimental tools production was somehow characterized by those inevitable internal fractures, which primarily presented the technical confinement as evident in stone tools (Figure 4.1).



a. *b.*

Figure 4.1. Breakage of lithic raw materials as an impact of internal fractures; a. broken flint chunks during the knapping process, b. experimental bifacially made large cutting tools impacted with internal fractures.

Each tool was given a unique experimental tool number, tools measurements were taken and recorded, and all the edges and tips on a tool were labelled separately. The sketches of the tools were made to present the specific edges (Table 4.1). However, the experimentation was extended for the training purpose by adding supplementary experimental scope that involves flakes. Additional experimental tools (n=13) flakes were selected by considering the efficiency of working edges. All the flakes were assigned to an experimental tool number and the measurements were taken and recorded. Sketched documentation was made for all the tools, and the edges were indicated respectively (Table 4.1).

a. 

.

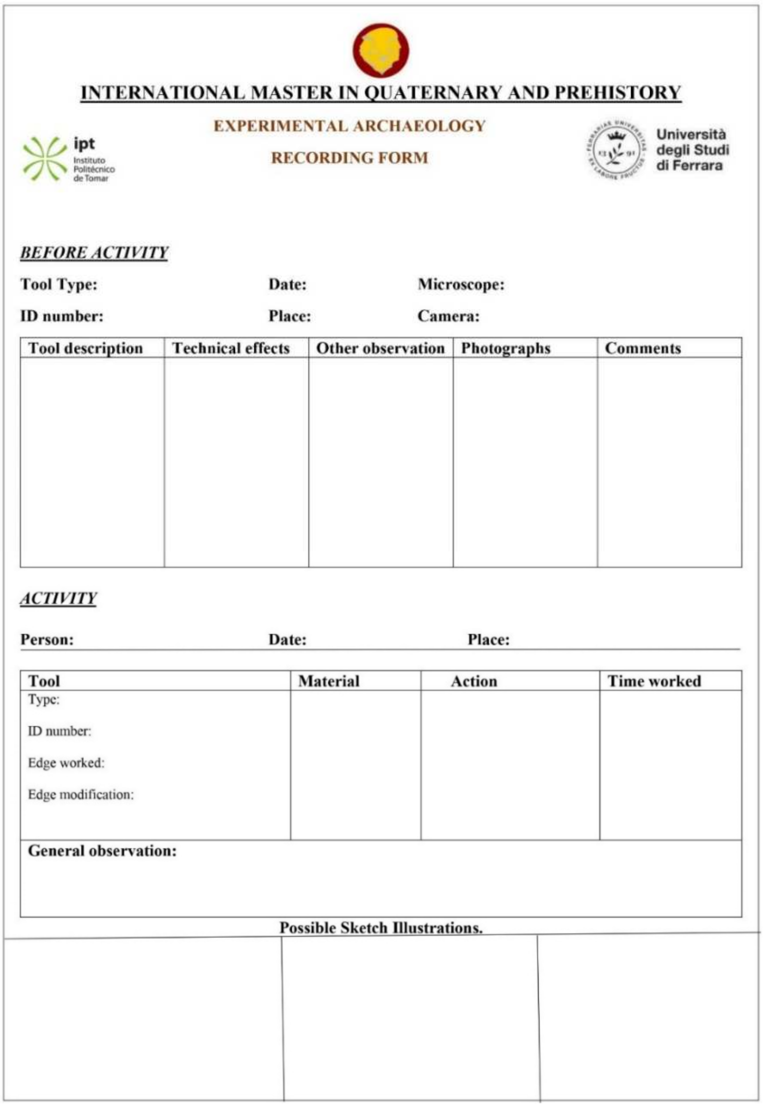
b. 

Figure 4.2. Pictures of experimental tools collection; a. Experimental flakes b. Experimental bifaces.

Bifaces	Length	Width	Thickness	Edge 1	Edge 2	Tip
ExB-01	82.45mm	46.92mm	30.65mm	ExB-01_1	ExB-01_2	ExB-01_T
ExB-02	103.00mm	78.58mm	30.80mm	ExB-02_1	ExB-02_2	ExB-02_T
ExB-03	95.30mm	74.50mm	31.65mm	ExB-03_1	ExB-03_2	ExB-03_T
ExB-04	78.00mm	44.00mm	28.40mm	ExB-04_1	ExB-04_2	ExB-04_T
ExB-05	75.00mm	50.00mm	16.88mm	ExB-05_1	ExB-05_2	ExB-05_T
ExB-06	70.55mm	45.69mm	28.35mm	ExB-06_1	ExB-06_2	ExB-06_T
ExB-07	106.85mm	50.10mm	26,58mm	ExB-07_1	ExB-07_2	ExB-07_T
ExB-08	99.89mm	64.92mm	29.45mm	ExB-08_1	ExB-08_2	ExB-08_T
ExB-09	95.15mm	68.95mm	31.00mm	ExB-09_1	ExB-09_2	ExB-09_T
ExB-10	73.95mm	48.98mm	25.82mm	ExB-10_1	ExB-10_2	ExB-10_T
ExB-11	81.95mm	65.80mm	24.97mm	ExB-11_1	ExB-11_2	ExB-11_T
ExB-12	106.00mm	79.97mm	37.10mm	ExB-12_1	ExB-12_2	ExB-12_T
ExB-13	123.80mm	80.00mm	43.38mm	ExB-13_1	ExB-13_2	ExB-13_T
Flakes	**Length**	**Width**	**Edge 1**	**Edge 2**	**Proximal end**	**Distal end**
ExF-01	63.02mm	33.62mm	ExF-01_1	ExF-01_2	ExF-01_P	ExF-01_D
ExF-02	33.08mm	20.98mm	ExF-02_1	ExF-02_2	ExF-02_P	ExF-02_D
ExF-03	32.97mm	13.00mm	ExF-03_1	ExF-03_2	ExF-03_P	ExF-03_D
ExF-04	32.75mm	27.05mm	ExF-04_1	ExF-04_2	ExF-04_P	ExF-04_D
ExF-05	60.89mm	29.22mm	ExF-05_1	ExF-05_2	ExF-05_P	ExF-05_D
ExF-06	44.21mm	23.35mm	ExF-06_1	ExF-06_2	ExF-06_P	ExF-06_D
ExF-07	30.85mm	22.46mm	ExF-07_1	ExF-07_2	ExF-07_P	ExF-07_D
ExF-08	43.65mm	23.65mm	ExF-08_1	ExF-08_2	ExF-08_P	ExF-08_D
ExF-09	76.90mm	53.60mm	ExF-09_1	ExF-09_2	ExF-09_P	ExF-09_D
ExF-10	43.14mm	19.40mm	ExF-10_1	ExF-10_2	ExF-10_P	ExF-10_D
ExF-11	54.16mm	25.40mm	ExF-11_1	ExF-11_2	ExF-11_P	ExF-11_D
ExF-12	68.00mm	30.79mm	ExF-12_1	ExF-12_2	ExF-12_P	ExF-12_D
ExF-13	61.30mm	57.72mm	ExF-13_1	ExF-13_2	ExF-13_P	ExF-13_D

Table 4.1. A table represents the numbers, measurements, and details of experimental tools separately for Experimental bifaces (ExB) and Experimental flakes (ExF).

An experimental preparation database was made, including all the details, sketches and photographs of the edges and tips of the entire experimental assemblage. The purpose of this protocol and database is to enhance training aid during the data analysis process in determining the tools function according to specific wear traces left on a lithic tool. All the tools then were assessed microscopically using a stereoscopic microscope 8x-35x (LEICA EZ4HD) under the magnifications of 8x, 16x and 25x, and Optika metallographic microscope (40x-500x) under the magnifications of 40x and 100x. All the edges and tips were photographically documented under these magnifications using microscopic built-in cameras, and technical effects were also identified and documented.


INTERNATIONAL MASTER IN QUATERNARY AND PREHISTORY

ipt Instituto Politécnico de Tomar

EXPERIMENTAL ARCHAEOLOGY

RECORDING FORM

Università degli Studi di Ferrara

BEFORE ACTIVITY

Tool Type: **Date:** **Microscope:**

ID number: **Place:** **Camera:**

Tool description	Technical effects	Other observation	Photographs	Comments

ACTIVITY

Person: **Date:** **Place:**

Tool	Material	Action	Time worked
Type: ID number: Edge worked: Edge modification:			
General observation:			

Possible Sketch Illustrations.

Figure 4.3. Experimental archaeology recording form

4.3 Experimental activities

Experimental activity protocols are adapted from (Keeley, 1980) and somehow refined following the protocols of (Tringham et al., 1974). The considered variables include the action of the utilization and worked materials. The materials worked and actions of tools in processing the materials are summarized in the table below (Table 4.2). The tools were used to work on different materials, and each edge was subjected to a single activity. Tringham et al. (1974) defined the direction of the edges to the worked materials as longitudinal (unidirectionally-cutting; bidirectionally-sawing), transverse (scraping; shaving; planning), circular motion (boring) (Tringham et al., 1974). Additional action motion is high-intensity activities mainly utilizing the distal end of the tools. (e.g., chopping, adzing, digging, and shucking) (Keeley, 1980; Murray, 2017), which are all combined into "percussive activities" (É. Claud et al., 2015; Lambert-Lauriston, 2015; Murray, 2017; Viallet, 2016b). The classification of some specific activities as described by (Tringham et al., 1974) represented below as follows;

Cutting, is a one-way movement of a tool on a working material, while a flake held at various angles to worked material.

a.  b. 

Figure 4.4. Experimental pictures representing meat cutting (Butchering) activity with a. biface; b. a flake

Sawing refers to a two-way movement of a tool on a working material, while the tool held at a position of 90°.

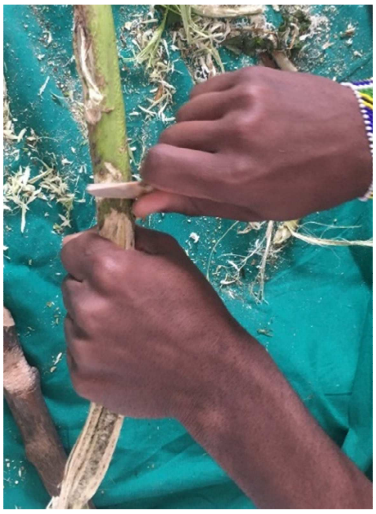
a.  b. 

Figure 4.5. Experimental pictures representing sawing activities **a.** a biface on antler; **b.** a flake on fresh wood

Transverse actions are variously defined as "**scraping**," "**shaving**", or "**planning**", depending on whether the one-way movement is towards or away from the operator and the angle of a flake to the worked material during activity performance.

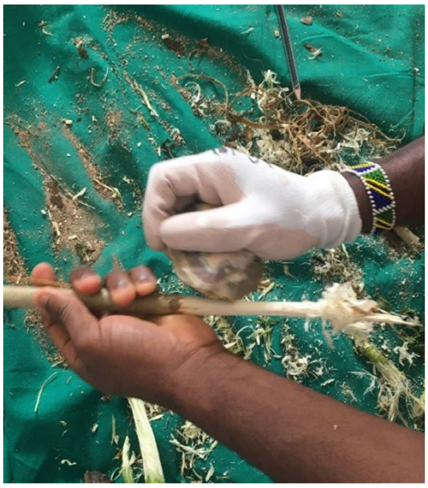
a.  b. 

Figure 4.6. Experimental pictures represent scraping activities a. biface on fresh wood; b. a flake on dried wood.

Boring refers to a highly localized contact of a point or projection of a flake with the worked material in a circular movement, held at 70°-90° to the worked material.

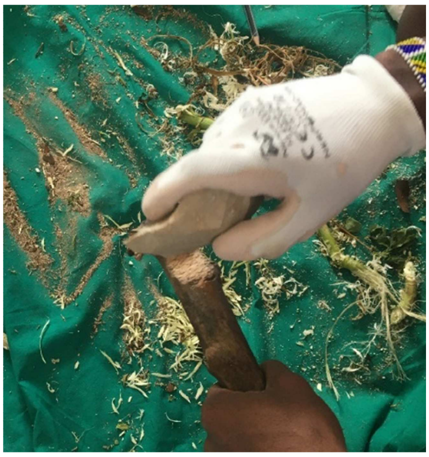
a.  *b.* 

Figure 4.7. Experimental pictures represent a. chopping a dry wood with a biface, b. Digging

Activity	Materials	Tool ID		Edge used		Time worked	
		EXF	**EXB**	**EXF**	**EXB**	**EXF**	**EXB**
Sawing	Antler	EXF-13	EXB-02	2	1	13 Min	13 Min
	Fresh bone	EXF-03	EXB-05	2	2	13 Min	12 Min
	Fresh wood	EXF-11	EXB-10	2	2	13 Min	15 Min
	Dried wood	EXF-12	EXB-12	2	1	15 Min	20 Min
Cutting	Meat	EXF-05	EXB-01	1	2	10 Min	10 Min
	Plant leaves	EXF-07		2		13 Min	
	Dried skin	EXF-02	EXB-02	P	1	10 Min	10 Min
Scraping	Dried wood	EXF-12	EXB-11	1	2	12 Min	15 Min
	Fresh wood	EXF-10	EXB-03	2	2	13 Min	12 Min
Chopping	Fresh bone	-	EXB-06		2		07 Min
	Fresh wood	EXF-09	EXB-04	1	1	13 Min	13 Min
	Dried wood	EXF-08	EXB-09	1	2	10 Min	12 Min
	Digging		EXB-07		T		12 Min

Table. 4.2. A table represents a summarized recording of experimental activities, worked materials, tools used, and tool use time.

5. ARCHAEOLOGICAL MATERIALS AND USE WEAR ANALYSIS METHODS

5.1 Archaeological materials

Most currently accessible artifacts analysed for this study were recovered from Guado San Nicola stratigraphic unit B, and very few from unit C. All the tools stored at the University of Ferrara were considered for analysis, apparently without exemption. Therefore, a total of ten artifacts were analysed for this study (Table 5.1).

#	Artifact Id	S. U	Field No	Length	Width	Thickness	Cortex
1	AR.14	B		68.05mm	39.38mm	30.10mm	Absent
2	I. 16	B	No. 161	62.41mm	46.13mm	21.75mm	Present
3	L. 15	C	No. 81	89.50mm	55.00mm	28.92mm	Present
4	Q. 09	B	No. 669	116.40mm	57.55mm	35.28mm	Present
5	AQ. 15	B	No. 57	69.75mm	39.95mm	31.04mm	Present
6	Q. 77	B	No. 497	84.02mm	46.57mm	21.70mm	Absent
7	I. 13	B	No. 21	99.93mm	62.56mm	28.07mm	Present
8	N. 16	B	No. 10	78.17mm	56.80mm	31.83mm	Absent
9	H. 75	C	No. 35	101.51mm	51.30mm	36.25mm	Present
10	M. 14	B	No. 314	103.62mm	47.39mm	36.38mm	Present

Table 5.1. A table presents measurements of all analysed archaeological tools.

Statistically, 7% of the whole bifacial assemblage from Guado San Nicola was analysed, including 9.3% and 4.7% of the entire bifacial artifacts collection from Stratigraphic units B and C, respectively. Generally, the total investigated sample (n=10) comprises (n=8) of artifacts from unit B and (n=2) of artifacts from unit C, whereby all the artifacts were measured, and the recorded measurements are presented in the table above (Table 3). The collection is characterized by comprehensive variation in morphology, appearance, and size (Figure 5.1). Nevertheless, further statistical descriptions and comparisons of the assemblage are considered unnecessary concern to this study.

Figure 5.1. An image of all archaeological artifacts intended for this study

5.2 Integrated analytic approach

Analytical approaches in this work involve the low-powered approach (Tringham et al., 1974) and the high-powered approach (Lawrence H Keeley, 1980) extensively. The macroscopic approach, e.g. (Andrefsky, 1998; Young & Bamforth, 1990), has been reliably disapproved as the method does not include the use of microscopes. Odell (2006) argued that microscopic magnification is necessary for use-wear analysis to identify wear traces resulting from tool use. Therefore, the macroscopic approach is generally disregarded in use-wear discussions (Law-De-Lauriston, 2014). However, recent use-wear analysis methodological review complimented the approach (Marreiros et al., 2020). Therefore, visible (with naked eyes) traces and damages were observed, documented, and analysed. They are also a significantly informative indicator of tools functional analysis and at least for training purposes in this work.

5.3 Materials Cleaning

Before the analysis, all experimental tools were gently cleansed with warm water and soap. Then, all experimental and archaeological tools were subjected to electronic rinse in an ultrasonic cleaning tank (2013_VDEMA-USR 1400/70 E) (Figure 5.2) for eight minutes and sixteen minutes respectively, in a mixture of water (50%), denatured ethyl alcohol 90° - 524/96 (45%) and soap (5%). The tools were dried in an open-air environment before analysis. However, due to feasible handling contaminations, some tools were further cleaned immediately before and or during the analysis using alcohol and cotton swabs.

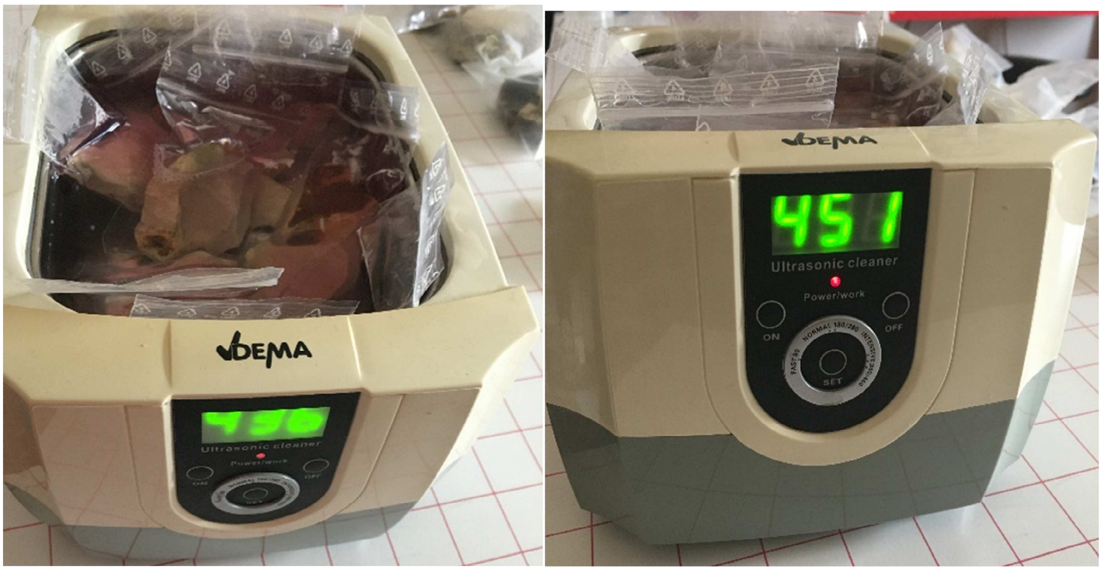


Figure 5.2. Images of an ultrasonic cleaning tank during the materials cleaning process

5.4 Microscopic analysis

The microscopic analysis of the materials pertaining this study was conducted at Ferrara University research facility in Italy. The study employs two different microscopes including a stereoscopic microscope-LEICA EZ4HD (8x-35x) (Fig. 5.3a) for Low-powered approach, and metallographic microscope-OPTIKA_B383MET (40x-500x) with a built-in camera 4083.B3 (Fig. 5.3b) for high-powered approach. An archaeological analysis recording form was designed to document all the procedures and observations during the analysis process

(Appendix 1). All the analysis results for archaeological and experimental tools are presented on the next chapter.

a

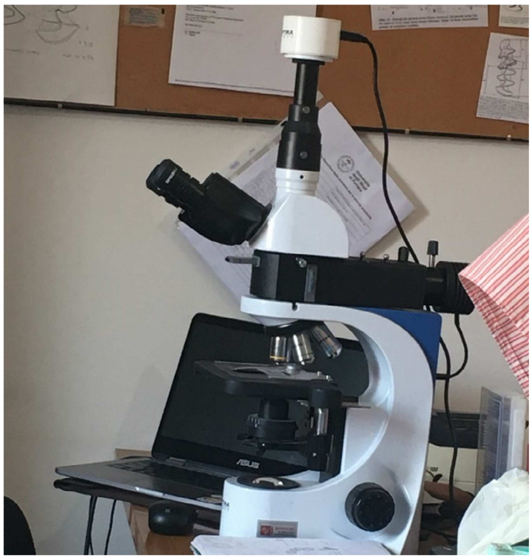
b


Figure 5.3. Images of microscopes, a. Stereoscope b. Metallographic

6. RESULTS

6.1 Experimental Assemblage

This section presents the observation and analysis results of experimental tools according to different activities and worked materials. The section incorporates the results and observation of both experimental flakes and experimental bifaces. Including macroscopic observation, the integrated analytical approach of lithic use wear analysis employed by combining the Low-powered approach and High-powered approach.

Scraping

Dry wood, tools used for scraping dry wood portrays uniform edge removal scars with the structure retained. However, it shows the progression and change of the scars size from minimal to more basin like. The subjected changes of scars size perhaps impacted by the general performance on how the tool were held during the activity. The traces are observed from both sides, although only well-developed on dorsal side of a flake. Slight signs of polishes are hardly visible.

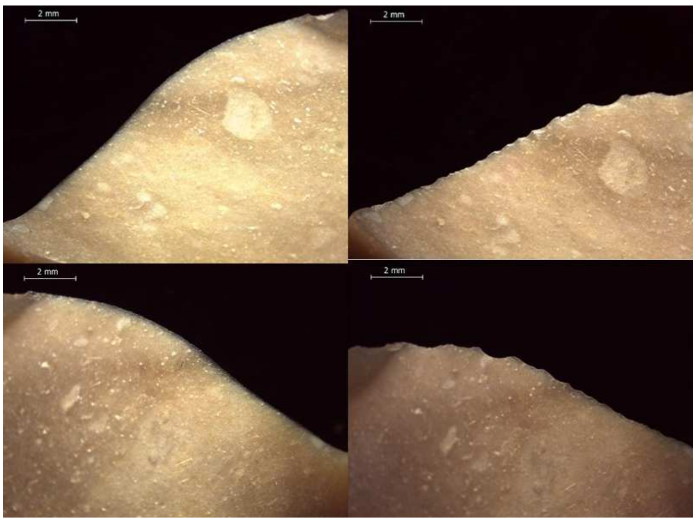


Figure 6.1. Microscopic pictures of the edge used on scraping a dry wood under 8x magnification before and after the use, upper is the dorsal side and lower is ventral side of a flake.

Fresh wood, scraping of fresh wood shows minimal traces of abrasion which can be observed in high magnification and very small sized traces of edge removal. A limited micro flakes detachment on the edge was also observed (Figure 6b). The clear traces of edge removal and very slight polishes can be spotted only with high-powered microscope (Figure 6a), although polishes are very minimal developed with limited distribution. Nevertheless, edge removal traces seem to develop and dispersed equivalently to those of scrapping a dried wood, only they are tiny.

a.

b.

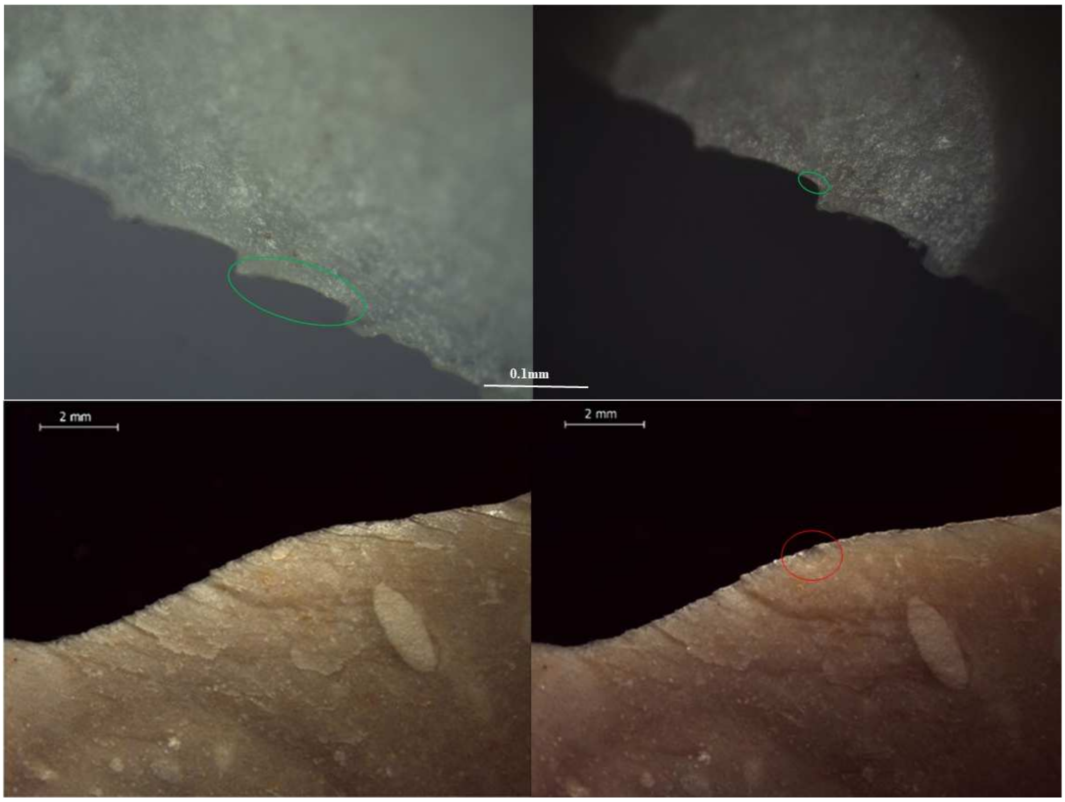
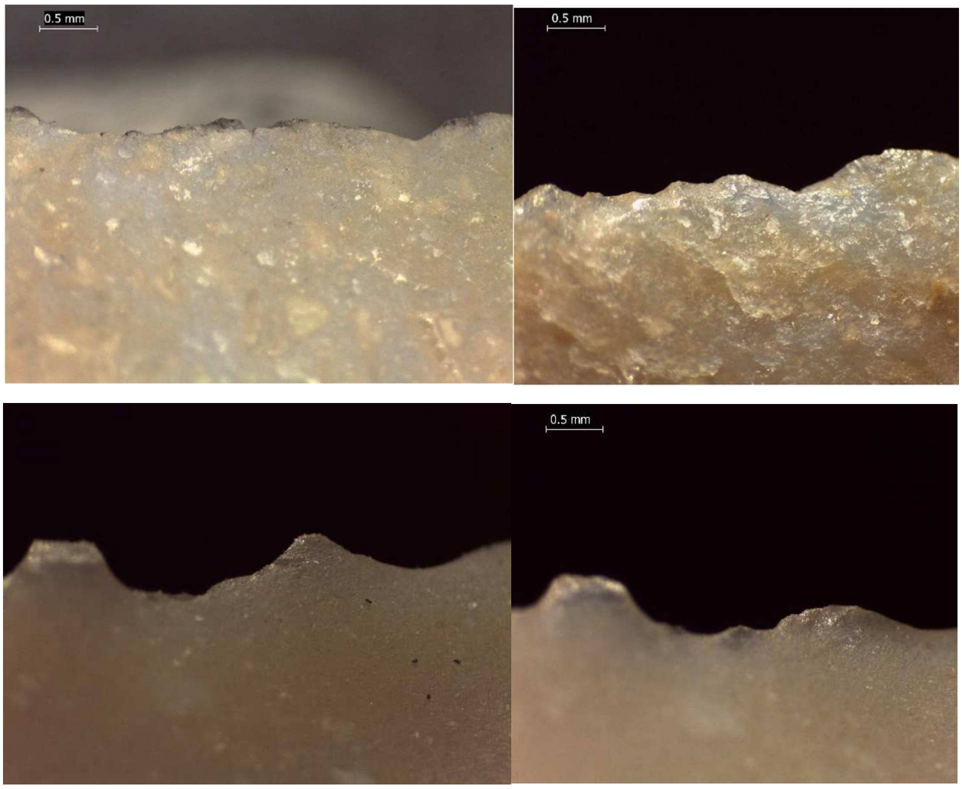


Figure 6.2. Microscopic images of the edge used for scraping a fresh wood before and after use; a. Traces of the scraping edge observed only from 100 x magnification under metallographic microscope, marked green are the surfaces developed sign of micro polishes b. The edge of a flake under 8x magnification, marked red is a stepped micro flake detachment scar.

Sawing

Fresh bone, lithic tools worked on fresh bone for sawing portrayed the development of polish in lower medium scale, abrasion and marginally edge removal, mainly presented in triangular form and obviously from both sides of the tool. Also, the removal of micro flakes can be identified from both sides with the stepped micro flake scars.

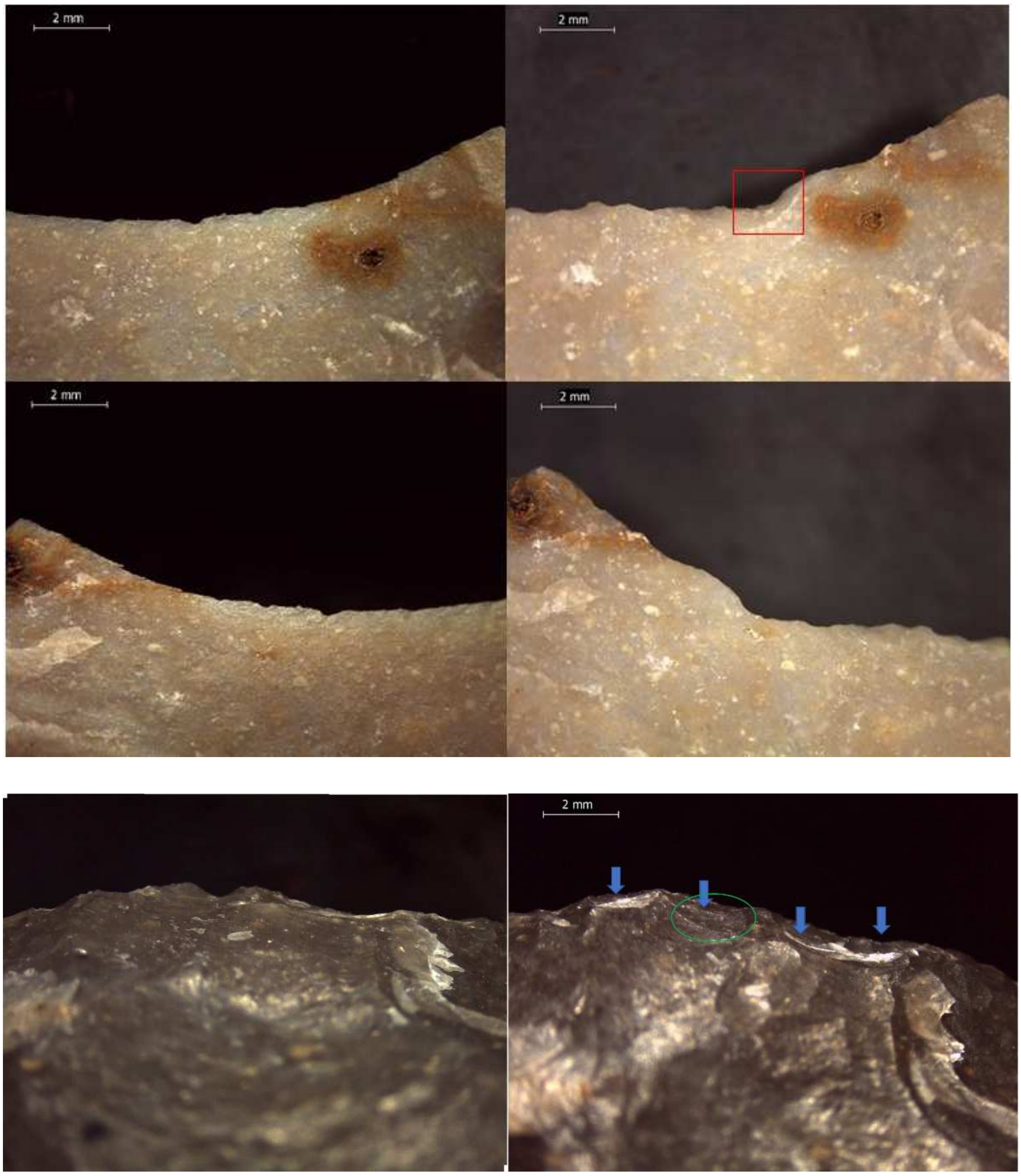


a.

b.

Figure 6.3. Microscopic images of edges used for sawing fresh bone before and after the activity under 25x magnification, a. The edge of a flake; b. The edge of a biface.

Antler, the tools worked on antler in this activity presenting a slight development of polish and scalar edge removal scars in rectangle shape and somehow amorphous. Also, stepped micro flakes detachment are presented from both sides. However, despite the angle of sawing being 90°, the stepped flake scars are more pronounced on the ventral side of the tool. Both experimental flake and biface used for this activity presents similar ultimate effects and they were effective during activity performance.



a.

Figure 6.4. Microscopic images showing edges of the tools used for sawing an antler; a. Images of an edge of a flake under 8x magnification before and after the use, ventral side on the top and dorsal side below. Marked red is a stepped detachment scar for edge removal with sign of polish; b. Images of an edge of a biface before and after the use shows the traces under 8x magnification, pointed with blue arrows presents edge deformation and marked green is an example of observed polishes.

Dry wood, the tools worked on a dry wood presents micro flakes detachment most likely to those from antler but less developed. The detachment scars have no definite structure and more pronounced on the dorsal side of the tool. Well developed and widely scattered polish are also presented on a tool used for this activity and can only be observed under the high-powered microscope.

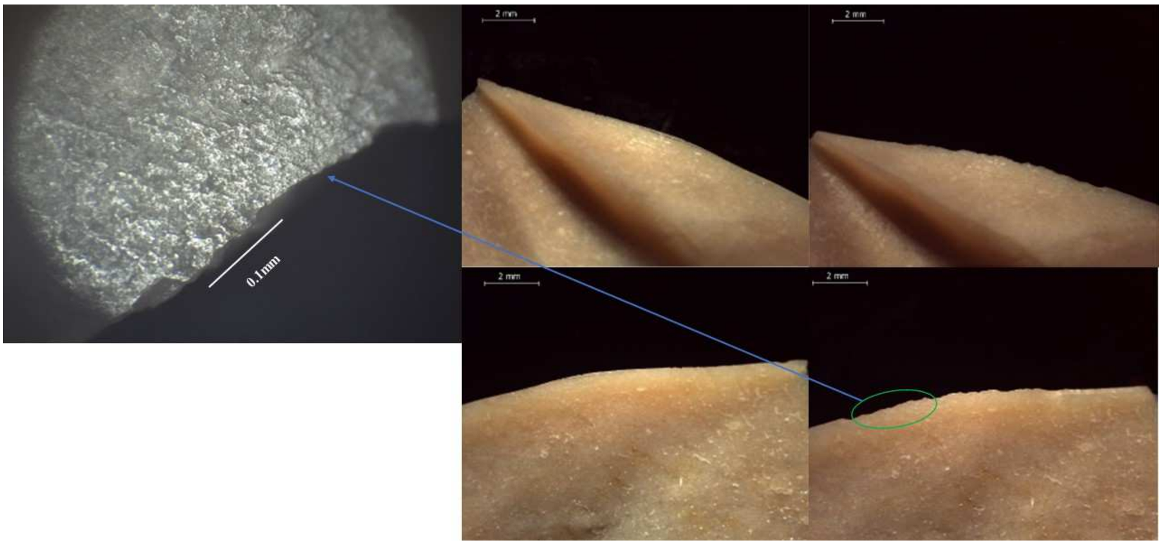


Figure 6.5. Microscopic pictures of the edge used in sawing a dry wood before and after the activity, at the top is a dorsal side of a flake followed by the ventral side before and after the use under 8x magnification.

Fresh wood, the tools worked for sawing on a fresh wood presenting relatively pristine edges, however slight abrasion traces and less developed polish can be observed from the magnification of 25 x.

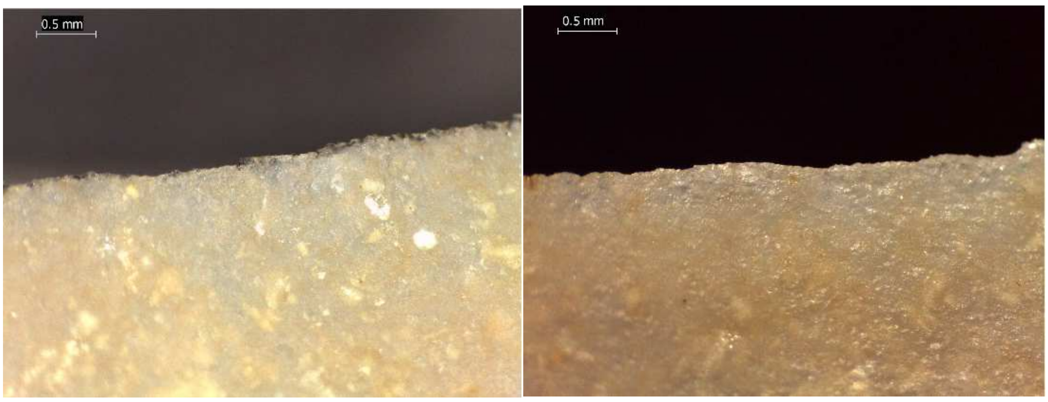


Figure 6.6. Microscopic pictures showing the edges of a flake used for sawing a fresh wood before and after the use under 25x magnification

Cutting

Meat, wear traces can be seen from the magnification of 25x. Developed scalar edge deforms from abrasion are observed in triangle shaped. The wear features are not well developed but can be observed from both sides. Random scatters of polish development are also available along the used edge.

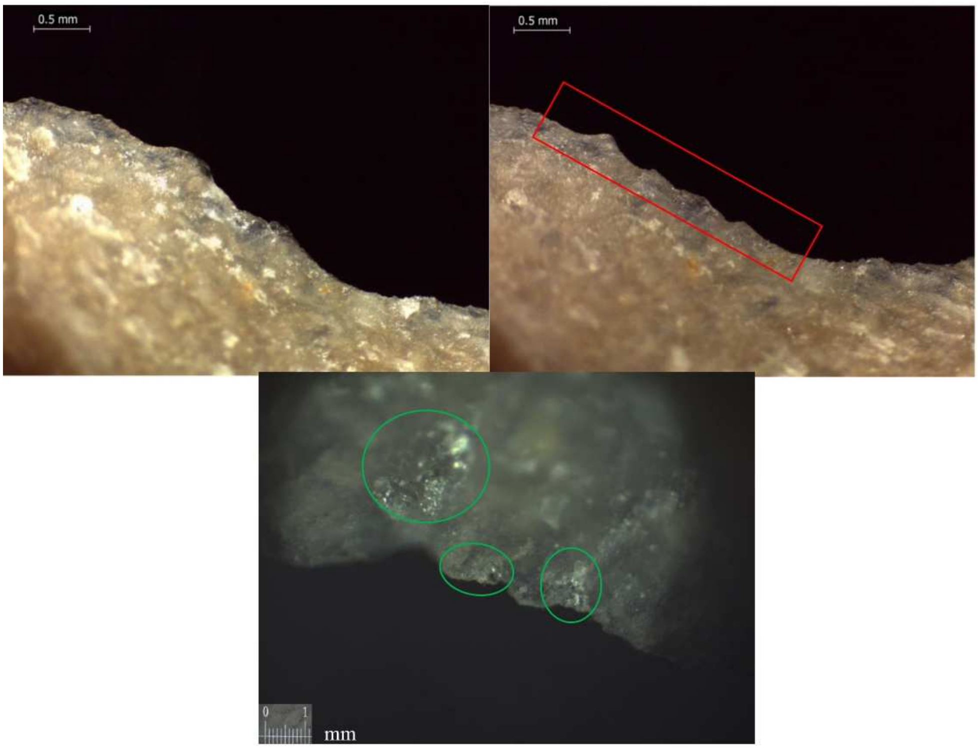


Figure 6.7. Microscopic images of the edge used for cutting meat (butchering) before and after the use under 25x magnification top images, marked red represents the edge deformation traces. Below is an image of the edge at 100x on metallographic microscope, marked green presents the random distribution of polishes.

Dry skin, cutting of dried skin shows the traces of random edge waning and micro flakes removal. These traces can be visible under lower magnification.

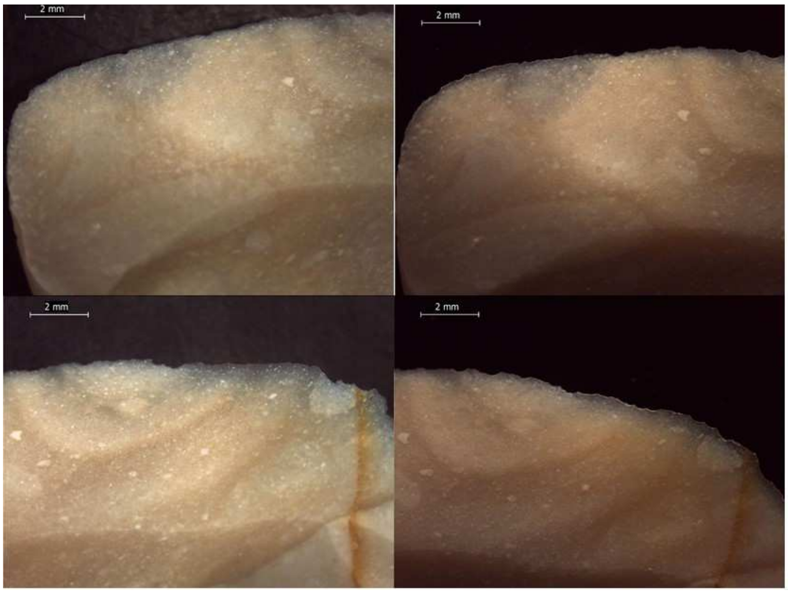


Figure 6.8. Microscopic images of the edge used for cutting dried skin before and after use under 8x magnification

Plant leaves, an experimental tool used for cutting plant leaves presenting abrasion and scalar edge removal scars more or less similar to that of cutting meat but less developed, which can be observed from at least 25 x magnification on a stereoscope and on a high-powered microscope. The tool also portrayed a minimal development of polish which developed strictly along the edge of a tool and less scattered.

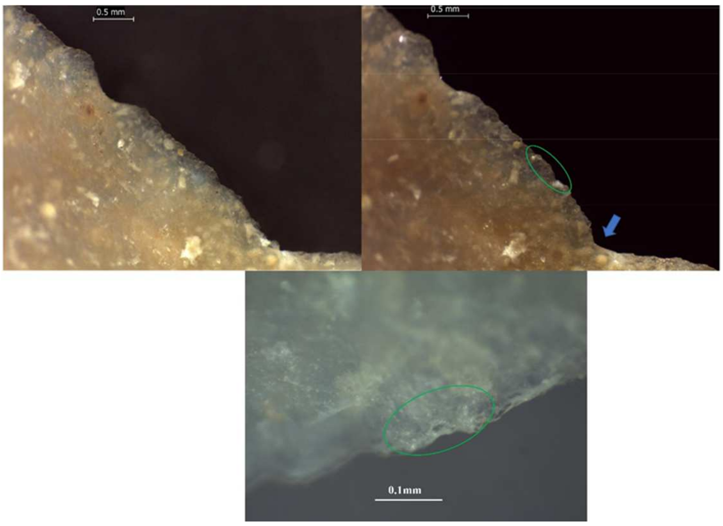


Figure 6.9. Microscopic images of an edge used for cutting plant leaves before and after the use under 25x magnification on stereoscope, pointed with blue arrow is one of the scalar scars and marked green is developed polish along the edge, and below is an image under 100x on metallographic.

Chopping

Dry wood, a tool presents buttering features and random edge removal, the detachment was observed during the activity and somehow can be observed macroscopically. The detachment of micro flakes is ventral side oriented. Seemingly, the edge removal depends on the structure of a flake rather than controllable variables during experimentation.

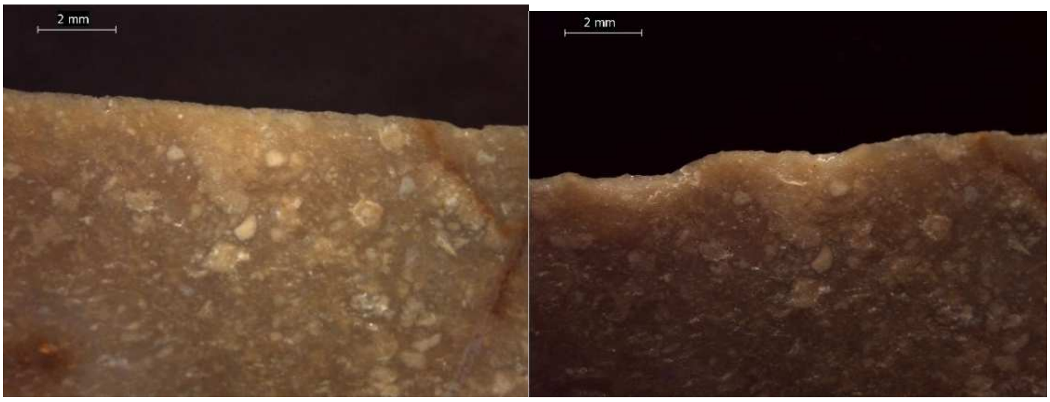


Figure 6.10. Microscopic images of the edge used for chopping a dry wood after and before the use under 8x magnification

Fresh wood, chopping of fresh wood portrays minimal traces of edge removal. Edges are relatively in pristine condition. However, the development of polishes is more evident on one side.

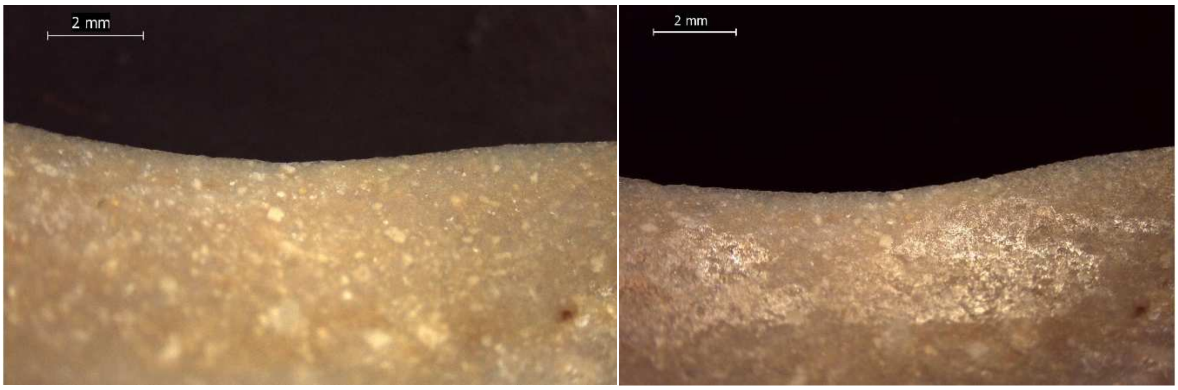


Figure 6.11. Microscopic images of the edge used for chopping fresh wood after and before the use under 8x magnification

Digging, lithic experimental tool used for digging activity presents the traces of minimal edge removal where the tip utilized presents certain limited damage. Also, development of polish can be observed for the tool worked on this activity. The combination of the distribution of polish and the patterns of edge removal, together can easily commemorate the impact of this activity on lithic tools.

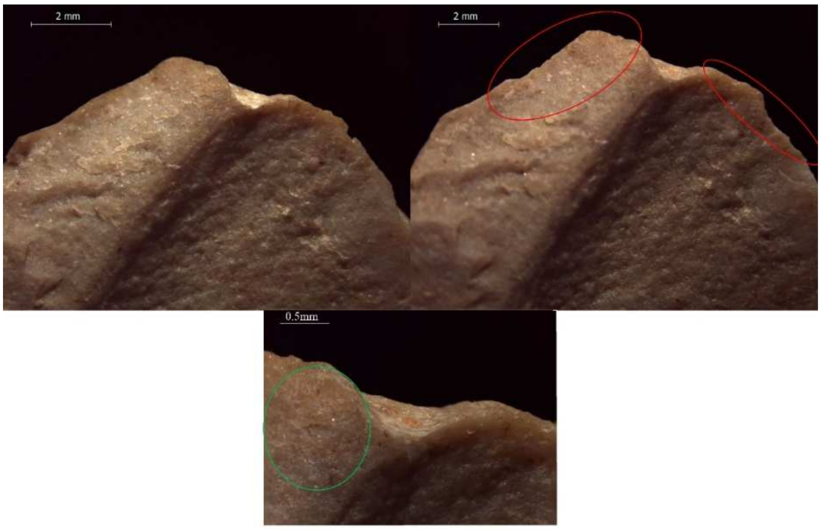


Figure 6.12. Microscopic images of a tip used for digging experiment; Top are the images before and after the activity under 8x magnification, marked red presents edge deformation and marked green below shows polishes under 25x magnification in stereoscope

6.2 Archaeological artifacts

L 15, almost 75% a tool is covered by cortex. Small part on the distal end including the tip shows that the tool was prepared for effective utilization. Artifact's investigation through a Low-powered approach shows utilization traces including scalar scars of edge removal associated with less developed and scattered polishes (Tringham et al., 1974), and indication of post depositional alteration presented by widely distribution of bright spots (Berruti & Daffara, 2014). The tool presents a broken tip whereby the analysis indicates most likely to be the impact of utilization due to the incorporation of edge removal and polishes which fits the concept. Edge rounding traces are relatively similar to those associated with cutting soft animal tissues especially meat.

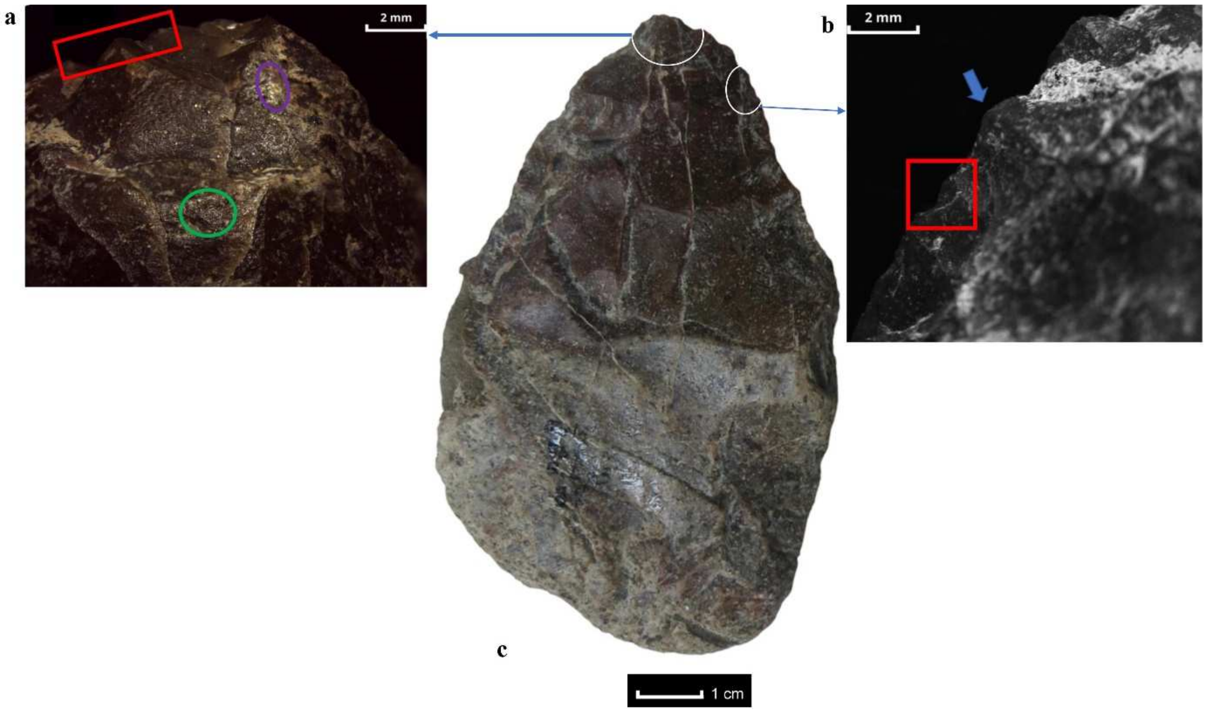


Figure 6.13. An artifact and microscopic images showing traces on an artifact; Red rectangles indicating edge removal scars, a blue arrow is indicating edge rounding, green circle indicating polishes and marked on purple is bright spot under stereoscope 8x.

I 13, through the Low-powered analysis an artifact presents wear traces associated to both utilization and post depositional alteration (bright spots, patination). The traces of edge rounding involve the sharpening of protruding edge structure is evident (abrasion). These features have been identified to be associated with the cutting of animal's soft tissue (Butchering). Edge rounding is clearly observable, Scattered distribution of polishes developed on the edge's vicinity are also associated with similar activity (Tringham et al., 1974). High powered analysis was not very effective in analysing this artifact due to the large size of the tool and the poor general state of preservation.

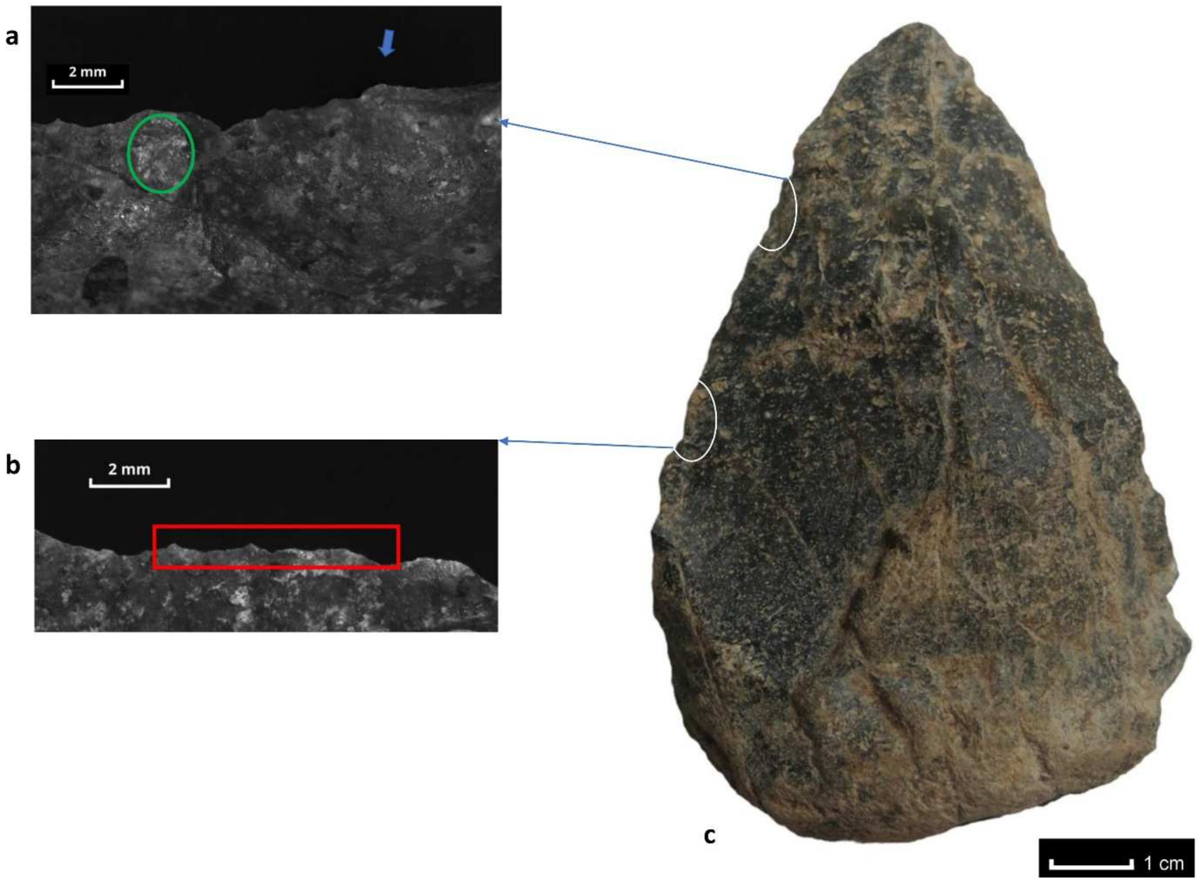


Figure 6.14. An artifact and microscopic images of an artifact; Red rectangle indicating edge removal in triangle shape and rounding, a blue arrow shows edge rounding and green circle showing a sign of bright spot under stereoscope 8x.

N 16, An artifact shows a relatively good state of preservation, and it lacks the cortex. In Low-powered analysis an artifact shows scalar scars of edge removal which to a certain extend has shaped the edge in triangle and rectangle shapes. These traces usually associated with sawing activity on either a bone or antler respectively (Tringham et al., 1974). Developed polishes presents a limited distribution around the very distal end (tip) and bright spot can be visible around the tool. Nevertheless, the form and distribution of the polishes is evident for a tool to be used on cutting animal tissue. The artifact can be interpreted as used for butchering activity whereby perhaps the activity involved disarticulation of carcase joint section and or a meat yielding segment associated with bones.

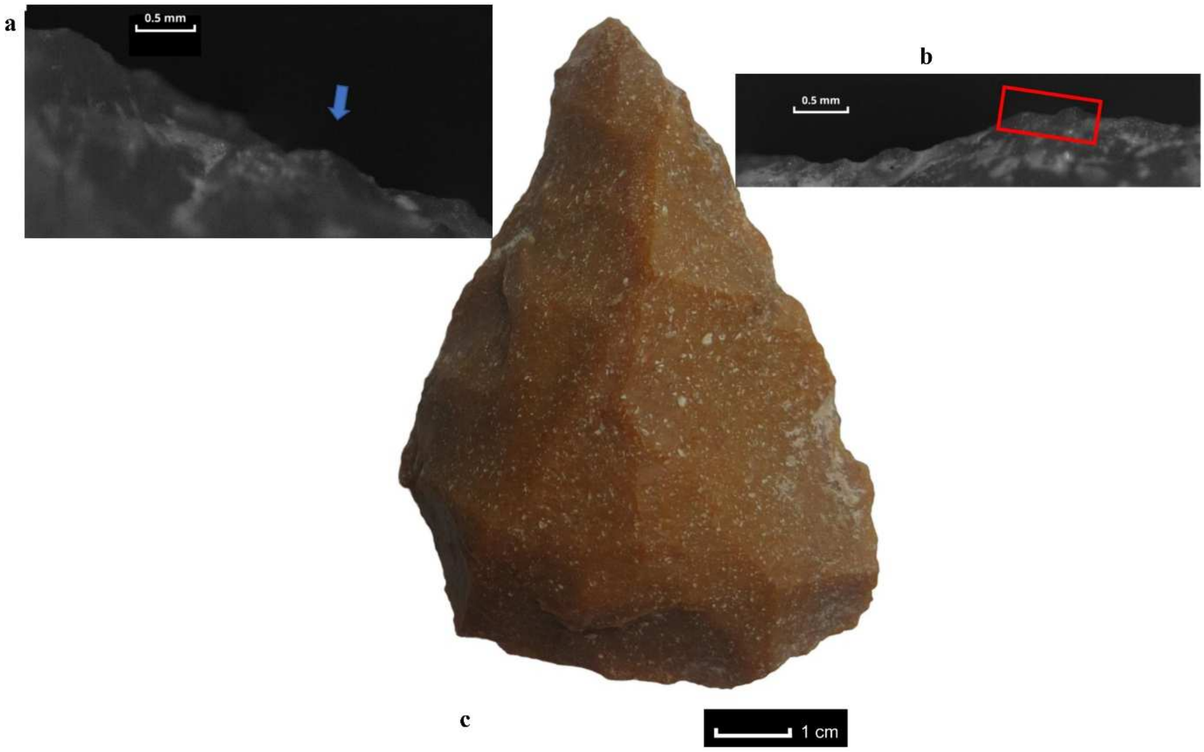


Figure 6.15. An artifact and microscopic images on stereoscope 25x; Red rectangle indicating edge removal and blue arrow shows edge rounding.

H 75, an artifact is generally roughly produced perhaps without proper finishing and edges sharpening. However, Low-powered analysis on this tool have shown a complex and comprehensive traces of utilization and post depositional alteration. The artifact is extensively affected by white patina, manganese, and bright spots. The edges present abrasions and scalar scars of edge removal which deformed in a triangle structure as obvious indication of the tool use on sawing a flesh bone (Tringham et al., 1974), these traces appear entirely around the edges. Development of polishes restricted around edges margin while the distal end also presents a sign of utilization (polish) although associated with unrelated traces which could be formed during archaeological activities of data recovery. Traces on this artifact shows that a tool was intensively used for butchering activities especially associated with the removal of meat from bones or disarticulating a carcass.

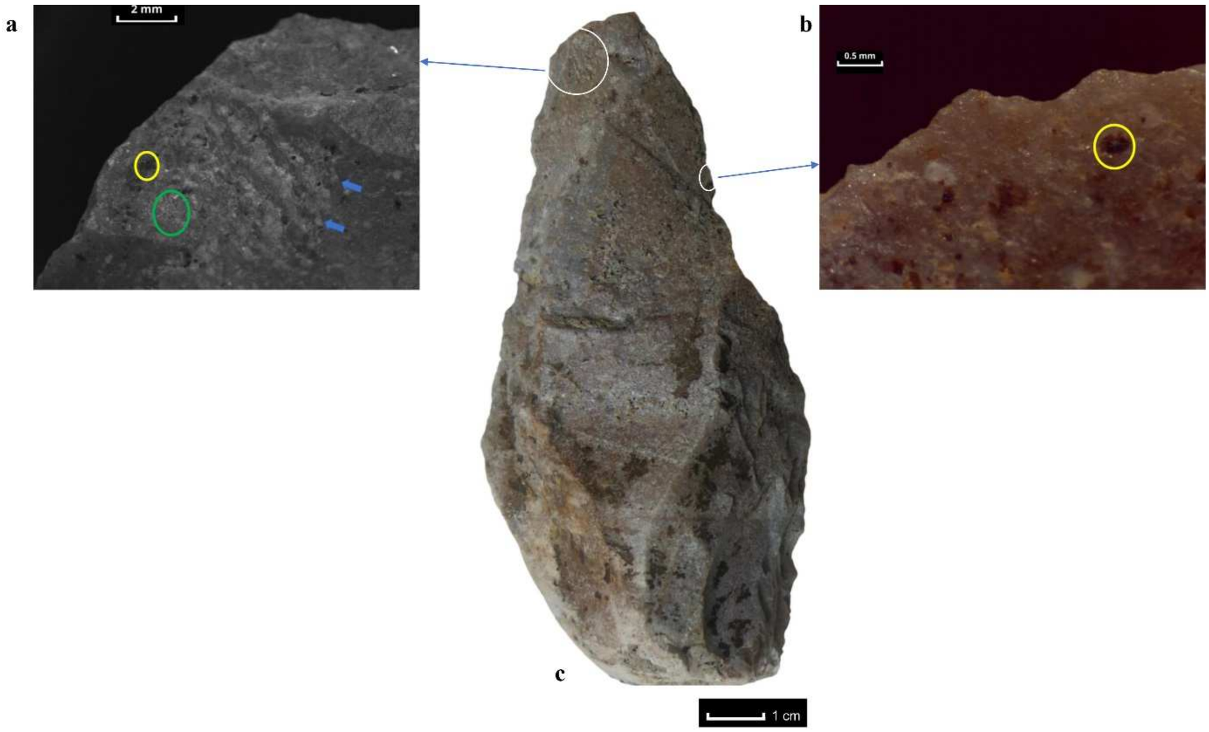


Figure 6.16. An artifact and microscopic images on stereoscope 25x and 8x; Yellow circles indicating form of manganese (iron oxide), marked green are polishes and blue arrow shows traces which possibly occurred during archaeological activities.

Q 09, an artifact presents the traces of both utilization and post depositional alteration. Low-powered analysis on this tool have shown the traces of edge rounding and edge removal associated with the traces of polishes. The distal end despite of being intensively affected by white patinas and bright spots, it shows traces of utilization by presenting edge removal from both sides. Edge damage traces could also be referred to associate with the cutting an animal tissue especially hide.

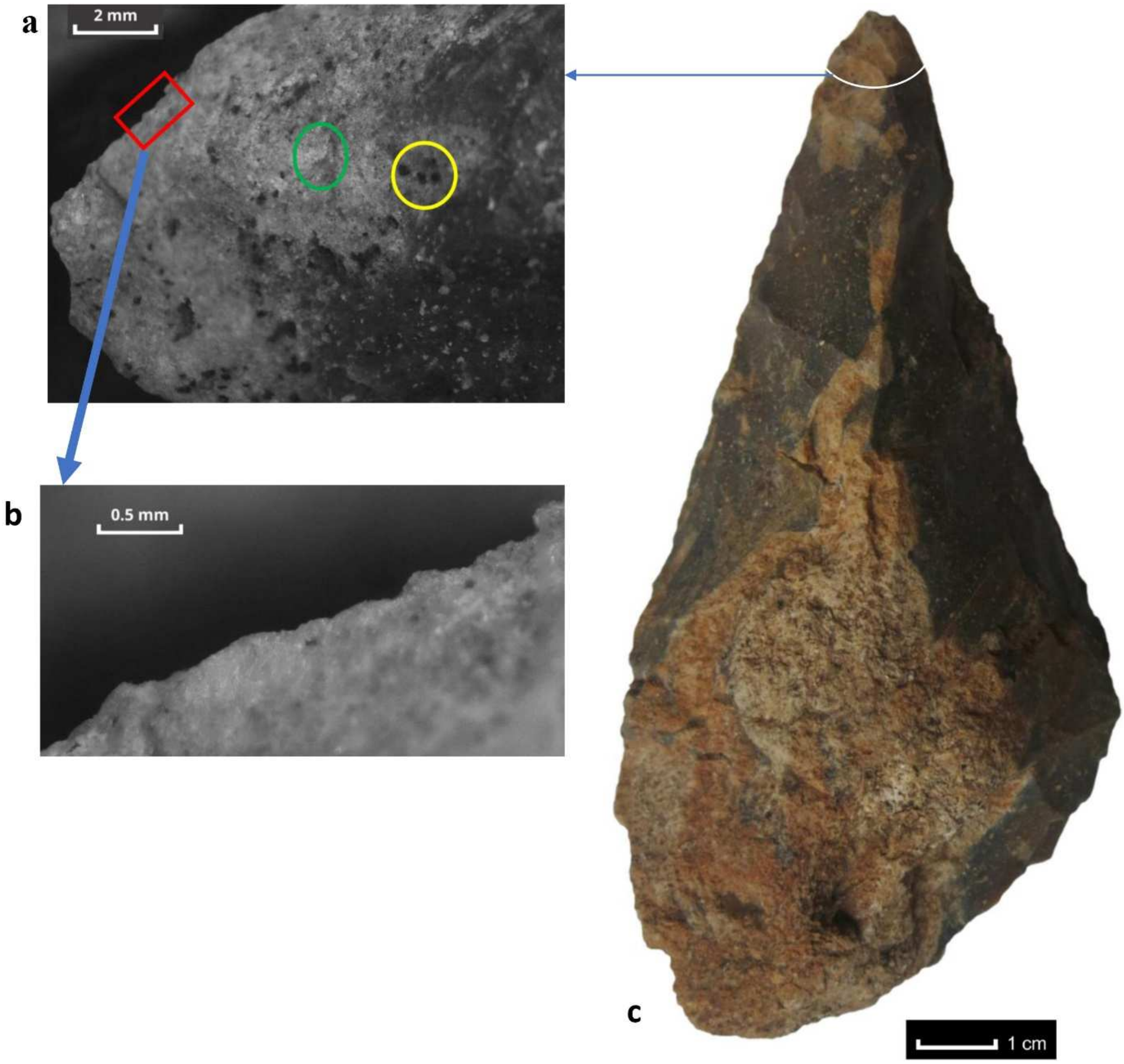


Figure 6.17. An artifact and microscopic images on stereoscope 35x and 8x of the tip affected by patination; Red rectangle indicating edge removal, which is a zoom in the other image, marked green is blight spot and yellow is manganese (iron oxide).

M 14, through a Low-powered analysis an artifact presents the traces of both utilization and post depositional alteration. A tool shows a wide distribution of white patina, abrasion, edge rounding and the development of scalar scars of edge removal. On the other edge a tool shows the traces of edge removal in triangle shape similar to the formed through the sawing of fresh bone (Tringham et al., 1974). The interpretation for this artifact shows the tool was used on carcass processing.

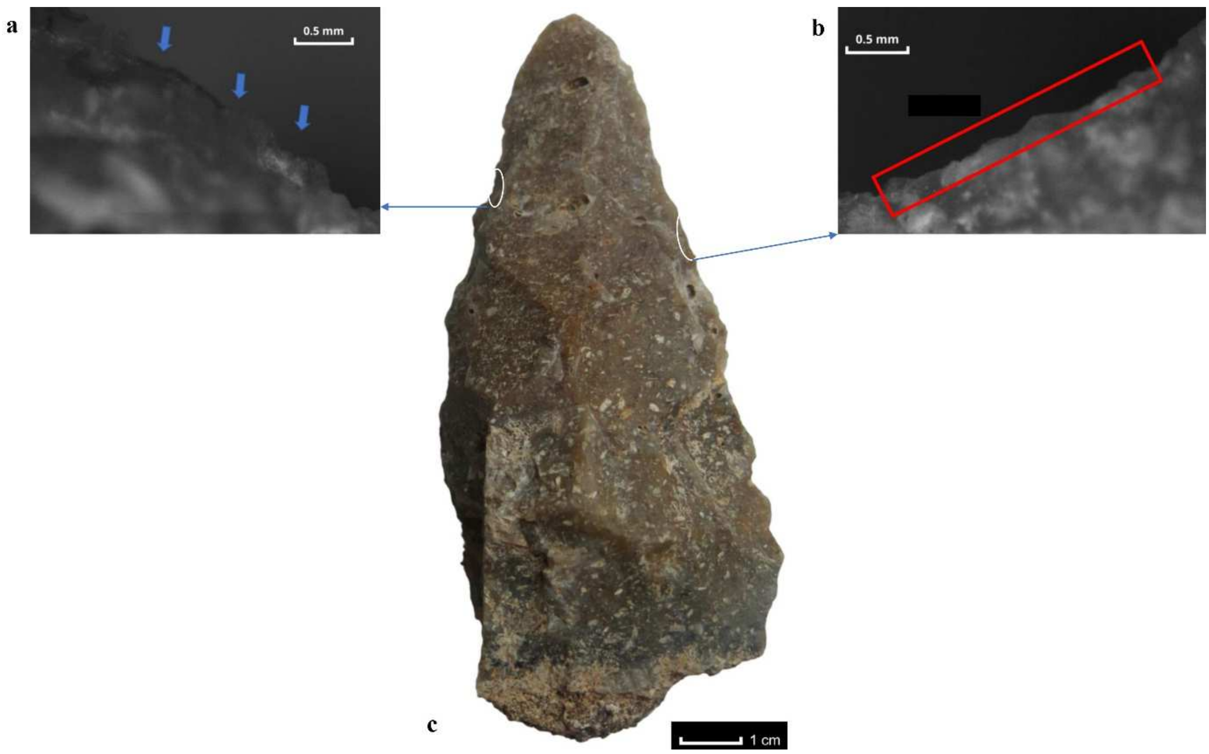


Figure 6.18. An artifact and microscopic images on stereoscope 35x; Blue arrows indicating edge removal traces associated with the cutting of soft tissue and red rectangle indicating edge removal and abrasion traces associated with sawing fresh bone.

AR 14, An artifact lacks both bifacial and bilateral equilibrium. Low-powered analysis on this tool shows the traces of both utilization and post depositional alteration. The tool presents an intensive and widely developed traces of post depositional alteration including bright spots, polishes, patinas and buttering traces which somehow is also visible on naked eyes. The tool shows traces of edge flake removal from one side associated with polish and stepped micro flaking on the edge (Keller, 1966; Tringham et al., 1974). The interpretation on the use of this tool indicates that it was used for sawing on hard material (Keller, 1966). However, the presence of buttering traces and intensively developed polishes and bright spots all over the tool confining this notion and therefore the precise functional interpretation for this tool remaining elusive through low-powered approach. On High-powered approach the tool shows the distribution of polishes are well defined on edge's vicinity on one edge and other edge portrays the obvious edge removal traces related to sawing activity on a fresh bone without polishes (Tringham et al., 1974). The tip is associated with polishes most probably caused by post depositional alteration.

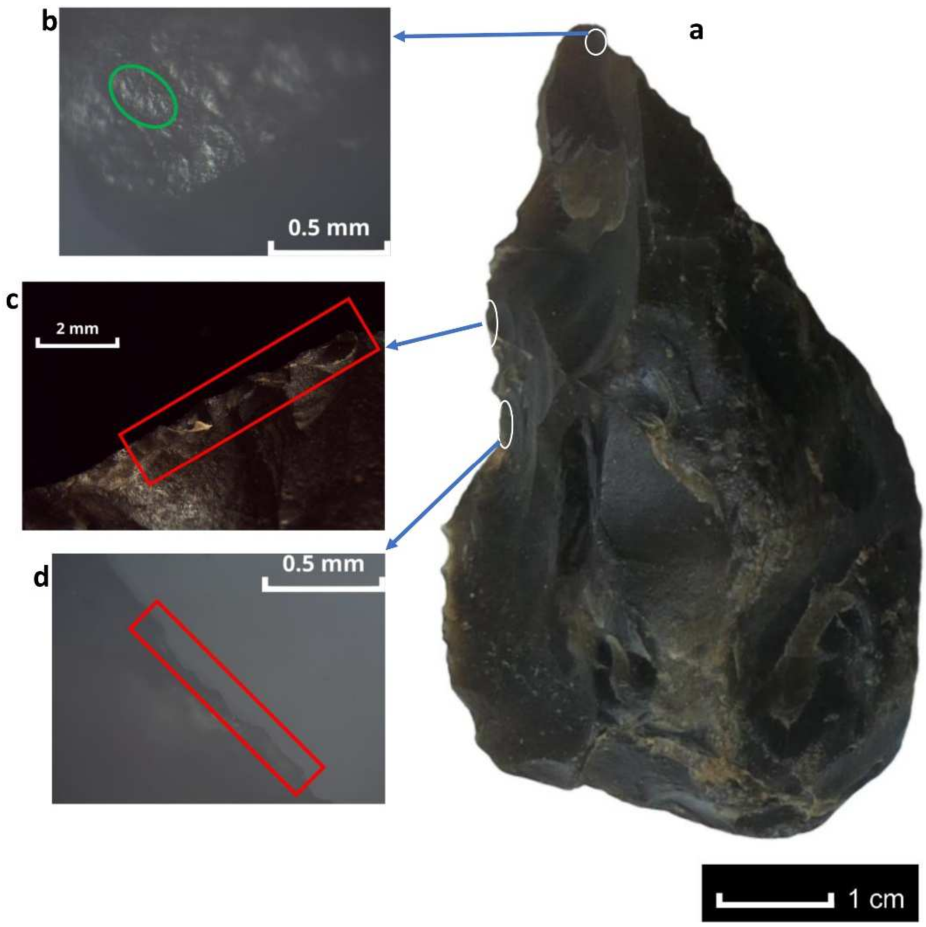


Figure 6.19. An artifact and microscopic images on stereoscope 8x and metallographic 100x. red rectangle indicating edge removal traces, on the first picture including stepped micro flaking scars. Green circle indicating the polishes under metellographic100x.

AQ 15, Low-powered analysis presents this artifact with observable traces only associated by the utilization of the tool. The tool shows scattered distribution of less developed polishes directly associated with edge rounding and Scalar scars of edge removal (Tringham et al., 1974). All the traces are directly associated with the activity of cutting animal soft tissue and therefore the tool was used for carcase processing activity. Through the High-powered analysis the tool has shown irregular distribution of edge removal and triangle shapes of edge removal traces which are similar to those associated with the working on hide and sawing of fresh bone, respectively. In both cases the development of polishes could be hardly spotted.

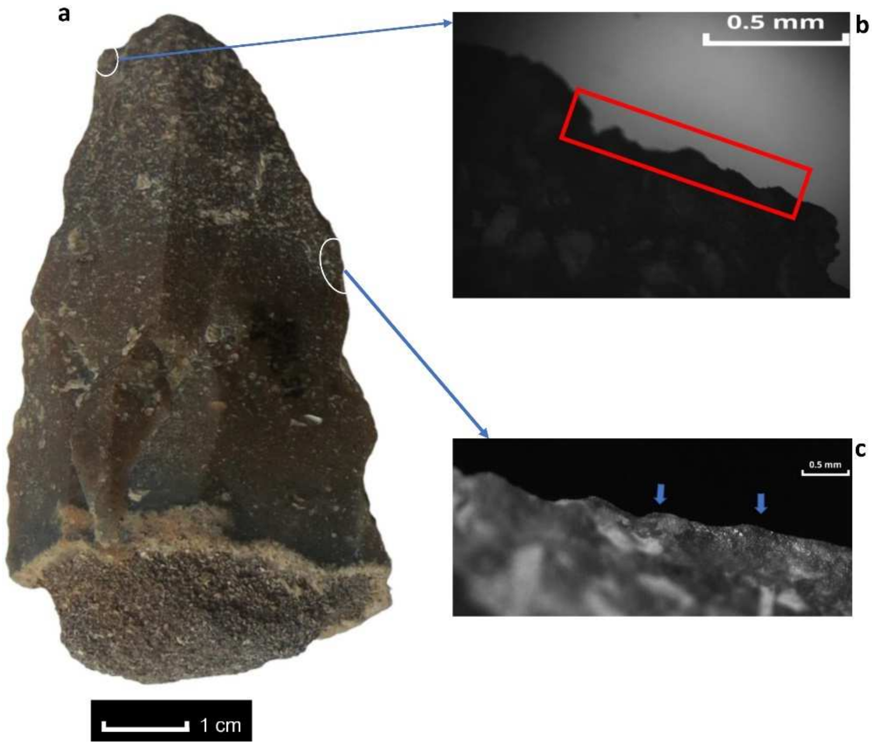


Figure 6.20. An artifact and microscopic images on stereoscope 25x and metallographic 100x. Blue arrows indicating edge rounding traces on stereoscope and red rectangle indicating edge removal traces on metallographic.

I 16, An artifact is characterized by partial flaking without bifacial equilibrium where the top of ventral side is fully covered by the cortex and almost a half of one side comprise a cortex. Low powered analysis reveals the traces associated with the use of the tool. An artifact shows the traces of edge rounding, edge removal precisely associated with a limited distribution of polishes. In high powered analysis the polishes are more evident, the edge rounding, and scalar edge removal are more distributed on the distal end including the tip. The interpretation indicating this tool was used for butchering activities.

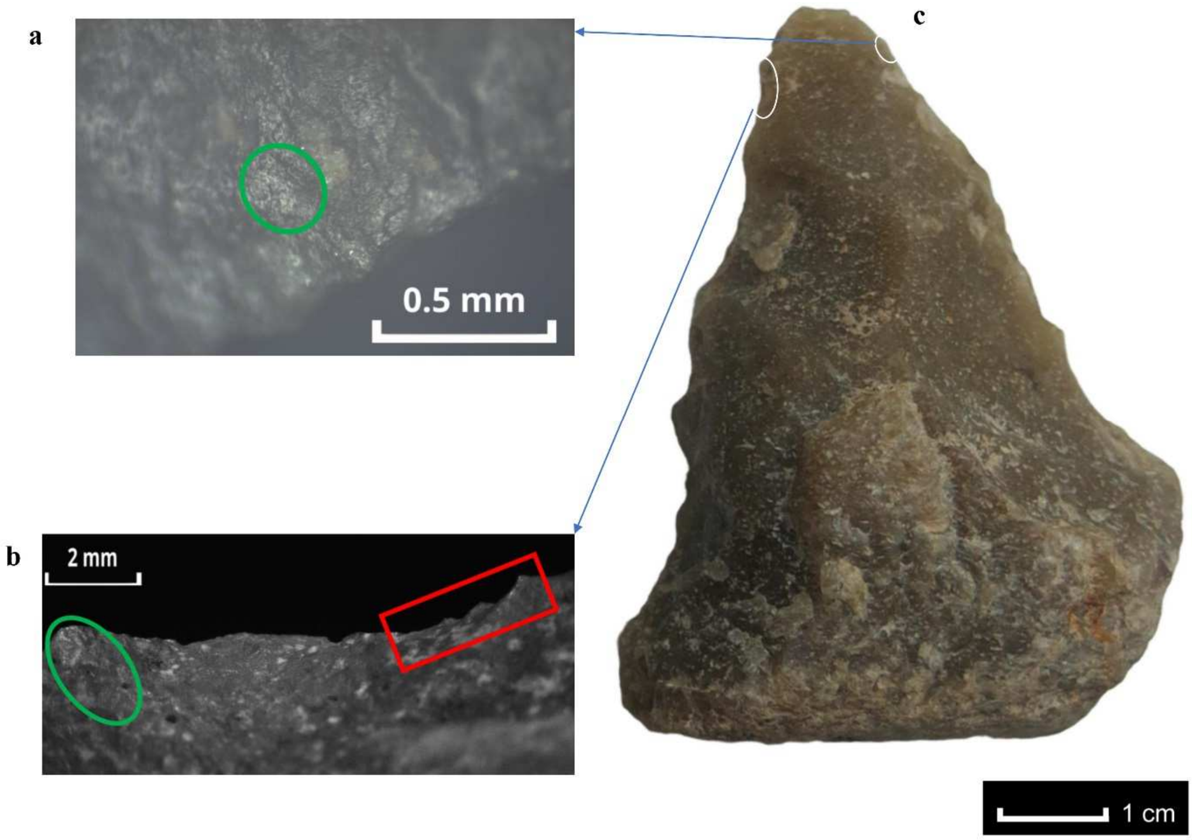


Figure 6.21. An artifact and microscopic images on stereoscope 8x and metallographic 100x. Red rectangle indicating edge removal traces and green circles indicating polishes.

Q77, this tool presents traces of both utilization and post depositional modifications. Only one side of a tool along the tip shows the traces of utilization. Scalar scars of edge removal, edge rounding and triangled structures of edge removal presented on this tool. Polish is well appeared to complement edge modification traces. Post depositional modifications are characterized by patination, bright spots, manganese, and polishes restricted to the distal end of the tool. The tool can be interpreted to be used for carcasses processing activities including being worked on hide, soft tissue, and fresh bone.

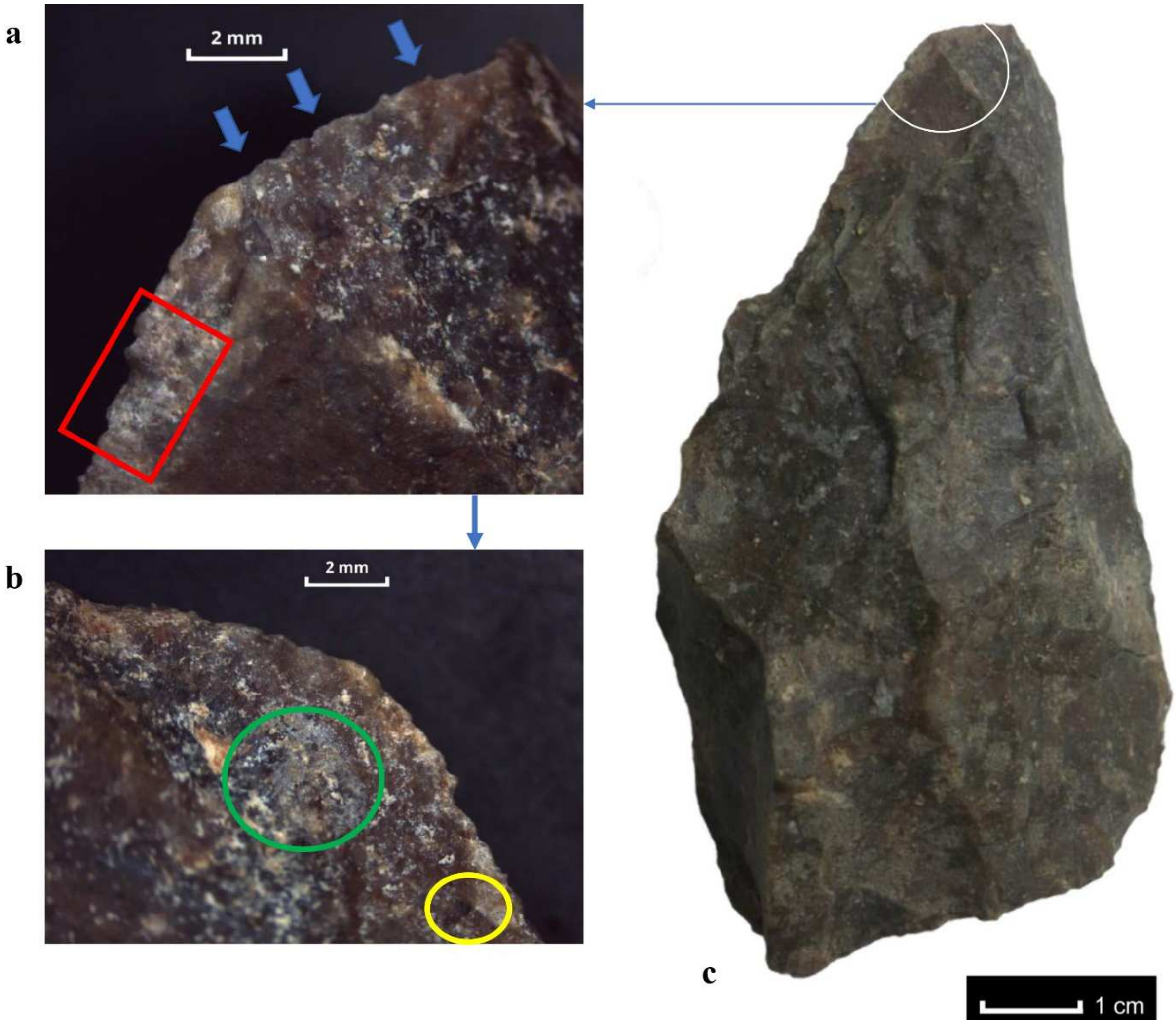


Figure 6.22. An artifact and microscopic images on stereoscope 8x; Red rectangle represents scalar scars of edge removal, abrasions and polishes associated with the utilization of an artifact. Blue arrows show edge rounding and triangled edge removal traces, green circle represents polish (sheen) and faded bright spot and yellow circle represents manganese.

Table 6. 1. A table representation of archaeological analysis to show identified traces

Presentation of observed utilization traces						
Artifacts	Polish	Edge rounding	Scalar scars	Stepped flake removal	Abrasions	Edge removal (Triangle, rectangle)
L 15	x	x	X	x		
I 13	x	x			x	x
N 16	x		x			x
H 75	x		x		x	
Q 09		x	x			x
M 14		x	x		x	x
AR 14	x		x	x	x	x
AQ 15	x	x	x			x
I 16	x	x	x			x
Q 77	x	x	x		x	x
Presentation of observed Post depositional modification traces						
Artifacts	Polish (Sheen)	Patination	Bright spots	Edge removal (Trampling)	Abrasions (Buttering)	Manganese (Iron oxide)
L 15	x		X			
I 13		x	x		x	
N 16	x		x			
H 75	x	x	x		x	x
Q 09	x	x	x			
M 14	x	x	x			
AR 14	x	x	x	x	x	
AQ 15						
I 16	x		x		x	
Q 77	x	x	x		x	x

7. DISCUSSION

The Late Acheulean bifacial tools in western Europe are characterized primarily by a limited modification of flint nodules mostly presenting cortical maintenance while, more worked on the distal end (M. H. Moncel et al., 2018). Although presenting a broad variation within and between sites, general morphologies are restricted to oval and pointed (García-Medrano et al., 2022; Hardy et al., 2018; M. H. Moncel et al., 2018). Vast variety of the above-mentioned morphologies has been reported at Guado San Nicola where the latter seems dominant and even more improved overtime in terms of distal end sharpening while retaining the tip effectiveness (Muttillo et al., 2014; Peretto et al., 2016). It has been argued either way that bifacial tools variation shows distinctive culture and population groups (Ashton & Davis, 2021), while on the other hand the concept of bifacial appearance especially during transitional period may only affirm functional variation within a single population group and culture (Ceruleo et al., 2015; M. H. Moncel, Biddittu, et al., 2020). Different sites with bifacial tools in central Italy e.g. Torre in Pietra - MIS 10 (Villa et al., 2016), Castel di Guido - MIS 11 (Ceruleo et al., 2019), Compogrande, Colle Avarone, Selvota, and Lademagne at the Ceprano basin, all dated between 400 – 340 kya (M. H. Moncel, Biddittu, et al., 2020), and Guado San Nicola - MIS 11 (Muttillo et al., 2014; Peretto et al., 2016), are characterized by common morphological and technological aspects and the majority seem to occur during MIS 11/MIS 10, hence the Late Acheulean. The regional contexts and occurrences suggested the trends of traditional persistence for about 50,000 years where hominids behavioural adaptation conferred by local constrains (M. H. Moncel, Biddittu, et al., 2020). Notwithstanding, perhaps the suggested traditional trends had spread even beyond reaching afar geographical areas. Recent research on the UK's bifaces comparative morphology has reported similar dynamic technological and morphological configuration of the bifacial tools beginning a temporal range as of Guado San Nicola and other sites in central Italy (García-Medrano et al., 2022).

> "From MIS 11c, the technology behind the morphological groups (oval vs. pointed) does not reflect the particularities used to define each site by itself. There is variation in the combination of the same technological features, adapted to the final shaping aim. Technology reveals less standardization, with the major heterogeneity documented on tips, but without any statistically significant difference. The technology acquired a new sense of plasticity, becoming flexible and adapted to the features of the blank and towards achieving the final template. Thus, the only difference between sites is the relative abundance of particular features over others" (García-Medrano et al., 2022).

Recent theoretical and methodological advancement on Use-wear analysis studies has distinguished terminological concept of use-wear analysis from traceological analysis. However, use-wear analysis is still considered as a fundamental research approach to investigate prehistoric hominin cultural and technological dynamics. Lithic use-wear analysis involves studying all the traces associated with hominin's use of the artifact while traceology analysis involves studying all the physical traces on the surface of the lithic artifact including use wear traces (Marreiros et al., 2020). Despite the conferred terminology categorization, it has been argued by many authors that in use-wear analysis, use related wear and other surface modification must be incorporated to ensure better assessment of a tool functional interpretation (Asryan et al., 2014; E. Claud, 2015; Galland et al., 2020; Keeley, 1980; Lemorini et al., 2014; Levi Sala, 1986; Semenov, 1964; Tringham et al., 1974).

Bifacial tools use wear studies in Europe have shown a great encompasses of their utilization i.e., La Noira, France, the analysed sample has shown equal ratio of utilization between wood, meat and plants (Hardy et al., 2018), Hoxne in the UK has also presented the variety of tools utilization on meat and wood working (Keeley, 1980), Boxglove, UK bifacial tools were used for various activities such as butchering, digging and wood working (Mitchell, 1998). The major reported traces of use wear studies on the Acheulean bifaces are those associated by carcase processing. Apparently this fact has been widely noted from both European contexts (García-Medrano et al., 2014; Viallet, 2016b) and the Levant (Solodenko et al., 2015; Zupancich et al., 2021), although other activities have also been reported such as wood working (Keeley, 1980; Viallet, 2016b) and digging (Mitchell, 1998; Rots & Van Peer, 2006). Unlike Europe and Levant, the studies of bifacial use wear analysis from African Acheulean bifaces have reported contradicting results. For instance, Wonderwerk cave's assemblage in South Africa have revealed the major functions of analysed Acheulean bifaces to be associated with digging and wood working (Binneman & Beaumont, 1992). On the other hand, Hearth cave, in south Africa have shown the predominant functional analysis result on the Acheulean collection to be associated by wood working, followed by butchering, digging and plant working (Lambert-Lauriston, 2015). Given such impinged comparison, cave contexts could significantly contribute to the major functions of the tools. The scant of Acheulean cave sites in the world hinders the optimal justifications of such comparative interpretations.

Late Acheulean bifaces during the European Lower to Middle Paleolithic transitional period has been reported to have no distinctive functional interpretation compared to the cooccurred Levallois lithic industries (Aureli et al., 2016; Grimaldi et al., 2020; Nicoud et al., 2016). Berruti et al., (2020) reported the functional interpretation of Levallois flakes and *façonnage* flakes at Guado San Nicola, where the lithic tools were extensively associated with carcases processing activities (Berruti et al., 2020). Results from this study have also confirmed that distinctive lithic typologies during transitional period is certainly a representation of diverse hominin activities. Most likely the domination of big games (Galerian Mammal Age) during this period had somehow influenced the persistence of large cutting tools (Grimaldi et al., 2020; Peretto et al., 2016). Despite the low number of sampled artifacts for this study, the functional interpretation has mainly revealed major functions of almost all the artifacts to be associated with carcasses processing activities (Table 7.1). Other than previous use wear studies to the contemporaneous lithic industries (Berruti et al., 2020), zooarchaeological studies and faunal taphonomic investigation at Guado San Nicola (Muttillo et al., 2014; Peretto et al., 2016) have revealed interpretations of intensive hominid utilization of big game. Lithic technological results especially on bifacial tools have shown a deliberate technical advancement overtime which suggests the improvement of tools effectiveness (Peretto et al., 2016). Nevertheless, technological overlap and functional equifinality also presenting a comprehensive hominid adaptation in game for subsistence and other activities such as knapping as it has preserved in several antler remains at Guado San Nicola (Muttillo et al., 2014; Peretto et al., 2016).

Artifacts	Worked material	Major activity
L 15	Meat	Cutting
I 13	Meat	Cutting
N 16	Bone/Antler + Meat	Butchering
H 75	Fresh bone	Sawing
Q 09	Meat	Butchering
M 14	Fresh bone + Meat	Butchering
AR 14	Antler	Sawing
AQ 15	Meat + hide +Fresh bone	Butchering
I 16	Meat	Cutting
Q 77	Meat + hide +Fresh bone	Butchering

Table 7.1. A table representing functional interpretation of analyzed archaeological sample

Guado San Nicola's assemblage in this work has shown several major surface modifications which have been interpreted as post depositional alterations, including patination, polishes, bright spots, iron oxide (manganese) and edge removal. In general, there are three main factors responsible for the alteration of lithic artifact surfaces including; mechanical, chemical, thermic impositions (Galland et al., 2020). Mechanical and chemical are likely to be the main alteration factors on this assemblage, almost every analysed artifact has shown at least the traces of bright spots, polishes (sheen) and edge removal (Table 7.2). The assemblage is also affected by three different types of patinas which are white, coloured and gloss (Glauberman & Thorson, 2012; Stapert, 1976)

Presentation of observed Post depositional modification traces						
Artifacts	Polish	Patination	Bright spots	Edge removal	Abrasion	Manganese
L 15	x	x	x			
I 13		x	x		x	
N 16	x	x	x			
H 75	x	x	x		x	x
Q 09	x	x	x			
M14	x	x	x			
AR 14	x	x	x	x	x	
AQ 15	x	x				
I 16	x	x	x		x	
Q 77	x	x	x		x	x

Table 7.2. A table representing identified post depositional modification traces on analyzed artifacts, modifies from table 6.1.

Artifact	White Patina	Colour Patina	Gloss Patina
L 15			x
I 13	x	x	x
N 16			x
H 75	x	x	
Q 09	x	x	x
M 14	x	x	x
AR 14			x
AQ 15			x
I 16	x	x	x
Q 77	x	x	x

Table 7.3. A table representing a characterization of identified Patina in each artifact

All types of patinas and iron oxides at Guado San Nicola are related to wet context and general geochemical composition of the underlying limestone rock (Berruti et al., 2020; Glauberman & Thorson, 2012; Hill, 1982; Levi Sala, 1986). Such kinds of patination have been described by Stapert (1976) for instance, colour patina is principally formed after the decomposition of iron oxides from wet soil or composed within the flint (Rottlander, 1975; Stapert, 1976), while white patina is basically formed on the presence of alkaline solution but it forms quickly and intensively with Calcium carbonate as a catalyst (Stapert, 1976). Gloss patina may result from polishing in sand matrix due to soil movements and dissolved silica from soil water, which essentially indicates both mechanical and chemical alterations respectively (Glauberman & Thorson, 2012; Rottlander, 1975; Stapert, 1976). Bright spots could substantially originate from similar mechanical alteration (Berruti & Daffara, 2014). Extensive distribution of the abovesaid post depositional phenomenon on Guado San Nicola's assemblage (Table 7.3) signifies both formation categories (chemical and mechanical). Geological characterization of the site indicating its placement on the ancient flood plain and the entire archaeological stratigraphic sequence is featured by the alluvial and fluvial deposits (Pereira et al., 2016). Guado San Nicola's stratigraphic unit B have been clarified to undergo a double successive debris flows (Pereira et al., 2016), while the context have yielded a considerable quantity of archaeological data especially bifacial lithic artifacts of 60.56% Table 7.4 (Berruti et al., 2020; Muttillo et al., 2014; Peretto et al., 2016).

	S.U. B	**S.U. B*C**	**S.U. C**
Bifaces	86	13	43
Façonnage flakes	40	38	40

Table 7.4. Guado San Nicola. The number of bifaces and bifacial shaping flakes per stratigraphic unit adapted after Berruti et al. (2020), Repeated after table 2.4 in this work.

Nonetheless, the interpretation for site formation process is supporting the previous studies that the whole archaeological assemblage at Guado San Nicola has been exposed to a heavy environmental process event resulting the mass transport and alteration of archaeological data. (Berruti, 2017; Berruti et al., 2020; Muttillo et al., 2014; Pereira et al., 2016; Peretto et al., 2016).

8. CONCLUSION

The main aim of this work was to assess the affiliation of bifacial tools within a transitional context between Lower and Middle Palaeolithic, specifically at Guado San Nicola in central Italy. Despite a small sample analyzed for this research, the results have provided an informative and reliable contribution to the intended subjects. Technologically, the site has yielded typical bifacial tools morphologies (ovate and pointed) reported in many other Late Acheulean sites in Europe, as discussed in the previous chapter. Although Guado San Nicola bifaces present a significant alternation of morphological prevalence, there has not been reported any viable evidence of distinctive cultural or functional traits (García-Medrano et al., 2022). Therefore, it can be preliminarily surmised that the double morphologies at Guado San Nicola only demonstrate technological change over time, as noted from their distributions and occurrences in archaeological units (Muttillo et al., 2014; Peretto et al., 2016). Perhaps, however, the changes may represent technological advancement and hence tools' effectiveness and comprehensive utilization.

The majority of analysed tools were recovered from stratigraphic unit B, and they fall in a category of pointed morphology. Nonetheless, functional interpretation of all the tools has revealed a major function on a sampled assemblage to be butchering. There was no functional distinction among various lithic industries overlapped during a transitional period. This interpretation could be partial but certainly substantial to supplement a functional understanding of Late acheulean bifacial implements during the Lower to Middle Palaeolithic transition in Europe. Although, by any chance for further functional investigation on Guado San Nicola's bifacial assemblage, one would increase a sample size by perhaps considering the whole assemblage and separate morphologies to provide specific statistical details of functional interpretations reflecting different morphologies.

The assemblage presents obvious post depositional modification traces, polishes are the most pronounced traces to almost all sampled artifacts. Polishes can be formed through mechanical or chemical alteration but specific characterization of these aspects on Guado San Nicola's assemblage is quite ambiguous, perhaps the site is featured by both alteration forces. Geologically the extent of a whole assemblage alteration including sediments, fauna and lithics suggests the massive environmental process specifically a double successful debris flows (Pereira et al., 2016). But the site's contextualization has revealed it to be placed on the ancient flood plain characterized with alluvial and fluvial environment, wet condition and geochemistry of the underlying limestone rock could have suppressed the chemical alteration of the artifacts. In this case, both scenarios are more probable had happened, specific characterization of these prominent alteration factors would be reliable to assess a comprehensive setting for a site formation processes.

The analysis implied a very modest sample size (n=10 of n=142) or 7%, but the interpretation results and discussion from this study should not be overlooked. However, a comprehensive analysis of the whole sample could significantly reveal more variables and information concerning the intended objectives.

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APPENDICIES

Appendix 1. Archaeological analysis recording form

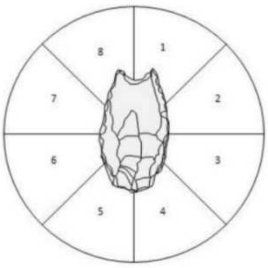
INTERNATIONAL MASTER IN QUATERNARY AND PREHISTORY

ARCHAEOLOGICAL ANALYSIS RECORDING FORM

Tool No: **Date:**

Tool description		
Observed traces	**Stereoscope**	
	Metallographic	
Motion & activity		
Processed materials		
Post-deposition alterations		
Additional observation		

Wear distribution



Further comments and illustration: