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Anđa G. Petrović

MESOLITHIC-NEOLITHIC TRANSITION IN IRON GATES (SERBIA): HUMAN ACTIVITIES FROM USE-WEAR PERSPECTIVE

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ФИЛОЗОФСКИ ФАКУЛТЕТ

Анђа Г. Петровић

ПРЕЛАЗ ИЗ МЕЗОЛИТА У НЕОЛИТ У ЂЕРДАПУ: ЉУДСКЕ АКТИВНОСТИ ИЗ ПЕРСПЕКТИВЕ ТРАГОВА УПОТРЕБЕ НА ОРУЂУ ОД ОКРЕСАНОГ КАМЕНА

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LA TRANSIZIONE MESOLITICO-NEOLITICA NELL' IRON GATES (SERBIA): LE ATTIVITÀ UMANE INTERPRETATE CON UNA PROSPETTIVA DI ANALISI DELLE TRACCE D'USO

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Student: Anđa Petrović, matricola 1877042 (Sapienza University of Rome), index number 7A16-1 (University of Belgrade)

Thesis supervisors:

Dr Dušan Mihailović, Professor, University of Belgrade

Dr Cristina Lemorini, Associate Professor, Sapienza University of Rome

Thesis reader:

Dr Cecilia Conati Barbaro, Associate Professor, Sapienza University of Rome

Dissertation Committee:

Dr Boban Tripković, Associate Professor, University of Belgrade

Dr Emanuela Cristiani, Associate Professor, Sapienza University of Rome

Dr Federica Fontana, Associate Professor, Unversity of Ferrara

Dr Jasna Vuković, Associate Professor, University of Belgrade

Date of defense:

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Mesolithic-Neolithic transition in Iron Gates (Serbia): Human activities from use-wear perspective

A closed eco-niche as the Iron Gates region in Northeastern Serbia has enabled specialists to explore the transition to sedentary life, with an atypical record of human occupation during the Late Glacial and Early Holocene. Following a series of published studies and analysis, varying from prehistoric diet to architecture, this research aims to present the newest results of the use-wear and residue analysis performed on the chipped stone assemblages from Lepenski Vir, Padina and Vlasac, with a broader focus on the transition from Mesolithic to Neolithic period. Applying the use-wear analysis was done by using both low and high-power approach, in combination with FTIR and SEM-EDX analyses.

Further, this study is established and enforced with a reference collection made specifically for the purposes of the research. The gained results were interpreted based on the hypotheses focused on the daily routine, but also addressing some long-term aspects, like changes in the economy and following the difference and innovations in the habits between the communities inside the region. The chipped stone artefacts, originating from buildings, pits, hearth areas, and open-air spaces, were analysed. Based on the results, some of the main activities that took part in the Iron Gates are singled out, as processing hide, bone, antler, fish and vegetable-based resources. A higher number of complex activities, as softening antler or hide tanning, were noted which make this already specific area more peculiar.

The obtained data highlights the activities of the advanced hunter-gatherers and fishermen, and first farmer groups. Additionally, observed through the spatial analysis, the results revealed the dynamics and processes in the Late Mesolithic and Early Neolithic period in the Iron Gates, but also posed many questions regarding the specialization of the prehistoric settlements on the Danube.

Keywords: use-wear analysis, residue analysis, chipped stone tools, experimental archaeology, Mesolithic, Neolithic, Transitional period, Iron Gates, Lepenski Vir, Padina, Vlasac

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Прелаз из мезолита у неолит у Ђердапу: људске активности из перспективе трагова употребе на оруђу од окресаног камена

Затворена еко-ниша, попут Ђердапа у североисточној Србији, омогућила је стручњацима да истраже почетак седентарног начина живота захваљујући богатом археолошком запису људског насељавања током касног глацијала и раног холоцена. Након низа објављених студија и анализа, од праисторијске исхране, сахрањивања до архитектуре, ово истраживање има за циљ да представи најновије резултате функционалних анализа и анализа огранских остатака на артефактима од окресаног камена са истакнутих насеља као што су Лепенски Вир, Падина и Власац, са фокусом на прелаз из периода мезолита у неолит. Функционалне анализе извршене су применом малих и великих увећања у комбинацији са ФТИР и СЕМ-ЕДКС анализама.

Ова студија је спроведена уз помоћ посебно оформљене референтне колекције креиране за потребе истраживања. Добијени резултати су интерпретирани на основу хипотеза усмерених на свакодневне активности праисторијских заједница, са освртом на дугорочне аспекте, попут промена у економији и праћење иновација у навикама унутар региона. Анализирани су артефакти од окресаног камена који су пронађени у кућама, јамама, огњиштима и са отворених простора. На основу резултата издвојене су неке од главних активности, попут прераде коже, кости, рога, рибе и биљних ресурса. Примећен је већи број комплекснијих радњи, као што је обрада омекшаних рогова или штављење коже, које ово већ специфично подручје чини сложенијим у погледу свакодневице у односу на претходна сазнања.

Добијени подаци истичу у први план активности напредних ловаца сакупљача и рибара, и првих група пољопривредника. Поред тога, резултати су посматрани кроз призму просторне анализе који су указали на посебну динамику процеса и ужу специјализацију праисторијских насеља у касном мезолиту и раном неолиту у региону Гвоздених врата.

Кључне речи: функционалне анализе, анализе органских остатака, артефакти од окресаног камена, експериментална археологија, мезолит, неолит, транзициони период, Ђердап, Лепенски Вир, Падина, Власац

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La Transizione Mesolitico-Neolitica nell' Iron Gates (Serbia): le attività umane interpretate con una prospettiva di analisi delle tracce d'uso

Un'eco-nicchia chiusa come la regione delle Porte di Ferro nella Serbia nordorientale ha consentito agli specialisti di esplorare la transizione alla vita sedentaria, con un record atipico di occupazione umana durante il tardo glaciale e l'inizio dell'olocene. A seguito di una serie di studi e analisi pubblicati, che variano dalla dieta preistorica all'architettura, questa ricerca mira a presentare i risultati più recenti dell'analisi delle trace d'uso e dei residui eseguita sugli assemblaggi in pietra scheggiata di Lepenski Vir, Padina e Vlasac, con un focus più ampio sul passaggio dal Mesolitico al Neolitico. L'applicazione dell'analisi delle tracce d'uso è stata eseguita utilizzando un approccio sia a basso che ad alto ingrandimento, in combinazione con analisi FTIR e SEM-EDX.

Inoltre, questo studio è istituito e rafforzato con una collezione di confronto realizzata appositamente per gli scopi della ricerca. I risultati ottenuti sono stati interpretati sulla base delle ipotesi focalizzate sulla routine quotidiana, ma affrontando anche alcuni aspetti a lungo termine, come i cambiamenti nell'economia e seguendo le differenze e le innovazioni nelle abitudini tra le comunità all'interno della regione. Sono stati analizzati i manufatti in pietra scheggiata, provenienti da case, fosse, aree focolari e spazi all'aperto. Sulla base dei risultati, vengono individuate alcune delle principali attività che hanno preso parte alle Porte di Ferro, come la lavorazione di pelle, osso, corno, pesce e risorse vegetali. Si è notato un numero maggiore di attività complesse/composite, come l'ammorbidimento delle corna o la concia delle pelli, che rendono più peculiare questa zona già specifica.

I dati ottenuti evidenziano le attività dei cacciatori-raccoglitori avanzati e dei pescatori e dei primi gruppi di agricoltori. Inoltre, osservati attraverso l'analisi spaziale, i risultati hanno rivelato le dinamiche e i processi nel tardo Mesolitico e nel primo Neolitico nelle Porte di Ferro, ma hanno anche posto molte domande sulla specializzazione degli insediamenti preistorici sul Danubio.

Parole chiave: analisi delle trace d'uso, analisi dei residui, strumenti in pietra scheggiata, archeologia sperimentale, Mesolitico, Neolitico, Periodo di transizione, Porte di Ferro, Lepenski Vir, Padina, Vlasac

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1. INTRODUCTION

1.1. RESEARCH SUBJECT

One of the key issues of the Early Prehistory of the Iron Gates region in eastern Serbia is the contact between the indigenous, hunting-gatherer communities, and the newly arrived groups of farming communities. Their encounter resulted in the final acceptance of Neolithic elements, such as the processing of the polished stone, pottery production, or the erection of permanent settlements, cultivation of plant and animal life species in the second half of the seventh millennium BC. Due to the appearance of Early Neolithic attributes in the Lepenski Vir site, as well as in other sites of this isolated paleo-ecological region, it is possible to raise research questions about the availability, substitution, assimilation of new human groups or contracting with the indigenous peoples, the acquisition of new knowledge and the transfer of new products in the long process of the Neolithization of Southeast Europe. In outlining a possible scenario, some elements support the facts about knowledge acquisition and product flow. This situation is known based on the results of previous studies, which point to an image of the lifestyle change that has become more complex and sensitive to study (Srejović 1969, Radovanović 1996, Antonović 2006, Bonsall 2007, Mihailović 2007, Bogosavljević, Starović 2013, Borić 2016). The angle from which these phenomena have not been observed so far is the study of the function of stone tools that can more accurately and realistically influence the interpretation of the basic habits of the Iron Gates inhabitants.

In the 1980s, the hypothesis of a Neolithic demographic expansion of farmers in the waves from the Middle East and along the Adriatic coast emerged, explaining the disappearance of Holocene hunter-gatherers, that is, the Mesolithic groups are completely being marginalized and left behind (Ammerman and Cavalli-Sforza 1984). The authors did not pay much attention to the hypothesis that the idea of first farming could be conveyed as such, and not just through the physical appearance of human groups. However, more recent research is based on overcoming the concept of hiatus and not considering the Mesolithic itself as a set of isolated cases but to look at the broader economic, demographic and social structure. Therefore, to observe the contacts in the Iron Gates in a broader inter-regional framework, it should be taken into account the structure of the Neolithic package should be known as well in the hinterland of Montenegro in sites such as Crvena Stjena (Mihailović 2009, Mihailović 2017), Odmut (Đurićić 1980, Cristiani and Borić 2016), Vruća Cave (Đuričić 1997), localities in Istria and the Croatian coast – Ovčija peć, Pupičina Cave (Miracle and Forenbaher 2006), Vela Špilja (Čečuk and Radić 2001), in Slovenia – Victorijev Spodmol, Mala Triglavca (Turk 2004, Budja et al. 2013) as well as in caves and subsidence in northern Italy such as Edera Cave, Benussi, Cavernetta della Trincea, Gaban Rockshelter (Montagnari Kokelj 1993, Biagi and Voytek 1994, Biagi and Starnini 1999, Bassetti et al. 2009, Cristiani et al. 2009, Franco 2011). Based on the published data, these are localities where elements of interactions between hunter-gatherer and sedentary communities can be observed and determine possible routes of neolithization, viewed from the perspective of settlement at the end of the Mesolithic and during the Early Neolithic. One theory that has been tested lately is the idea of embracing the innovations brought about by the Early Neolithic (*pioneering*) populations during the Late Mesolithic and that complex hunter-gatherer-fishermen were rapidly adapting and embracing the knowledge of pottery production and agriculture (Thissen 2017). Recent research on the genome of prehistoric communities from Southeastern Europe indicates the existence of migrants in Lepenski Vir, who have a similar genetic material to the Neolithic population from the Anatolian region. At Lepenski Vir and Padina, the existence of individuals carrying a mixture of the genetic codes of the mentioned migrants and local hunter-gatherers was detected, which indicates Iron Gates was a zone of interaction of groups differing in origin but also with divergent lifestyle (Borić and Mirackle 2004, Mathieson et al. 2018).

Current studies are questioning the presence of Mesolithic in other areas of Serbia, as Šumadija within the Zapadna/Velika Morava catchment (Bogosavljević Petrović and Starović 2016) and Čačak-Kraljevo Basin micro-zone (Bogosavljević Petrović and Starović 2021) based on the analysis of palaeoclimate, plants and animals, and archaeological material record (principally the stone tools technology) integrated with the context of Early Neolithic sites in Central Serbia. New radiocarbon dates, of human and animal remains from the Pannonian Plan and souther of Danube, dated to the 8th millennium BC indicated the presence of the Early Holocene sequence outside the Iron Gates region (Živaljević et al. 2021). Additionally, based on these indications and population density couple of scenarios considering the Meso-Neolithic Transition in Central Balkans are available. These possible forms of interactions summarize the probable dynamic (rapid acculturation or slow and successive) of the assimilation based on the quantity of both Mesolithic and Neolithic groups. It is highlighted that possible reasoning of the emergence of Neolithic populations contributed to the dissolution of the Mesolithic groups, which are considered to endure in an isolated area of the Iron Gates region (Mihailović 2021).

The complex structure of this transitional period required the introduction of new knowledge of raw material exploitation, stone processing technology, hunting methods, plant cultivation or use of timber in societies that already have their own traditions and customs. These innovations have certainly influenced the use of natural resources, stronger human intervention in nature, especially when it comes to the production of new types of tools and weapons. It should be remembered that the changes observed here have profoundly affected the relationships between groups and individuals, which is one of the goals of archaeological research. It is these contacts of different populations that have caused a whole series of cultural and economic changes, whether economic products, such as domesticated species of plants and animals, or a single product and technology for making them, such as ceramics or standardized blades on non-local raw materials, such as Balkan flint in Iron Gates.

Despite a large number of published synthetic studies related to the technology and typology of stone tools production from the Iron Gates sites, there is a striking lack of functional analyses of chipped stone tools. This type of research is necessary and at the same time complementary to technological studies, first of all in order to get to know in detail the work process, specific technological practices during artefact production. Secondly, this study is needed to understand the system of social development during the Mesolithic and early Neolithic. Until now, we did not have the opportunity to view these phenomena from the perspective of the utilization of the chipped stone of tools.

1.2. AIM OF THE RESEARCH AND EXPECTED RESULTS

The primary goal of the research is to enable the reconstruction of human activities in Mesolithic and Early Neolithic communities from the sites of Lepenski Vir, Padina and Vlasac. In other words, to determine the daily work processes in the lives of two different populations and monitor their amalgamation in the period c. 6300 cal. BC, especially just before and after 6170-5940 cal. BC, the period associated with the Mesolithic-Neolithic transition (Borić et al. 2018).

Since functional analyses have not been conducted so far on the chipped stone artefacts from the Iron Gates sites, it remained unknown for what purpose were they used - the method of use at all stages of the reduction process, from knapping of the raw material to post-depositional processes. Another, and no less important aim of this research is the creation of a reference collection of traces of use, a process that began as part of a master's thesis[1]. At the same time, this experimental approach will result in a large amount of data about the technology of knapping, which are typologically and technologically related to the Mesolithic and Neolithic period, its usable capabilities, but also human cognitive abilities.

The obtained data should clarify the system, the rhythm of the procedures during the making of the tools, as well as the handling of tools, specifying the type of force or the amount of time it takes

[1] *Transition period at Lepenski Vir site: functional analysis of chipped stone artefacts* (mentor Prof. Dr. Dušan Mihailović), thesis defended on September 30, 2016 at the Department of Archeology, Faculty of Philosophy, University of Belgrade.

to perform a certain action. This information can be obtained through experimental research. During the design of the experiments, different attributes of the experimental tool are observed, which retains traces of use whose later decryption provides insight into work activities. Technological and typological analyses of the chipped stone artefacts from Lepenski Vir, Padina and Vlasac have previously been published on a wider or shorter scale as articles, doctoral dissertations and monographs (Kozłowski and Kozłowski 1982, Kozłowski and Kozłowski 1984, Radovanović 1996, Mihailović 2004, Šarić 2014, Mitrović 2018). Based on the obtained results, the spatial interpretation of human activities will be followed. Looking at the results based on microscopic observations, with a detailed analysis of the archaeological contexts of the whole, thanks to the information on the identified array of archaeobotanical and zoological data, we expect that this thesis will contribute to the consideration of individual and group activities in the transition period in the Iron Gates area.

1.3. HYPOTHESIS AND RESEARCH QUESTION

Based on the published data, the transition period is a time of change with multiple nuances of the transition from one quality of life to a new value system. On one hand, there are mobile Mesolithic groups with traditionally rooted habits and on the other, there are clues about the arrival of foreigners in the closed Iron Gates region, with whom begins the sedentary lifestyle as we define it today. Certainly, it is the arrival of the first wave of early Neolithic populations that bring new knowledge and new goods, transferring them to others (Mathieson et al. 2018; Borić et al. 2018; Garašanin 1979). The flow and character of the processes that had to take place in such a set of circumstances are in themselves complex and specific to explain. As already pointed out, the first step in exploring encounters and creating new patterns is to carry out technological and typological analysis and selection of chipped stone artefact samples for microscopic observations.

A large number of realized and published researches of the sites in Iron Gates should be held in mind when one is dealing with the topic of transition and creating new hypotheses. This relates primarily to the absolute dating of archaeological contexts (Bonsall et al. 2004, Borić et al. 2004, Borić and Mirackle 2004, Borić and Dimitrijević 2007, Bonsall et al. 2008, Borić 2016, Borić et al. 2018, Borić 2019), paleoflora analysis (Filipović 2010), paleofauna (Bökönyi 1972, Dimitrijević 2000, Dimitrijević 2008, Dimitrijević et al. 2016, Živaljević et al. 2017), anthropological remains (Borić and Stefanović 2004, Roksandić 2012, Radović, Stefanović 2015, Borić 2016, Cristiani et al. 2016, Jovanović et al. 2021), isotope analysis (Jovanović et al. 2019), technological and typological analysis of chipped stone tools (Kozłowski and Kozłowski 1984; Radovanović 1996, Mihailović

2004, Šarić 2014, Mitrović 2018), ground stone tools (Radovanović 1996; Antonović 2006), and osseous industry (Vitezović 2011, 2017, 2021).

1.3.1. Hypothesis

Hypothesis 1: In the transitional period of Iron Gates, there were two strategies of using the tools: multifunctional tools on non-standardized knapped products (characteristic of Mesolithic) and specialized tool on primary flakes and blades of standardized dimensions (characteristic of Neolithic).

The premise here is the encounter of two different populations that are supposed to be carriers of two different lifestyles, two different economic systems, as well as two different technological strategies of chipped stone tools processing. If we assume that there are differentiated goals of food supply, as well as other types of materials necessary for the survival and development of two different communities, then it would be logical to assume that there were differences in daily activities as well. In this sense, it is to be expected that functional analyses of stone tools from representative stone assemblages will "show" key differences in use, indicative of life reconstruction. The starting point is that the overlapping buildings were used in different phases over a long period, that is, during the transition from the Mesolithic to the Early Neolithic, and the idea is to see if there is a diversity of the activities that could be connected to some of the stages of occupation specifically.

Hypothesis 2: Specialization in the use of stone tools existed within the settlement, that is, at the community level in the Iron Gates region. The communities of Lepenski Vir, Padina or Vlasac have „taken the lead“ in making certain products.

The results of the functional analysis should confirm or deny the affinity of one community with respect to another, that is, whether there are elements to confirm the hypothesis of specialized communities that produce solely for themselves, for themselves and others, or we can talk about far more complex communications. Having this in mind, an important part of the research will be devoted to the analysis of workplaces within settlements.

Based on our knowledge of the sites of Lepenski Vir, Padina and Vlasac we know that some segments of activities such as the procurement and preparation of food, clothing and objects made of leather, shells, bones, horns and clays were performed as a routine activity program or, more simply, daily obligations. The operative part of the research will influence the confirmation or denial of the listed work operations, as well as the discovery of new activities, such as processing of material of mineral character, or the role of additives.

Hypothesis 3: Wild and cultivated species of grasses and cereals are present, of which certain types were consumed during the Mesolithic, Transitional, and Early Neolithic period in Iron Gates.

The species were introduced gradually into the daily life of the residents using different processes during their processing.

The utilization of vegetable raw materials is a particularly important field of research especially in defining the type of diet. The level of cutting of wild grass species or the potential occurrence of traces from cutting early cultivated cereals is the basis on which a complex order of microscopic observations should be made. The manufacture of wooden objects is not known from archaeological data and it should be one of a series of materials whose traces can be uncovered. Preliminary functional and residue analyses of ground stone artefacts did not record focus on the processing of wood, tubers or even plants on the Padina, while the situation on Vlasac showed a small percentage of activities related to the processing of vegetable resources[2]. However, it is evident that the inhabitants of Vlasac at the end of the Mesolithic (~6600 cal. BC) consumed domesticated species of wheat and barley, as determined by analysis of dental calculus, the results of which coincide with the result of human teeth from Neolithic individuals from Lepenski Vir (~5900–5700 cal BC), (Cristiani et al. 2016). Some of the recent studies, also based on the dental calculus, discovered that the variety of vegetals consumed by the individuals of the transitional period in the region expanded on the grasses, and woody plants, tree taxa, while the cereal consumption for confirmed in the Neolithic layers of Lepenski Vir (Jovanović et al. 2021). The current findings suggest that questions have been raised as to whether plant food processing was a regular practice in Iron Gates, or whether they were taking place in another manner unknown to us, given the development of agriculture in and around Iron Gates during the Neolithic period.

Hypothesis 4: Chipped stone tools from Lepenski Vir, Padina and Vlasac were recycled several times during the various stages of life of the analysed objects (house floors, pits, hearths).

It is a well-known notion of recycling chipped stone artefacts, resharpening them for reuse and maximum utilization. This type of phenomenon has rarely been viewed from the perspective of functional analyses. The example of Qesem cave material demonstrates the effectiveness of such problem-solving (Lemorini et al. 2014, Venditti 2019). More than two decades ago, Odell (1996) pointed to the fact that the idea of recycling was as relevant in the past as it is in the present but also neglected because it is more difficult to identify in an archaeological context. Hence, by combining in-depth analysis of technology and function there is an opportunity to understand human behaviour and recycling behaviour during the transition period in Iron Gates. It is important to determine the

[2] Personal communication with Emanuela Cristiani and Isabella Caricola, Sapienza University of Rome, October 2018.

chronologies of the different use zones on a single blade or unretouched flake. The assumption that different activities (or the same ones) were performed by the same tool through different chronological periods can greatly contribute to the understanding of the production of the tools itself, as well as the scope of the tools available to one generation. Testing whether recycling was an integral part of the system or a less represented technological aspect may affect the overall picture of human activities in the Iron Gates region.

1.3.2. Research questions

Microscopic analyses of traces of use should yield results that clarify concerns about determining the basic human activity of both Late Mesolithic and Early Neolithic communities in Iron Gates, the existence of differences in habits, types of processes, and the technology used in the production of tools. In this regard, a long list of research questions is imposed, which can be divided into four sections.

The first group of questions - *the spatial organization of activities*

- Were there any specific activity areas?

- What is the spatial arrangement of the used artefacts in the context of the Iron Gates sites?

- How does this change the interpretations so far?

The second group of questions - *the role of tools and individual artefacts*

- On what contact materials were chipped stone tools used?

- Is there a tendency to store certain types of tools for another later the subsequential utilization?

- What types of artefacts were used to process cereals? What types of cereals were processed?

- If the traces are from grass cutting, are they wild or cultivated species?

- The role of the burin: bone or wood, clay or stone?

The third group of questions - *raw materials and tool function*

- Is there a differentiation regarding the choice of raw materials for specialized activities?
- Is the utilization of the Balkan flint tools, as one of the markers of the Neolithic package in Iron Gates, different from the role that had tools made on another raw material?

In addition to the above-mentioned issues concerning the activities of individual sites and certain types of tools and raw materials, it is necessary to consider a group of specific issues of general methodological character, which have not been sufficiently addressed or studied in Serbian literature. Particularly sensitive is the issue of determining the assessment of typological determinants with the functional role of the tool. It is to be expected that some tools, named by their typological form, were not used for activity suggested by the name, as it appears in the published technological-typological studies. We also assume that there are specific activities performed by specific typological groups of tools, which need to be precisely defined with specific examples. It follows that the results of the agreement, disagreement or partial overlap of the archaeological determinants and function of the tool should be analysed in the context of the archaeological entities from which they originate.

1.4. INTRODUCTION TO THE METHODOLOGY AND SAMPLE

The methodological basis for the proposed topic is to carry out use-wear analyses and to form a reference collection of traces of use, as well as to analyse the remains of organic and inorganic traces on chipped stone artefacts. Two methods are used - the low-power and high-power approach method, as well as the analysis of archaeological material using SEM microscopy.

Before proceeding to microscopic analysis it is necessary to observe all the chipped stone artefacts from sites of Lepenski Vir, Padina and Vlasac were carried out. This examination is macroscopic and is performed with the naked eye and magnifying glass with larger and smaller magnifications. It involves analysing the technological and typological features of tools to record their preservation, fragmentation, deformation, and fracture. Such preliminary analyses and databases are useful for many reasons. For example, they are performed to single out the artefacts that have a patina that endangers their surface (Lemorini et al. 2014). An example of this type of observation is the experiment on *used flakes*, a term used in Ontario for flakes that allegedly had traces of use (Shen 1999). However, it is known that edge damage can also be caused by other activities such as weathering, trampling and by various post-depositional surface modifications (PDSM). Therefore, it is more than clear that microscopic analyses can change our current views on the typology of the stone industry, especially when it comes to the functional category of a tool such as used flake (Yerkes and Kardulias 1993: 103).

After the primary observations of the archaeological material, more complex analyses are made using an optical microscope. The smaller magnifications are mainly related to stereomicroscope analyses, which magnify 4-10x and even up to 60x. The key value of these analyses is that the edges and surface have been thoroughly and systematically analysed to detect small fractures and features, but also to determine the micro-region that will be further examined under different higher magnification (Odell and Odell-Vereecken 1980, Odell 1981). On the other hand, access to larger magnifications is possible with metallographic microscopes operating on direct light (90º). To identify, classify and record different traces of use, such as polishes, larger magnifications (50-400x) are needed (Marreiros et al. 2015: 11). The combination of both approaches gives a much more complete picture of the results of functional analyses (Grace 1996, Clemente and Gibaja 1998). A third method to which a sample from these sites will be subjected is a scanning electron microscope (SEM), which provides a wider range of capabilities than the results of an optical microscope (Olle and Verges 2008). The better resolution allows a more detailed view of the artefact surface (which is rarely flat, making the analysis more complex), at much higher magnifications (up to 500,000h) than those of an optical light microscope (OLM), much easier to detect patterns of trace formations and stone tool modifications (Borel et al. 2014: 52). Also, this apparatus enables a chemical surface analysis of the object (EDAX).

Use-wear and residue analysis is being performed at the *Laboratory of Technological and Functional Analyses of Prehistoric Artefacts* (LTFAPA), which is part of the Department of Ancient Sciences at the Faculty of Literature and Philosophy at the Sapienza University of Rome. In total seven hundred fifty-three (753) artefacts were sampled for use/wear and residue analysis from all three sites. From the Lepenski Vir site, 393 artefacts come from dated contexts, and also from contexts that are directly related to those zones (e.g. under the floors of the houses). The material was sampled from various contexts as houses, middens, hearth and spaces between houses. The material from the Padina site (209 artefacts) is sampled from all three sectors: I, II and III, including the dwelling areas, houses, hearth and stone structures. The majority of the sampled artefacts comes from dated contexts. Archaeological material from Vlasac site (150 artefacts) was not easy to sample given the very small number of absolute dates made for the site. Having this in mind, closed contexts such as houses or graves were chosen.

A considerable part of the thesis is devoted to the experimental programme, which is an inseparable part of the functional analysis protocol. In this sense, the experimental trials aim to replicate the traces of different activities on diverse materials and compare them with the traces of use found on the archaeological sample. In addition to excellent methodological practice, this method is useful for observing the entire process from the making of the tools, their use, to the loss of its efficiency and discard. During these experiments, a large number of variables are recorded and observed, and they relate to the tool position itself, method of use, the power consumed, time of work, and then the results of the experiment itself are analysed, in this case, efficiency and trace characteristics.

It is very important to use all the materials that were available to the population in the Iron Gates region in the late Mesolithic and early Neolithic, as well as stone raw materials similar to the originals, and typologically similar tools. Since the diet of the Iron Gates inhabitants is well defined and the knowledge about paleoflora and paleofauna is more complete than the period when the sites were discovered, published studies and reports have been the necessary framework for making a more specific selection of animal and fish species that served in experiments and thus provided satisfactory legitimacy.

The traceological analysis is followed by quantification of the results and numerous statistical analyses, depending on which research question is being answered. The archaeological interpretation of the results is made based on the spatial distribution of the artefacts by sites. This type of observation of the data obtained is indicating activities in settlements whose reconstruction of life is the goal of the research. With a comparative analysis of archaeological contexts from multiple localities, a complex picture of the activities of the Iron Gates inhabitants at the end of the Mesolithic and early Neolithic periods is drawn.

1.5. GENERAL FRAMEWORK OF THE STUDIED SITES IN THE IRON GATES REGION

Iron Gates represents a unique ecological niche in the area of northeast Serbia on the border with Romania. In terms of geomorphology, the Iron Gates is an enclosed space with special features of relief and erosion processes. This natural and geographical entity is viewed as an isolated ecosystem, and all processes in the past are treated separately due to the characteristics that do not exist nowadays.

Intensive archaeological research was conducted on two occasions, from the sixth to eighth decade of the 20th century, with the participation of several museum and scientific institutions on the territory from Veliko Gradište to Sip, (Đerdap I, 1964–1971), and from Karataš to Prahovo (Djerdap II, 1978–1990). These extensive excavations recovered over 100 multi-layered archaeological sites.

Archaeological rescue excavations that have been carried out in several research seasons were, firstly, published as preliminary results in a specially formed edition of Đerdapske sveske I, II, III and IV (1980, 1984, 1986, 1987). Archaeological material is kept in the Museum of Đerdap, at the Faculty of Philosophy in Belgrade, and as part of the special collections of the National Museum in Belgrade.

The archaeological material that is the subject of this thesis comes from three sites in the Iron Gates region: Lepenski Vir, Padina and Vlasac – all of them situated on the right terrace of the Danube river in the Upper Gorges (Fig. 1).

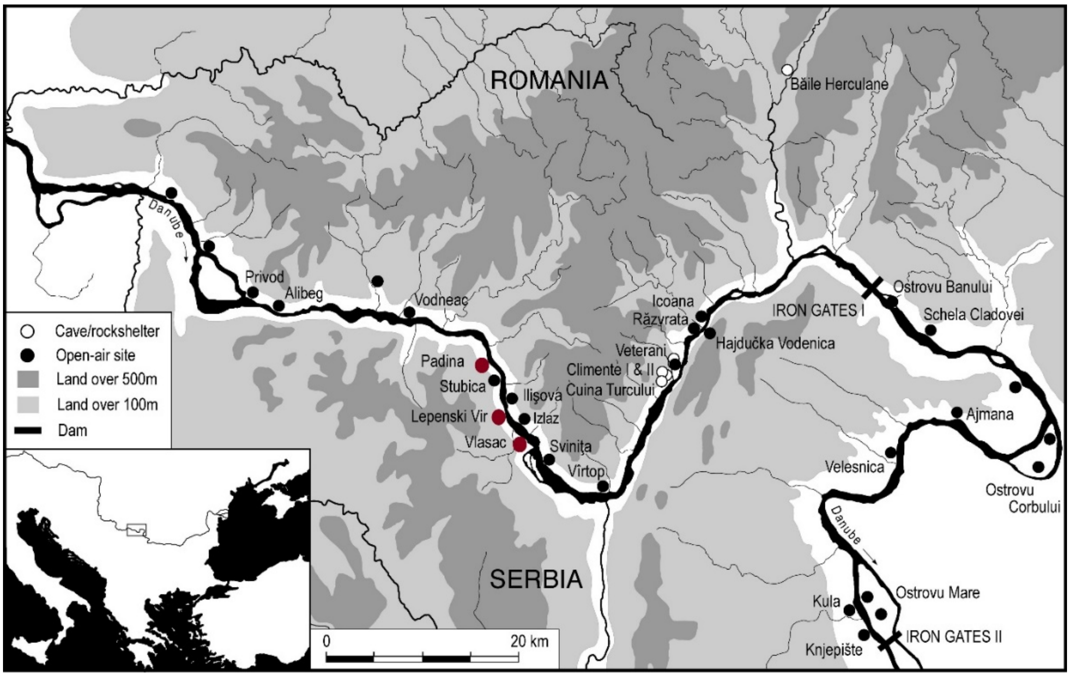

Figure 1: Map of Iron Gates region, map courtesy of C. Bonsall (after Bonsall et al. 2008)

Lepenski Vir and Padina were excavated during the 1960s and 1970s (Srejović 1969, Jovanović 1987), and Vlasac in 1970 and 1971 (Srejović and Letica 1978). After the excavations, the sites were submerged with water, to construct the hydropower plant Đerdap I. However new, revisionary, fieldwork, made across the preserved area of the Vlasac, in the period from 2006 and 2009 provided a unique opportunity for a re-evaluation of stratigraphy, chronology and the character of the occupation (Borić et al. 2008, Borić et al. 2014).

The period of inhabitation of the prehistoric open-air settlements in the Iron Gates is long, from the Early Holocene, around 9600 cal BC to the Late Eneolithic-Early Iron Age/during Subboreal and Subatlantic, respectively through the III to I millennium BC (Borić 2011, Radovanović 1996, Mihailović 2021). The earliest phase of occupation that will be observed in the study is the Early Mesolithic period (c. 9500-7400 cal BC). A smaller portion of the sampled chipped stone tools originates from the contexts associated with the Early Mesolithic. In this period the groups inhabited the river terraces and built the elongated rounded constructions together with stone hearths. The presence of burials is marked (mostly) by supine inhumations.

The following period Late Mesolithic (c. 7400-6300/6200 cal BC) is characterised by first dwellings and structures with rectangular hearths. The zooarchaeological remains witness that the groups hunted the species in all the sessions which indicate on lower mobility (Dimitrijević et al. 2016). The diet was mostly based on the consumption of the fish and hunted game (Dimitrijević et al. 2016, Živaljević 2017). The sampled material that belongs to this period is from the houses and dwellings from Padina and Vlasac. According to the previous researches, there are indications for the contact with the broad settlements based on the presence of the non-local flint (Kozłowski and Kozłowski 1982), but also it can be testified by the presence of ornamented beads made of *Cyclope neritea* gastropods which are not common in the region (Borić and Cristiani 2016).

As already specified this study will be focused on the Transitional period (c. 6200-5900 cal BC) and most of the sampled artefacts from Lepenski Vir and Padina are coming from the contexts dated to this period. The Transitional period is characterized by the trapezoidal buildings and sculptured boulder, but also in the changes in the mortuary practices of the children (Borić and Stefanović 2004). Furtherly, as it is indicated by the appearance of Balkan flint, Starčevo pottery, and *Spondylus* beads this was a period of contact between the hunter/fisher/gatherer groups and first farmers (Borić 2002, Borić and Price 2013). The diet is characterized by consumption of terrestrial and aquatic resources (Dimitrijević 2000, 2008, Dimitrijević et al. 2016, Živaljević 2017).

The last phase which would be observed from the point of the functional analysis of the chipped stone tools is the Early/Middle Neolithic (c. 5900-5600 cal BC). The samples coming from these contexts are mostly connected to the previous phases, for example, the overlapping buildings at Lepenski Vir or house 18 and 15 from Padina. Only one burial from Vlasac is dated to this chronological span. This period is a time where trapezoidal dwellings were slowly abandoned and domed ovens together with domesticated animals occur together with the change in the burial practices. This period corresponds to the spread of the Early Neolithic sites in the region (e.g. Whittle et al. 2002) well visible by the acceptance of the Starčevo culture elements in the foraging settlements of the Iron Gates region.

2. SAMPLE AND ARCHAEOLOGICAL CONTEXT

In total 753 artefacts were sampled. The main filter for choosing the exact context that should be studied was the availability of absolute dates for the given area and site. As it was mentioned earlier, since the main aim of the thesis is the monitoring of the daily prehistoric activities in the transitional period from the Late Mesolithic to the Early Neolithic period in Iron Gates the chronological frame of the research is the end of the 7th to mid-5th millennium BC.

The detailed discussion regarding the single context, the available absolute dates, and other types of the artefacts found, besides the chipped stone tools in the analysed settlements, will be presented in Chapter 5, together with the use-wear and residue results. However, in this section, a concise review of the previous techno-typological analysis together with the basic information about the context of the sampled tools will be provided.

2.1. LEPENSKI VIR CHIPPED STONE ASSEMBLAGE

The technological and typological analysis of the chipped stone industry of Lepenski Vir was published by Polish authors J. K. Kozłowski and S. K. Kozłowski (1984), and it was later summarized by I. Radovanović (1996). The classification of stone raw materials originates from the first authors of the analysis and it was done with the help of petrologist M. Pawlikowski (Kozłowski and Kozłowski 1984: 253-293).

Most of the tools originating from the Preneolithic layer I, which includes artefacts made from 18 different raw materials, are made of grey radiolarite and greyish flint and quartz (Kozłowski and Kozłowski 1984: Table 1). The first two groups appear in the limestone from the geological era of the Mesozoic and the third can be found in the alluvial deposits of Danube. The smaller group consists of the raw materials that were brought from different regions, as grey non-transparent flint, grey transparent, Balkan flint and black flint. Grey flint was used for the production of the cores, splintered pieces and flakes, while greyish flint was used for flakes and blades (Kozłowski and Kozłowski 1984). The general structure of the Preneolithic layer I consist, mainly, of flakes and debitage, unretouched blades, cores, splintered pieces and retouched tools (Radovanović 1996), (Fig. 2).

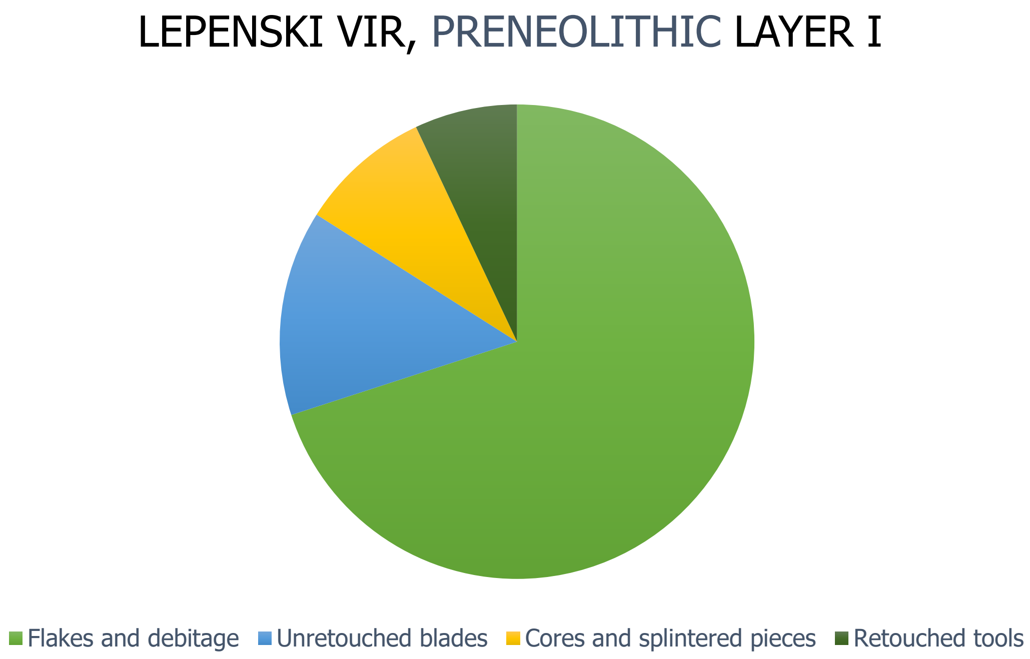

Figure 2: Preneolithic layer I, Lepenski Vir (after Radovanović 1996)

In Neolithic layer III, the most used raw material is Balkan flint (65.73% of use in the total structure). The exact source of this raw material has not been determined at the time of processing the technological characteristics, and the situation has not been resolved satisfactorily to date (Bogosavljević Petrović, Starović 2013, Gurova 2008, Kozłowski and Kozłowski 1984: 267). In the last study where laser ablation analyses were mainly performed on samples of Balkan flint, a strong signal of origin points to the area around Nikopol and Pleven in Bulgaria (Gurova *et al*. 2016: 438-440). Quartzite is in the second place of extraction, flint with stripes is in the third place, while grey radiolarite and grey flint are less frequent (Kozłowski and Kozłowski 1984: 271). The typological structure of the industry in this layer is similar to the Preneolithic layer I, consisting mainly of flakes and debitage, unretouched blades, retouched tools, and cores and splintered pieces, which are represented in a lower amount compared to the older phase (Fig. 3). It can be concluded that for the Neolithic layer III phase of the settlement the population exploited less the local sources and main used imported raw materials from eastern regions (Kozłowski and Kozłowski 1984), emphasizing the production of cores, blades and tools on Balkan flint in the early Neolithic horizon (Bogosavljević Petrović and Starović 2013: 87).

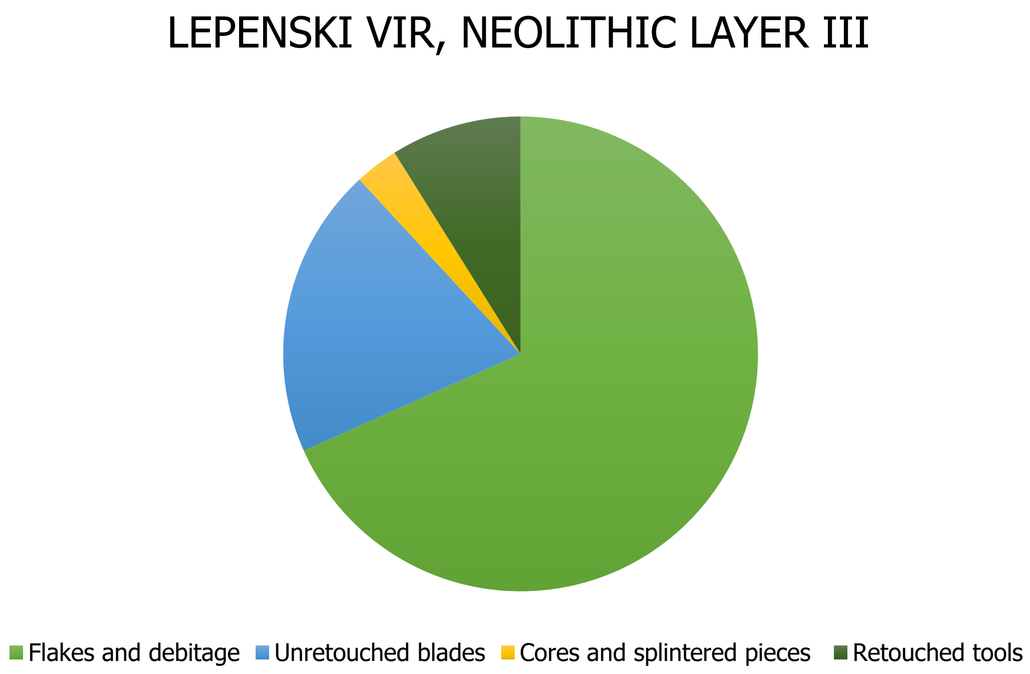

Figure 3: Neolithic layer III, Lepenski Vir (after Radovanović 1996)

The new detailed study of applied knapping techniques and spatial analysis singled out a couple of contexts marking them as areas of importance for the production of the chipped stone tools. The research indicated that the knapping of grey flint took place in houses 32, 36 and 35, where also Balkan flint was knapped (Mitrović 2018).

2.1.1. Lepenski Vir sample

Three hundred ninety-three (393) artefacts were sampled from Lepenski Vir site. The samples come from the dated contexts or the areas that are directly related to those zones (e.g. under the floors of the houses). The material was sampled from houses 54, 32, 37, 35, 36, 8, 26, 28, 34, 47, 40, 41, three pits, hearth 70 and spaces between houses, in order to establish relationships and interpret activities in different zones and functionality of overlapping buildings (Fig. 4). The tools that were subject to analysis are all the artefacts found in the mentioned context, and they were analysed in total. The general chronological frame for the sampling filter of the Lepenski Vir tools was the establishment of the trapezoidal-base buildings, stone-lined hearths, sculpted boulders and pottery (c. 6170-5940 cal BC, Borić 2018), including a few building where the previous phases of occupation were noted (e.g building 26, 47) dated to the Early-Middle Mesolithic (c. 9900-6860 cal BC, Borić 2018).

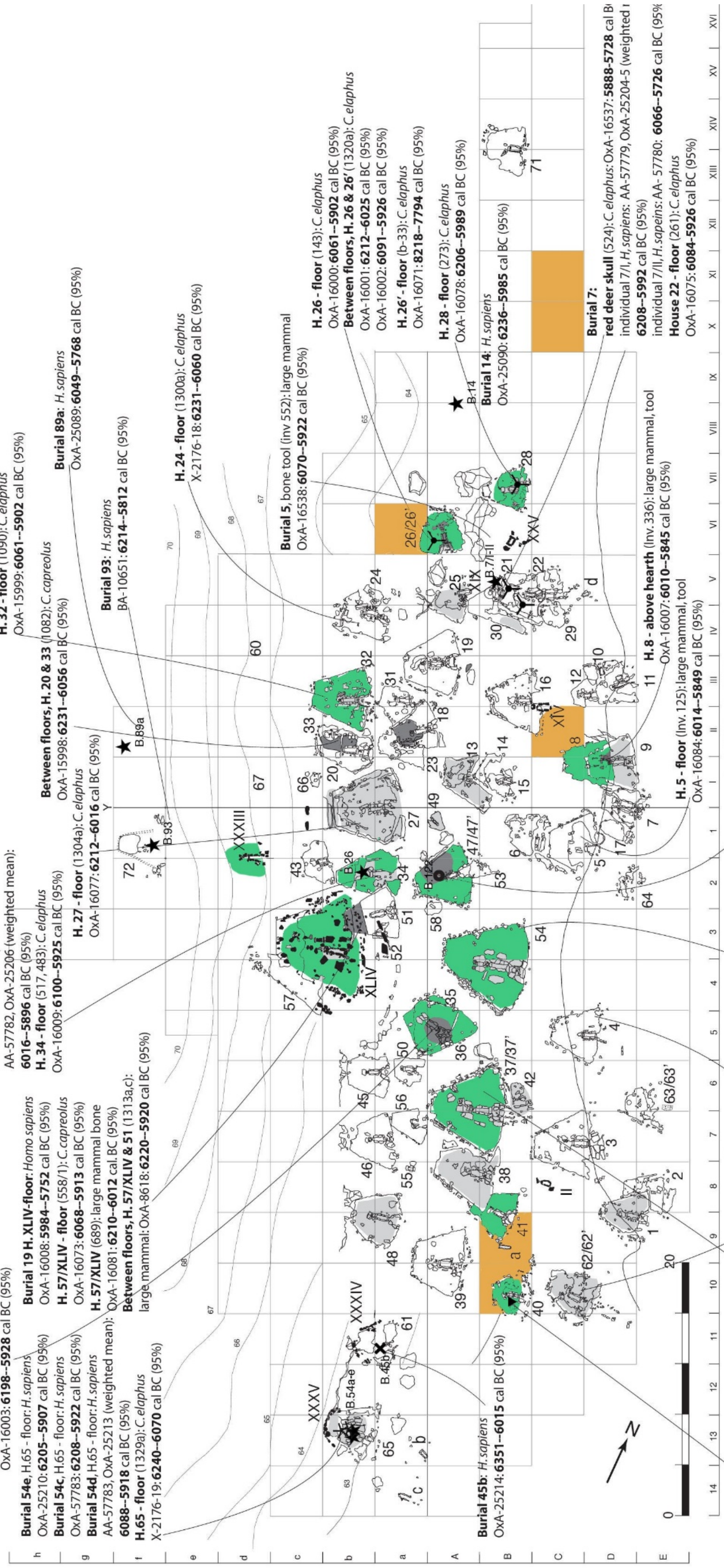

Figure 4: Lepenski Vir, with marked areas of sampled artefacts (after Borić and Dimitrijević et al. 2008)

Lepenski Vir is one of the sites where the amount of the dated context is the highest compared to the dates from the other settlements in the region, and a synthesis of the dated contexts will be represented in this section.

Terminus post quem for the construction of building 54 is 6393-6116 cal BC (Borić 2019) and this is the only range that is taken into consideration for this study. A couple of dates are connected to the context marked *as under the level of the house XLIV* where the chipped stone tools are recovered: 1) stone construction above the floor of the house 6210-6012 cal BC; 2) on the house floor 6068-5913 cal BC; 3) burial, level of the floor 5984-5752 cal BC (Dimitrijević and Borić 2007). Tools from neighbourhood buildings (40 and 41) together with the artefacts found in the space between are sampled. The only dated feature is hearth a in the space between the two houses and it is dated to a range 7740-7587 cal BC. House 41 is considered to belong to the early building horizon of Lepenski Vir (6200-6050 cal BC) together with the buildings 4, 20, 24(?), 26', 27, 28, 29, 33, 34, 38(?), 51, and 65, while houses 21, 22, 26, 32, 35, 36, 37 are connected to the later phase (c. 6050-5900 cal BC), (Borić and Dimitrijevič 2007). This division is solely hypothetical, and it requires more absolute dates and more statistical and Bayesian modelling of the data. House 28 is dated also to the transitional period in the range 6206-5989 cal BC (Borić and Dimitrijević 2007), followed by building 34, dated to 6100-5925 cal BC. House 34 had another indicator of the inhabitation, and that is the burial 26, which was dug in behind the hearth and dated to 6078-5880 cal BC. Building 37 is dated to 6071-5992, while building 32 to the 6061-5902, and building 8 to 6010-5845 cal BC (Borić and Dimitrijević 2007). Houses 26 and 26' are one of the overlapping buildings found at the Lepenski Vir site. The oldest date is 8218-7794 cal BC, and it comes from the antler found on the floor of house 26, and a date in the range 6023-5849 cal BC is dating the house 26 (Borić and Dimitrijević 2007). Another example of stratigraphically connected buildings is 47' and 47. The date from underneath the floor of house 47' (9441-9241 cal BC) is the oldest date from Lepenski Vir and it confirmes that this location was inhabited in the Early Mesolithic, similarly to the other sites in the region as Padina and Vlasac (Borić and Dimitrijević 2007). Regarding the house 47', there are two indicative dates, an older one (9295-8926 cal BC), which is probably from the secondary deposition of the material, and a younger one, which was double-dated (6208-5987/6206-5988 cal BC), (Borić and Dimitrijević 2007). Building 36 is probably belonging to the latter building horizon at Lepenski Vir and this house is one of the numerous overlapping objects overlayed by building 35. The dating of the object comes from the date of an animal bone from the hearth of the building 36 – 6198-5928 cal BC (Borić and Dimitrijević 2007).

Figure 5: Lepenski Vir, chipped stone tools from and under the house floors,
selection 1 – under the floor of house 26, 2-12 – house 36, 13-17 – house 32, (photo A. Petrović)

Even though the buildings (Fig. 5) and house features, were sampled for dating there are no absolute dates for the observed pits. The only chronological indication is established in the case of the pit C/X, XI (Fig. 6), where, besides the chipped stone tools, fragments of Early Neolithic Starčevo pottery were found.

Figure 6: Lepenski Vir, chipped stone tools from the pit C/X, XI (photo A. Petrović)

2.2. PADINA CHIPPED STONE ASSEMBLAGE

The chipped stone industry of Padina was studied with a focus on procurement and exploitation of the raw material (Mihailović 2004, Radovanović 1981, 1996). The site is characterized by two archaeological horizons. Padina A belongs to the second half of the ninth millennium BC and Padina B to the transition from Mesolithic to Neolithic period (Jovanović 1987).

Padina A

Most of the Padina A chipped stone tools are collected from Sector II and almost 50% of finds from this sector come from block 2a. It is possible to distinguish two horizons in this block, Padina A1 and A2. According to I. Radovanović (1996), chipped stone tools found in the A1 and A2 are characterized as tardigravettian chipped stone industry with Aziloid elements, and a high frequency of bipolar technique applied to the local lithic resources (Fig. 7 and 8). The horizons are separated by stone construction which probably represents the remains of a dwelling. However, this division is artificial, and the transition is probably gradual and long-lasting, and the stone construction is taken as a borderline between which completely covers the artefacts determined as the phase A1 (Radovanović 1996). The density of finds in block 2a is very high and clearly visible, since as many as 75% lithic artefacts per square meter were recovered. The cause for this quantity of tools is that the dwelling object was situated in this place, but there is also a possibility that some smaller artefacts were transported by water from higher ground (Mihailović 2004).

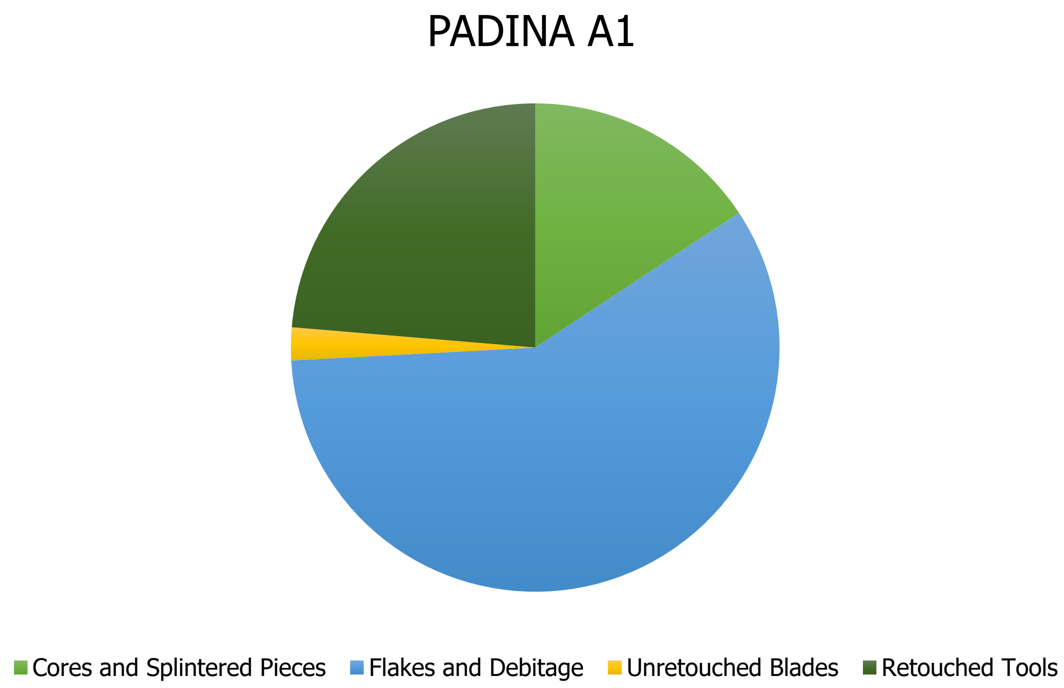

Figure 7: Padina A1, the general structure of assemblage (after Radovanović 1996)

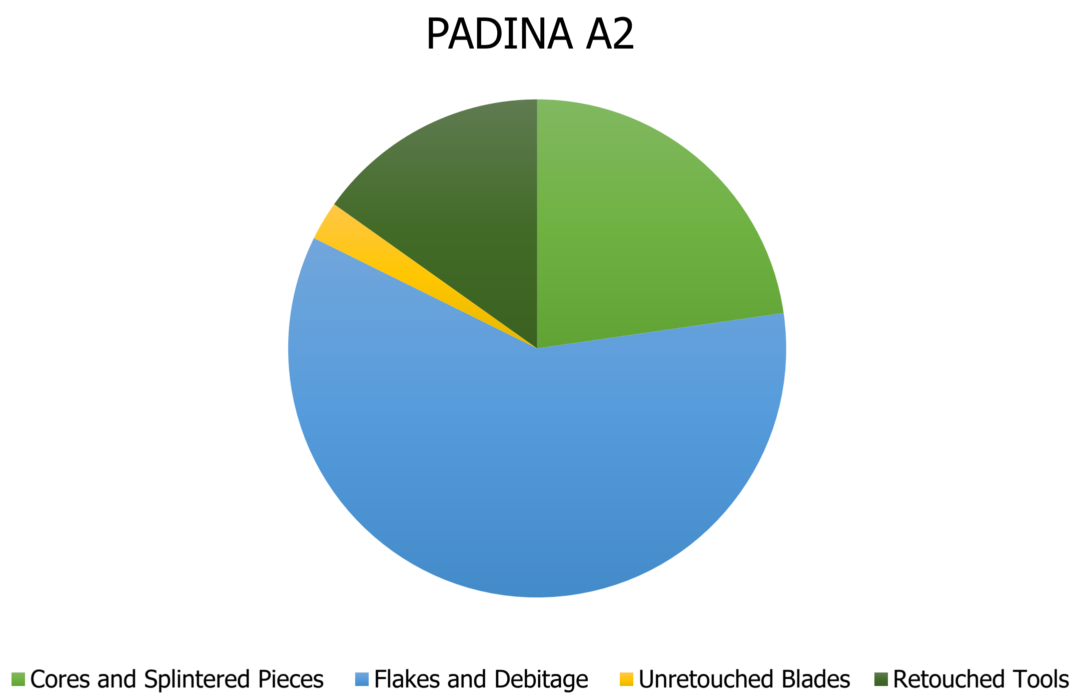

Figure 8: Padina A2, the general structure of assemblage (after Radovanović 1996)

The technology of chipped stone tools from Padina A is based on three traditions: lamellar, flake technology and bipolar technology (Mihailović 2004, Radovanović 1996). The large variability of the raw materials used for knapping is visible, and tools made of local grey flint prevail. Technological analysis of the chipped stone industry from Padina confirmed that the full technological cycle can be observed only on the grey flint artefacts. The structure of used raw materials differs from the preferences of other (both, earlier and younger) sites in the region, and Padina A has most similarities with Vlasac site, quartz, and quartzite apart (Kozłowski and Kozłowski 1982, Mihailović 2004)).

In Padina A structure there is a high predominance of flakes over blades. The presence of cores and tools such as end-scraper, retouched flakes, side scrapers and backed pieces is observed as well, together with burins, notched, denticulated and truncated pieces (Mihailović 2004, Radovanović 1981, 1996), (Fig. 9).

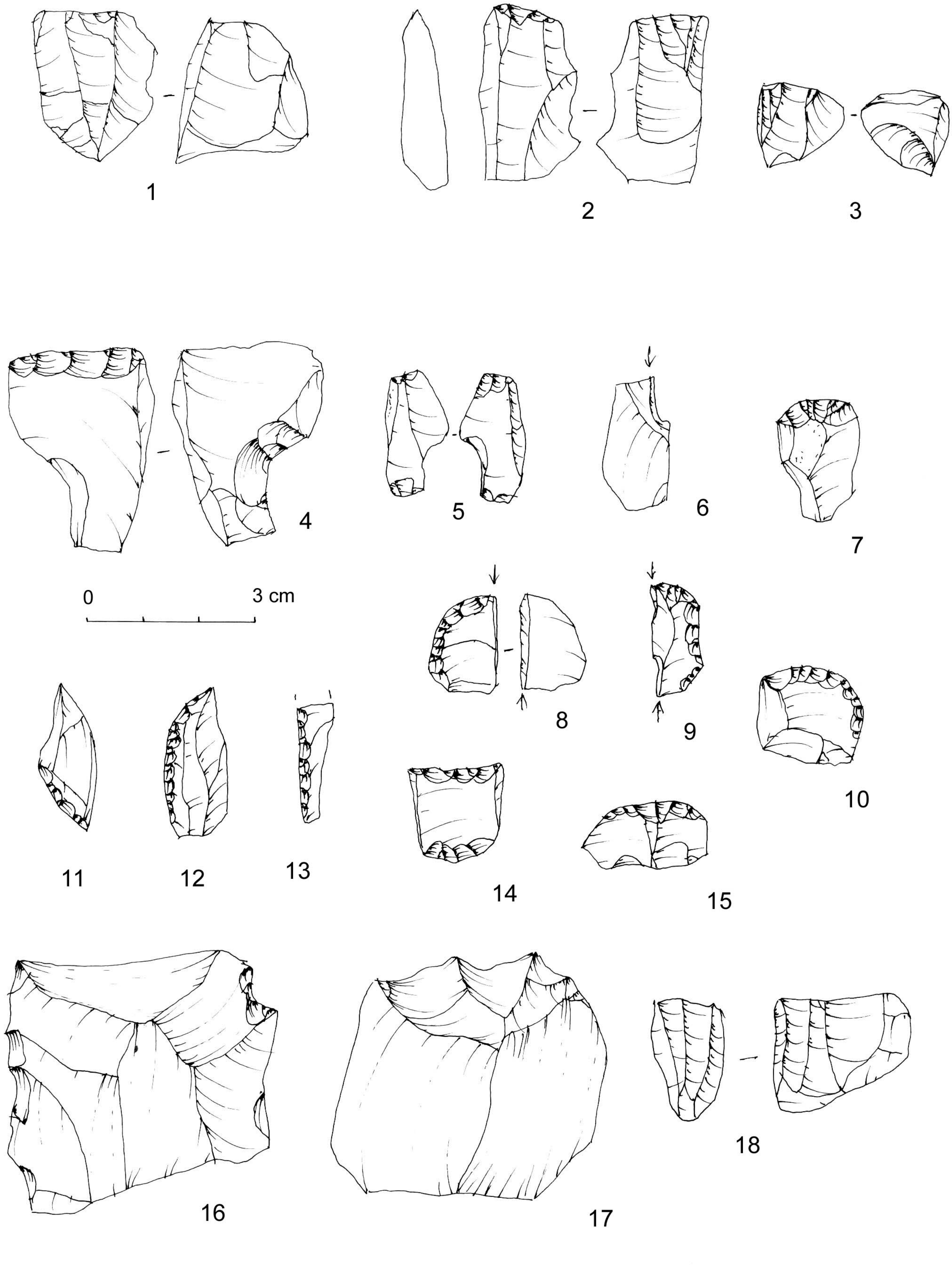

Figure 9: Padina A: 1-8, 11, 13 cores and tools produced of grey flint, 9, 18 chalcedony, 10, 15 brown flint, 12 jasper, 14 Banat flint and 16, 17 alevrolite, (Mihailović 2004:63)

Padina B

Tools that can be attributed to the Padina B horizon are noted mostly in Sector III. Two traditions of technology are present at Padina B. The older tradition is represented with quartz tools, bipolar technology and a high percentage of flakes and flake tools. The second one, a younger tradition, is characterized by blade technology (Mihailović 2004:67).

The general structure shows a very low percentage of cores, a higher number of tools, flakes and a smaller number of blades, implying that the workshop was situated outside of the settlement centre. Retouched tools are represented by retouched and notched blades (Mihailović 2004), (Fig. 10).

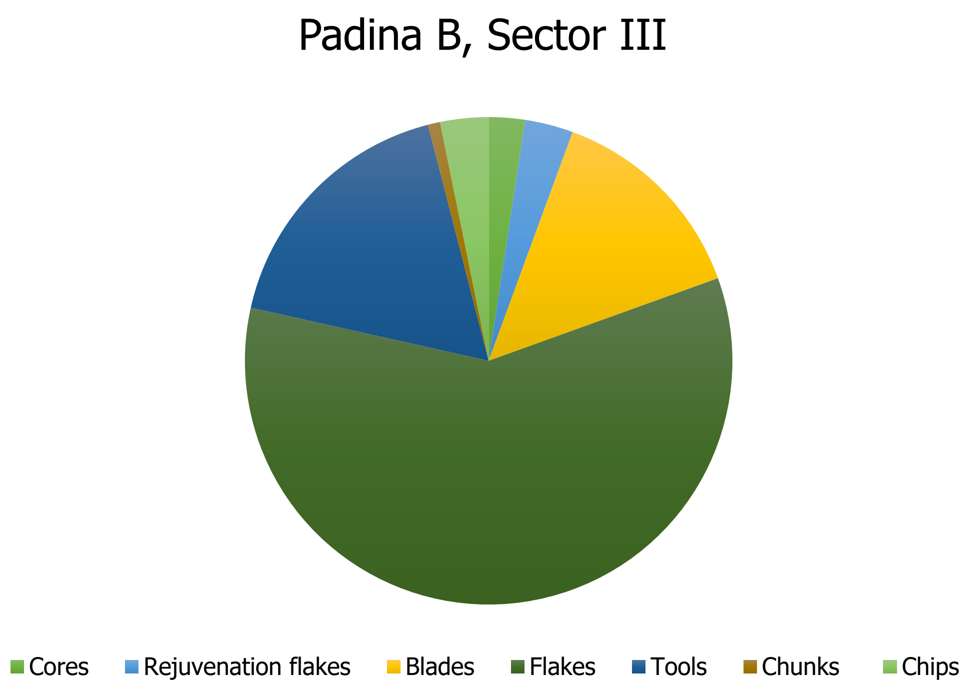

Figure 10: Padina B, the general structure of assemblage (after Mihailović 2004)

Almost two-thirds of the artefacts are manufactured on the so-called Balkan flint (29%) or quartz (29%). Tools made on brown transparent flint, grey flint, chert and other siliceous rocks (less than 10%) and finds of chalcedony and jasper (6,6%) are present in lower quantity (Mihailović 2004), (Fig. 11).

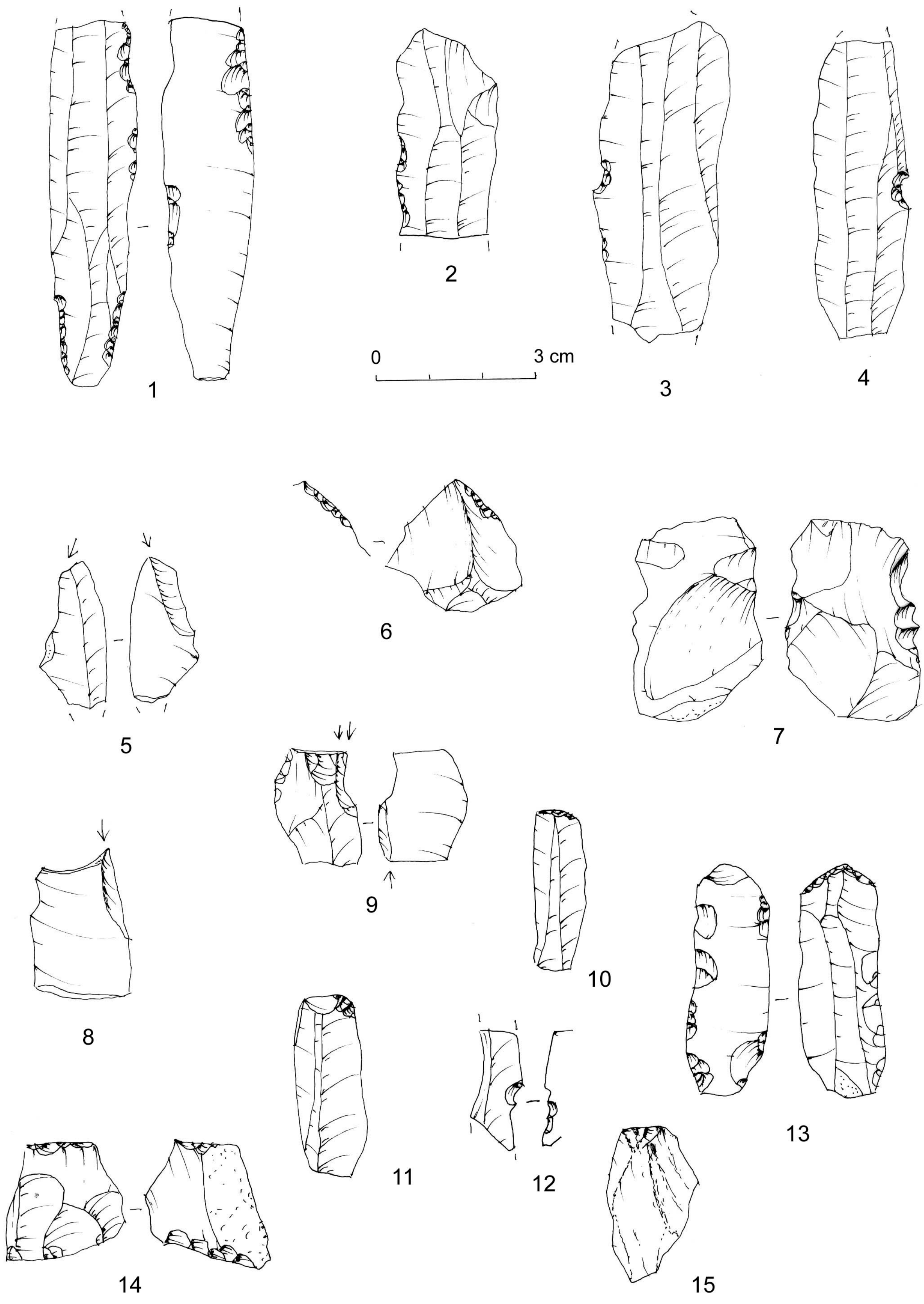

Figure 11: Padina B: 1-7, 14 chipped stone artefacts produced of beige-brown flint, 8-10, 13 grey flint, 11 chalcedony and 12 jasper, (Mihailović 2004:66)

2.2.1. Padina sample

The material sampled from the Padina site (209 pieces) comes from three sectors.

Sector I

Sector I is placed on the lowest part of the flat bay in a deeper depression, formed by river penetrations between diagonally lowered ridges (Jovanović 1974), (Fig. 13).

In total, 19 tools were sampled from Sector I, and the material comes from Trench 1, block 1b, 2b and profile 3, segment 2 (Fig. 12). Regarding sector I, block 1b is marked as house 2 and block 2b to house 3, all belonging to Padina B horizon. In house 2, a rectangular hearth was found with sign/support (block 1b). In the context of the level underneath the hearth (number 1614) one sample (PA 1) was found. Regarding the absolute dates, samples from block 1b are dated to 6650-6460 cal BC (Borić and Miracle 2004). In the case of the burial Ia two dates are available. The burial offer, an antler mattock revealed the older date 6650-6460 cal BC, and the skeleton was dated to the range 6470-6230 cal BC indicating the use of this area of settlement in the Late (terminal) phase of Mesolithic (Borić and Miracle 2004). In segment 2, a rectangular hearth was found with a vertically placed stone slab and pebbles found in the level of light-coloured soil with chipped stone tools. This is attributed to the later phase (A2). In this context, samples PA 3 and 4 were found together with the fragments of Starčevo pottery placing them in the Early Neolithic (Radovanović 1996).

Figure 12: Padina, selection of the samples from Sector I (photo A. Petrović)

Sector II

An arched plateau, connected to the previous sector, runs parallel to the coast and is connected by a narrow gully with a gap in the background. This way the material was washed away and deposited over the central part of the sector (Jovanović 1974). This kind of situation can be the reason for the quantity of material found in the specific blocks of Sector II, (Fig. 13).

From Sector II, 97 tools were sampled. Different categories of artefacts were selected from block 2a, given that 50% of the findings from this sector had just come from this context (Mihailovic 2004). Having this in mind, 5-10 pieces were taken from different morphological categories such as retouched tools, splintered pieces, as well as unretouched tools. This block 2 is the level of the found feature described as amorphous stone construction of small niveaus of stone slabs and pebbles, with abundant chipped stone and bone industry (especially in block 2a) and it belongs to Padina A horizon (Radovanović 1996).

There are no available absolute dates for block 2a. The only date (8250-7600 cal BC) from Sector II, comes from burial 7, found in block 1b (Borić and Miracle 2004). This date is corresponding to the technological and typological analysis of chipped stone tools from Sector II in general.

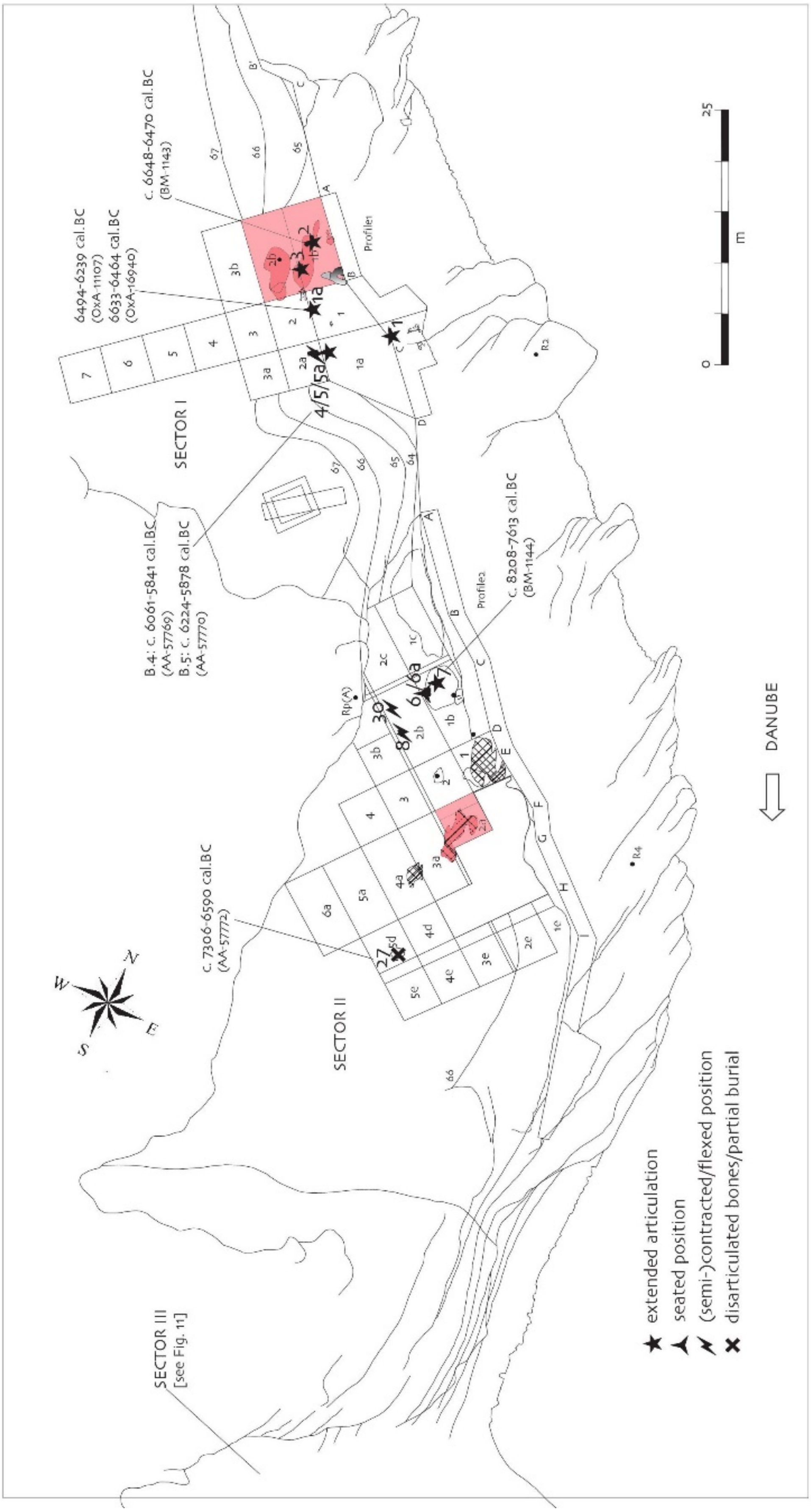

Figure 13: Padina, Sector I and II, with the marked area where the samples were collected, site map courtesy of D. Borić (after Borić 2011: Fig 11)

Sector III

Sector III (Fig. 15 and 16) is located in a long coastal belt, whose strong loess base lies at the foot of vertical limestone cliffs. Padina A horizon is noted in Sector III as a stone construction of the necropolis, made of four nearly horizontal levels of stones piled up in dry stone wall technique (Radovanović 1996). Everything else found in this area is belonging to Padina B – three successively dug-in rows of habitation in NE part of the cove. These rows are Padina B1 (lowest) with houses 5-10, B2 (middle) houses 11-15 and B3 (upper) with houses 16-21 (Radovanović 1996). In this sector, 17 features were found, and they are described as semi-dugout habitations with trapezoidal levelled base, ash place in the front (dug in) with rectangular hearth recipient behind it. The conical pit was covered by a stone slab with a pebble in the rear of the hearth and all these elements were covered by the floor coating. The massive stone blocks reinforced the rear of the habitation together with roof beams, and the sides were supported by the dry-stone wall. Some of the beams were placed leaning on the central roof beam, whose carbonized traces were found in house 8. The entrance of the houses was a fan-shaped threshold in front of the ash place (Radovanović 1996).

From sector III, the material was taken from trenches 3, 5, 6, 7, from blocks in which the remains of houses, hearths and stone structures were found, and 93 tools were sampled in total. Besides the artefacts from trenches, tools from profile III, segments 1, 2, 3, between segments 1 and 2, and from the level of the construction (segment 2) were collected and analysed (Fig. 14).

Figure 14: Padina, selection of the samples from Sector III (photo A. Petrović)

There are no dates that are dating trench 3 (Fig. 15), which is situated in the coastal belt of the Danube. Having this in mind the results of the use-wear analysis of chipped stone tools coming from this area will be discussed based on the information about the stone construction found in block 1.

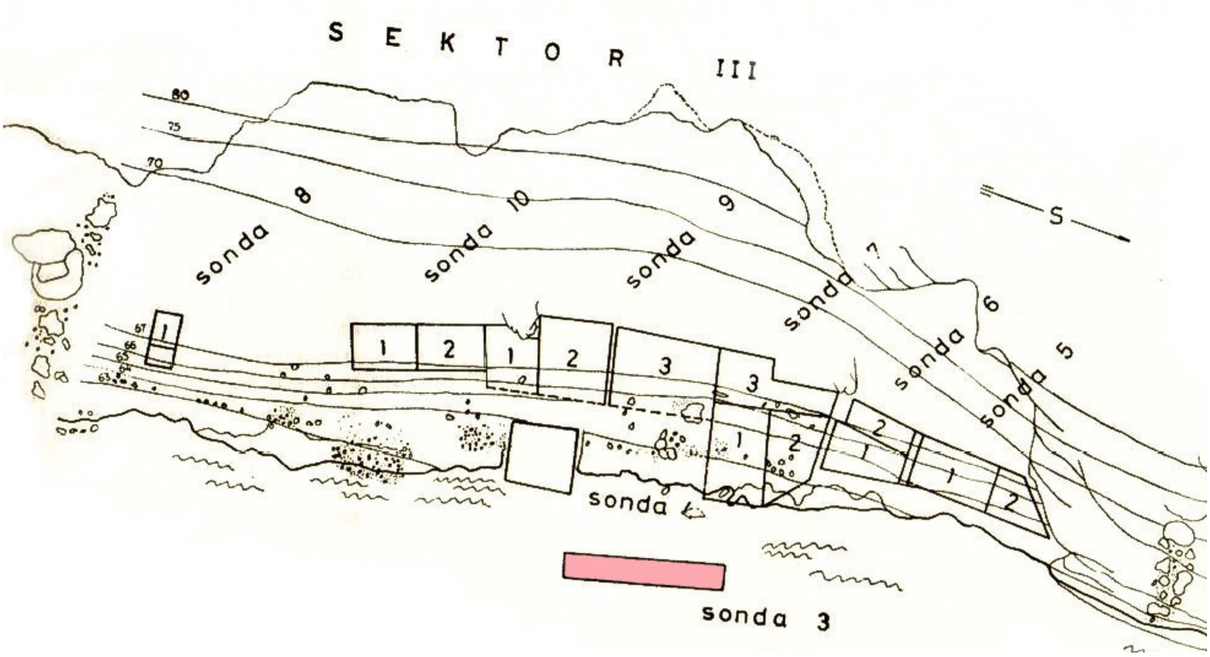

Figure 15: Position of Trench 3, Sector III (after Jovanović 1974)

Four houses were found in trench 5. In the block 1 three houses were recovered (house 16, 17, 18). Indicating the occupation or abandonment of the house 17, one date was gained in the range 6250-6025 cal BC. Regarding house 18, antler found on the object floor is dated to 5990-5720 cal BC, and dog ulna found underneath to 6440-6210 cal BC (Borić and Miracle 2004). From the material deposited beneath house 15, in block 2 two dates were attained, one from the burial 9360-8920 cal BC, and another one from used bone 5780-5560 cal BC, a period corresponding to the occupation of the house (Borić and Miracle 2004). The dates from house 15 and 18, 5990-5720 cal BC and 5780-5560 cal BC indicate the later phase of the Early Neolithic occupation of the site.

Trench 6 has three dated burials: b. 15 – 8450-7960 cal BC, b. 14 – 8690-8230 cal BC, b. 12 – 8750-83330 cal BC. These dates are corresponding to the Early Mesolithic period, implying that maybe the area was used for funerary practices at the time (Borić and Miracle 2004).

Dates from trench 7, as burial 21 from the stone construction (9250-8790 cal BC), indicate Early Mesolithic use of this location as a burial ground (Borić and Miracle 2004).

Regarding the AMS dates from profile III, segment 1 (in the area near house 6), one date in the range 7600-7340 cal BC is available from the mandible of a red deer. A higher date (9965-9275 cal BC) is gained from the red deer bone found beneath house 14 in the same area. The large chronological gap is explained with the possibility that the place was used continuously over the different periods of the Mesolithic period, and that only the large number of new dates from single features can indicate the dis(continuity) of settlement use over the millenniums (Borić and Miracle 2004).

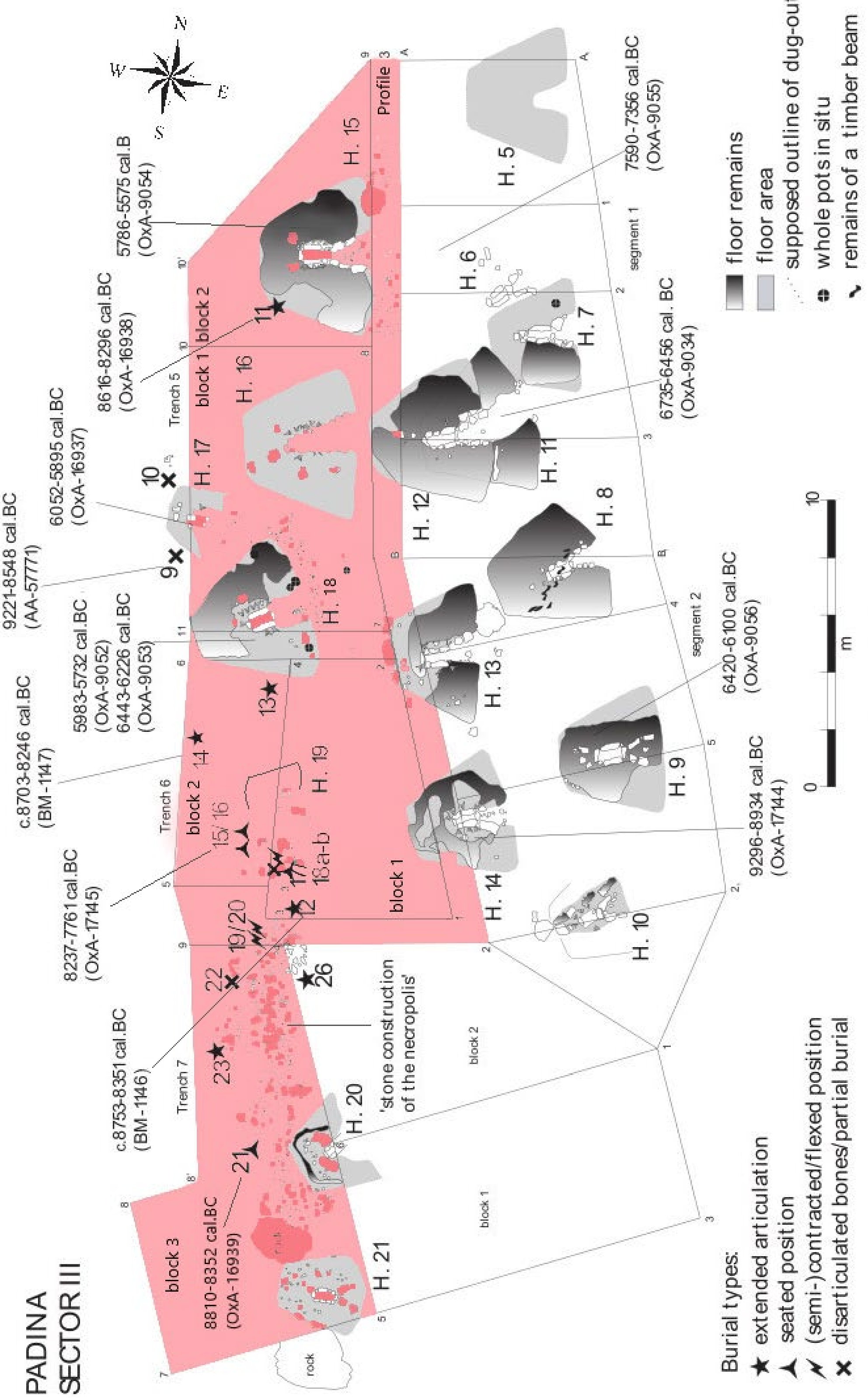

Figure 16: Padina, Sector III with marked areas where the samples were collected, site map courtesy of D. Borić (after Borić 2011: Fig 12)

2.3. VLASAC CHIPPED STONE ASSEMBLAGE

The Vlasac chipped stone assemblage was analysed based on the excavation layers and blocks of the excavation. Some of the tools were enlisted in the first publication together with other data and analysis of archaeological materials found at Vlasac site (Srejović and Letica 1978). More complete results were published, based on the typological division (Fig. 17, 19 and 21), together with the origin and categorisation of the raw materials (Kozłowski and Kozłowski 1982). Based on the observed material, presence of designated workshop spots did not exist at Vlasac. This is reflected in the general percentage of retouched tools, which is typical for *home* camps, where the overall flint working took place without the assistance of specialized workshops (Kozłowski and Kozłowski 1982). The general structure of the three building horizons at Vlasac was synthesized by I. Radovanović (1996), and there are no major deviations visible from phase to phase (Fig. 18, 20 and 22). However, it should be highlighted that these analyses excluded the artefacts connected to dwellings, graves and hearths.

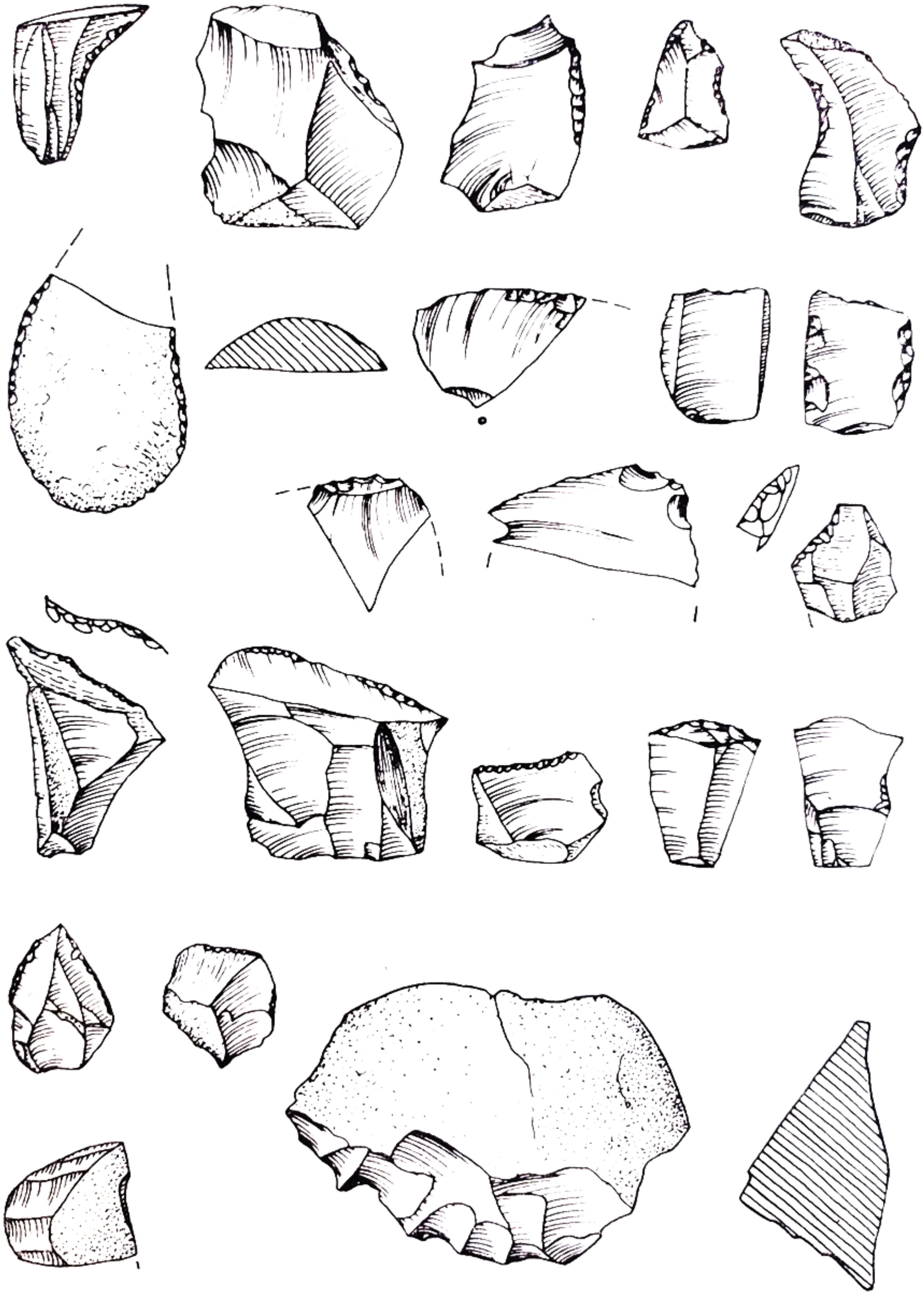

Figure 17: Vlasac I, retouched flakes (after Kozłowski and Kozłowski 1982)

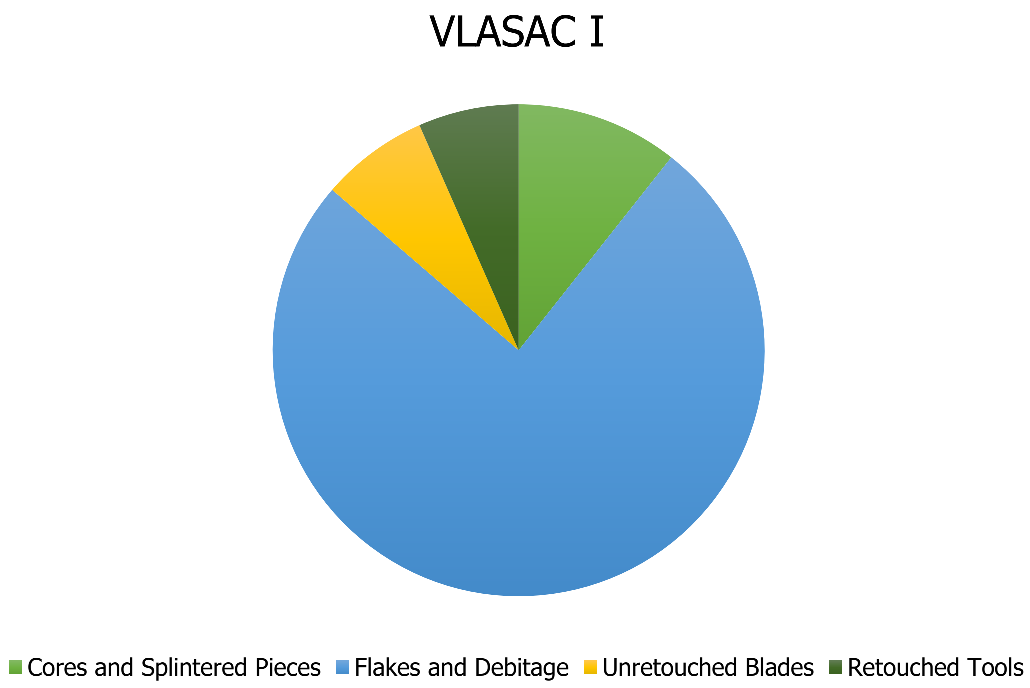

Figure 18: Vlasac I, the general structure of the assemblage
(after Kozłowski and Kozłowski 1982, Radovanović 1996)

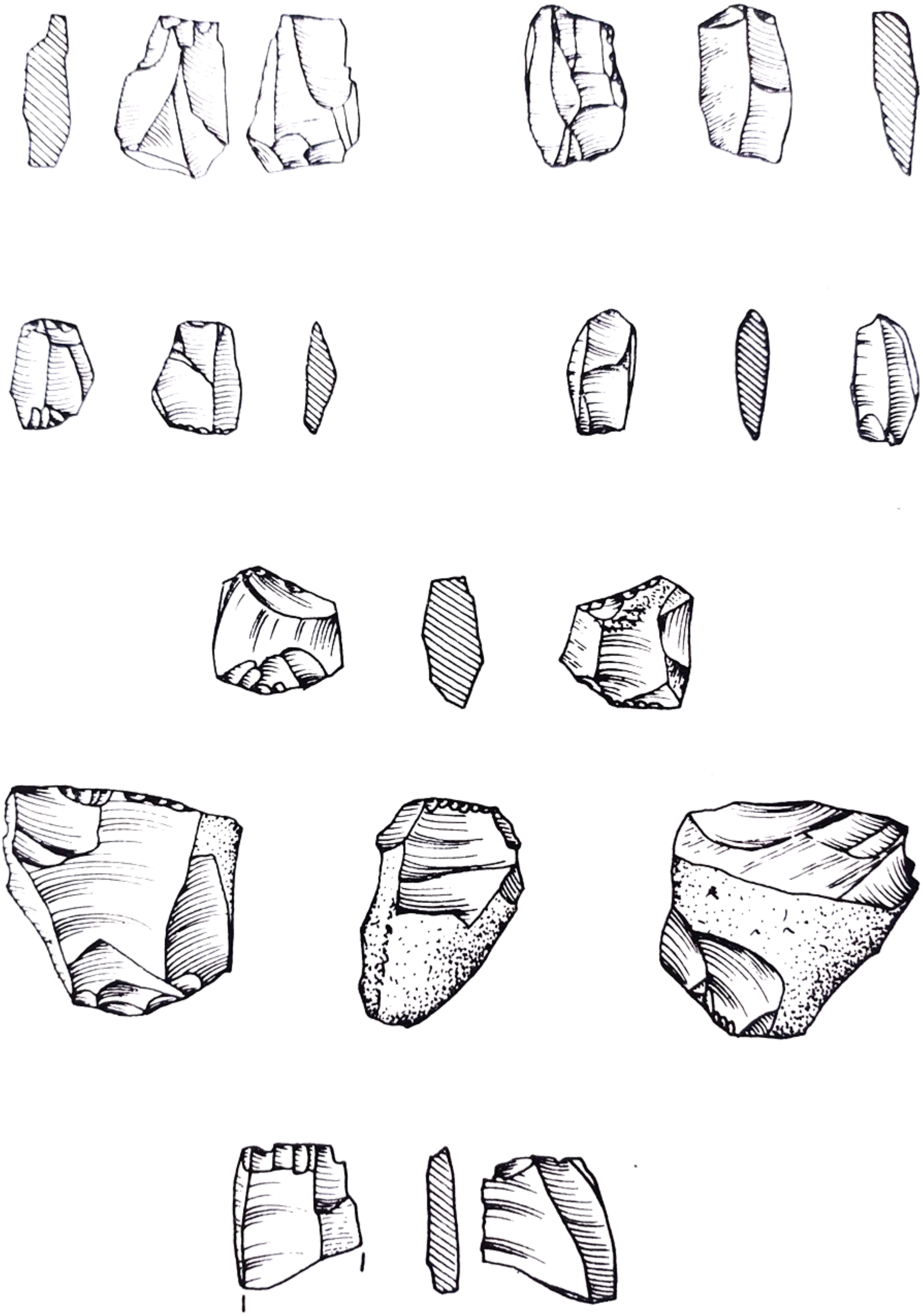

Figure 19: Vlasac II, splintered pieces (after Kozłowski and Kozłowski 1982)

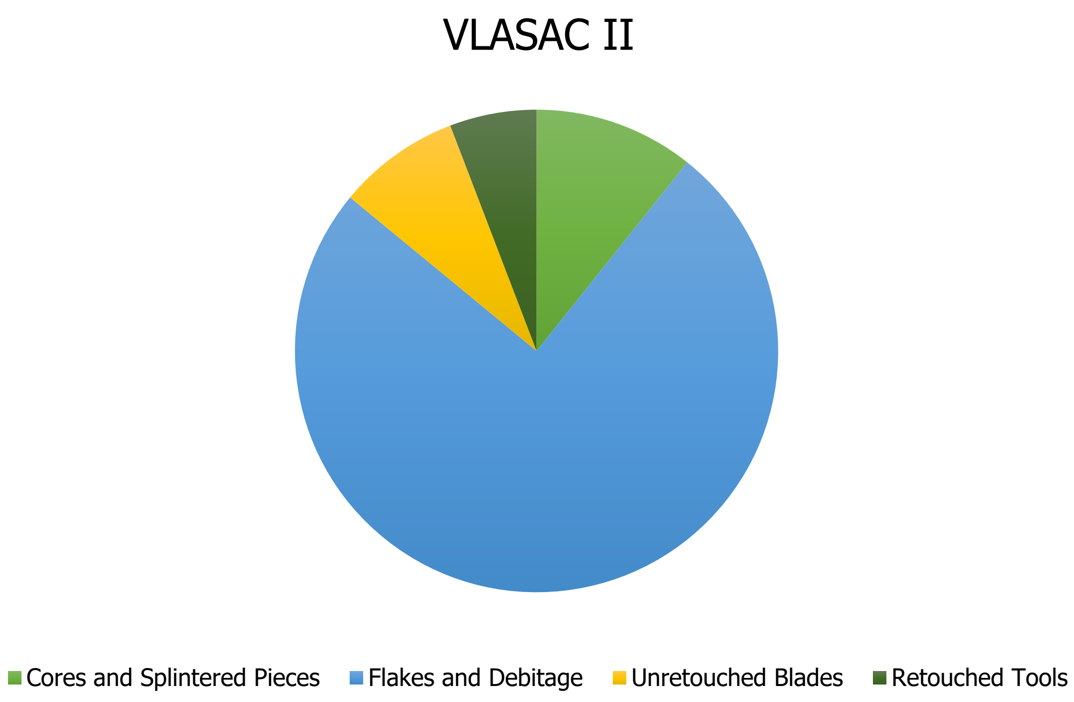

Figure 20: Vlasac II, the general structure of the assemblage
(after Kozłowski and Kozłowski 1982, Radovanović 1996)

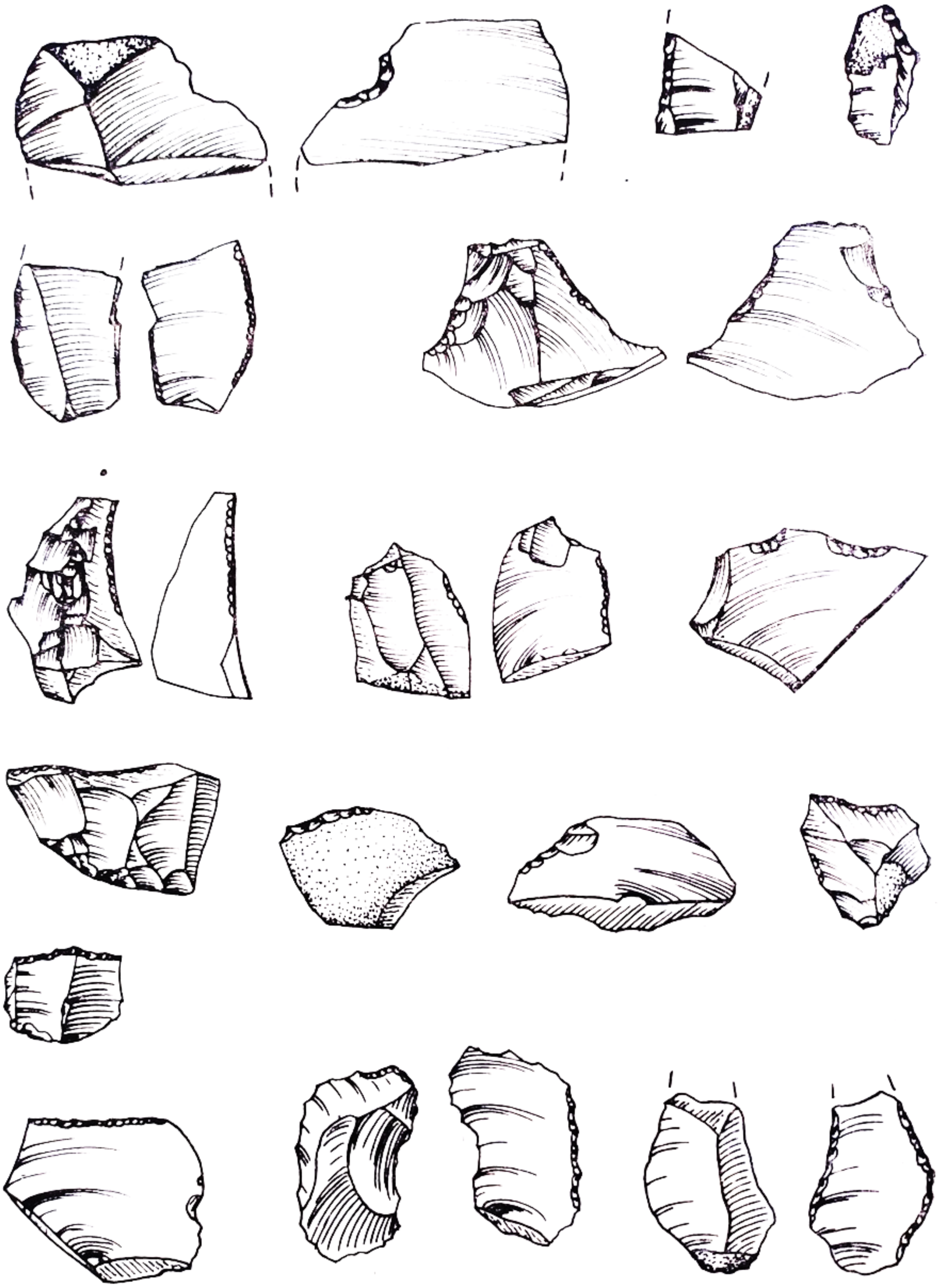
Figure 21: Vlasac III, retouched flakes and raclettes (after Kozłowski and Kozłowski 1982)

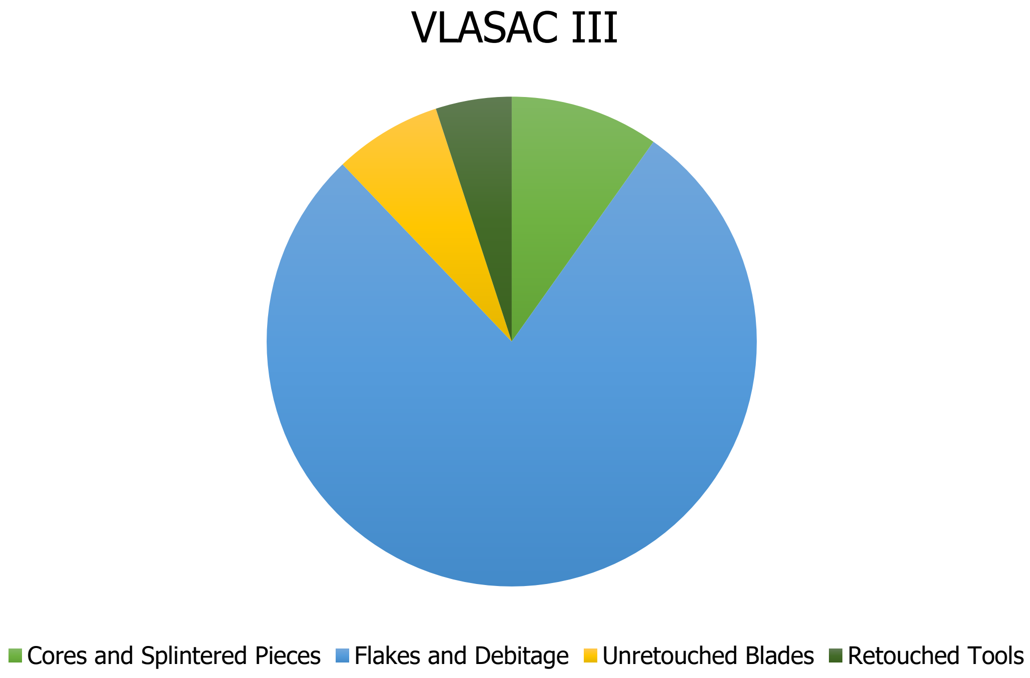

Figure 22: Vlasac III, the general structure of the assemblage
(after Kozłowski and Kozłowski 1982, Radovanović 1996)

New technological analyses of both quartzite and flint tools coming from closed contexts were done by M. Mitrović (2018), and the study was accompanied by spatial analysis which indicated some of the differences both between the area, and phases I and III. The diversity of raw materials was noted, depending on the context between the phases. For example, in phase I, in the houses the quartzite prevails, while the flint is predominant in the burial contexts. In phase III the quartzite is equally dominant in both types of contexts. Dwelling 2 should be singled out based on the presence of the entire operational chain, together with burials 49, and 30, from phase I and burial 14 from phase III. Pressure technique is present as early as in the phase Vlasac I (Mitrović 2018).

2.3.1. Vlasac sample

Archaeological material from Vlasac site (150 samples) was not easy to sample given the very small number of absolute dates made for the site, and closed contexts such as houses or graves were selected (Fig. 23). Chipped stone tools from houses 2, 4, 5, 6, burials 51, 14, 11, 33-34, 5, 40, 24, 30, 78, 72, 64, 38, 49, 15, 5, and lithic artefacts found below hearth 3 were sampled.

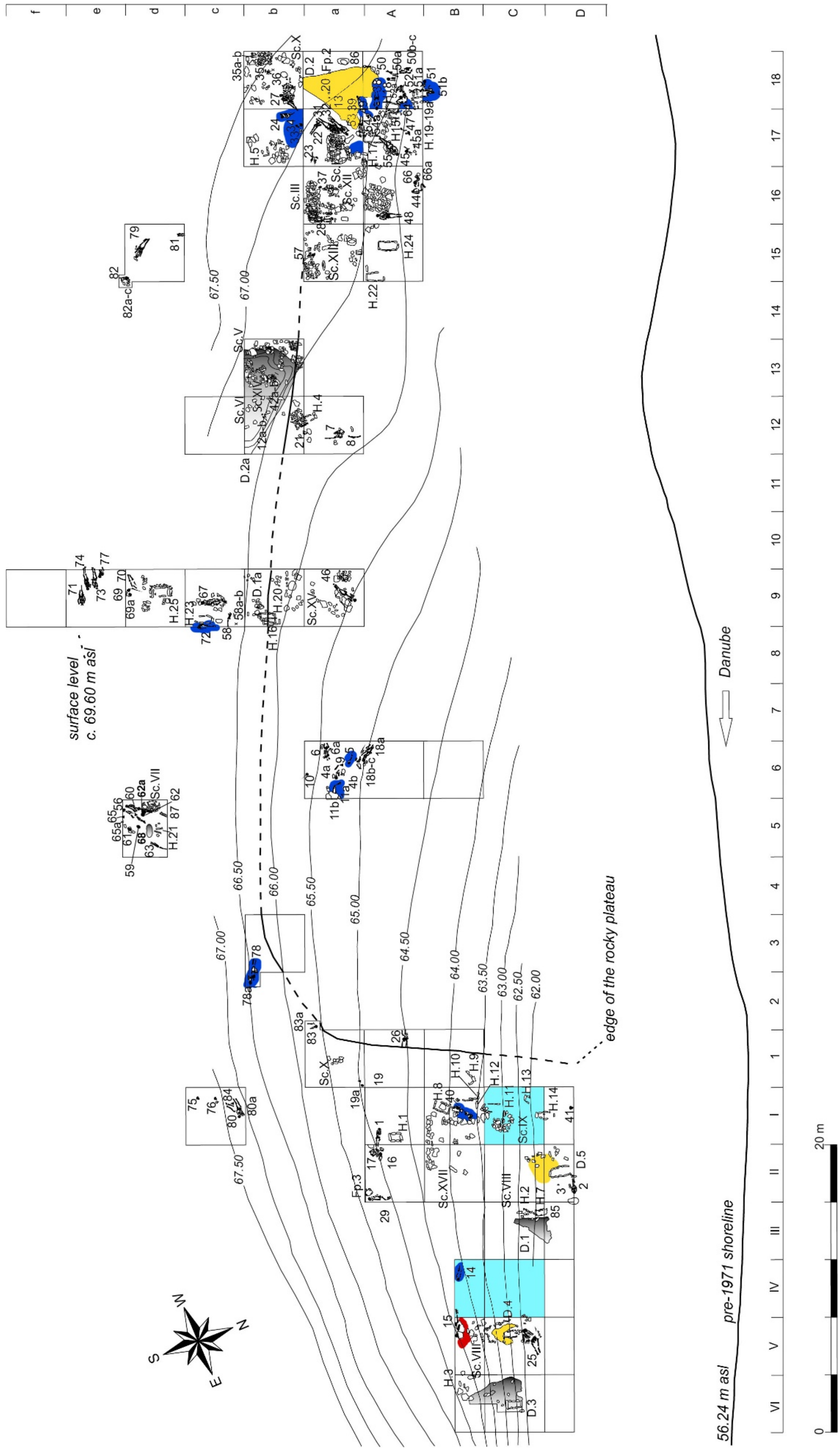

Figure 23: Map of Vlasac, with marked areas where the samples were collected (after Borić et al. 2008)

Dwellings

Dwelling 2 is connected to the first phase of the occupation of the Vlasac Ia, and it is positioned in the west sector. Dwelling 2 was only partially recovered. Besides the animal and fish bones, fragment of the human cranium, antler and bone tools were found together with chipped stone tools discussed in the study. The roe deer antler was dated and the sample is in the range 7047 to 6699 cal BC, which corresponds well with the date obtained from the Dwelling 1 (phase Ia), and may indicate the overall contemporaneity of construction and use of these two dwellings (Borić et al. 2008). The second date came from the red deer tool from beneath the floor (6900 to 6593 cal BC), and it is younger than expected and may indicate a later intrusion. It is most likely that the date does not come directly from beneath the floor of the dwelling, as it was initially assumed, but from the level on its side, *i.e.* lower than the floor of Dwelling 2, but next to it rather than directly beneath the floor. This possibility is supported by the date for Burial 31 (6823 to 6436 cal BC), (Borić et al. 2008).

Dwelling 4 is belonging to the later phase of occupation – Vlasac Ib. The hearth from this house was preserved together with bone, antler tools, some fragments of the human cranium, animal and fishbone. In the layer that covered the foundation some fishbone, shells, a larger amount of antler tools, two pebbles with traces of shaping and ornamented object of deer antler were found (Srejović and Letica 1978). Earlier charcoal date dates this dwelling in the range 7036 to 6496 cal BC. However, the new date was taken from the modified red deer antler surprisingly gives the range 9756 to 9321 cal BC. It is less possible that this date represents the actual date for the construction/use of this object, and it is more likely that it represents residual materials that come from older layers (Borić et al. 2008).

In dwelling 5 (Vlasac Ib) beside the elongated ellipsoid hearth smaller surfaces of firmly packed reddish limestone, clay and sand a larger amount of animal and fish bones and deer antler and bone tools and chipped stone tools were found in the limits of the foundation. One date is connected to this structure (7034 to 6693 cal BC), which overlaps with other features that had traces of reddish limestone flooring (Borić et al. 2008).

Additionally, it should be noted that dwelling 6, or house 6 as it was indicated on the notes found in the bags where the chipped tone tools were preserved, was not found in any publication or site map. It could be assumed that this is maybe the *stone construction VI*, but in the cases of the tools coming from the stone constructions, found at Vlasac site are always clearly indicated so this presumption/explanation is less possible.

Burials

Based on the anthropological findings, and according to the stratigraphy, the burials at Vlasac site are dived into five groups (Srejović and Letica 1978):

A – burials connected to the building horizons of Vlasac I, II and III;

B – burials inside the frames of the building horizons of Vlasac I, II and III;

C – burials excavated in the cultural layer that is not precisely defined;

D – burials which lay on the periphery of the settlement, and which are outside of the cultural layer;

E – burials discovered in the layers of sipar, above the cultural layer.

The chipped stone tools, sampled from burial contexts are coming from the first three groups (A. B and C).

Burials from the building horizon I (Vlasac Ia and Ib) are classified in both group A and B. Sampled chipped stone artefacts from group A are coming from burial 30, 33-34, 38, 49, 51, 72, and these tombs are characterised as used in the phase of forming the horizons Vlasac Ia and Ib. The burial 72 was dated to the range of 9756 to 8804 cal BC and this is considered to be the oldest human burial at Vlasac. This date is ambiguous, having in mind the new Late Mesolithic date of a wild boar task tool (7033 to 6686 cal BC) associated with the burial 72. Accordingly, it is not clear did the human bone, dated in the early Mesolithic, came from the burial or from the vicinity (Borić et al. 2008). The burial 51 is belonging to an earlier phase of the Late Mesolithic (the second half of the 8th millennium BC). For burials from group B, it could only be suspected that they belong to the horizon Vlasac I. Only one grave was taken into consideration, and that is burial 64.

Three burials, 14, 24, and 40, belong to group B of the building horizon Vlasac III. The burial 24 is dated to the range 6640 to 6220 cal BC (Borić et al. 2008). The burials 5, 11, 79 are belonging to group C. This group is found in the Mesolithic cultural layer, but the small thickness of the layer and the absence of the objects could not associate these burials to any layer of Vlasac specifically. Grave 11, from group C, was dated to 4763 BC (Srejović and Letica 1978). The date was corrected, and it is calibrated to the range 5762 to 5480 cal BC, placing the burial to the Middle Neolithic, which is considered according to the revisionary study of the Vlasac stratigraphy as the intrusion from the upper levels (Borić et al. 2008).

Hearths

Artefacts were sampled from diverse layers underneath the hearth 3, which belong to the stratum Vlasac II. The hearth 3 is discovered in the block B/V and it is only partially discovered. The heath is built from the limestone slabs and only three of them were recovered, which does not provide enough information about the exact shape of the hearth. Around hearth 3, in a lower layer, on a small and limited surface, the floor of crushed and firmly packed reddish limestone was recovered. It is not clear did this floor belong to the dwelling to which hearth 3 is connected, or it is a part of an older structure (Srejović and Letica 1978).

3. METHODOLOGY AND TECHNIQUES

3.1. USE-WEAR ANALYSIS: THE STATE OF THE ART

3.1.1. History of use-wear analysis in the world

Although use-wear analyses are just getting more and more embedded into archaeological research projects all around the world, the interest dates back to the second half of the 19th century. In 1872, J. Evans published a book *The Ancient Stone Implements, Weapons and Ornaments of Great Britain*, where the author from a functional perspective observed flint tools, their edge rounding, and striations on scrapers and correlation to the use on the animal skin. Twenty years later, research was focused on the explanation and appearance of high optical polish or gloss on the blades from the Middle East, and J. Spurrell (Spurrell 1892) experimentally tried to obtain information (Meeks et al. 1982; Marreros et al. 2015). However, the gloss and its origin obtained by cutting cereals were interpreted and demonstrated only in 1930 by E. Curvew (Curvew 1930).

In 1957, the first book dealing with functions of the prehistoric tools was published by S. Semenov under the name *Prehistoric technology* (Первобытная техника), and in 1964 it was translated and expanded to the West. It is a capital and pioneer work. *Prehistoric Technology opened* the door with functional analysis, and Semenov is a scientist who first mentioned the necessity of an experimental approach within use-wear analyses. It is interesting to note that the book was published in the period when the New Archeology arrives all over the world (Binford 1962). Having in mind that the New Archaeology emerged from an American anthropological school that highlighted the use of the artefact as a result of the human activities and processes in correlation with the environmental and cultural influences (Hayden and Kamminga, 1979, Schiffer 1975, 1976), the functional analyses are interpreted as crucial for the development of the interpretation of archaeological data, or indicators for analysing the human behaviour in the past.

Semenov's work was mostly conducted as a series of analyses of low-power approach (LPA) involving stereo microscopes ranging from 5x to 60x. These magnifications are not the greatest, as it was stated by the author, but the limits seem sufficient in the early stages of use-wear analysis and they gave positive results (Semenov 1964). The main aim of this work was to implement the systematic experimental programme and constant engagement of the microscope.

The success of the results obtained and described by Semenov influenced others, among them R. Tringham, a researcher focused on the Neolithic of the Central Balkans, and L. Keeley, who later developed a new methodology. The essence of the implementation of the larger magnifications (High Power Approach - HPA) is the possibility to determine the exact type of worked material and activity

(Keeley 1977). Of course, although the division was initially formed based on the power of the microscope, in the archaeological public, among scientists who conducted these analyses, as mentioned, there was a divergence of opinions. R. Tringham mainly dealt with damage to the edges of the tool and the formation of micro-retouchers using smaller magnification (LPA) with mandatory insight and work on an experimental approach (Tringham et al. 1974). Her work was continued with G. Odell, an advocate of low power approach to use-wear analyses when the first discussion between researchers on both sides developed (Keeley 1974 cf. Odell 1975). In the beginning, some criticism of the low-power approach has been raised based on the inability to distinguish the post-depositional surface modifications (PDSM) and technological aspects from traces (Keeley and Newcomer 1977).

During the next decade, L. Keeley presents a new approach – the use of a reflected-light microscope with high magnification from 10x to 400x (HPA), (Keeley 1980). Keeley observed 127 experimental edges to define the macro traces, polish, striations and breakage patterns. His strength was focused on describing the polish, and this term will be elaborated in the sub-chapter specifically dealing with traces (Chapter 3.3.3). Keeley inspired many other researchers that later on incorporated edge-removals in their work (e.g. Andreson-Gefraud 1981, Vaughan 1981, Moss 1983, Jensen 1986, Van Gjin 1988) having in mind that indicative value of these removals could be the result of other factors other than use. A strict distinction between the LPA and HPA has been less defined through time mostly because of the researchers who concentrate on polish incorporated edge-rounding observations as well (Van Gijn 1990: 3).

All the problems associated with both LPA and HPA approaches are noted by D. Olausson (Olausson 1986). However, we have to bear in mind that this was a review made in 1986 right after the boom of use-wear analysis happened. Edge-damage identification acquired through practical use and important observations that today are a basis of use-wear analysis was highlighted in this article. Among them, Olausson is describing what should a reference collection have, how it should be made, what can be gained from both approaches, their disadvantages, relations of the PDSM and traces of use, how chemical alterations can be (un)helpful, and how microwear analysis should be applicated in archaeology. However, it must be emphasized that the names (low and high power approaches) originated primarily due to available equipment during that period. And even though these approaches in a way divided the researchers it is important to note that both approaches are a huge breakthrough in chipped stone studies in their time and that the method of combining them is the only possible way of conducting the use-wear analysis successfully today.

The debate resulted in a number of papers dealing with various approaches to functional analyses that were presented at the conference *The interpretative possibilities of microwear studies*, in Uppsala, (Gräslund et al. 1990). It has been shown that both results are complementary and that the exclusion of one or the other contributes to poor quality of interpretations (Olausson 1986) which led to a more integrated methodology. The discussion led to the conclusion that interdisciplinarity and specialization are more than necessary, and together with the critical observation of results these can be the elements to improve future studies. For example, some very important steps towards the quantification of traces, in the last few years, were noted and various approaches and methods were tested as laser profilometry and confocal microscopy (Stemp 2014, Macdonald et al. 2018).

3.1.2. Application of use-wear analysis in Serbia

Traceological studies so far conducted in Serbia are modest, but regardless of the fact that functional analysis did not represent a regular methodological procedure, several studies have been devoted to this topic.

The first functional approach tested on mesolithic material together with the problems of secondary knapping and morphological shape of artefacts are topics of the Magister thesis of Lj. Đuričić (Đuričić 1980). In this detailed study, in addition to the function and morphological categorization of artefacts from the Mesolithic, mixed, Early Neolithic, Neolithic and Eneolithic/Bronze Age layers of the Odmut[3] cave were analysed. The analysis was performed using a binocular microscope with oculars ranging from 10x to 100x. The main results of this extensive work have drawn many conclusions, among them was the microlithization of artefacts which was not connected to the layer in which they are located. The long Mesolithic tradition was explained by the exploitation of ecological conditions in which various economic practices were performed. Functional analysis was related to the key methodologies published so far:

- identification of three main activities: cutting, scraping, and drilling
- identification of the type of contact material.

An important result of this use-wear analysis was the noted knowledge of the process of preparing the flakes for hafting and deliberately rarely inserting the retouched flakes into the handles. Also, this study has erased the theory that the microliths were used as the tops of the arrowhead, a very popular thesis at that time. Namely, if this theory was true, there would be traces of use on soft material, which was not the case here (Đuričić 1980: 71).

[3] Odmut is located in northern Montenegro. The reason for including the study in this sub-chapter is because, at the time when the excavations and analysis were done, Montenegro was a part of the same state with Serbia (Yugoslavia), and Ljiljana Đuričić is a Serbian researcher from the Faculty of Philosophy, University of Belgrade who conducted the archaeological excavations and studies on the territory of Montenegro for longer period of time.

A couple of years later, in addition to the technological analysis of chipped stone assemblage of Vlasac site, all retouched tools underwent the traceological analysis carried out by stereoscopic microscope (magnification 125x), (Kozłowski and Kozłowski 1982). Two groups of retouched tools: end-scrapers and irregular scrapes. Around 66% of the endscrapers have shown traces of use, out of 50% used tools were used for scraping of the soft homogenous materials, and 30% for scraping the hard materials. Regrading the irregular scrapers, 40% were used and 66% of the utilized tools have the same wear found on the end-scrapers, while the remaining taces are connected to cutting (Kozłowski and Kozłowski 1982).

The next studies that followed were the processing of famous Late Neolithic collections of Vinča communities. The first traceological observations were made on the archaeological record from the site of Vinča-Belo Brdo, the eponymous site of Vinča culture during 1980, followed by a more extensive study by B. Voytek (Voytek 1984: 54-58). The larger study concerned 1101 pieces from the Archeological Collection of the Faculty of Philosophy in Belgrade. The results of the analysis did not include the types of microscope, but the text refers to the macroscopic observation of artefacts and their comparison with the experimental tools from series of experiments carried out at Harvard University (Tringham et al. 1974). The result of the study is statistics showing that 65.2% (718 pieces) of the observed material were used. The activities were also observed and described during this examination. The classification of activities is divided into the most important subcategories: cutting, scraping, drilling and hafting.

In addition to analysing material from the Vinča-Belo Brdo site, functional analyses were carried out on material from the Late Neolithic sites: Selevac (Voytek, 1990), Opovo (Tringham et al. 1992), Divostin (Tringham et al. 1988) and Gomolava site (Kaczanowska and Kozlowski 1986). From the Selevac site, 3875 pieces of chipped stone artefacts were analysed, of which 1121 (28.9%) had traces of use, and 60 pieces had traces of hafting (Voytek 1990: 474). Additionally, the study has shown that the most represented tool in terms of function and materials on which it was used was a sickle. At the Opovo site, the use-wear analysis was done on 812 pieces. The technology relies on the production of blades - typical of Late Neolithic and Eneolithic. Functional analyses have shown that the most used were scrapers made on blades. The traces were formed by scraping and cutting on the lateral sides. The 24% of the blades, found at Opovo were never used, which could contribute to a hypothesis that these tools could have been saved for future use.

Followed by technological and typological analyses 772 artefacts from Divostin were examined with a low-power approach. Traces of use were confirmed at 75% of the total amount of test material (Tringham et al. 1988: 210). The elongated and shorter blades were used for cutting, and on wider pieces, traces of scraping were found. Material from the Gomolava site - mostly retouched pieces were subjected to use-wear analysis, of which more than 58% were used. However, some samples from certain phases were not most suitable for making more concrete conclusions because of the small amount of sampled artefacts.

As mentioned, local authors have enriched the professional public with several references in the past few years. J. Šarić wrote an article dealing with basic traceological concepts with several examples from Neolithic sites in Serbia in the form of drawings with activity zones (Šarić 2011). The function of selected tools was examined with a magnifying glass, the monocular and binocular microscope is analysed primarily, while the text deals with the basic problem of traceological investigations.

Since 2005, in the Physical and Chemical Laboratory of National Museum in Belgrade, within the project *Interpretation, origin and distribution of stone raw materials from Neolithic and Eneolithic sites on territory of Serbia*, 1935 samples from the site of Vinča-Belo Brdo (Bogosavljević-Petrović 2015: 382) were functionally analysed. This resulted in a more extensive pioneering work that presented groups of artefacts that were identified by problems that may arise in the field of tool functionality, the relationship between the quality of the raw material and the activities that could be performed, all in order to trace research interests and pretensions in the future. The important analysis is certainly a microscopic observation of 70 artefacts (60 from the Vinča-Belo Brdo and 10 from the Late Neolithic site Belovode). The importance of this research is reflected in the collection of the reference (microphotographic) recordings of the damage that was created, the protocol of operation, and the methodology used in the analysis. The focus of the functional analysis was on blade fragments, as the largest group of tools, however, other groups of artefacts were also selected in the second round of research (Bogosavljević-Petrović 2015: 384). Samples were observed under a binocular and metallographic microscope, and ten artefacts were singled out for observation with an electronic (SEM) microscope, where the first visual traces of cutting, scraping, and gloss were registered.

The entire study was completed with an experiment, which had two important results in terms of data on the functioning of the sickle, the cutting of cereals, and the cultivation of old varieties of wheat and barley, on a substrate that is geographically close to the site of Vinča-Belo Brdo. In addition to basic information concerning the function of the sickle- deformation of the edges, the formation of gloss - which became visible after nine hours of harvest experiment, data on the quantitative requirements for human consumption were obtained (Bogosavljević-Petrović 2016). This experiment is still in progress. Functional analyses and experimental results are presented with photographs and descriptions that belong to a detailed and methodologically clear and correct approach.

In 2016, the first results of traces of the use of a limited sample from Drenovac (Gurova 2016) were published. These analyses opened new debates mostly due to the neolithization process of the Central Pomoravlje area, but also the function of quartz artefacts of Vinča and Starčevo culture (Bogosavljević-Petrović et al. 2015; Gurova 2016). However, the context of the samples that came from the Drenovac site is not specified, therefore these results will not be chronologically compared with the analyses that are the subject of this study, but certain aspects of functional prospection will be more closely observed.

3.2. METHODOLOGY OF USE-WEAR ANALYSIS

The following section is dedicated to the equipment and methods that applicated in the use-wear analyses. In theory, it is very important to use adequate equipment, to modify or supplement it in relation to the type of material being observed. However, in reality, researchers work with equipment and devices that are available to them.

3.2.1. Macroscopic observations

Before going to the methods that are the fundamental base of use-wear analysis and microscopic equipment, I would like to direct the attention to observations of material with the naked eye or using a magnifying glass. This type of observation is used to examine the preservation of the object, its fragmentation, and also to detect certain roundings, deformations or fractures. Such preliminary analyses are useful, for example, to isolate pieces that have a patina that endangers their surface (Lemorini et al. 2014).

This approach was tested on *used flakes*, the term used in Ontario Archaeology for flakes that allegedly had traces of use (Shen 1999) by a series of blind test. Artefacts that are characterized as utilized flakes are considered *informal tools* opposite to deliberately made *formal tools* (Shen 1999:63). Wider explanation and deliberation on formal tools is done by Andrefsky and includes all the additional efforts in production, but also products that can be used for many different tasks and that are connected to more mobile populations (Andrefsky 1994:22). It has become more than clear that microscopic analyses can alter our current views on the typology of the chipped stone industry, especially if we talk about a functional category of artefacts such as the *used flake* (Yerkes and Kardulias 1993: 103). The result of the blind test was that half of the samples were misinterpreted, and it was clear that identification of use traces is only possible based on macroscopic analysis (Shen 1999: 65). Additionally, as previous experiments did not produce encouraging results (Young and Bamfoth 1990), it can be concluded that macroscopic observations are suitable for the preliminary examination of materials, determination of sample preservation, selection of pieces that will be further observed with more complex equipment. However, we should be extremely careful when interpreting such modifications.

About the equipment that can be used in the use-wear analysis can be spoken very thoroughly, however, we will try to focus on the most common methods used worldwide and by different laboratories. The most important and most frequent methods (Marreiros et al. 2015: 11) that are used for functional analysis and residue analysis, based on used equipment are:

- low-power approach (LPA)
- high-power approach (HPA)
- Scanning Electronic Microscope (SEM)
- Laser Confocal Scanning Microscope (LCSM)

3.2.2. Optical microscope

Optical microscopes are precisely ones that perform functional analyses of artefacts in most cases. As already mentioned, they are differentiated with respect to magnification, therefore there is access with lower macroscopic magnitudes (low-power approach) and larger microscopic magnification (high-power approach). Smaller magnitudes are mainly related to stereomicroscopic analyses, and they range from 4-10x to even 60x. Such an apparatus also includes reflected light, that is, auxiliary lamps that the person conducting the analyses directs by changing corners to depict the focus of the observation, disabling the shadow effect (Marreiros et al. 2015: 11). This follows from the test itself, that is, changing the light significantly affects the visibility of the traces of use, therefore it is important to record the position of the lamps in the activity logs. The key ability of these analyses is that the edges and surfaces are systematically analysed to detect small fractures and characteristics but to determine the micro-region that will be further investigated under different higher magnification as well (Odell and Odell-Vereecken 1980, Odell 1981). The low-power approach is used mainly to observe macro traces, like edge damage. On the other hand, access to larger magnification is possible using metallographic microscopes that operate based on direct light (90º). To identify, classify and record various traces of use, such as polish formation, larger magnitudes are needed (from 50 to 400x) (Marreiros et al. 2015: 11). The metallographic microscope helps identify the specific used material. The combination of both mentioned approaches gives a much more complete picture of the results of functional analyses (e.g. Grace 1996; Clemente and Gibaja 1998).

3.2.3. SEM (Scanning Electronic Microscope)

The scanning electron microscope (SEM) functions based on the electron beam that is controlled by magnetic or electronic fields as opposed to light control that is crucial to the aforementioned optical microscopes (Marreiros et al. 2015: 11). This configuration enables images that are larger in magnification, resolution and better depth, as well as performing chemical analysis on the surface of the findings (EDX). In addition, this method provides the possibility of a wider range than the results of an optical microscope (Olle and Verges 2008). A better resolution allows a more detailed overview of the surface of the artefact, which is rarely straight, which makes the study more complex. With much larger magnifications (up to 500 000 times) than those of an optical light microscope (OLM), it is much easier to detect patterns of trace formation and modification of chipped stone tools (Borel et al. 2014: 52).

However, this method is limited mostly due to the very expensive equipment - whether the equipment is purchased, rented or a sample is given for analysis. It is also necessary to extract a little more time since the preparation of the sample is more complex and only a limited number of pieces could be separated for analysis (Marreiros et al. 2015: 12). Cleaning of the samples for analysis must be done very thoroughly and sometimes requires combining several procedures for cleaning the surface of the artefact. The image obtained through the software application and based on which object is placed in the chamber depends on how well the chamber is cleaned (vacuumed) and this very often implies the coating of the artefact with gold or carbon. Since these coats can be removed only with strong chemicals, not all the samples, depending on the raw material, are suitable. Gold is easier to take off from the subject, however, it covers the residue remains that could be detected by the EDX approach (Borel et al. 2014: 52).

3.2.4. LCSM (Laser Confocal Scanning Microscope)

This apparatus functions based on related images of reflected light from the different focal plane, in other words, this technique forms a multi-focus image in real-time (Marreiros et al. 2015: 12). Technically, the condenser and lenses of this microscope are focused on one point (Derndarsky and Ocklind 2001: 1149). The magnification of this microscope ranges from 25x to 800x. This type of microscope was, for the first time used for biomedical purposes. However, for archaeologists, this equipment is very useful for illustrating the model, the textured topography of the analysed surface, and primarily because of the possibility of more detailed quantification of the traces. Analysis of this type, which would determine the activity and contact material on the surface, is determined based on simple roughness measurements (Evans and Donahue 2008: 2229). The confocal microscope is a combination of ease and speed control of a metallographic microscope and high depth sharpness, magnification, and resolution that are associated with SEM (Evans and Donahue 2008: 2229). Compared to other analyses, this may be an approach that should be emphasized in the future, due to the large range of benefits – the number of samples is not limited, there is no need to create casts and coatings, artefacts of all sizes can be taken. From the perspective of time spent this is a very economical method that benefits the archaeological sample.

3.3. USE-WEAR TRACES

Various traces of use can be seen on the surfaces of the chipped stone artefacts and they are of different origin. Some of the modifications are made by humans by flaking, retouching and using, and some of the artefacts are affected by natural processes. Methods that developed over the past decades have been complementary and fundamental in their goal of discovering as many types of traces of use as possible. The classic division of tracks is divided into:

- macroscopic: edge rounding, edge-removals
- microscopic: striations, polish, hafting traces, and residues (Marreiros et al. 2015: 12).

3.3.1. Trace formation

Tringham and Odell argued that *it is not too difficult to distinguish the damage caused by the deliberate use of those occurring by accident or from the ones that were modified by natural process* (Tringham et al. 1974). The categorization of the hardness of the contact materials on which it was worked has been developed, as well as the definitions of their traces (Odell and Odell-Vereecken 1980):

- Soft materials (meat, skin, leaves): the size of the scars is small in the formations of the feathers
- Medium-soft materials (softer wood): bigger scars, usually in the formation of feathers
- Medium-hard materials (hard wood, antler, fresh bones): scarlet scar, mostly medium to large
- Hard materials (bone and antler): scars with stepped ends, mostly medium to large

Nevertheless, Vaughan experiments resulted in different types and sizes of the scars of each category of material. Their appearance did not always correspond with the categorization made by the Odells (Vaughan 1985). As the distinction between the edge-removals that occurred in production and the ones formed in use is a different and complex process, it has been decided that researchers refrain from incorporating micro scars into the interpretation of the samples in which the intended retouch is present (Van Gijn 1990: 4). E. Moss argued that edge damage may occur at any stage (production, use, reduction, rejection), but that only those forces that can produce macroscopic traces could have certain causal factors (Moss 1983: 239).

It is considered that the random retouch derives from non-anthropogenic factors and that the retouch with distribution pattern is exclusively connected to the tools processed or used by man (Tringham et al. 1974). Having this in mind, various researchers contributed to the development of software-based GIS that can observe the pattern formation (Bird et al; 2007; Schoeville 2010; McPharron et al. 2014). Although this approach is still in progress, C. Bird and her team have noted that retouched tools by human activity are followed by the pattern (Bird et al. 2007). However, another group of researchers, years later, found that the pattern could be created during trampling, highlighting the importance of the raw material type (McPharron et al. 2014: 81).

3.3.2. Edge removals and formation of edge rounding

Edge-removals or edge rounding relates to the change in the edge affected by anthropogenic factors after the tool is made. Scars that leave certain forms were created during activities associated with various contact materials such as scraping of wood, animal skin, cutting of bones and many other activities.

Edge rounding is a result that could be obtained by processes other than using a particular tool. Every material that came in contact with the chipped stone tool rounded the edge to some extent, which is most noticeable when the tools came into contact with the hide, which would result in longitudinal and transferal movements (Van Gijn 1990: 8). A series of different categories are used to describe the level of the rounding, and the method of low-power approach is the most effective for observing this type of trace and at the same time representing the first level of analysing an artefact. The most common attributes that are observed are the point of scare formation (with or without bulb), scar ending (snap, step, feather, half-moon, indefinite), trace orientation (transversal, longitudinal, oval one-way or two-way, combined and indefinite). They together form a result that is reflected in what type of material is used and after what activity the edge rounding has occurred. It must be borne in mind that each material influences the artefact's edge rounding to a certain extent (Van Gijn 1990: 8).

3.3.3. Polish and (questions) of its formation

One of the traces of use, which formation and quantification were discussed in the literature and which was elaborated in detail by a large number of researchers (e.g. Keeley 1980, Unger-Hamilton, 1984, Van Gijn 1990, Gonzales and Ibanez, 2003, Schmidt et al. 2020) is polish. P. Vaughan describes a micro-polish as *an altered surface of silica that reflects light and which is impossible to remove with acids, bases and solvents* (Vaughan 1981: 132). L. Keeley says that each polish can be linked to the concrete material on which it was worked, therefore, the polish from wood and bone activity can be recognized (Keeley 1980: 23). Later on, R. Unger-Hamilton mainly dealt with the formation of polish on the tools, and R. Fullagar studied more closely the effect of silicon dioxide on the emergence of polysaccharides (Fullagar 1991). Ž. Schmit together with his team made an experiment and, based on the mapping by the micro PIXIE method (Polar Ionospheric X-ray Imaging Experiment), by comparing experimental objects and original mesolithic scrapers spotted the localisation of certain chemical elements associated with the material on which it was intervened (Schmit et al. 1999). The formation of polish is one of the main discussions today: does it arise by mechanical or chemical processes? It is certain that polish is not only surface modification, but rather it goes deeper into the surface of the artefact (Anderson 1980: 183). J. Witthoft was one of the first researchers who associated the theory of the melting silica stating that opal molecules from the plant are blended with flint (Witthoft 1967), later on, this theory was continued and backed with different experiments by P. Anderson, testing it not just on plans but also on bone and antler working activities that were realising collagen that fused with flint. Theory elaborated by Anderson explained this process by asserting that the silica from the stone dissolves into an amorphous gel, where the worked plan residues and part incorporate (Anderson 1980). The big problem is also the differentiation of the polish from the residues which can also reflect light (Van Gijn 1990: 5). In the '90 it was concluded that polish is a visual phenomenon and can be verified using experiments. Naturally, polish depends on the length of use and the contact material and also the quality of the raw material (Jensen 1988).

On the other hand, polish quantification is another problem, and the first attempts to deal with some of the attributes included light reflection measurements (Keeley 1980: 62-63). Later on, new attempts were made by using interferometry – an optical method capable of measuring the distance in the reference mirror and one on the surface of the archaeological sample (Dumont 1982, 1988). Even though this approach is a good model because it can be recorded by a photograph and it can be transcribed into statistics and can be transferred to a depth of striations or to the degree of the penetration of the polish to the surface it has some flows as well – unpolish areas are very unregular and they cause complex patterns (Dumont 1982: 208). R. Grace and his colleagues tried to quantify the texture and intensity of the polishes by using the image processing techniques and translating them into cells and then into grey tones (Grace et al. 1985). Unpolish surface affects this method as well – clustering the briefly used tools with unused surfaces instead of contact material (Van Gijn 1990: 6). Grace (1996) created, using image-editing software, (Grace 1996) the "Fast expert system" that could use and recognize 33 variables during the polish formation and identify worked material and activity.

The debate on polish formation was expressed during the meeting *Technical aspects of microwear studies on stone tools* held in 1985 in Tübingen, where silica-gel theory, deposition model, abrasive theory as the main bases for possibilities of polish formation process (Witthoft 1967; Kamminga 1979; Anderson-Gerfaud 1980; Meeks et al. 1982; Grace 1990; Levi-Sala 1993; Yamada and Sawada 1993).

Later on, some of the specific polishes were connected to the hafting methods, but this will be argued in detail when we review the prehension traces (2.3.6.). Van Gijn concluded in her PhD thesis that even though maybe it is not possible to quantify it completely we still can note brightness, the roughness of the polish, and other nominal variables like topographical features (Van Gijn 1990:7).

3.3.4. Sickle gloss

Sickle gloss is a type of more visible, complete polish. During the first encounter with this type of trace, certain researchers thought that contacts with certain types of cereals result in a specific shine and that the silicone gel that is created is separated from the cereal (Witthoft 1967). It was later found that gloss does not create a new layer on the tool, but that surface changes due to specific mechanical friction (Meeks et al. 1982). However, the contradictory opinion consists of the hypothesis that silicon gel containing incorporated parts of cereals is formed on the edge (Anderson 1980; Anderson-Gerfaud 1986). Recent studies including a series of experiments uncovered that a new layer was formed. This layer was called a scram and showed that it consisted mostly of carbon, while the analysis of archaeological artefacts showed the same results with minimal silica (Kamińska-Szymczak 2002). The question that remains is where does the silicon come from artefacts. It may never be answered because until now no experiment has been produced that has made a replica of the trace of the gloss of this kind that has been noted on prehistoric tools.

3.3.5. Striations

S. Semenov (1964) describes striations as linear tracks that are present by the influence of abrasive contact between the tool and the material (on one, or another object, or sometimes on both). However, as this type is sought by frequent evidence of some of the post-deposition surface modifications, rarely are the functional analyses based solely on linear incisions (Marreiros et al. 2015: 14). The incisions can be formed by longitudinal movements when they are parallel to the edge, contrary to them they are formed by transferal movements, and there are diagonal striations, as well as unspecified ones. It is precisely the factor causing them in a particular position and the distribution on the surface of the tool that determines which force is used (Vaughan 1985). In his study Keeley made a classification of striations, where he found the relation of the depth of the striations and worked material (Keeley 1980:23):

- narrow - deep: deeper striations whose width does not exceed 2 microns
- narrow - shallow: shallow incisions, which would affect only microelevations of the microtopography (the existence of this category is hypothetical since this type of notch is not recorded on samples)
- broad - deep: deep striations with a width greater than 2 microns
- broad - shallow: shallow striations with a width of over 2 microns

The distribution and intensity (depth) of the striations were classified into different categories:

- dark background, as an observed thin dark line
- smooth background, characterized by a bright line, and
- grooves, that consists of a series of parallel grooves and perpendiculars to the orientation of the striation (Keeley 1980; Mansur 1983)

Other classifications, such as Vaughan's, are distinguishing: deep, superficial and direction indicator (Vaughan 1985: 24) or split into convex, similar comet traits and extended, described in the paper *Meccanica di formazione delle usure e funzione dei micrograttatoi mesolithic* (D'Errico 1985).

In the practice, the striations are connected mostly and serve as an indicator of the movement (Van Gijn 1990: 7). It must be noted that these traces are visible with the metallographic microscope and their definition and observation are done by applying the high-power approach.

3.3.6. Hafting traces

Since the begging of the use-wear practice authors claimed that certain tools have been embedded with a handle of other material according to the morphology of the tool and some traces that could be indicative (e.g. Semenov 1964; Odell and Odell-Vereecken 1980; Odell 1981; Keeley 1982). It was not optimally worked on these questions, and as the biggest argument was that if it a tool was inserted in wood or antler (anything that would constitute the second part of the composite tool), that friction would be minimal, and the traces for this kind activities would not be enough. However, new analyses, data, experiments, and ethnoarchaeological studies, and the views on the traces of hafting are published by V. Rots with results that illuminate this branch of functional analysis and finally gives it a deserved space (Rots, 2002a, 2002b, 2002c, 2003, 2008, 2010). However, sometimes blades used and embedded do not show visible traces (Steensberg 1943; Meeks et al. 1982). Specifically, a series of experiments that would reconstruct the very process of embedding and using the tool is the first step in resolving the dilemmas when reviewing the archaeological collections.

As it was mentioned before, some polish is associated with the prehensile mode of the tool, but still making this area of research a debatable topic in the use-wear analysis. Also polish is just one of the hafting variables together with striations, edge rounding – so it is more valuable to observe the morphology of the artefact, functionality, other traces, and their distribution when we discuss the probability of hafting (Marreiros et al. 2015:15).

3.3.7. Technical traces

These microscopic traces originate in the process of production itself (Keeley 1980: 25). Scars of this type often point to the mistakes of the craftsmen during the creation itself. The angle of impact, the impact force, or the direction by which it is distributed by material, as well as the evidence of the indirect percussion, can be wrongly distributed, hence errors happen. All these factors reflect the process of core preparation or the control of the quality of raw materials.

3.3.8. Post-Deposition Surface Modifications (PDSM)

J. Evans and G. E. Sellers were one of the first to recognized natural processes noted on lithic artefacts that left similar traces as use traces made by humans (Baesemann 1986; Levi-Sala 1986, 1993; Plisson and Mauger 1988; Mazzucco et al. 2013). Experimental tests tried to replicate those processes – soil deposition, movement, erosion, trampling (Levi-Sala 1986; Evans and Donahue 2005). The problem is that the pattern that is created is random, resulting in isolated marks and it affects the use-wear trace (Vaughan 1985).

The PDSM modifications include chemical changes (patination), mechanical alterations (sediment movement), abrasion caused by wind and water, the friction of artefacts, trampling. Post-deposition surface modifications include also post-excavation alterations that incorporate damage during excavation (use of metal sieves), finds processing, further analysis.

3.4. USE-WEAR ANALYSIS: THE EXPERIMENTAL APPROACH

During various archaeological projects, researchers formulate a hypothesis and then it is tested so it could be *falsified* or not. From a scientific and *positivist* view experiments are part of the hypothetico-deductive process (Popper 1959). Some of the authors think that it is still not clear what experimental archaeology is and they wonder is there a difference between *experimental archaeology* and *archaeological science* if the experiment is the pillar of modern science (Outram 2008:1).

A couple of decades ago, this term signified the imitation or replication of archaeological objects. Today, experimental archaeology has the task to apply experimental methods to collect data, describe, interpret and explain the material culture and process behind it. Every attempt to experiment was created to define and control as many as possible variables within archaeological data. Experimental archaeology provides a way or one of the ways to explore archaeologically sensitive teaching systems and human behaviour in the past (Coles 1973:13). J. Coles also states that experimental archaeology aims to reproduce „former conditions and circumstances“ (Coles 1979:1), and these thoughts did not change even twenty years later when J. Mathieu said that experimental archaeology is designed to „replicate the past phenomena“ (Mathieu 2002:1). Some of the authors were strictly against the „re“ prefix (Reynolds 1999:159), and as the main explanation, they provided the fact that one is not certain how the past looked like – so it can not be *re*constructed (Outram 2008:2).

The experimental approach within use-wear analysis has become mandatory since the first publications and analyses. Semenov pointed out that this approach is very important because the replicas can show more than the appearance of the tool (Semenov 1964). Microwear analysts need to be able to recognize the basic range of variation already established by existing researches that were nearly universal in the past (e.g. working wood, hide, cutting meat, working bone) – simply because the researcher cannot go further and widen the knowledge if he is not familiar with already known (Bamforth 2010:102). In this case, the performance of the experiment is of multiple significance. Namely, the main goal of the experiment would be the production of traces of the use of the tools. In other words, experiments need to replicate realistic use contexts to the extent possible (Bamforth 2010: 102). However, in order to achieve this result, it is necessary to pass various processes:

- selection of raw material
- production process – use of certain prehistoric techniques to make tools or weapons,
- use – forming traces on the tool
- efficiency – time to discard the tool, or to reshape or sharpen the object

Interpretation of the experiment also can describe important archaeological questions, for example as an introduction to prehistoric agriculture. In this specific case besides the tool production and use, it is very important to cultivate adequate cereals in experimental fields and plan the time required for harvesting. Quantification of the time for the realization of the plan, the quantification of the people necessary for the performance of the experiment, the observation of the time span when the first signs of use of the tools appear, how to use the tools, the number of people in the average family or household that will be able to be fed from the products of harvesting - these are just a couple of questions that can be answered and they show how wide could be the scope of just one experiment.

The inquiries that the experiment can reveal are never the same because no process is identical: let's take for example the scraping of animal skin for secondary use. Accordingly, neither the tool we use will be morphologically identical. After the experiment and a series of photographs and video recordings enabled by modern technology, experimental objects will be able to join other tools in the collection or to form reference collections independently. The importance of these collections is enormous: based on them, it is possible to visualize the traces of use. It is necessary that each laboratory or any researcher dealing with functional analyses has access to a particular reference collection, or if it is not possible then a collection of photographs.

For the use-wear experiments to be successful it is important to try different models, so that the observed process could be reliable. Some of the controlled parameters should be respected during the experiments and general guidelines that should be considered when dealing with the experimental protocol are:

- formation of the hypothesis – based on archaeological research
- experiment arrangement – finding similar raw materials, and use of morphologically similar tools to the ones present in the archaeological sample
- recording of the process of the experiments – notes, photo, video, audio, creating the special database with all the needed variables
- observation of the experimental tools and comparing the results with the ones from the archaeological material
- interpretation of the final results
- discussion.

Except for these fundamental guidelines there also other directions that should be followed. It is very important to carry out the experiments in open-door spaces since that is the place where ancient people mainly used their tools and the laboratories are much cleaner than outdoors. Also, the experiment should be carried by candidates or by the persons who are conducting the use-wear analysis on the archaeological sample so they could get familiar with trace formation and handling of the tool.

Basic and universal experiment program should be similar to the one described by Keeley (1980) and Vaughan (1985). It means they should involve all the motions and contact materials that would produce distinctive use-wear patterns. This would include bone, wood, antler, hide, shell, meat, and non-woody plants. All these categories could be extended by sub-categories, depending on the researchers. It is known that traces develop during the time so it is very important to learn to describe and notice the poorly developed traces as well. The experimental tools should be observed before and after some amount of time. The optimal range is after 30 minutes, then after 1 hour and some experiments, depending on the wanted result, demand to be observed even after 3 hours of use and more. D. Bamforth suggests that activities should vary in duration of use from a little as two minutes to thirty minutes (Bamforth 2010:103). From all mentioned about the specifics of experimental work it is concluded that series should be developed to address the specifics of archaeological material, but also train the analyst to detect all the traces - motions and differences between types of scars made by divergent contact materials.

Two types of experimental series have been developed during the research of the chipped stone tools from Iron Gates: general as cutting and scraping of various materials present in the chronological scope that is being studied as wood, hide, bone, antler and problem-oriented experiments as hide, fish processing, thermal stress that together represent a reference collection. The details and complete experimental approach is described in Chapter 4.

3.5. CLEANING PROCEDURES

An uncleaned sample could cause major problems in interpreting, and already before recording and observing the traces of use. As far as cleaning is concerned, it is mentioned by Semenov (1964) at the very beginning of the use-wear analysis development. As regards (non) organic residues on the surface of the artefact, the application of more complex cleaning procedures is not necessary. More specifically, if the goal of conducting residue analysis cleaning is avoided, at least in the initial phase. Different authors have individually approached this technical process. Although the consensus on how to clean and prepare samples for traceological analysis has not been achieved, an experimental study has yielded some results.

The experiment consisted of two microlites from the sickle that were cleaned by alcohol, plain water, soap, and chemical treatment, and then were observed using a confocal microscope (Macdonald and Evans 2014). The result was that the most effective cleaning is with chemicals, however, in circumstances where they are not available, the use of soap and water is also helpful.

After Semenov (1984) warned the use-wear researchers about the importance of the cleaning of the samples and after a brief description, Keeley made a small protocol of the cleaning process. The first step according to Keeley should be the observation of any deposits on the surface of the artefact, this is followed by whipping the implement with alcohol to remove the finger grease and then the sample is washed with water and detergent. Then the implements were immersed in warm HCL (10% solution) and NaOH (20% to 30% solution) to remove mineral and organics deposits. Afterwards, the washing in the ultrasonic tank is needed to remove small particles of sand, silt, dust, and clay. Also, sometimes it is needed for the sample to be recleaned because of the handling during the observations (Keeley 1980: 10-11).

Spanish colleagues are following the procedure consisted of ultrasonic bath in H2O2 for 10 minutes to eliminate organic residues followed by another ultrasonic bath in the neutral phosphate-free detergent Derquim®, with ionic and nonionic surface-active agents, for 10-15 minutes, and finally, a bath in an ultrasonic bath in pure acetone for 2 minutes to eliminate fatty residues resulting from handling (Ollé and Vergès, 2008:40, Vergès and Ollé 2011:1017).

This field is still open for new experiments that could contribute to the efficiency of sample cleaning. The acid solution can destroy very important residue evidence that can bring proof about the worked material, and it has to be underlined that not all the raw materials and samples can undergo the same procedures, also sometimes the application of the cleaning procedure depends on the final goal of the research.

3.5.1. Cleaning procedure used in the study

For the cleaning of the chipped stone artefacts from the Iron Gates region, we used a standard cleaning procedure in LTFAPA Laboratory. The protocol consists of 15 minutes of cleaning in an Ultrasonic tank with demineralized water and Derquim® soap and then another 10 minutes in of ultrasonic bath with only demineralized water.

The same procedure was applied to experimental pieces. Some experimental tools done at the beginning of experimentation were cleaned with chemicals as well, but that approach was abandoned later. In cases where residues were covering the experimental traces needed to be examined some additional cleaning was done. More specifically in the cases when the experimental tools were hafted with resina the hafted part was cleaned with oil that removed the beeswax successfully without damaging the tool.

3.6. MICROSCOPY AND PHOTOGRAPHY

For the use-wear analysis of chipped stone tools from Iron Gates sites following equipment has been used: Nikon SMZ-U stereomicroscope (x 0.5 lens, x10 oculars, magnification range 0.75x to 7.5x) along with Toupview camera software, Nikon SM2 745T stereomicroscope (x10 oculars, magnification range x0.67 to x5) together with a Nikon DXM1200 digital camera, then a Nikon Eclipse ME 600 metallographic microscope (x5, x10, x20, x50, x10 oculars) with transmitted and reflected light that supports Differential Interference Contrast (DIC) and a confocal system (Fig. 24).

The microphotography was also done with the Hirox RH 2000 digital microscope. Some of the selected tools were examined by SEM microscope HITACHI TM3000.

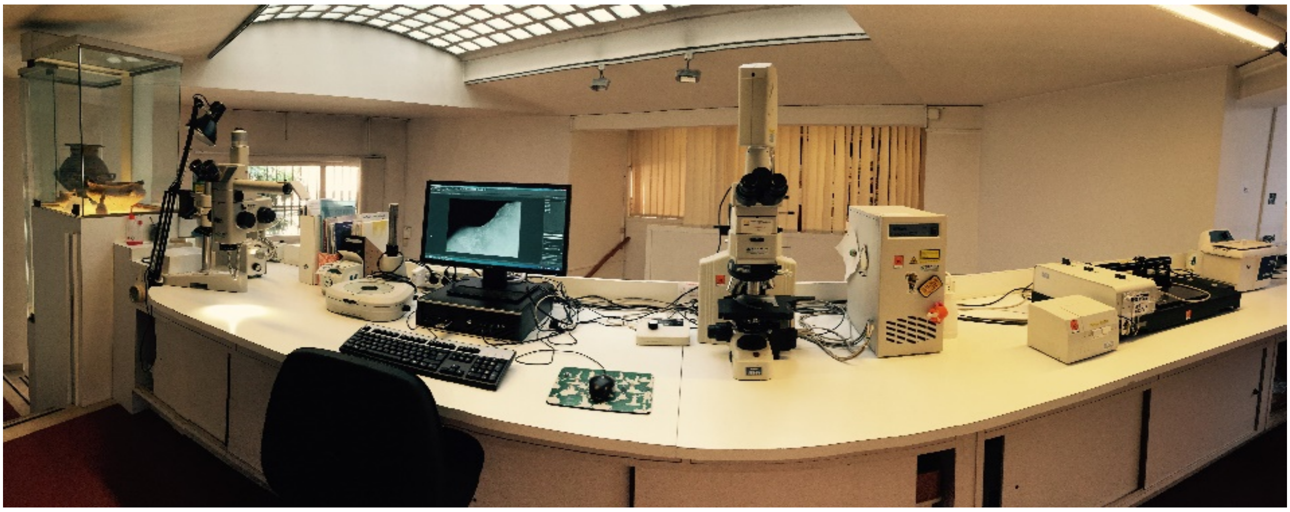

Figure 24: Equipment at LTFAPA Laboratory, Sapienza University of Rome.
From left to right: Stereomicroscope, Metallographic microscope with transmitted and reflected light equipped with DIC and Confocal System, ultrasonic tank. (photo: https://www.ltfapa.it/)

As there are differences in the equipment used, there are differences in the results that these methods provide. Therefore, using the smaller magnification method, we are able to record the basic characteristics of the trace, that is, the scar and its rough categorization of artefacts used on soft, medium-hard and hard materials and the basic activity: scraping, cutting, drilling. Larger magnification will determine the characteristics of the polish, and specifically what contact material was used: bone, skin, shell, fish scales, animal meat, cereals, silicate plants, etc. Detailed analysis of the movement itself is possible, whether it is a mixed activity, or it is dominated by a particular type of movement. Further, tools that have performed several diverse or same activities over different periods, that is, the location, extent, and type of recycling can be reliably determined.

3.7. DOCUMENTATION

3.7.1. Variables recorded per artefact: general information

The database that was used was made in File Maker Pro and it was used by other students and researchers in the LTFAPA Laboratory (Fig. 25). It contains a panel reserved for Archaeological Materials and Experimental tools (divided for technological, use-wear and prehension forms).

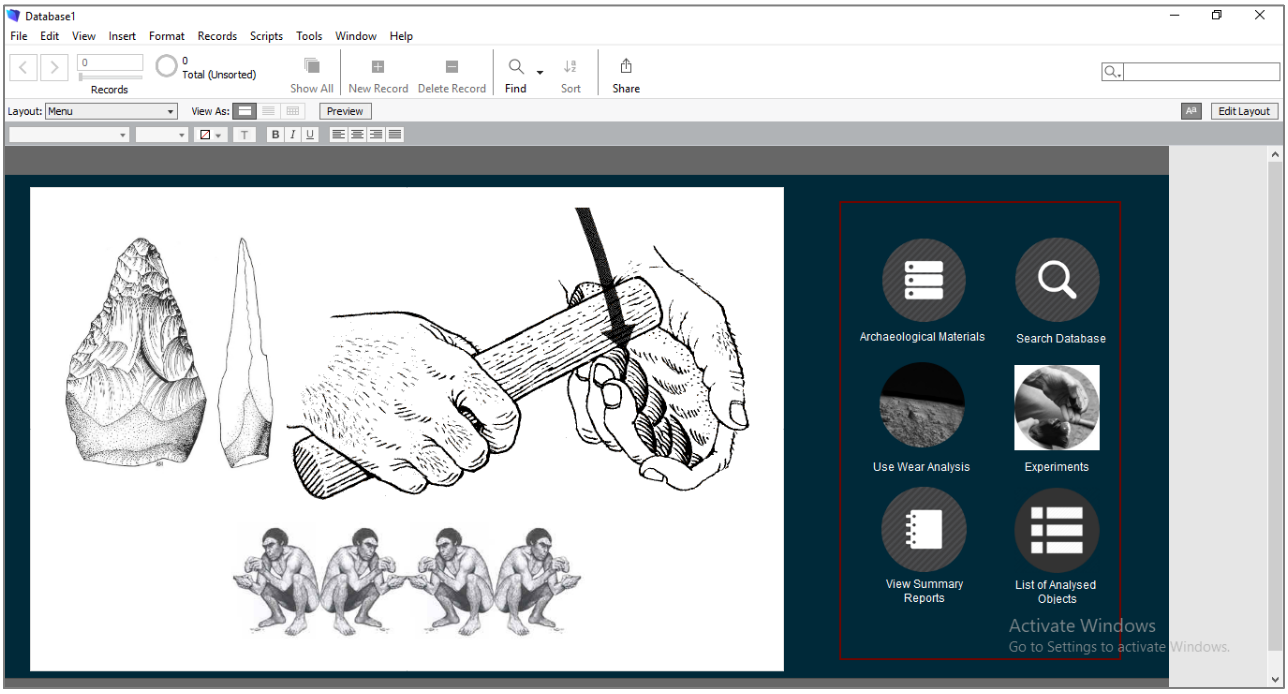

Figure 25: The interface of the database and the first panel/page

Data recorded in the database that is concerning general information are label number, the context of the find, measures of the chipped stone tool typology, cortex retain, edge morphology, profile, angle, bulb, striking platform (Fig. 26). There is an extra sheet in the database that is concerning the retouch sequences.

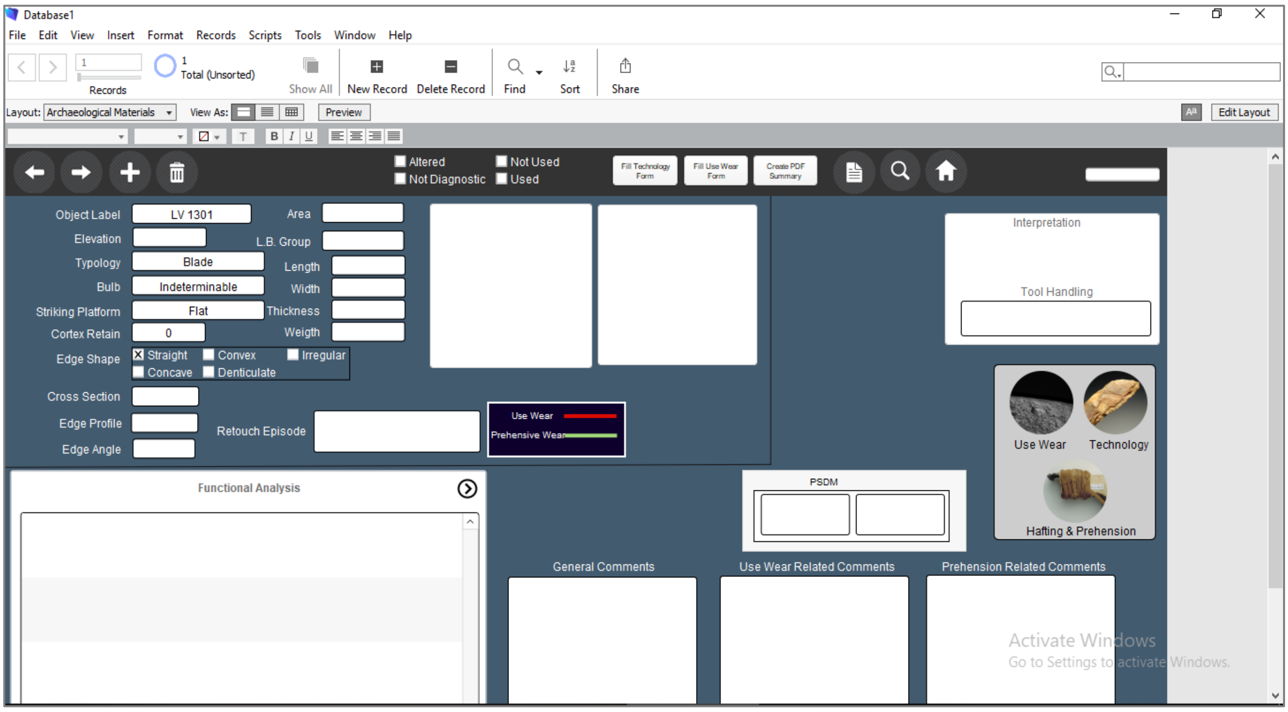

Figure 26: A general form of the Archaeological Materials

- *The Area and the Elevation of artefacts*: that means their position within the site grid excavation system or context, in general, depending on what kind of data is available. Excavation in Iron Gates brought both different but in some cases similar context description. Closed context as house, grave, hearth, ashplace is always noted as well as open-air spaces between the houses which is very important because these were the spaces where the majority of activities took part;
- *Typology*: the specific type of the artefact, blade, flake, retouched tools, scraper, etc;
- *Type of bulb and striking platform*: description of bulb type and the exact point of the knapping;
- *Length, Width, and Thickness*: length is measured from proximal to the distal end, the width is taken perpendicular to the length at its maximal point and thickness is also a maximum measurement. All measurements are expressed in cm;
- *Cortex retain* is a percentage (%) of the cortex left on the tool;
- *Edge shape*: straight, convex, concave, irregular with various possibilities (Fig. 27);

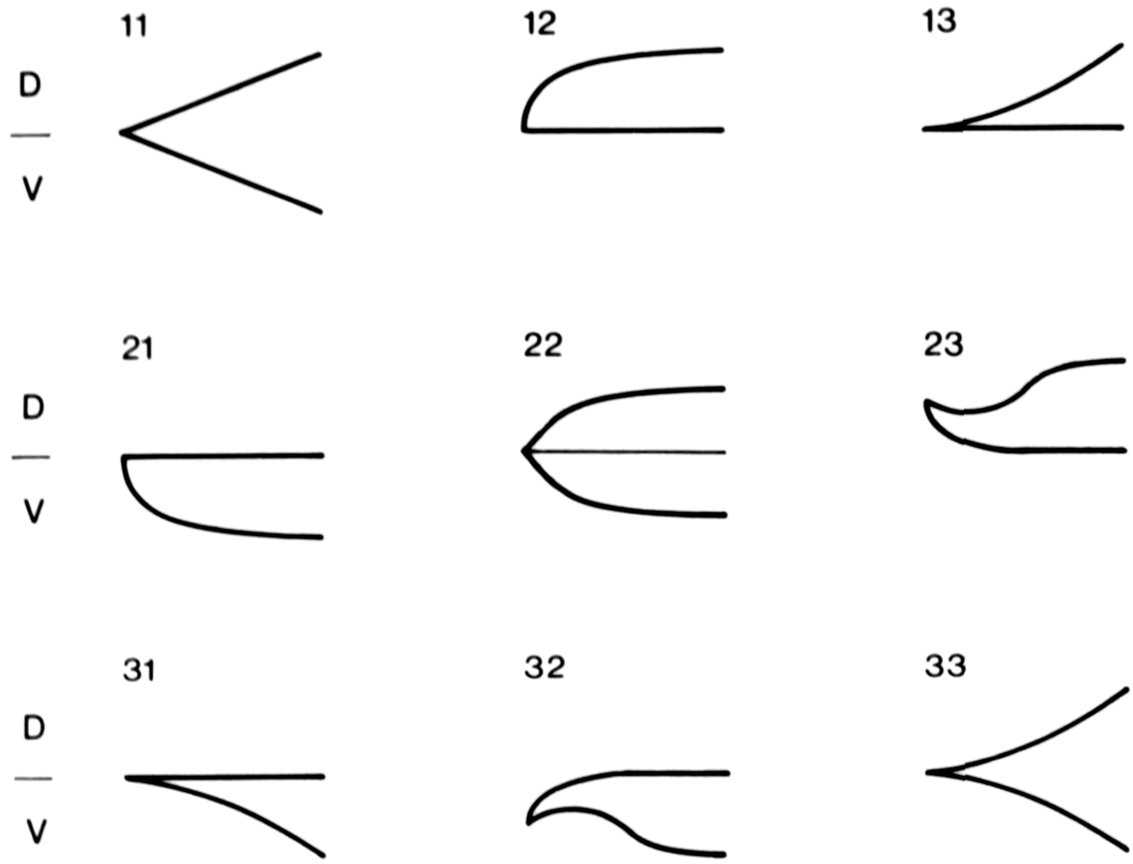

Figure 27: Variables for edge shape combinations: 1 = straight, 2 = convex, 3 = concave (after Van Gijn 1989)

- *The cross-section* is the result of the intersection of the dorsal and ventral surface that create an edge – straight, convex, concave and irregular (Fig. 28);

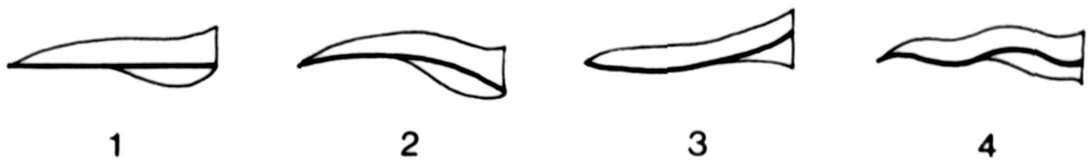

Figure 28: Cross-section – 1) straight, 2) convex, 3) concave, 4) irregular (after Van Gijn 1989)

- *The edge-angle* is measured on the used edge(s) with a goniometer.

Regarding the other fields on this page, later on, when other data is filled within the use-wear analysis form, PDSM, hafting form, the final interpretation appears also on the general page. Larger empty spaces are created for inserting illustrations and photos.

3.7.2. Variables recorded per artefact: description of the wear traces on the functional edges

Variables regarding the use-wear traces are divided on macro and micro observations and are part of a special *Use-wear form*. These variables (Fig. 29) are very detailed, and in many cases, this list is partially filled. Sometimes because some of the characteristics are undiagnostic, and they can not be identified.

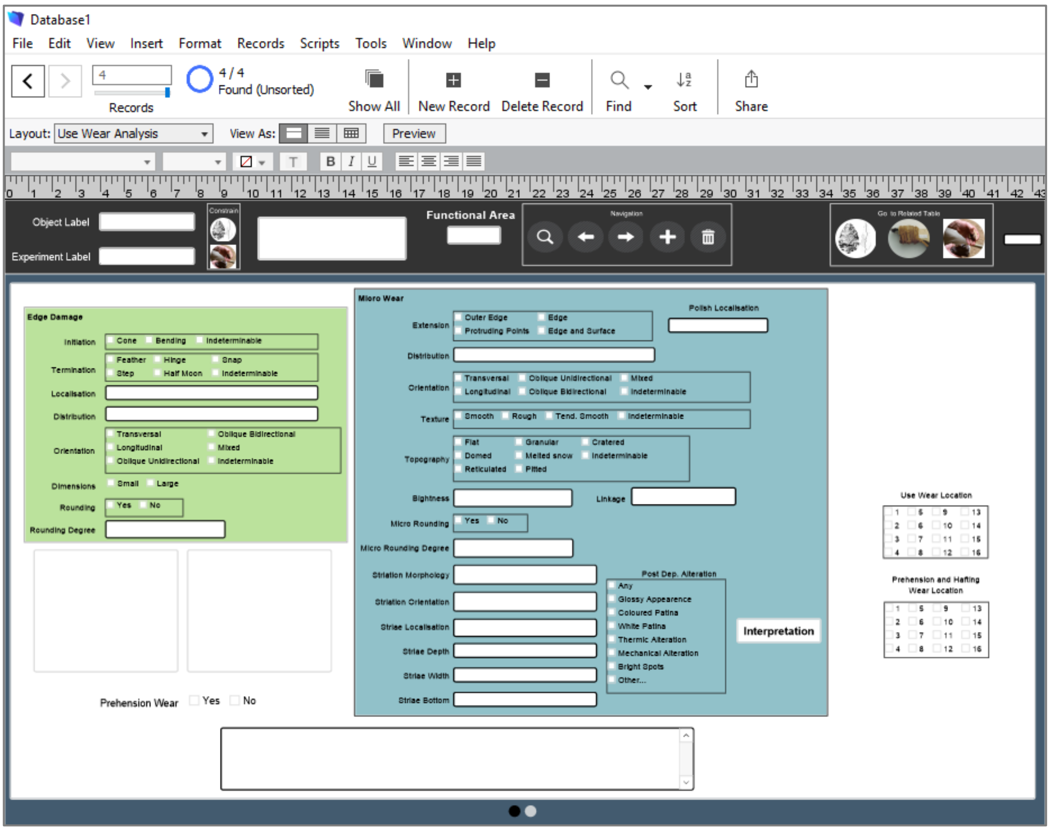

Figure 29: A use-wear form of the Archaeological Materials

Here the focus is on the most important variables that contribute to the final interpretation and that were used constantly both during training and analysing. Edge rounding or the macro variables that are observed by stereomicroscope are defining the type of material.

Variables used in the macro analysis are:

- *Termination* is probably one of the most important variables and it is referring to the shape of the scar and it can be a feather, step, snap, hinged, half-moon, or indeterminable, which indicates the material hardness (soft, medium, hard);

- *Edge damage localisation* is usually ventral or dorsal, or both ventral and dorsal and it refers to the position of the traces;

- *Edge damage distribution* can be a mix of things, like continuous regular, or discontinuous irregular referring to the size and diffusion of the scar traces on the working edge. Variables are close regular, close irregular, wide regular, wide irregular;

- *Orientation* refers to the activity or in other words the orientation of the traces: oblique is for cutting and transversal is scraping and a mix of both activities. Variables are transversal, longitudinal, oblique uni and bidirectional, mixed and indeterminable;

- *Dimension*s are addressing the scare dimensions, which sometimes can indicate the hardness of the worked material or state;

- *Rounding* is noted as is it present or not and to which degree (*rounding degree*). The edge rounding is indicating both hardness of the material, but also time and efficiency.

3.7.3. Variables used for micro traces

The parameters that are giving a general picture are extension, indicating where exactly is polish situated, distribution, localisation, orientation. New variables that are introduced on the microscale and are used to describe the polish are texture and topography. That is referring to the morphological shape of the polish features. Another new variable is linkage, which indicates the connection of the polish features and directs us more closely to the worked material, activity and time of work. An important set of variables focuses on striae from the use located on the polish or the used zone in general. Sometimes it can be connected specifically to the worked material indicating very detailed activities, as to hide depilation, but it usually indicates a connection between the material and activity.

- *Micro edge rounding:* low, medium, high

- *Polish extension:* edge, edge+surface, outer edge, protruding points, surface;

- *Polish localisation:* dorsal, ventral, dorsal+ventral, dorsal more, ventral more, indeterminable*;*

- *Polish distribution:* continuous, discontinuous, spotlike, indeterminable;

- *Polish orientation:* transversal, longitudinal, oblique uni and bidirectional, mixed and indeterminable;

- *Polish texture:* smooth, rough, rough to smooth, indeterminable;

- *Polish topography:* flat, domed, granular, cratered, melted snow, pitted, reticulated, indeterminable;

- *Linkage:* open, tight, half-tight, compact, indeterminable;

- *Micro striae morphology:* short, long, comet tails;

- *Micro striae orientation*: transversal, longitudinal, oblique, chaotic, mixed, various;

- *Micro striae location:* ventral more, dorsal more, ventral+dorsal, absent;

- *Micro striae depth:* deep, shallow, shallow+deep;

- *Micro striae width:* narrow, large, narrow+large;

- *Micro striae bottom:* polished, mat, pointed, corrugated, grooved;

There is also a field for post-depositional surface modification (trampling, glossy appearance, soil sheen). As previously said post-depositional surface modifications are very indicative and are usually the first feature that is being observed before even considering the traces because it suggests the state of preservation of the artefacts, but also the soil movement and other modification that happened after the object was used and discarded.

3.7.4. Variables recorded per artefact: description of the hafting traces

Analysing prehension and hafting traces is very important because they allow understanding how the tool was handled or if it was hafted what kind of pressure was applied during manipulation. Similar variables as ones used for macro and micro traces are used to describe the prehension part since this area can be very similar to the used zone (Fig. 30). Yet, very small details, together with localisation and distribution can distinguish active (used in activities) and passive (handled or hafted) edges. Prehension of the tools can leave both macro and micro traces. Macro traces have the same categories as scars from the used area but their variables are a bit different having in mind that hafting usually leaves scars that are distributed differently or randomly. Micro observations are focused on the description of the polish that is left, mostly in the shape of the patches, that can have striations, similar to the ones from use.

Even though it is important to describe the variables it is more important to look at the prehension area in general – how the patches of haft or prehension are distributed on the edge and how is the surface texture.

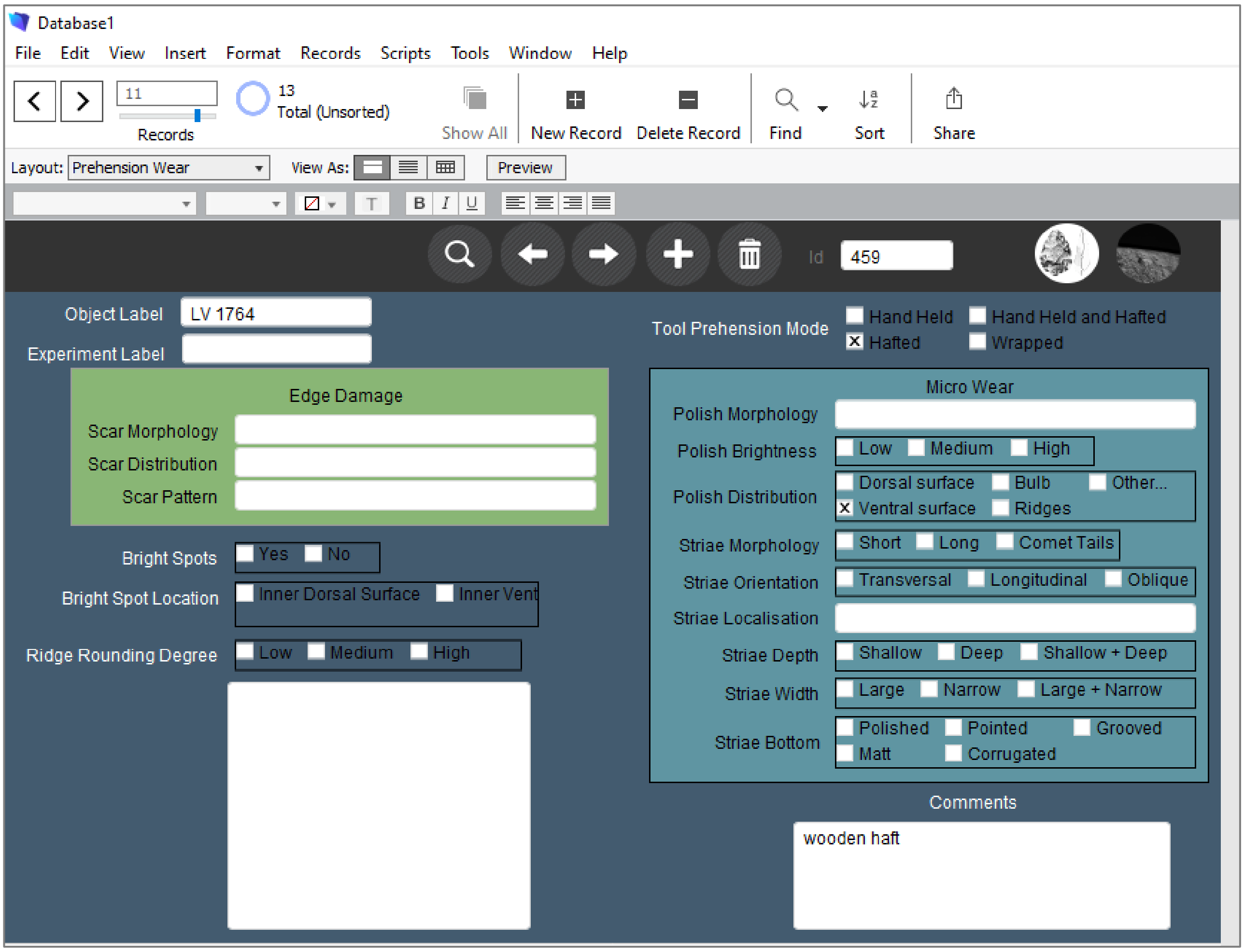

Figure 30: Hafting/prehension traces form and variables

Some of the important variables that should be noted are:

- *Tool Prehension Mode* is a general impression of how was the tool handled. Variables are handheld, handheld and hafted, hafted, wrapped;
- *Scar Morphology:* scalar, rectangular, trapezoidal, triangular, sliced, elongated, balloon, oblique;

- *Scar Distribution*: even and run-together, uneven and run-together, even and wide, uneven and wide, distinct patches, distinct patches wide in between;
- *Scar Pattern*: well-defined line; large scars with small scars inside; skewed saw pattern; inverse skewed saw pattern; largest scars at the centre; largest scars at the extremities;
- *Bright Spot*: yes, no;
- *Bright Spot Location*: inner dorsal surface, inner ventral surface, edges, bulb;
- *Ridge Rounding Degree:* low, medium, high;
- *Polish Texture:* smooth, rough, rough to smooth, indeterminable;
- *Brightness*: low, medium, high;
- *Polish Distribution Ridges*: dorsal surface, ventral surface, bulb, ridges, other;
- *Striation Morphology*: short, long, comet tails;
- *Striation Orientation*: transversal, longitudinal, oblique, chaotic, mixed, various;
- *Striation Localisation*: dorsal, ventral, more dorsal, more ventral, d+v, indeterminable;
- *Striation Depth*: shallow, deep, shallow+deep;
- *Striation Width:* narrow, large, narrow+large;
- *Striation Bottom*: Polished, Matt, Pointed, Corrugated, Grooved.

3.8. TECHNIQUES FOR RESIDUE DETECTION: THE STATE OF ART

The residue analysis deals with the traces of organic or inorganic matter and their presence on the artefact. While the use-wear analysis reveals the activity of the chipped stone tool and the worked material, the correct identification of a residue can potentially provide more specific information about the processed material as vegetal/animal taxa/species. Their preservation depends sometimes on (in the case of organic traces) mainly from the temperature, the amount of water (in the material with which the tool came into contact), and the amount of silicon dioxide in the raw material. The identification itself is possible based on microfractures, micro striations, and breakages.

In the very beginning, analysis of residual traces and function were seen as two different approaches (Grace 1996). For example, Odell has argued that residue analysts *are inclined to consider what they see, not what is missing* (Odell 2001:63). A. Van Gijn described at first residues all those deposits which can be removed with soapy water (Van Gijn 1986), and later on added and defined residues as all deposits that disappear after immersion in a lightly acidic solution (pH=5), (Van Gijn 1990: 8).

Today we can witness the collaboration between use-wear and residue analysis, which for and end product have more integrable studies backed with better identification of residues and a better interpretation (e.g. Jahren et al. 1997, Langejans 2010, Cristiani et al. 2012, Lemorini et al. 2012).

It is important to note that not all residues found on the lithic surface can be interpreted as use, hence, it is important to consider that modern contamination such as the manipulation of the stone tools during the analysis. In other words, fat from hands can easily be mistaken for a residue, so it very important to handle the tools with care and with the right equipment. Also, residues initially can be a part of sediment or a piece of a modern root that altered the surface and it is considered an alteration or it can be related to taphonomic processes.

The identification of the residue remains is done by polarized light microscopy and analysis, depending on the type of remain, may include different techniques, such as a simple biochemical or a spectroscopic analysis classifying the methodological observations on following methods:

- optical observation of artefacts under direct light

- microscopic observation

- removal of residues and their further, more detailed analysis (Marreiros et al. 2015: 17).

While dealing with residue analysis researchers stumble upon various problems regarding the post-depositional alterations from sediments, some organic remains that are not related to the use, and excavation and post-excavation handling of the material (Grace 1996; Evans and Donahue 2005). The important thing that should be noted is that interpretation based on residue analysis alone without combining them with other functional analysis should be avoided. Additionally, an integrated approach of diverse techniques of residue detection could help and improve the identification of the residues on the archaeological tools (e.g. Pedregnana and Olle 2018, Monnier and May 2019).

3.8.1. The methodology used for morphological detection of the residues of the archaeological sample

Morphological analysis of the organic residues of part of the sample is a complementary part of the overall result. Initial data showed that the implementation of the residue analysis on the Iron Gates sample was much needed and that it was more than useful on tools whose interpretation of use could not be made only based on the polish characteristic. This part of the analysis is conducted under the supervision of Professor Emanuela Cristiani from the Laboratory for the Study of Diet and Ancient Technology (DANTE) at Sapienza University of Rome. It is very important to note that the analyses of the function of the chipped stone artefacts and the analyses of ground stone tools from the same sites from the Iron Gates region that are being carried out within the *Hidden Foods* project[4] are representing sort of a *blind test*. This is an ideal comparative basis for generating a general picture of the activities of the Late Mesolithic and Early Neolithic communities of Iron Gates. Besides the archaeological sample, some experimental tools have been check, the ones that have been hafted and ones that left large amounts of residues as fish, liver, and spleen experimental trials.

During the residue analysis in DANTE Laboratory following microscopes have been used: Axio scope A1 with polarised light and magnifications up to 500x, and Axio Zoom V16 with magnifications up to 168x.

3.9. CHEMICAL TECHNIQUES FOR RESIDUE DETECTION: THE FTIR AND SEM-EDX

Samples showing satisfactory results with the proposed methods for visible (non) organic residues did undergo a series of chemical analyses using Fourier Transform Infrared Spectroscopy analysis (FTIR) and Scanning Electron Microscopy - Energy Dispersive X-Ray Analysis (SEM-EDX).

Both FTIR and SEM-EDX analyses have been identified as eligible since they do not require artefact modification and are not destructive. Sampling with a pipette would also bring with it alterations from the artefact, such as roots, which seriously affected the material from Lepenski Vir both mechanically and chemically, changing the structure of the raw material itself.

Sampling was done based on the additional interest and need. Meaning that all the chipped stone artefacts were resampled after previously being functionally analysed. The results that raised ulterior questions or uncertainties were subjected to residue analysis as artefacts where only macro

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[4] „Hidden foods project“ (http://www.hiddenfoods.eu), project director Emanuela Cristiani.

recognition of the traces was available or in the cases where the exact worked material or species could not be identified.

The potential of FTIR microspectroscopy to provide a chemical characterization of residues in a non-destructive way and without removal from the artefact has been recognized and exploited (e.g. Cesaro and Lemorini 2012; Monnier et al. 2013, 2017, 2018, Prinsloo et al. 2014). FTIR analyses of the sampled artefacts were carried out under the supervision of Dr Stella Nunziante Cesaro from Scientific Methodologies Applied to Cultural Heritage (SMATCH), ISMN-CNR c/o Department of Chemistry, Sapienza University of Rome. The FTIR spectra of the stone tools were collected with a Bruker Optic Alpha-R portable interferometer with an external reflectance head covering a circular area of about 5 mm in diameter (Fig. 31). The analysis does not require preliminary treatment of the samples. The investigated spectral range was 7500-375 cm^{-1} with a resolution of 4 cm^{-1} cumulating 250 scans or more. FTIR analysis is very important because they provide remarkable data in a small amount of time. The only downside of this technique is that it has a spectroscopic approach which means that the point that accumulates the data is not very precise implying that residues might not be detected even if they exist on the tool.

Figure 31: Bruker Optic Alpha-R portable interferometer,
INFN National Laboratory of Frascati (photo A. Petrović)

The SEM-EDX has shown great potential for archaeological residue analysis since it provides high-resolution images at large magnifications as well as elemental analysis of adhering material (e.g. Hayes and Rots 2019, Hayes et al. 2019, Pedergnana 2020). The main advantage of this instrument is that it is capable of operating in a low vacuum or *environmental* mode, allowing specimens to be examined uncoated and without additional preparation so that residues can be documented *in situ* on the tools. The analysis was performed under the supervision of Professor Cristina Lemorini. The smaller amount of the tools was resampled, in most of the cases, we are dealing with the artefacts in whose cases FTIR analysis did not offer clear identification of the residues.

3.10. FINAL REMARKS

This chapter focuses on the historical background, theory and methodological development of the methods and evolution of equipment used in the use-wear analysis. As it was seen, from the begging of the functional analysis, the attention of the researchers was divided into observation, identification, and interpretation of use-wear traces – all having one goal in common – to reconstruct the processes and human activities based on traces of motions and contact materials. Experimental work is also a crucial part of the functional analysis, and here little attention has been dedicated to this area since the separate chapter is dealing with the experimental protocol, its observations, results, and formation of the reference collection.

Many different variables are connected with the traces and we need to combine them to get the most objective results. This also demands constant methodological and technological improvement. Since this synthetic chapter showed us a variety of all the methods used in the field of functional analysis it is hard to single out the method and it is of the utmost importance to combine them. Additionally, incorporating the use-wear analysis on chipped stone artefact with other functional analysis results on other materials like bone, wood, ceramics is very important for the understanding of the social and cultural aspects of human groups. The use-wear analysis should be interpreted within spatial features of the excavated site with an emphasis on the context. The methods and techniques listed above are integrated into the study of the chipped stone tools from Mesolithic and Neolithic sites in Iron Gates with the aim to detect the traditions and habits of the local communities and the ones they acquired, that were brought by incomers, and how these activities were changing in transition.

4. EXPERIMENTAL APPROACH IN THE USE-WEAR ANALYSIS: FORMATION OF THE REFERENCE COLLECTION (EXPERIMENTAL PROGRAMME)

4.1. INTRODUCTION

Experimental trials are crucial for the interpretation of use-wear traces on stone artefacts, and they are considered a central part of the research and the training. The correspondence between the traces produced by modern experiments and traces on the archaeological sample is of the utmost importance and it validates the accuracy of the interpretation.

The key element of any experiment is the objective. The objective can be, for example, scraping wood or plants harvesting, in which case we observe the diverse use-wear patterns and the trace formation. Additionally, the objective can also be focused on some other elements of use or activity itself, as the time needed to debark the wood, the strength needed to shape the antler blank, or the efficiency of the chipped stone tools through time. This way it is possible to build up more complex experiments, as skin tanning, or we can acquire specific statistics as to how many crops we need to plant so it could feed a family of five or six during the Neolithic period. The focus is the formation of the reference collection, description of the experimental trials and results of use-wear analysis of the knapped tools.

Two broad categories exist general and problem-oriented experiments (Van Gijn 1990, 2010), and both types are addressed and represented in the study. The sets of problem-oriented activities were singled out immediately after preliminary use-wear analysis of the archaeological sample, while the *universal* experimental programme, as it is described by Keeley (1980) is consisted of processing all the general classes of materials to study the formation of different use-wear patterns. In the first stage of the experimental programme all the materials, that were available in the prehistoric communities during the Late Glacial and Eary Holocene were tested, as scraping and cutting antler, bone, hide, wood, plants and meat. The second phase consisted of more complex experimental trials. The idea was to observe the development of traces on the tools used for processing the materials in diverse stages (e.g. softened antler, dry hide, use of additives) and to generate complex experimentations that involve more contact matters (e.g. butchering, hide tanning). However, it should be emphasized that the fundamental need for creating these problem-oriented experiments were the preliminary results of use-wear analysis of chipped stone assemblages. These data indicated the prevalence of the use of the animal-based materials at Lepenski Vir and Padina (cf. Chapter 5) which led to the idea to explore the processes of softening of hard animal materials, butchering, hide tanning and the use of additives. Fish consumption in the Iron Gates region developed the need to test the possibility of processing fish with chipped stone tools. The quantity and traces of decapitation found on the fish bones (Živaljević 2017) additionally supported the need for experimenting. Another important factor was the discovery of the artefacts that were subjected to thermal stress. This phenomenon was noted in all the studied collections, but it is mostly represented in the Lepenski Vir and Vlasac assemblage, The thermal alteration trial was conducted to observe gradually all the macro and micro changes on the knapped tools. However, this experiment had another intention: to detect if the fire affected the traces. Based on the archaeological traces an important question is posed: where the tools used before the fire alterations or later and is it possible to extract any additional information?

In the beginning, a short introduction to the experimental approach and the applied protocol together with the procedure of documenting the experiments will be provided since no recent study in the region of Serbia has been dedicated to this matter. In the second part, the experimental series and its results will be described and discussed. Traces obtained by experiments were analysed with both low and high-power approach. Additionally, chemical analyses were applied as FTIR spectroscopy and SEM-EDX probes.

Except for the reference collection created by the author, experimental tools from the experimental collection of the LTFAPA laboratory at the University of Sapienza were used commonly during the methodology training and use-wear analysis of the artefacts. Their appliance during the elaboration of the results of the archaeological sample will be highlighted separately. This type of training consisted of both observation of the experimentally created traces, but also their making and the activity itself, which was very efficient. This way it is possible to observe all the components of the process from the creation of the tool, its utilization, the production of the first traces, to the establishment of the complete edge rounding.

4.1.1. Documenting of the experiment

It is essential to observe, prior to the use, edges of the tool including both the dorsal and ventral side, to create an illustration and make macro and microphotographs. The drawings are useful to mark the used area and prehension or hafting zone. The macro and micro pictures will serve as a comparison, after various phases of use. It is important to document the tool production, as well as if it is retouched and with what kind of a retoucher. Observation of the retouched area is necessary to check the traces formed by flaking.

During the experiment, all sorts of notes should be made (Bamforth 2010). Some of the most important ones are:

- Duration of use. Observation under the microscope is needed, for example, after the first 30 minutes, and then after one hour of use. This is a good protocol for learning about trace development. Gradual observation of trace formation helps to better understand how they form, and which kind of activity leaves what kind of traces after a specific period. Accordingly, some motions and materials that are more abrasive or durable can provide a very developed edge rounding in a short period.
- Surface and part of the tool (dorsal, ventral, and distal, medial, proximal) that was in contact with the worked material. It is important to note the contact side, so we can trace the scar development and to what extent is it connected to the motion itself.
- Direction or movement of the tool. It is very usual to change the direction to obtain the best efficiency of the tool, but also to avoid some irregularities in the contact material.
- The efficiency of the tool through time.
- The number of strokes during the specific activity (e.g. butchering) when such information is of importance.
- Details of contact material as vegetable species, animal species, the condition (e.g. dry/soaked wood, dry/fresh hide), and exact used part in the experimentation.

Video recording is fundamental, so the motions could be observed but also handling of the tool, change of the position, angle. Video also enables commenting immediately and gives us a chance to go back to the experiment and gather some more data (Bamforth 2010:105).

4.1.2. Experimental procedure: methods and materials

The experimental tools were washed with the standard procedure introduced and used by LTFAPA Laboratory, with Derquim® soap and ultrasonic tank:

1. First, the tools are washed with warm water.
2. Then the tools are put into demineralized water with Derquim® soap in the ultrasonic tank for 10-15 minutes.
3. Afterwards, the experiments were put into demineralized water in the tank for 5 more minutes.

Both low and high–power approaches are implemented and the experimental tools have been examined at LTFAPA Laboratory at the Sapienza University of Rome, using Stereomicroscope Nikon SMZ -U with reflected light (x 0.5 objective, x10 oculars, range of magnifications from 0.75x to 7.5x) together with Toupview camera Software, Stereomicroscope Nikon SM2 745T (x10 oculars, range of magnifications x0,67 to x5) together with Nikon Digital Camera DXM1200 and Metallographic microscope Nikon Eclipse ME 600 (x5, x10, x20, x50 objectives, x10 oculars) with transmitted and reflected light equipped with Differential Interference Contrast (DIC).

Regarding the residue analysis, FTIR spectra of chipped stone tools were done with a Bruker Optic Alpha-R portable interferometer with an external reflectance head covering a circular area of about 5 mm in diameter, and SEM-EDX analysis was completed with a digital microscope HITACHI TM3000 in total vacuum and Analy (15KV) mode.

All the flint replicas were created by direct percussion by D. Moscone and A. Petrović. So far, as specified in previous chapters more detailed petroarchaeological and geological analysis was done only for the volcanic rocks, found at the Lepenski Vir, suggesting the Sirinia Basin in Romania as the possible source (Šarić et al. 2021). In the absence of petroarchaeological analysis of geological sources regarding the Balkan flint in Serbia (Gurova et al. 2016) and materials available in the prehistory of the Iron Gates region, other raw materials were used to produce the replicas of chipped stone tools found at the archaeological sites. Raw material (chert) utilized to make unretouched experimental tools (flakes, blades and one burin) came from the Gargano region (Fig. 32)[5]. This chert is of very good quality, with a homogeneous nature, similar to the raw material found on the sites from Iron Gates, which makes it suitable for the experimental trials. Gargano chert is greyish or brownish translucent chert from a sub-primary source with spotted (à pois) structure and fine-medium texture (poor sorted grains; fraction 10% $< x >$ 50%), (Fig. 34a-b). Fossil fauna content features sponge spiculae, foraminifera and radiolaria, substrate rich in bioclast, no post-genetic processes and it has a conchoidal fracture (good quality at knapping; from flakes to blades), (Petrović et al. 2021a, in preparation).

[5] Gargano region is settled in the province of Foggia, Apulia, in south-east Italy.

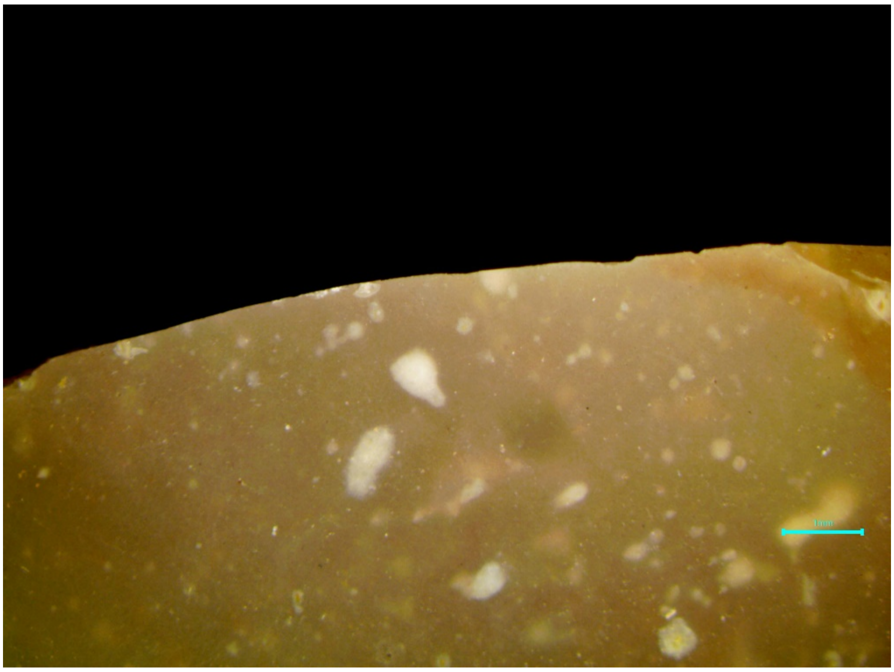


Figure 32: Gargano flint (photo A. Petrović)

Besides the Gargano chert, the flint of high quality from Israel (Fig. 33a) was used and some of the used blades were made on raw materials available in Marche region[6] and they were made by direct percussion (Fig. 34b).

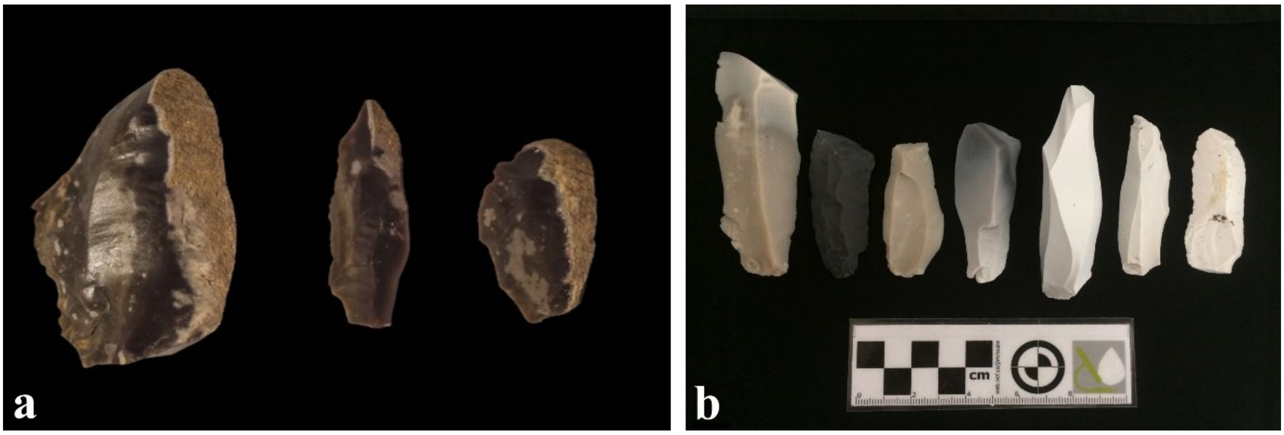


Figure 33: a) Flakes on flint from Israel, b) Blades produced by direct percussion on raw material from Marche (photo A. Petrović)

[6] Central Italy

Raw materials from Serbia – a hinterland of the Iron Gates and Lojanik quarry site (Bogosavljević Petrović et al. 2018)[7] have been used for thermal stress and post-depositional surface modification experiments.

One type of these raw materials comes from Vrelo Marice site[8] and it is from the secondary source. This is greyish non-translucent chert with original structure altered by post-genetic processes (dissolution and recrystallization of the silica phases; highly tectonized). The chert has no fossil fauna content, coarse texture (poor sorted grains; fraction > 50%) and uneven fracture (low quality at knapping; only flakes).

Flint from Lojanik quarry site is of a primary source. The nodules taken are reddish translucent because this type of chert has many colour variations. It is of mixed structure (shaded, spotted, and mottled), medium texture (poor sorted grains; fraction 10% < x > 50%), and it has recrystallized pores. Fossil fauna content features algae (?) and corals (Fig. 34c-d). The substrate of this chert is rich in organic matter and it has a sub-conchoidal fracture (medium quality; some parts of the nodule were fractured; from flakes to bladelets).

Quartz and quartzite from Serbia are from a secondary source, and are highly tectonized, and have an uneven fracture (Fig. 34e-f), (Petrović et al. 2021a, in preparation).

[7] West Central Serbia
[8] Eastern Serbia, hinterland of Danube region

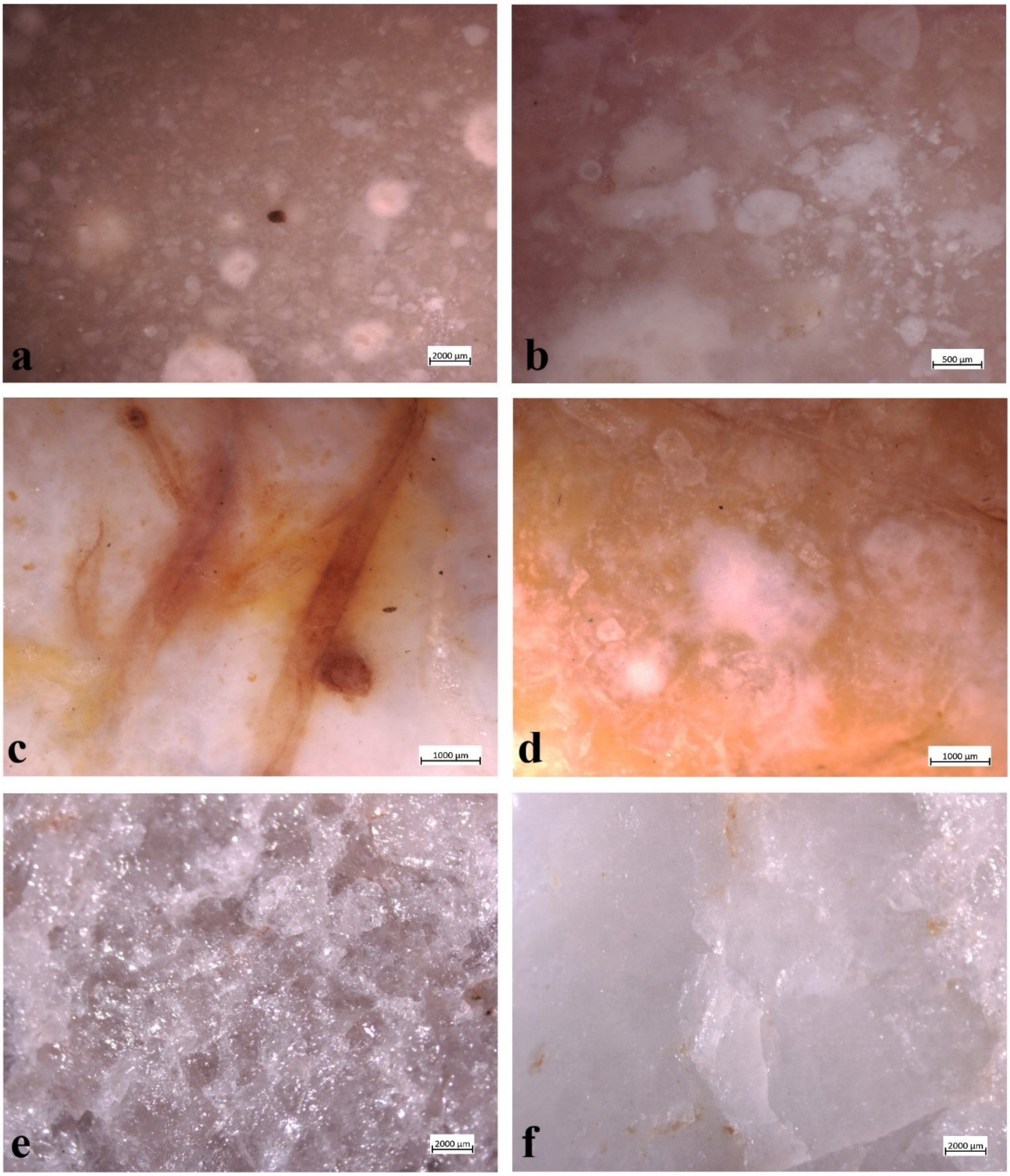


Figure 34: Stereo observations of raw materials used in the experimental programme – a), b) Gargano flint, c), d) Lojanik flint, e) quartz from Pločnik site, f) quartzite from Poloj (photo D. Moscone)

Before the experimentation, tools were observed under a stereomicroscope, metallographic microscope and their casts with Provil nuovo® gel were taken (Fig. 35). The main reason for cast modelling was to better understand the development of traces by directly comparing the appearance of the edge before use and after.

The procedure for taking the casts is composed of the following steps:

1. All the chosen pieces first are washed with water and dried with a blow-dryer.
2. Provil gel is applied on the working edges (Fig. 4) and they are left to dry for 5-10 minutes.
3. In the end, the casts are taken off without any contact with bearskin, they are numbered and bagged separately.

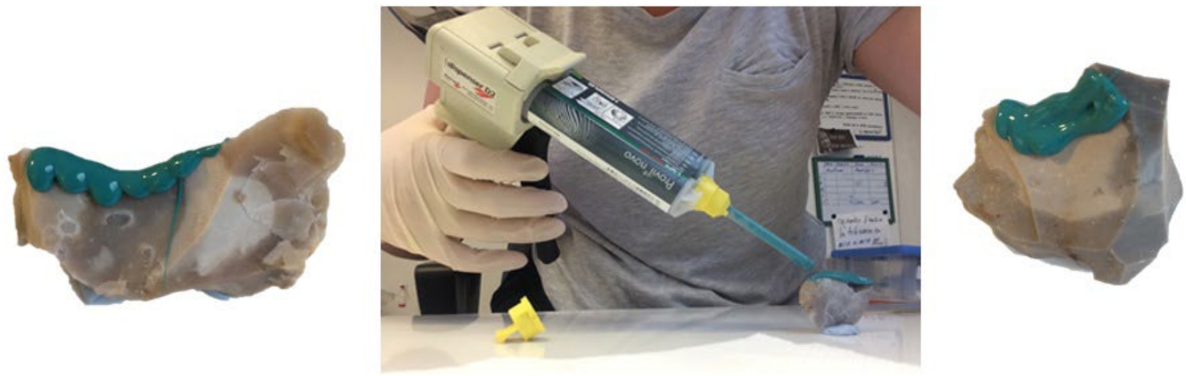


Figure 35: Examples of experimental tools and the application of Provil Nuovo gel (photo A. Petrović)

In total, fifty-eight (58) series of experiments were conducted (Table 1). During the previous studies seven (7) experiments were done (Petrović 2016), and these experiments will be listed together with the trials obtained for the purposes of the doctoral thesis (fifty-one (51) experiment) since some of them were reused in the thermal stress probes included in this study. The trials are divided into diverse groups: experiments with vegetal and animal resources, stone working, ceramics, thermal stress experimental trials, tool handling modes, and experiments dealing with PDSM.

Table 1: List of experimental trials

#	TITLE	ADDITIONAL EXPERIMENTATION	YEAR	PLACE	TOOL TYPE	RAW MATERIAL
1	Cutting soaked wood	+ Thermal stress, LTFAPA	2016, 2019	LTFAPA, Rome	blade	flint, Israel
2	Scraping hide	+ Thermal stress, Portonovo	2016, 2019	LTFAPA, Rome and Portonovo	flint	flint, Israel
3	Scraping bone		2016	LTFAPA, Rome	cortical flake	flint, Israel
4	Cutting bone		2016	LTFAPA, Rome	blade	flint, Israel

5	Engraving soapstone		2016	LTFAPA, Rome	massive flake	flint, Israel
6	Scraping soaked wood	+ Thermal stress, LTFAPA	2016, 2019	LTFAPA, Rome	blank for scraper	flint, Israel
7	Drilling ceramics		2016	LTFAPA, Rome	flake	flint, Israel
8	Bone scraping		2017	LTFAPA, Rome	sidescraper	flint, Marche
9	Wood scraping		2017	LTFAPA, Rome	scraper	flint, Marche
10	Soapstone engraving		2017	LTFAPA, Rome	massive scraper	Gargano chert
11	Shell (G*lycymeris insubrica*) working		2017	LTFAPA, Rome	sidescraper	Gargano chert
12	Wood cutting		2017	LTFAPA, Rome	flake	flint, Marche
13	Bone cutting		2017	LTFAPA, Rome	flake	flint, Marche
14	Hide scraping		2017	LTFAPA, Rome	flake	Gargano chert
15	Plant (grass) working		2017	Villa Borghese Park	flake	Gargano chert
16	Butchering a sheep (*Ovis aries*)		2018	LTFAPA, Rome	massive blade, a knife	flint, Israel
17	Butchering a sheep (*Ovis aries*)	+ Thermal stress, LTFAPA	2018, 2019	LTFAPA, Rome	flake	flint, Israel
18	Butchering a sheep (*Ovis aries*)		2018	LTFAPA, Rome	flake	flint, Israel
19	Butchering a roe deer (*Capreolus capreolus*)		2018	Abruzzo	blade	flint, Marche
20	Butchering a roe deer (*Capreolus capreolus*)		2020	Abruzzo	flake	flint, Marche
21	Tubers *(Asphodelus ramosus*)		2018	LTFAPA, Rome	blade	flint,Marche
22	Butchering a roe deer (*Capreolus capreolus*)		2018	Abruzzo	blade	flint, Marche
23	Antler working		2018	LTFAPA, Rome	blade	flint, Marche

24	Cutting liver		2019	LTFAPA, Rome	blade	flint, Marche
25	FTIR, nail polish experiment		2020	LNF, Roma	blade	Gargano chert
26	Antler working		2018	LTFAPA, Rome	flake	Gargano chert
27	Hide tanning		2018	LTFAPA, Rome	scraper	flint, Israel
28	Hafting, not used		2018	LTFAPA, Rome	scraper	flint, Israel
29	Hide tanning		2018	LTFAPA, Rome	endscraper	Gargano chert
30	Hide tanning		2018	LTFAPA, Rome	flake	Gargano chert
31	Hide tanning		2018	LTFAPA, Rome	flake	flint, Israel
32	Hide depilation		2018	LTFAPA, Rome	flake	Gargano chert
33	Scraping meat (tanning)		2018	LTFAPA, Rome	flake	Gargano chert
34	Removing fish (*Cyprinus carpio*) scales		2019	LTFAPA, Rome	flake	flint, Vrelo Marice
35	Cutting spleen		2019	LTFAPA, Rome	flake	flint, Vrelo Marice
36	Fish (*Cyprinus carpio*) processing (head cutting,		2019	LTFAPA, Rome	flake	flint, Vrelo Marice
37	Thermal stress, LTFAPA	+ scraping bone, 30 min	2019	LTFAPA, Rome	flake	Lojanik chert
38	Thermal stress, LTFAPA	+ working tubers (*Asphodelus ramosus*), 40 min	2019	LTFAPA, Rome	flake	Lojanik chert
39	Thermal stress, LTFAPA		2019	LTFAPA, Rome	flake	flint, Vrelo Marice
40	Thermal stress, LTFAPA		2019	LTFAPA, Rome	flake	flint, Vrelo Marice
41	Thermal stress, LTFAPA		2019	LTFAPA, Rome	flake	quarzite, Poloj
42	Thermal stress, LTFAPA		2019	LTFAPA, Rome	flake	quarzite, Poloj

43	Thermal stress, LTFAPA		2019	LTFAPA, Rome	flake	quartz, Pločnik
44	Thermal stress, LTFAPA		2019	LTFAPA, Rome	flake	quartz, Pločnik
45	Thermal stress, LTFAPA		2019	LTFAPA, Rome	flake	Gargano chert
46	Thermal stress, LTFAPA		2019	LTFAPA, Rome	flake	Gargano chert
47	Thermal stress, Portonovo		2019	Portonovo	flake	Lojanik chert
48	Thermal stress, Portonovo		2019	Portonovo	flake	flint, Vrelo Marice
49	Thermal stress, Portonovo		2019	Portonovo	flake	Gargano chert
50	Thermal stress, Portonovo		2019	Portonovo	flake	quarzite, Poloj
51	Thermal stress, Portonovo		2019	Portonovo	flake	quartz, Pločnik
52	PDSM, Sicily		2019-ongoing	Sicily	flake	quartz, Pločnik
53	PDSM, Sicily		2019-ongoing	Sicily	flake	quartzite, Poloj
54	PDSM, Sicily		2019-ongoing	Sicily	flake	flint
55	Texture wrapping		2020			flint, Kanyera
56	PDSM, Serbia		2020-ongoing	Belgrade	flake	quartz, Pločnik
57	PDSM, Serbia		2020-ongoing	Belgrade	flake	quartzite, Poloj
58	PDSM; Serbia		2020-ongoing	Belgrade	flake	Lojanik chert

4.2. EXPLOITATION OF VEGETABLE RESOURCES

4.2.1. Scraping wood – debarking

Figure 36: Scraping wood – debarking (photo A. Petrović)

After 30 minutes of scraping wood (Fig. 36) the dorsal side of the scraper displayed snap, step and feather trace terminations with present medium edge rounding (Fig. 37a). In contrast to scars on the dorsal side, traces and polish on the ventral side were more pronounced and polish extension is noticed on edge with a smooth polish texture distributed continuously (Fig. 37b) which is directly connected to the wood debarking.

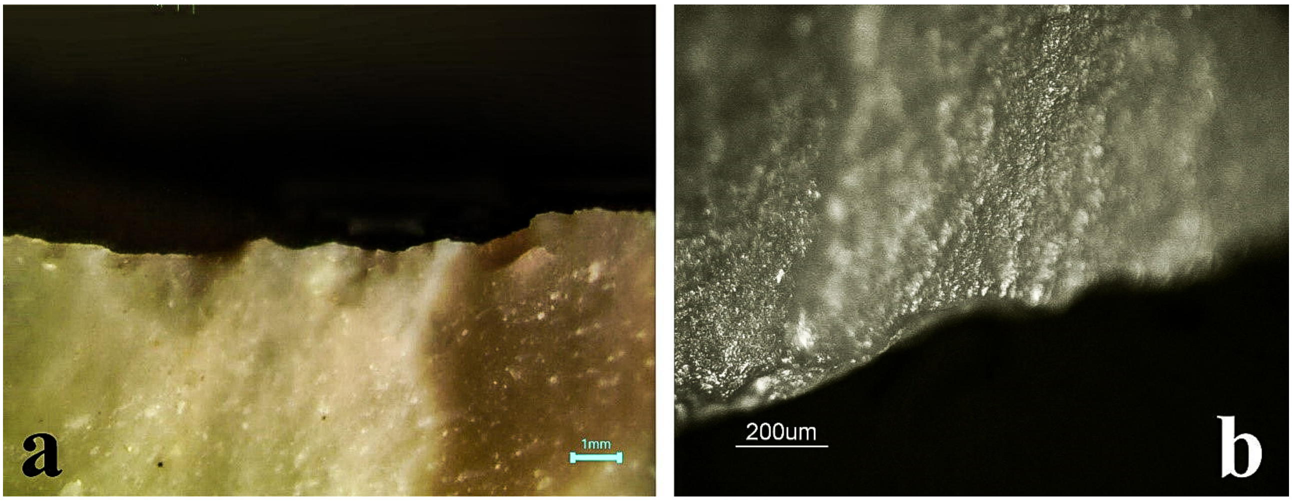


Figure 37: a) Snap and step termination, b) Smooth polish texture (photo A. Petrović)

4.2.2. Cutting wood

Figure 38: Cutting wood (photo A. Petrović)

A flake was used for cutting the same branch (Fig. 38). Both surfaces of the experimental tool were used. The traces on the ventral surface were more defined with feather termination and some step scars (Fig. 39a) which is specific for medium-hard materials, as wood in this case. According to the micro-observations the polish, of smooth texture, was developed on the outer edge (Fig. 39b).

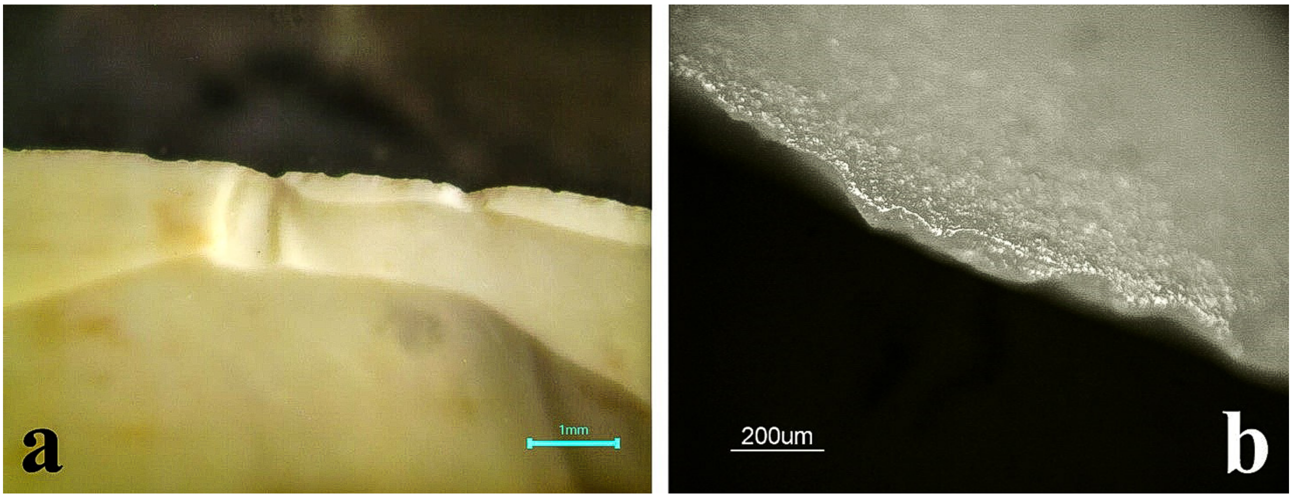


Figure 39: a) Step scars, b) Smooth polish texture (photo A. Petrović)

4.2.3. Peeling off and cutting the tubers (*Asphodelus ramosus*)

This experiment involved two different kinds of activities: peeling off the tubers and, afterwards, cutting. Tubers from the genus of *Asphodelus ramosus* were used in the experiment since this species is very widely spread all over Europe especially in the Mediterranean (Fig. 40).

Figure 40: Peeling off tubers (photo A. Petrović)

The right edge was used for 21 minutes for peeling off the cortex (Fig. 9), and it developed small traces with snap and half-moon terminations that are oriented oblique-bidirectionally (Fig. 10a). These traces can be defined as traces associated with medium-hard materials. The left side was used for 10 minutes for cutting (Fig. 41a).

Similar traces were observed on the right edge, but less pronounced with a smaller amount of edge rounding defined as traces associated with soft materials. The metallographic microscope showed domed topography and internal distribution with tight to covered linkage. The best-preserved polish was on higher parts (Fig. 41b). Cutting edge showed signs of soft material very similar to butchering, which led to observing both experimentally induced polishes and comparing them. The main difference was the polish distribution on the higher part that was represented by domed topography and tight linkage.

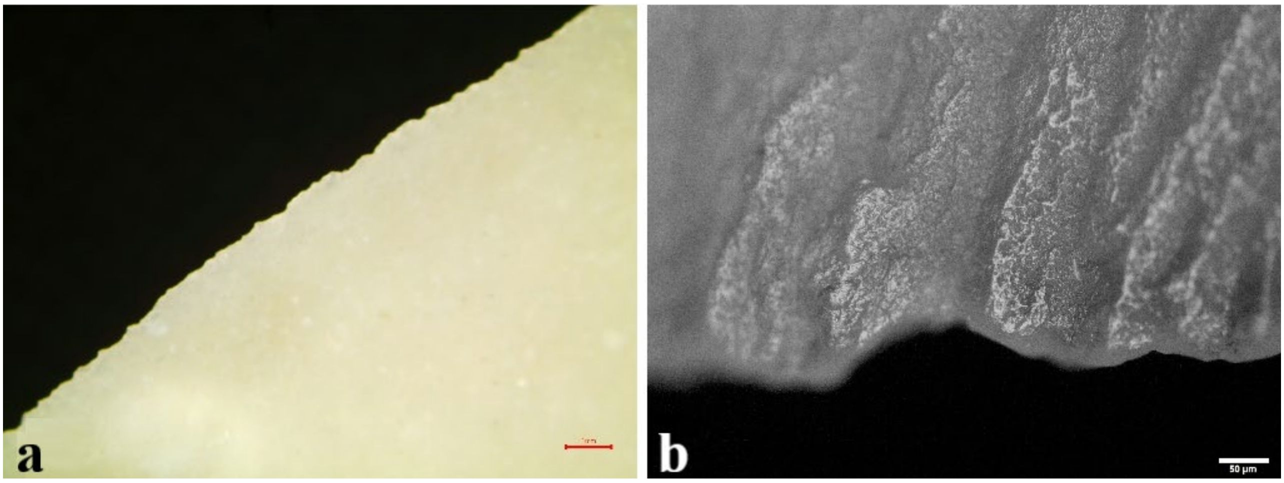


Figure 41: a) Small snap and half-moon scars, cutting,
b) Domed topography and tight linkage on higher parts of the polish (photo A. Petrović)

FTIR analysis, done two years after the experimental trial, showed values interpreted as adipocere, a greasy lipid mixture, observed at 1576,1540 cm^{-1} (Fig. 42). Fats of both animal and vegetable origin can undergo a phenomenon called hydrolysis in the presence of anaerobic bacteria and transform into adipocere, that is, a mixture of saturated fatty acids. This process can take up to a couple of months.

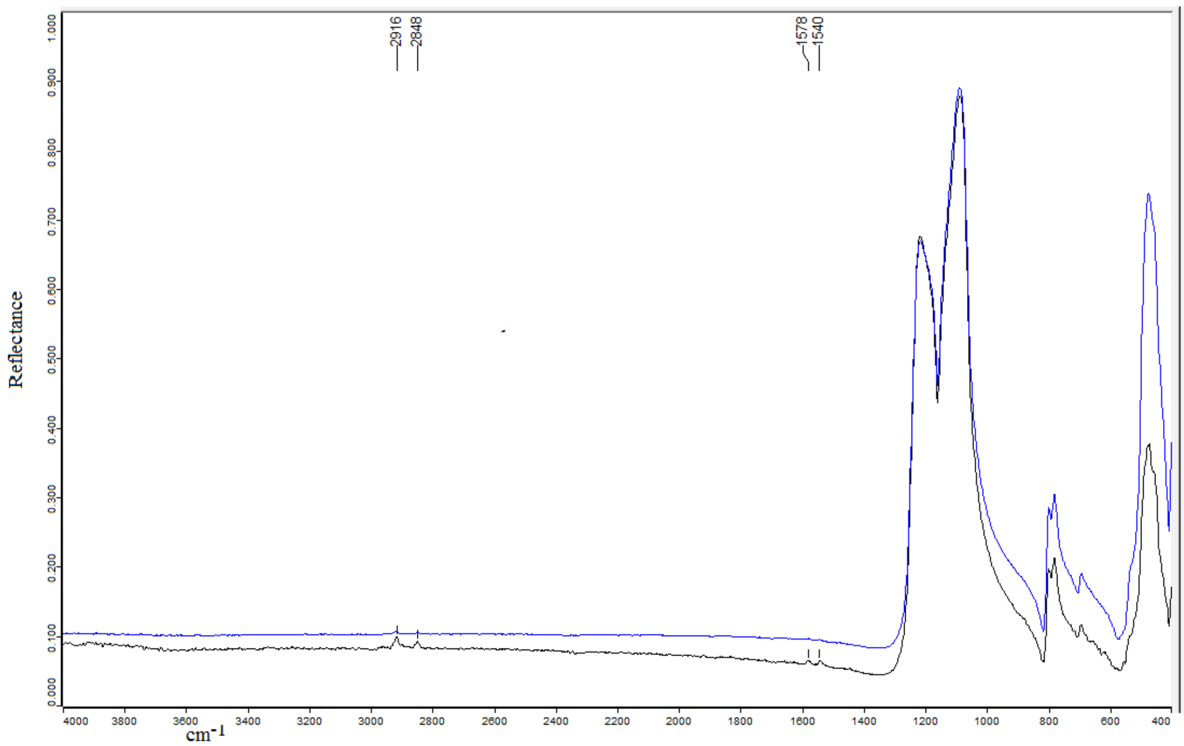


Figure 42: Results of FTIR analysis of tools used for working of tubers (*Asphodelus ramosus*),
(spectra S. Nunziante-Cesaro)

4.2.4. Plant working – grass cutting

The first edge was used for 15 minutes, but it was very inefficient since it was hinged (Fig. 43a). Another, lateral, sharper edge, used for 30 minutes, was more potent (Fig. 43b).

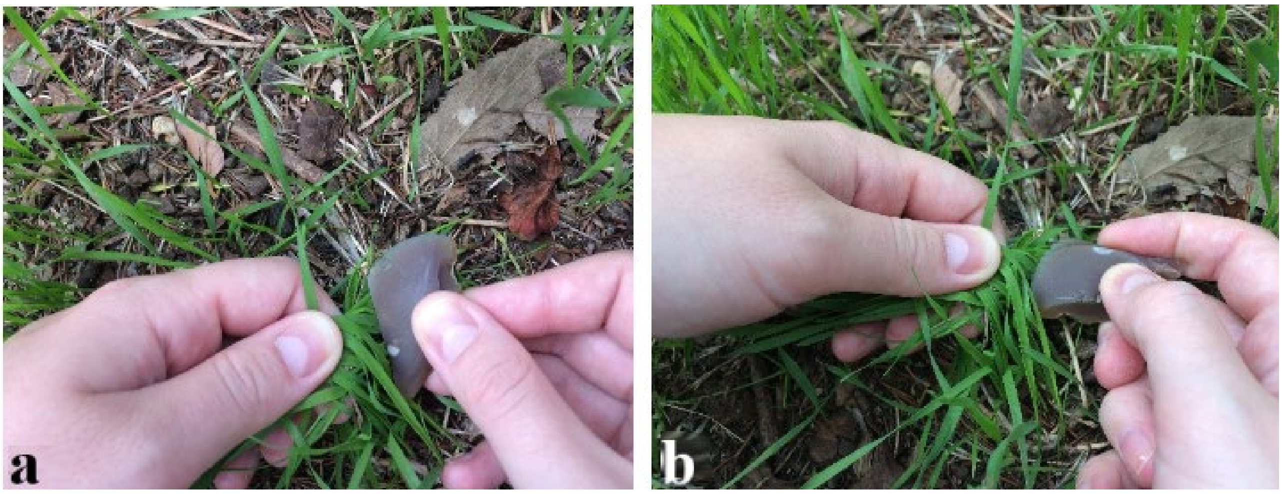


Figure 43: a) Inefficient edge used for 15 minutes, b) Efficient edge used for 30 minutes (photo A. Petrović)

On both microscopes, the edge rounding on the ventral side was more pronounced. The scars are continuous and a mixture of step, snap and feather trace terminations creating a very developed edge rounding (Fig. 44a). Polish is distributed continuously, and it is very bright while the texture is characterized as smooth localized on the edge area (Fig.44b, 45a). In the more developed areas, the linkage is tight to covered and the topography is flat (Fig. 45b), (Petrović 2016).

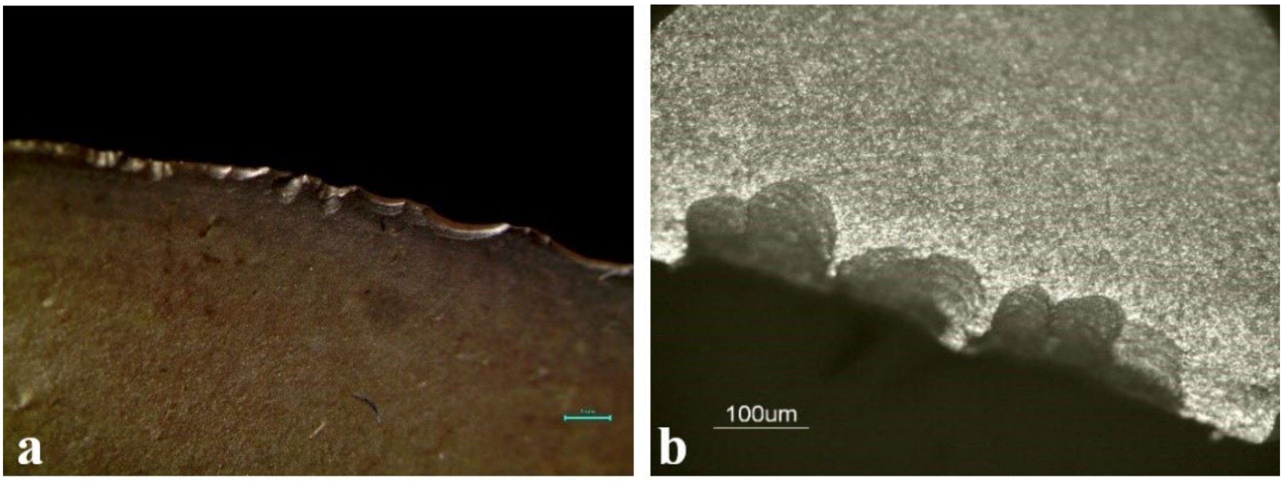


Figure 44: a) Mixture of snap, step and feather terminations, high level of edge rounding, b) Smooth texture (photo A. Petrović)

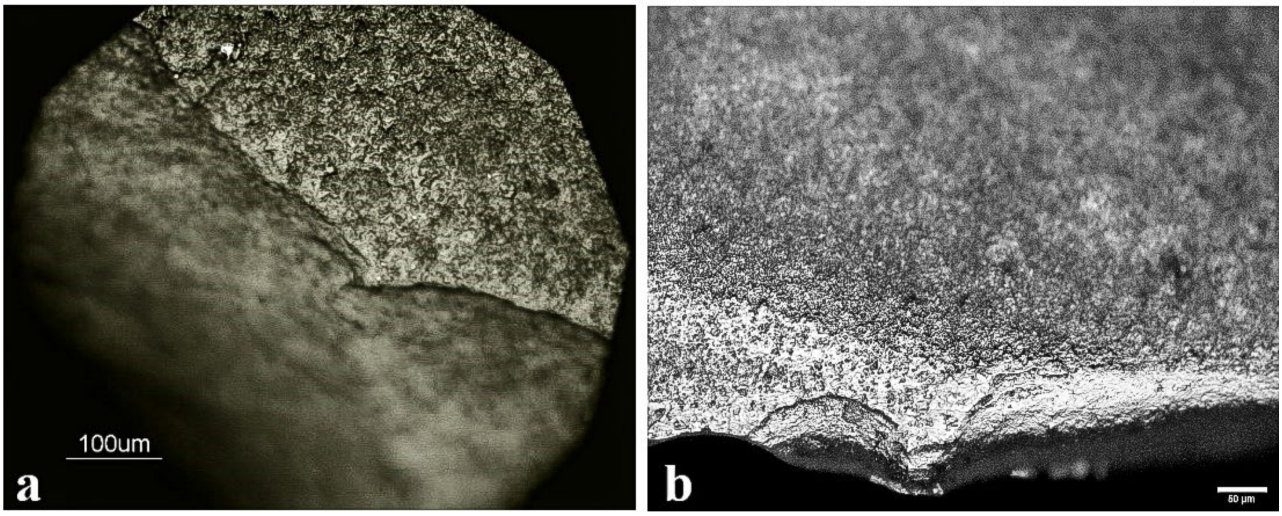


Figure 45: a) Smooth polish texture on the edge,
b) Flat topography, tight to covered linkage of the polish (photo A. Petrović)

4.3. EXPLOITATION OF ANIMAL RESOURCES

4.3.1. Scraping semi-dry bone, preserved in ash

A bone in the semi-dry state, preserved in ash was scraped for 30 minutes (Fig. 46a). The need for experimentation with the bone which was previously conserved in ash was based on the archaeological samples (Chapter 5). The general bone working without the presence of additives was observed on the pieces from LTFAPA reference collection. Both ventral and dorsal surfaces of the scraper were active and in equal contact with the material. However, macro traces on the dorsal side were more pronounced. The distribution of the scars is overlapping continuous with step termination of traces typical for working with medium-hard and hard material (Fig. 46b). The orientation of traces is between transversal and oblique bidirectional (Fig. 46b) confirming the motion of activity and the angle, which changed during time.

Micro observations noted polish extension visible on the edge of the tool and smooth texture on higher parts and rough on lower levels (Fig. 46c). Bone creates rough and rough to smooth texture usually. The main reason for the smooth texture is the fact that edge removals cancelled the areas with more developed micro polish. This type of bone preservation is explaining why the polish is very light and gives us a bit modified picture of the contact material that was used.

Figure 46: a) Scraping of semi-dry bone, previously preserved in ash
b) Oblique bidirectional traces with overlapping distribution and step and snap terminations,
c) Smooth texture on edge (photo A. Petrović)

4.3.2. Bone cutting

The same bone, used in the previous experiment, held in ash, was cut for 30 minutes (Fig. 47a). The angle of cutting was changed frequently to obtain better efficiency. On stereomicroscope, both surfaces showed use-wear traces, mostly snap and step scars continuous. During the examination of micro traces, the smooth texture was noted on the edge and on the surface distributed continuously along the margin together with flat topography, one of the main factors of bone working (Fig. 47b). In this case, the micro polish was developed on a larger surface covering both edge and surface area than in the case of the scraping of the bone. This is due to the exposure of the specific tool areas to the bone and the activity of the cutting which in this case left traces that penetrated the working edge more than in the case of the massive scraper used in the previous trial where larger surface cam less frequently with the bone and only with the edge area.

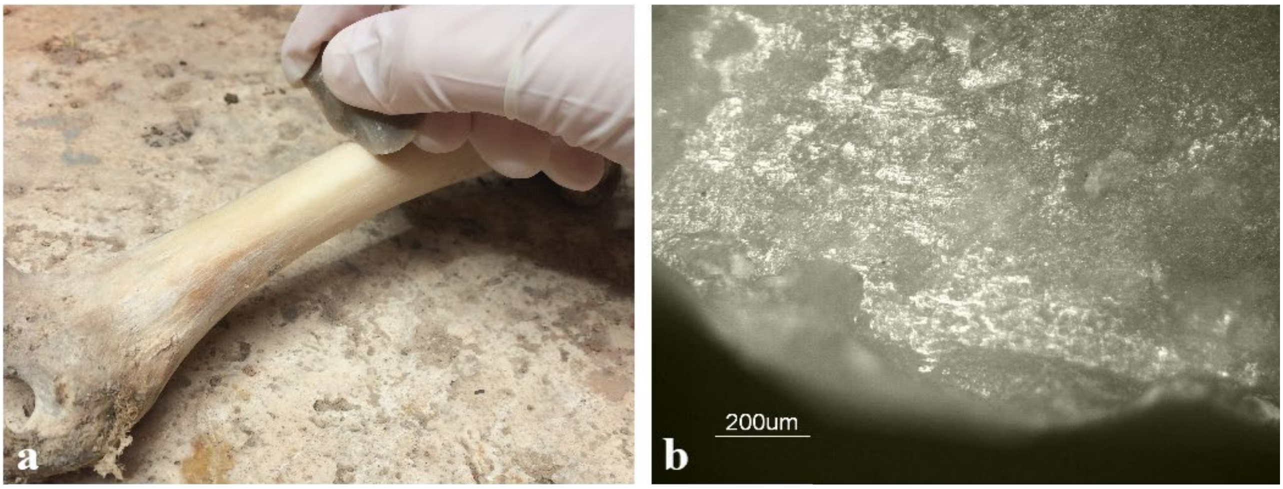


Figure 47: a) Cutting of the semi-dry bone, previously preserved in ash, b) Flat topography with small striae, smooth texture on the edge and surface and higher brightness (photo A. Petrović)

4.3.3. Working softened antler

The experiment lasted a couple of days and before every session, the antler was submerged in the water and it was left overnight. This procedure of preparation was done since the antler was very dry and hard to work without previous softening as mentioned before. However, the soaking of antler as a part of the *chaîne opératoire* is still to be explored in detail and this experimental trial represents one step forward. Various methods as immersing in water, boiling, softening in sorrel or sour milk were tested in previous studies (Osipowicz 2007, Langley, Wisher 2019) and these techniques have proved to be efficient.

During this experimental trial two tools were used, a blade and a flake, and a pebble that was used to apply pressure and percussion in the areas hard to reach and shape (Fig. 48).

Figure 48: Equipment: pebble percuter, antler, experimental flake, and blade (photo A. Petrović)

Two types of activities were performed. The main motion which consumed most of the time and efficiency, detaching the blank from raw material (Fig. 49a) and the second activity shaping the blank. Overall, the white blade was used for around 3 hours for blank extraction and 10 minutes for the shaping. The flake was used a little bit over 2 hours for detaching the blank and 6 minutes for modifying the blank. The antler was very hard to model since this specific piece came from an older species and soaking it down in the water was partially helpful. The most resistant part was the upper antler part, the compact bone.

The results of the use-wear analysis on the experimental replicas were very successful. The motion was very distinctive on all different zones of activity, having in mind that there were areas of the blade specifically used for cutting, other for scraping and the mixed zones. The part that was extensively used (distal end of the blade) for detaching the blank had overlapping lines of traces indicating a change of strength, angle, and speed. Polish was characterized by domed topography and flat in some areas (Fig. 49b).

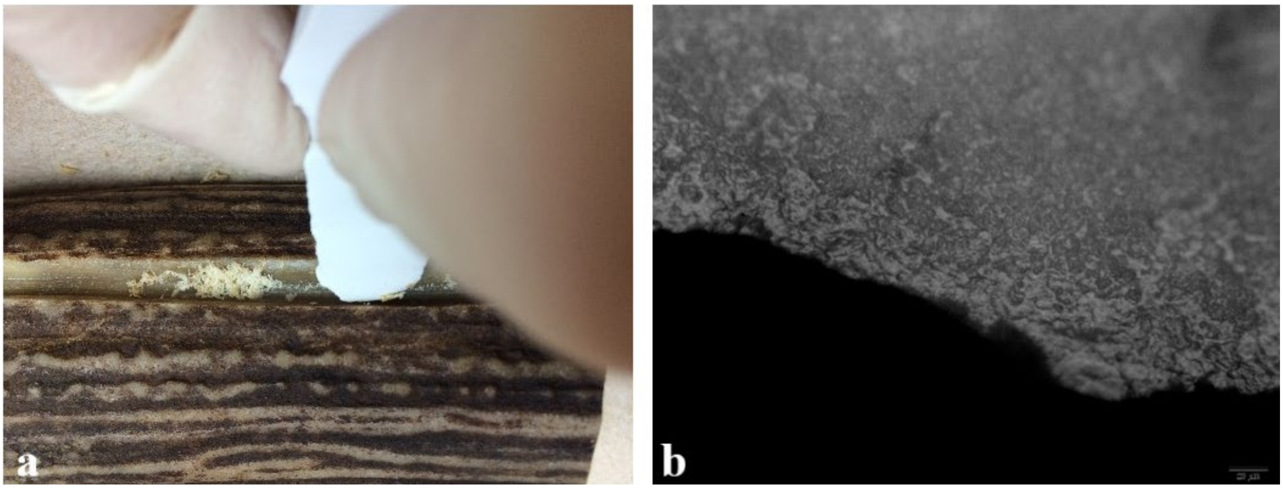


Figure 49: a) Detaching the blank from the raw material,
b) Traces on the blade after 3 hours of use, localization, and distribution (photo A. Petrović)

This experiment contributed to the understanding of the key elements in the micro polish needed for the differentiation between bone and antler. Sometimes the micro-wear resembles the wood polish as well (Van Gijn 1990, 2010). Beside the blade, a flake was used for later phases of detaching the blank and shaping (Fig. 50a). Bone usually has a flat topography and more covered linkage. However, the topography connected to the antler is flat in some cases, but in most examples, it is melted (Fig. 50b) and it is the most suggestive characteristic for the surface used for antler working. However, the presence of both smooth and rough texture is associated with the diverse movements (Van Gijn 1990). The flake, near the end of the extraction process, was in the contact with the cancellous bone which is spongy-structured and creates a softer texture of the polish (Fig. 50c).

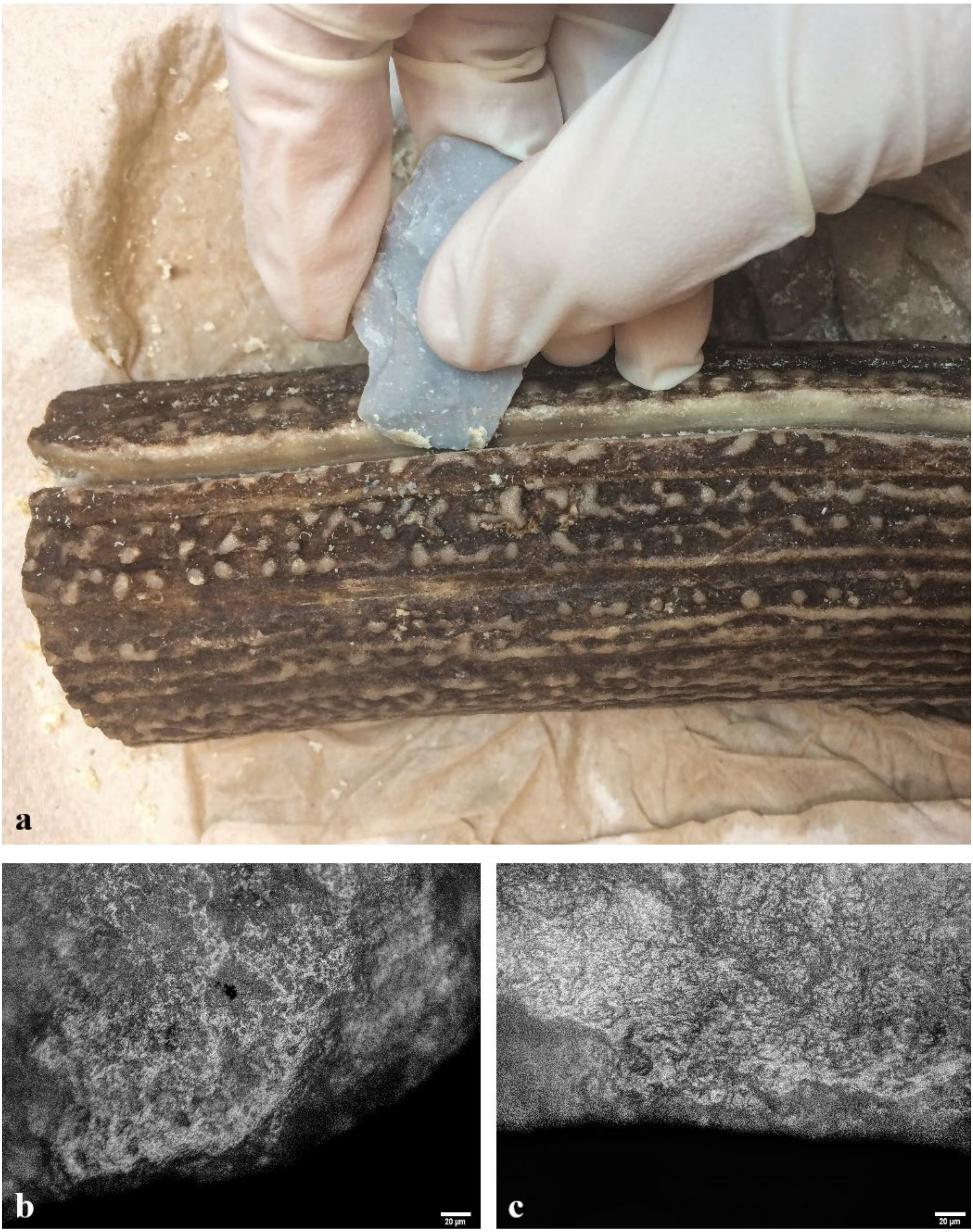


Figure 50: a) Detaching the blank with flint flake, inner part of the antler, b) Melted traces with pits on the experimental flake, after 2 hours of work, c) Melted topography and smooth texture of polish (photo A. Petrović)

4.3.4. Engraving shell (*Glycymeris insubrica*)

The shell used in the experimental trial was *Glycymeris insubrica* (Fig. 51). Engraving and cutting of the shell were challenging and these activities required a lot of strength. The results of etching on the outside and inside area of the shell were minimal, but the traces on the flint tool were very pronounced.

Figure 51: Shell engraving (photo A. Petrović)

The used tool was a burin. As mentioned, two activities were applied: engraving near the top left lateral side and cutting on the medial part of the same left lateral edge. Macro traces on the ventral surface are overlapping, continuous with snap and step terminations (Fig. 52a). Scar orientation is oblique bidirectional (Fig. 52b) suggesting the mixture of movements since the angle of the handling of the tool was changed during the experimentation for better efficiency.

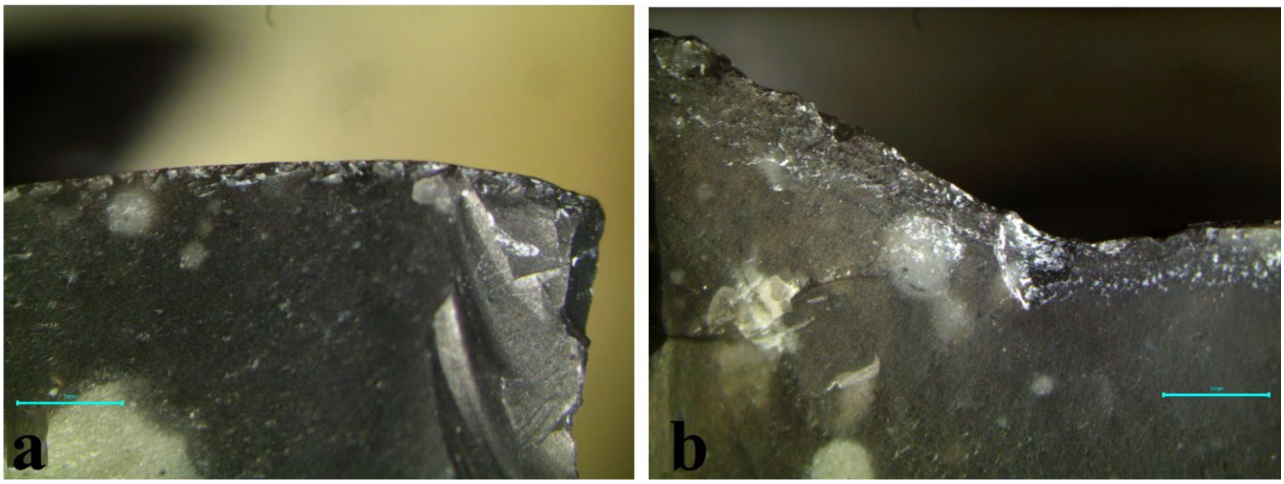


Figure 52: a) Overlapping continuous traces, b) Oblique bidirectional scars (photo A. Petrović)

Analysis with the metallographic microscope revealed that the dorsal side had more pronounced polish with flat topography and tight linkage, in general being abrasive (Fig. 53a) which was localized on edge and the surface. Polish texture was described as smooth (Fig. 53b).

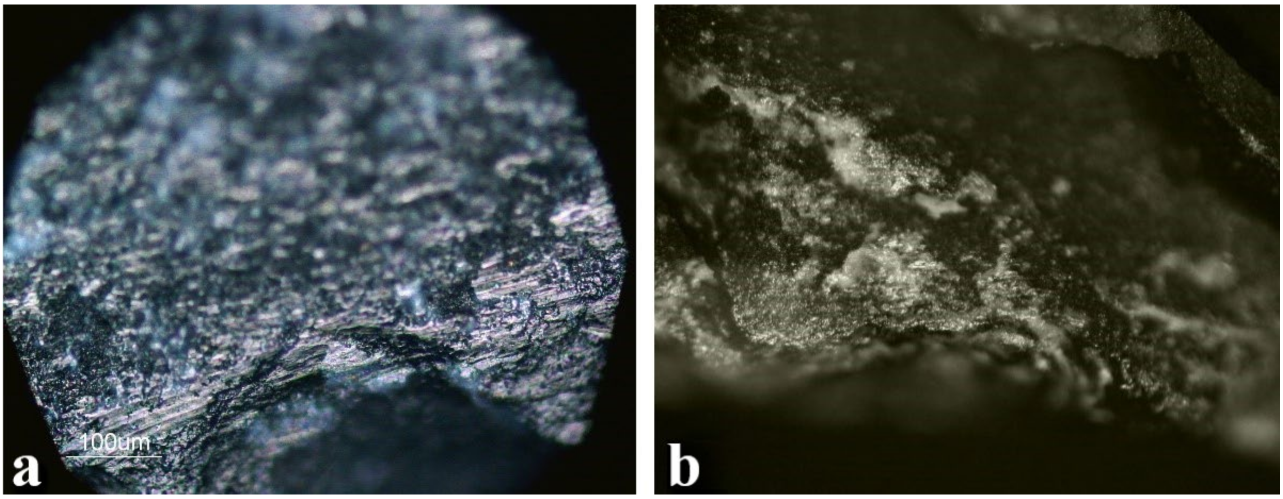


Figure 53: a) Flat topography, dorsal side b) Polish texture, ventral side (photo A. Petrović)

FTIR analysis is showing traces of adipocere, at 1576,1538 cm^{-1}, even the worked activity was used for shell engraving which usually consists of calcium carbonate or chitin. Traces of adipocere correspond to the activity because the inner part of the shell was also processed and engraved, and this area still had residues of the animal organism (Fig. 54). The variety in the portion of adipocere between two points, blue being the point taken from the inner part, is precisely corresponding to the presence of animal residues left inside the shell.

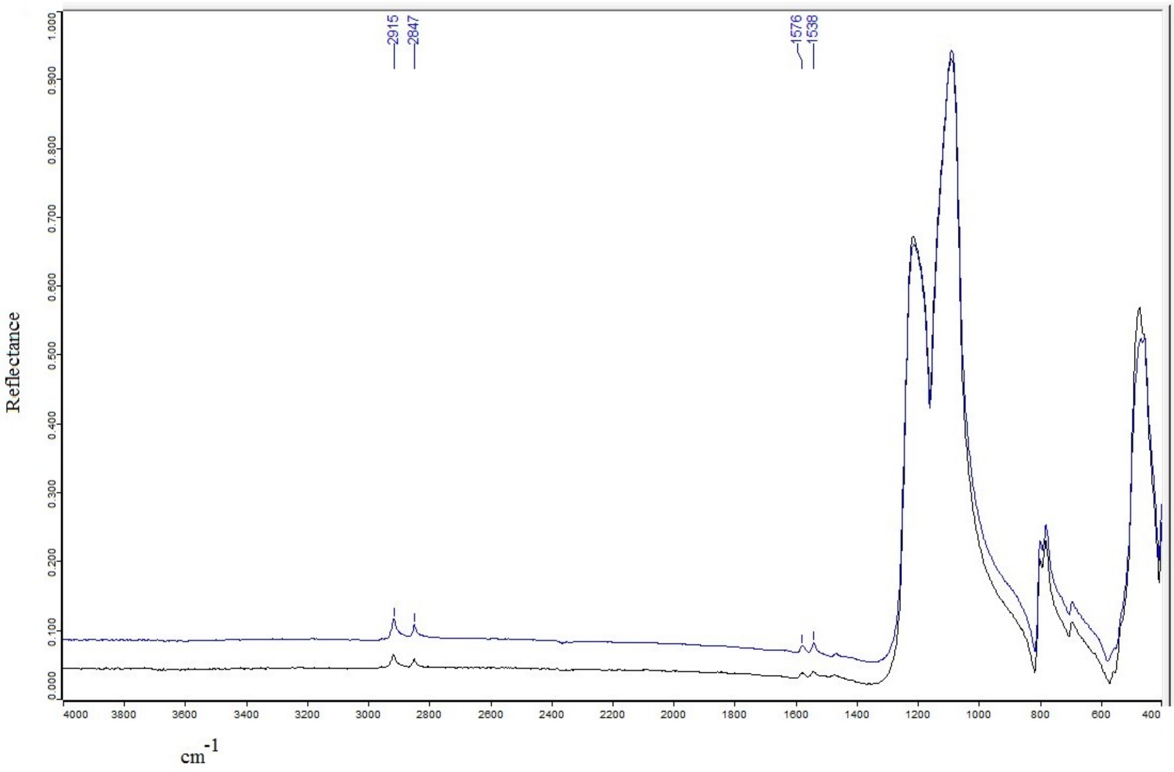


Figure 54: Results of FTIR analysis (spectra S. Nunziante-Cesaro)

4.3.5. Scraping hide with additive

The experiment with dry hide lasted 30 minutes (Fig. 55a). The hide was softened with ochre before, so the traces are more connected to the medium-hard, hard material. The ochre, as an additive softened the inside area, producing a very rough surface through time, hence traces more comparable to rough and hard materials.

The ventral side yielded more pronounced traces in the forms of small snap terminations with transversal orientation implying the activity of scraping (Fig. 55b). Regarding the micro traces, the polish was distributed continuously on the edge and characterized by rough to smooth texture (Fig. 55c).

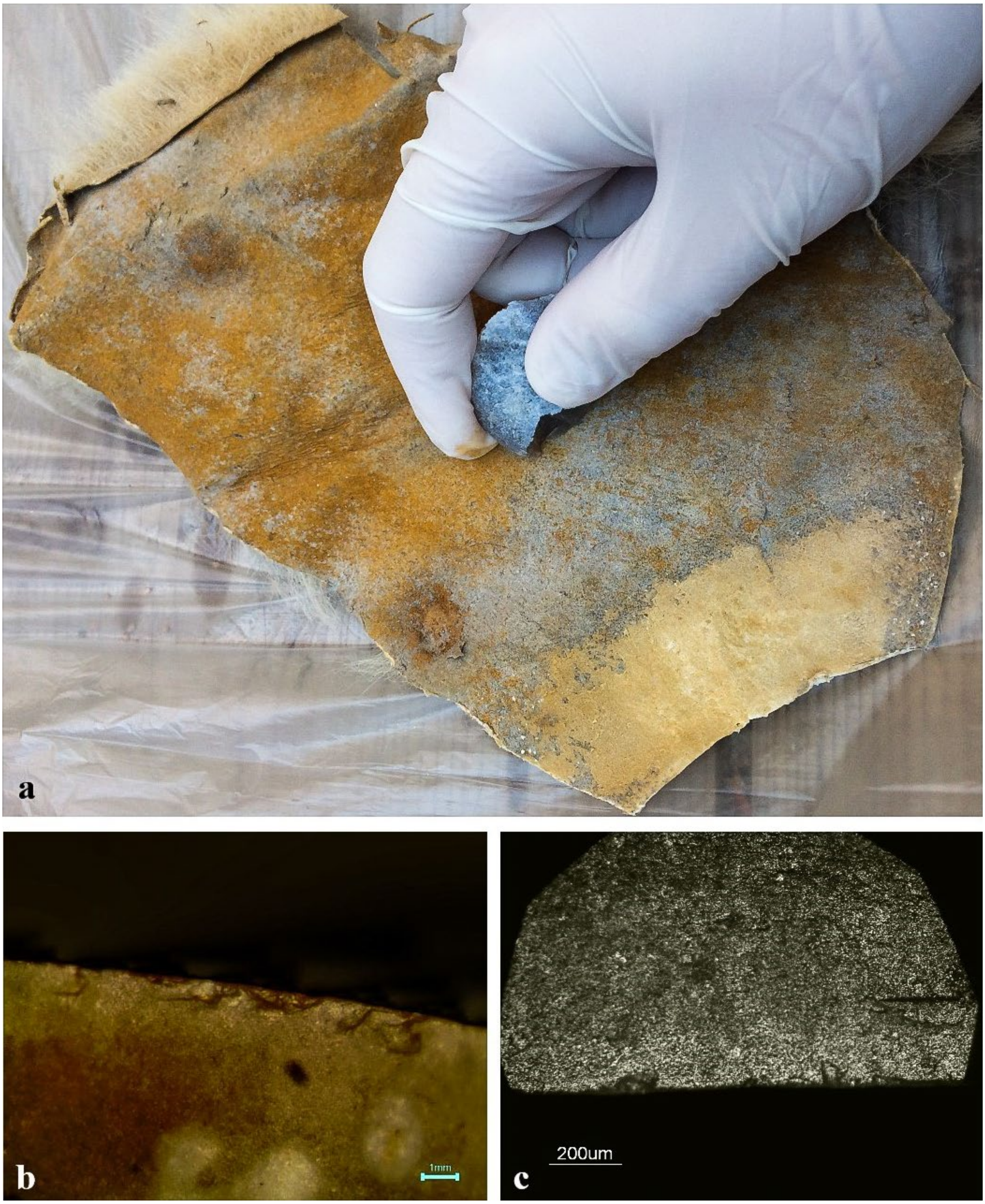


Figure 55: a) Scraping the hide with ochre, b) Snap terminations, transversal direction, c) Rough to smooth texture (photo A. Petrović)

4.3.6. Butchering sheep (*Ovis aries*)

The experiment trial of butchering lasted two hours, and three knapped tools were used, a large blade and two flakes (Fig. 56a-b). Tools lost their primary efficiency at the very end. The large blade was used for most of the butchering activities, as removing bigger pieces of meat from the bone (10% contact with the bone) and slicing. Flakes were used for detail work, as cleaning the bones and scraping the meat off (70% contact with the bone).

Figure 56: Butchering experiment a) Part I, b) Part II (photo A. Petrović)

Results of experimentally obtained traces were successfully associated with butchering traces found on the archaeological samples. In figures 57, 58, 59 we can see macro traces on experimental tools – small snap, and step scars with developed edge rounding. The majority of worked areas have an overlapping distribution which is in correlation to the working time, but also with the facts that tools were used in the contact with the bone. Hard animal materials can create this specific distribution of scars.

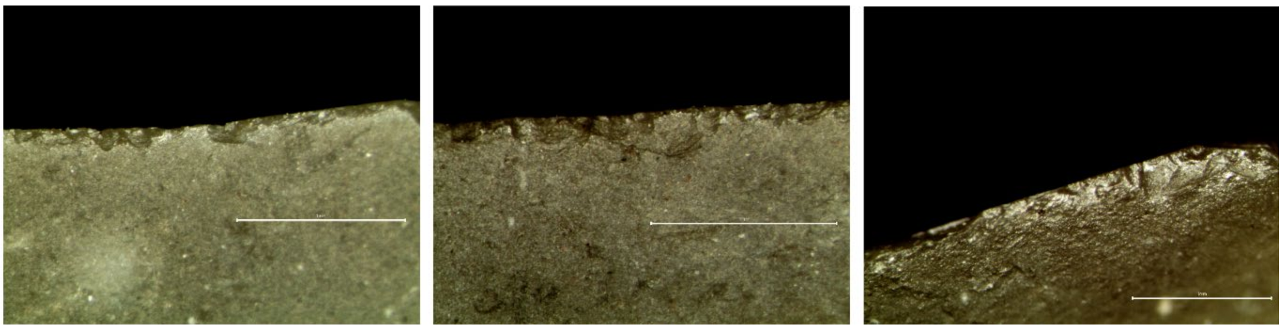


Figure 57: Macro traces on the experimental knife, after 2 hours of total use (photo A. Petrović)

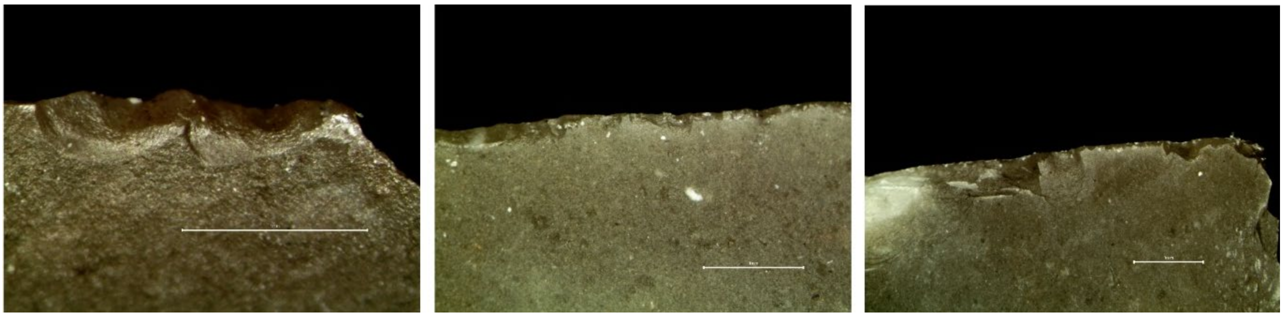


Figure 58: Macro traces on the experimental flake, frequent contact with the bone (photo A. Petrović)

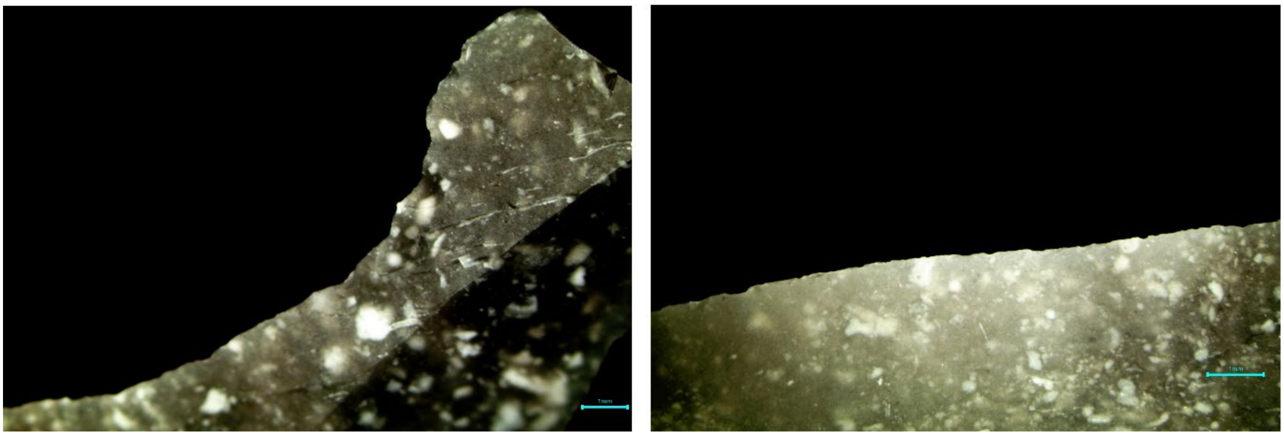


Figure 59: Edge rounding on a used flake (photo A. Petrović)

Traces on the experimental knife have all the indications for the butchering with constant contact with the meat, and a lot of fat residues still present after washing. The other two tools have characteristics of frequent bone contact mixed with meat noted as flat topography with tight linkage (Fig. 60a-b).

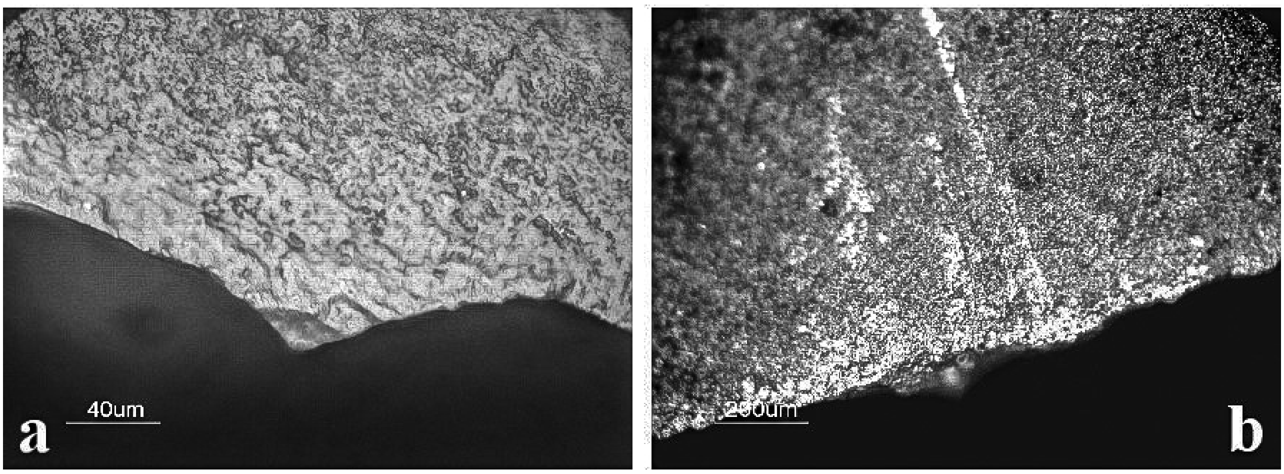


Figure 60: a) Micro traces, flat topography, smooth and tight linkage indicating frequent contact with the bone, b) Area of bone scraping (photo A. Petrović)

4.3.7. Butchering roe deer (*Capreolus capreolus*)

This butchering experiment of two roe deer took place in National Park of Abruzzo, Lazio and Molise (Parco Nazionale d'Abruzzo, Lazio e Molise). During the butchering of both animals, two tools in total were used. This was a group experiment, and three more researchers were involved – everyone performing the experiments with their tools (obsidian flakes and blades, small tools replicated for the purposes to mimic tool forms from Qesem cave, Israel), (Fig. 61a). Two blades were used in this experiment (Fig. 61b). The bigger one was used most of the time, for 1,30 hours in total, and it was used for removing the hide (Fig. 61a, c), slicing the meat, cutting the tendons. The smaller blade was used for details in total for 44 minutes. It was in the contact with the bone (50%), and it was used for cutting the tendons.

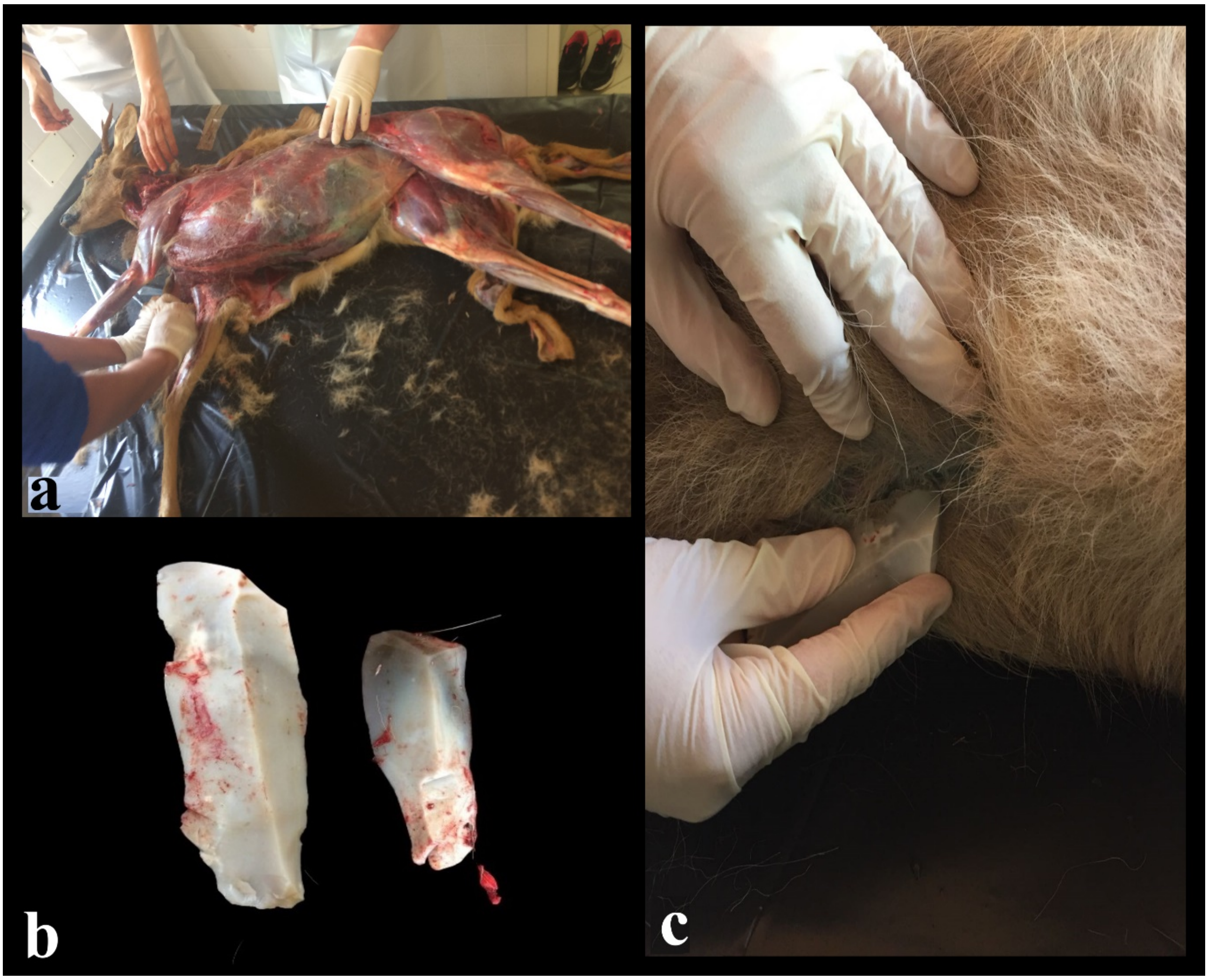


Figure 61: a) Butchering a roe deer, removing the hide, b) Experimental tools, c) The first contact with hide (photo A. Petrović, F. Venditti)

This experimental trial, besides the use-wear traces, provided an important insight into the whole process of butchering an animal: from the hide removal, disarticulation of the bones, slicing of the meat, cutting of the tendons, to bone cleaning.

The traces of use on the knife were left both on the dorsal and ventral surface (Fig. 62a). The scars are in the shape of halfmoon and step and they are more and less continuous both irregular and regular (divided into two sections). The direction is oblique bidirectional indicating the motion of cutting. Edge rounding is pronounced. Polish is continuous, linear on the edge with a tight linkage. The edge was in contact with hide, meat, ligaments and to a lesser extent with the bone. On the other edge, visible traces of prehension are noted (Fig. 62b). Scars are concentrated on the edge on the dorsal side. The texture of the polish is rough with a half-tight linkage.

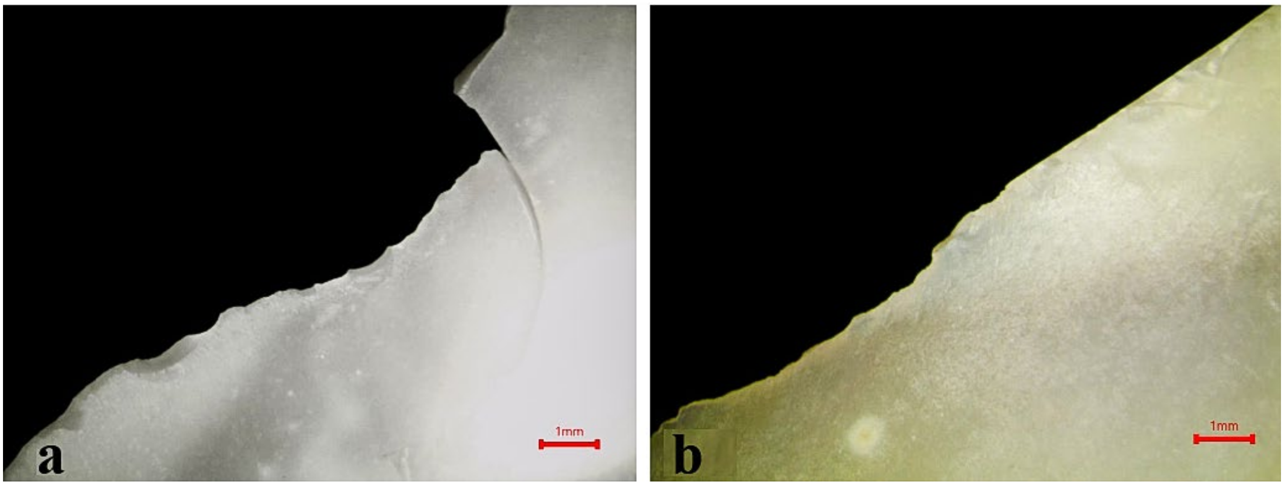


Figure 62: a) Edge rounding on the active edge, b) Prehension area, scars from handling the tool (photo A. Petrović)

The scars on the flake were less diagnostic mostly snap and step, irregular and localized in specific areas in oblique bidirectional position.

FTIR analysis done on the larger blade, used for a longer time and in a mixed activity. It showed the presence of adipocere bands at 1575,1538 cm^{-1}, which is connected to the work with meat and animal material in general (Fig. 63).

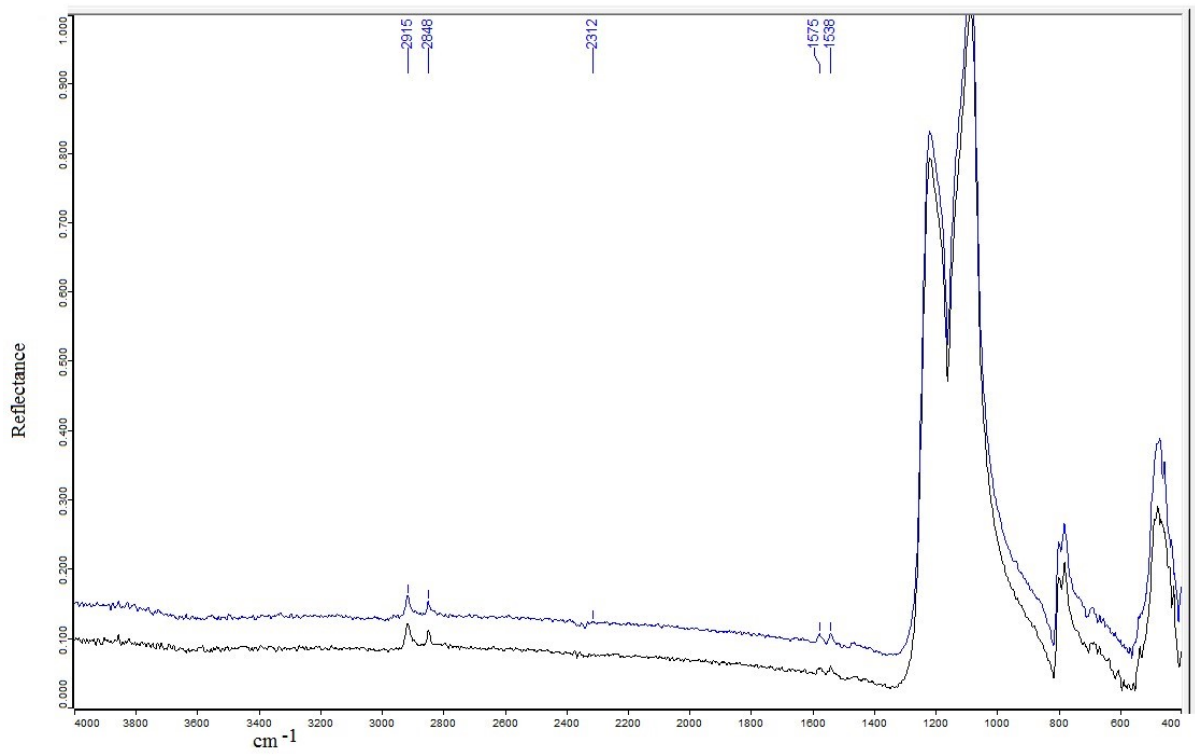


Figure 63: Traces of adipocere found on the blade used for mixed activities (spectra S. Nunziante-Cesaro)

4.3.8. Hide processing (tanning)

Hide tanning is one of the complex experimental trials and it is undertaken to transform animal skin into the hide practical for the making of clothes and other leather goods. The main aim of tanning is to permanently alter the protein structure of the skin, making it more durable and less susceptible to decomposition (Deferrari 2001, Brown and Taylor 2003). The hide consists of the superficial part (epidermis), with hair, scales, nails, plumage, and the internal part (dermis) created by many bundles of elastic fibres. The part underneath, adhering to the muscles is called meat. During the hide processing, all parts are worked, depending on the desired product. The internal part of the hide (corium/dermis) needs to be submitted to the chemical and mechanical alterations. This process is called tanning and it can be done with oil, minerals, or vegetables. It transforms collagen of skin from porous and softer to less spongy maintaining the fibrous structure of the skin. The process can vary depending on the wanted final product, but there are a couple of steps that should be followed as skin cleaning. The first one is cutting and scraping of the meat that remained after the butchering on the inside part (subcutis). This membrane needs to be removed so that tanning agents can reach the dermis (Stambolov 1969). Subsequently, the skin is submerged into the water. The next step is the application of the additives and they should be left to be absorbed, if possible, for a day or a couple of days, then larger scrapers or flakes depending on the skin dimensions are used to scrape the surface. Finally, the product is put into the water again, and the skin is drained and strained.

In total five chipped stone tools were used in the trial. The hide used in the experiment was kept in the freezer for a couple of months. In the autumn, it was taken out and it was put into the water with a bit of ash to clean it. Afterwards, the ash was applied on the inside part so it can soften the surface, and it was strained on the wooden structure attached with fine twine.

The first step of hide working was cutting and scraping the meat remains (Fig. 64a). The whole hide was processed by two people, and hence, two tools were used a larger quartzite scraper and a smaller regular flake made of flint. The same flint flake was used with one part for drilling the string holes. In total, the flake was used for 2 hours and 50 minutes for scraping the interior part of the hide, and 15 minutes for piercing the punctures.

The used edge of the flint flake displayed continuous scars with snap terminations. The direction of these traces was oblique bidirectional which coincided with the fact that meat was taken off by the motion of cutting the small pieces. Micro traces are a bit discontinued and have domed and granular topography with half-tight linkage and rough (to smooth) texture (Fig. 64b). The polish is bright.

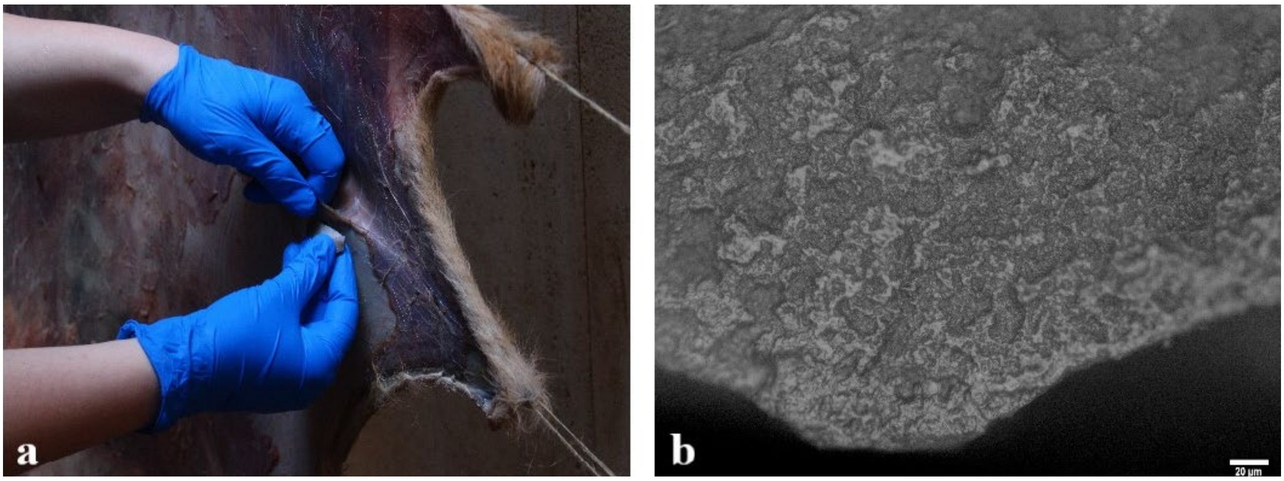


Figure 64: a) Cleaning of the hide from meat remains on the inside, b) Domed topography and half-tight linkage, polish from scraping meat from the interior part of the hide (photo A. Petrović)

After the meat was removed ash was applied for better preservation of skin during the night. The next day the hide was submerged in the water. Subsequently, the pig brain, used as an additive for tanning was mixed in the ceramic vessel with the pebble and applied to the interior part of the skin (Fig. 65). The hide was left for some time so that the mixture of pig brain could be absorbed.

Figure 65: Tanning with pig brain (photo A. Petrović)

After the compound is soaked different tools were used for scraping the surface. Four tools were tested and two of them were hafted. One of the hafted tools broke immediately after 4 minutes of use. The other three tools were used for a total of 3 hours, among them the second hafted tool that was used for most of the work and time (Fig. 66a). This tool also broke but at the end of the process. The activity aimed to remove all the epidermis from the interior part of the hide. During the final phase, the skin was drained and strained so it can reach the maximum of its flexibility.

Scraping of the tanned skin developed the micro polish that is described as rough on the lower parts (Fig. 66b). On the higher areas, the texture is smooth, and the topography is more domed. The polish distribution is on the edge and in some areas on the surface of the tool (Fig. 66c).

Figure 66: a) Scraping of the inside part of the hide with the hafted tool,
b) Micro traces, granular topography, rough texture, c) Polish penetration (photo A. Petrović)

Hafting was proven as the best tool handling mode for skin scraping, even though the haft of the tool was in some cases broken or the tool came out during the activity. The resin left residues that were hard to clean (Fig. 67a), and it was only possible to wash them with oil. Hafting traces are very pronounced (domed and flat topography with tight linkage) with striations. The polish from hafting is visible by linear distribution on the outer edge (Fig. 67b), but also evident in the shape of patches on the internal area.

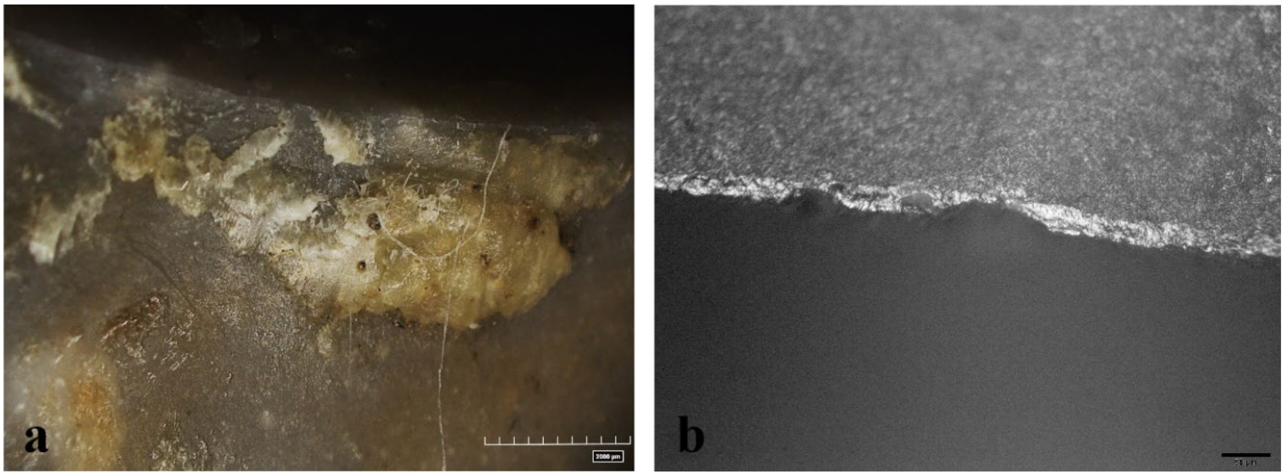


Figure 67: a) Residues of resin with particles of hair near the hafting area,
b) Linear distribution of hafting polish (photo A. Petrović)

4.3.9. Depilation

The tanned hide was used in the depilation experiment, and it was preserved in the ash for a month. Before the processing, it was washed and softened with a mixture of water and charcoal. The experiment aimed to examine the traces created by the friction of hairs. Additionally, to distinguish within the possibility of creation of the striae inside the polish as a consequence of hairs (material) or motion (activity). The idea came from the archaeological sample where small striae were seen on the tools that worked hide, with no connection to the movement.

The experimental hafted scraper worked for 1 hour and 20 minutes in total for scraping (Fig. 68). The tool was used in the contact on the ventral surface for 90% of the time, and about 10% of the time on the dorsal side.

Figure 68: Hair removal from the outside part of the hide (photo A. Petrović)

After the use, the tool was still efficient. The residues remained on the working edge. Macro trace terminations were snap, step, and feather-shaped forming a couple of rows. The orientation was transversal, with some areas of mixed activity where the scars had a bidirectional direction. After the cleaning, some of the parts of the tool had resin residues that covered the hafting traces (Fig. 69a). The micro polish has a granular topography very close to the topography seen on the experimental tools that worked dry hide. Linkage is generally tight to compact on the outer edge (Fig. 69b), where the polish is mostly developed which is connected to the fact that it was used on the ground. Small striation was noticed inside the developed part of the polish on the edge. These striae are the result of the contact between hair and the tool since they do not always follow the direction of the motion.

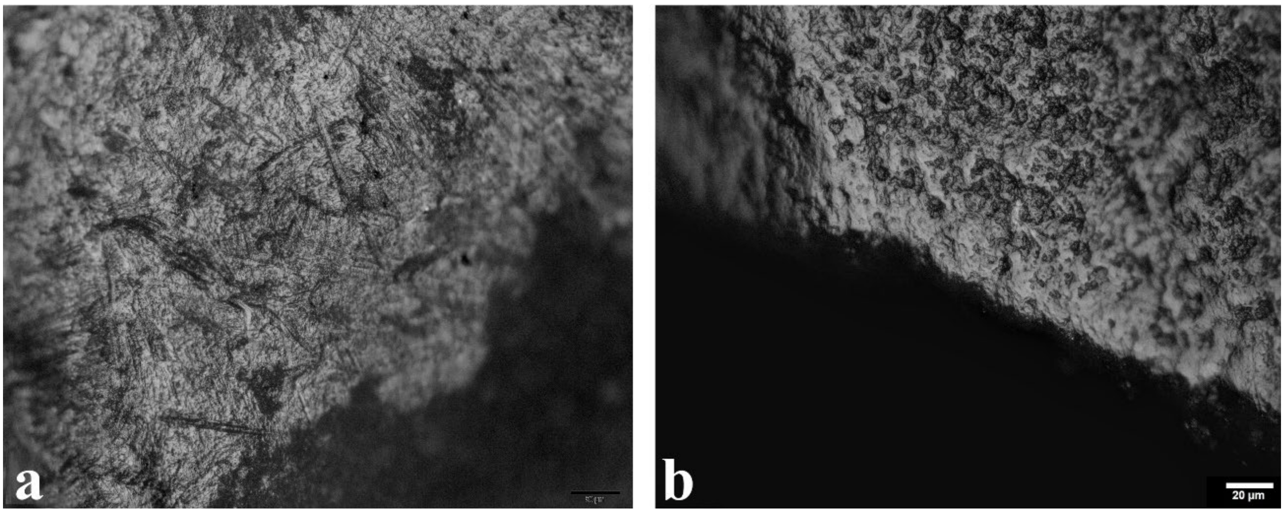


Figure 69: a) Area with traces that remained covered by residues

b) Traces on the working edge, tight to compact linkage (photo A. Petrović)

4.3.10. Liver (*Bos Taurus*)

The set of experiments on the animal organs was conducted for the purposes of the observation of the micro traces and to detect the way residues bond. The internal organs, as the liver and spleen, are rich in proteins and fat, and in communities of the Iron Gates region where the consumption is based on meat (see Chapters 5.1.16, 5.2.4, and 5.3.5.) the targeted and detailed experimentations focused on the mentioned agencies are needed.

The first trial was done with the cow (*Bos Taurus*) liver with a larger flint blade. The tool was in the contact with both the dorsal and ventral side (Fig. 70). The total time of work was 31 minutes. Both macro and micro-observations, and FTIR analysis were done.

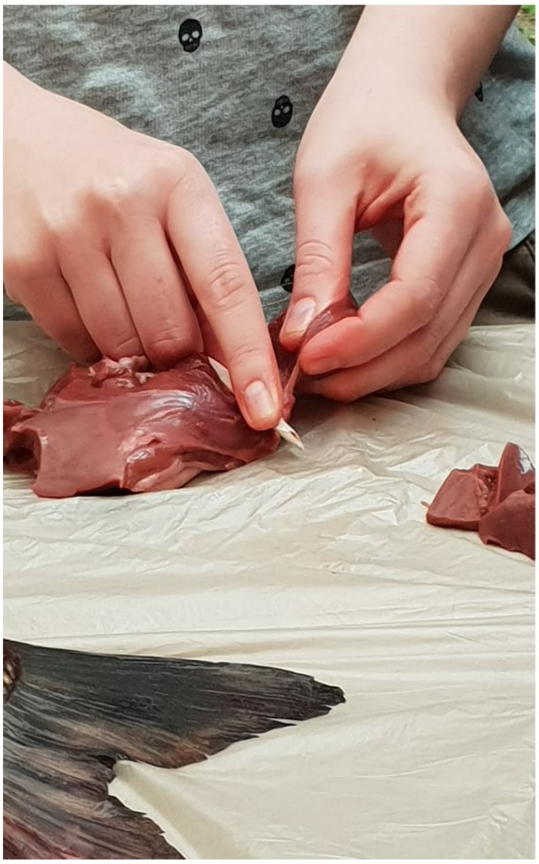


Figure 70: Liver working with a blade, contact with both dorsal and ventral side (photo A. Petrović)

The macro scars are present both on the prehension area and working edge represented by smaller snap and step scars (Fig. 71). The direction is mostly oblique. The edge rounding is connected to use on the medium materials.

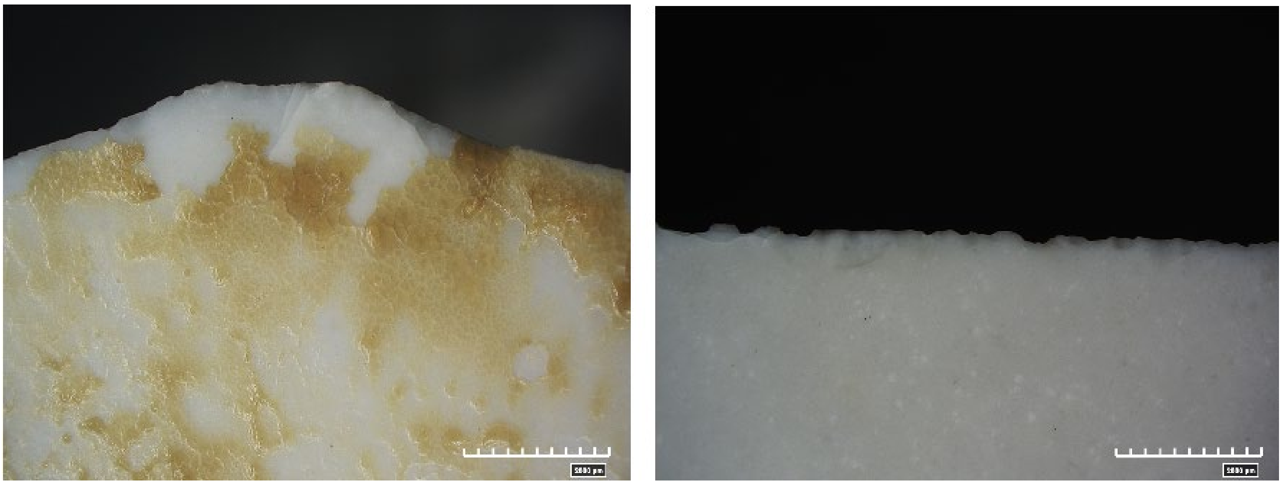


Figure 71: Edge rounding on prehension and use area (photo A. Petrović)

Micro polish is very pronounced with tight linkage on the outer edge, and in some areas on the surface. The topography is mostly granular and flat (Fig. 72).

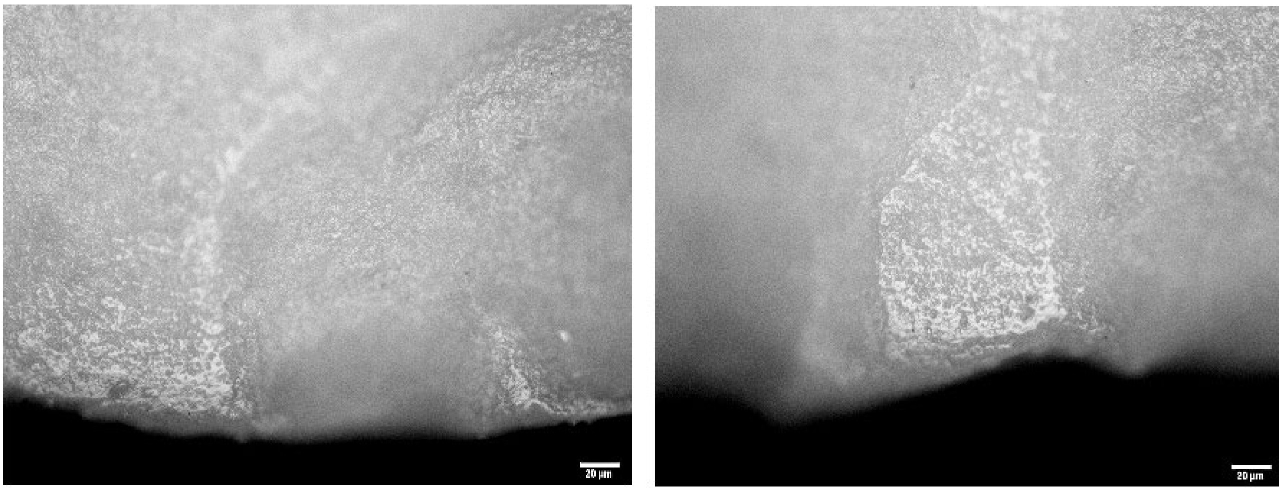
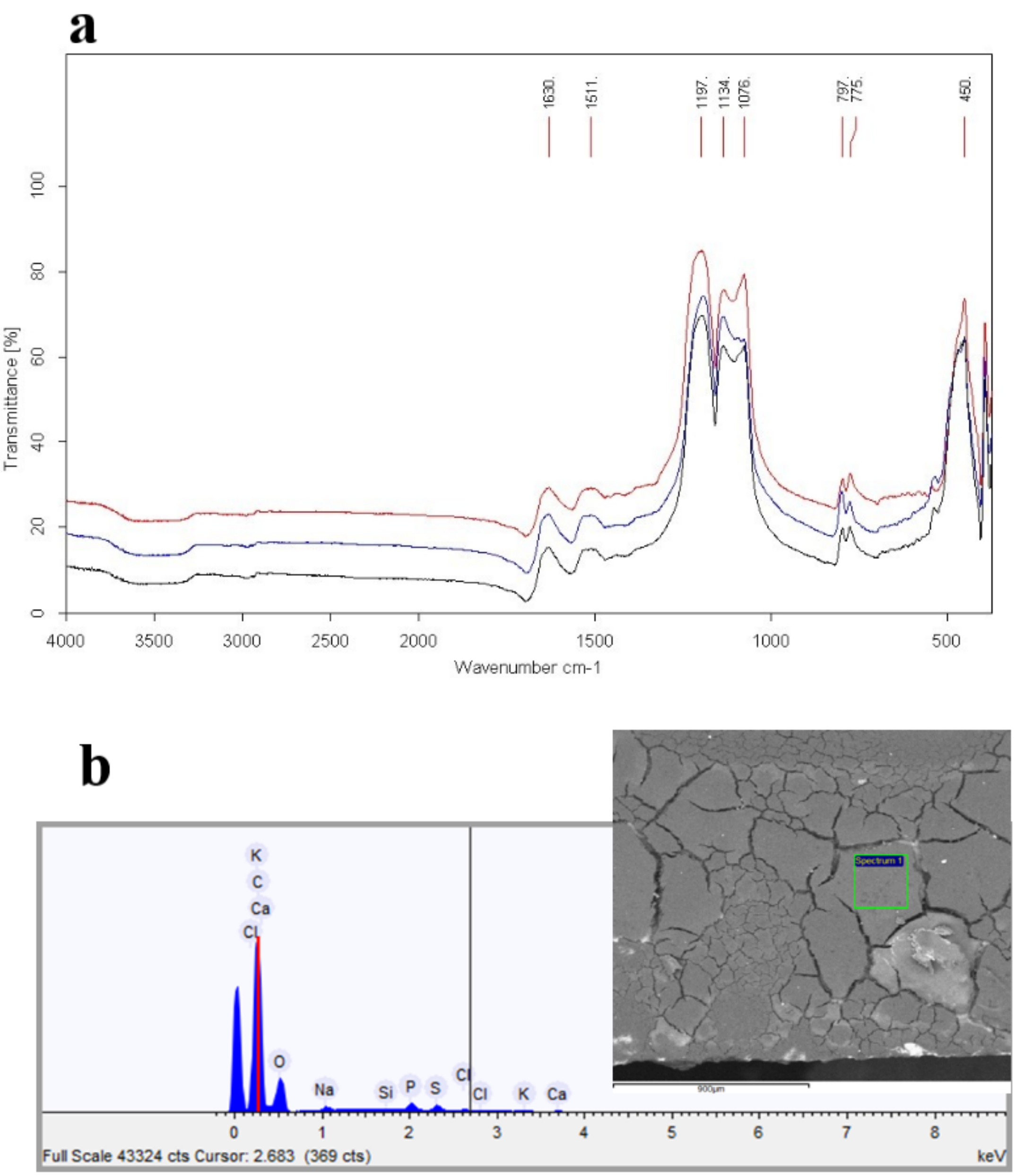


Figure 72: Polish from liver working for around 30 minutes (photo A. Petrović)

The first FTIR analysis was done a couple of days after the experimental trial and the analysis revealed the presence of collagen (at ~1630 cm^{-1}) on all the three points of residues that were tested (Fig. 73a). SEM-EDX showed a larger amount of Sulfur and Phosphorus, indicative of animal-based matters (Fig. 73b).

However, the secondary FTIR testing after a 1,4 year showed the same results as the first observations and no traces of adipocere were formed (Fig. 74).



Element	Weight %	Weight % σ	Atomic %
Carbon	42.284	1.746	51.126
Oxygen	49.498	1.509	44.930
Sodium	1.603	0.088	1.012
Silicon	0.250	0.044	0.129
Phosphorus	2.558	0.101	1.199
Sulfur	2.029	0.085	0.919
Chlorine	0.700	0.054	0.287
Potassium	0.771	0.055	0.286
Calcium	0.308	0.048	0.112

Figure 73: a) Results of first FTIR analysis, b) SEM-EDX results

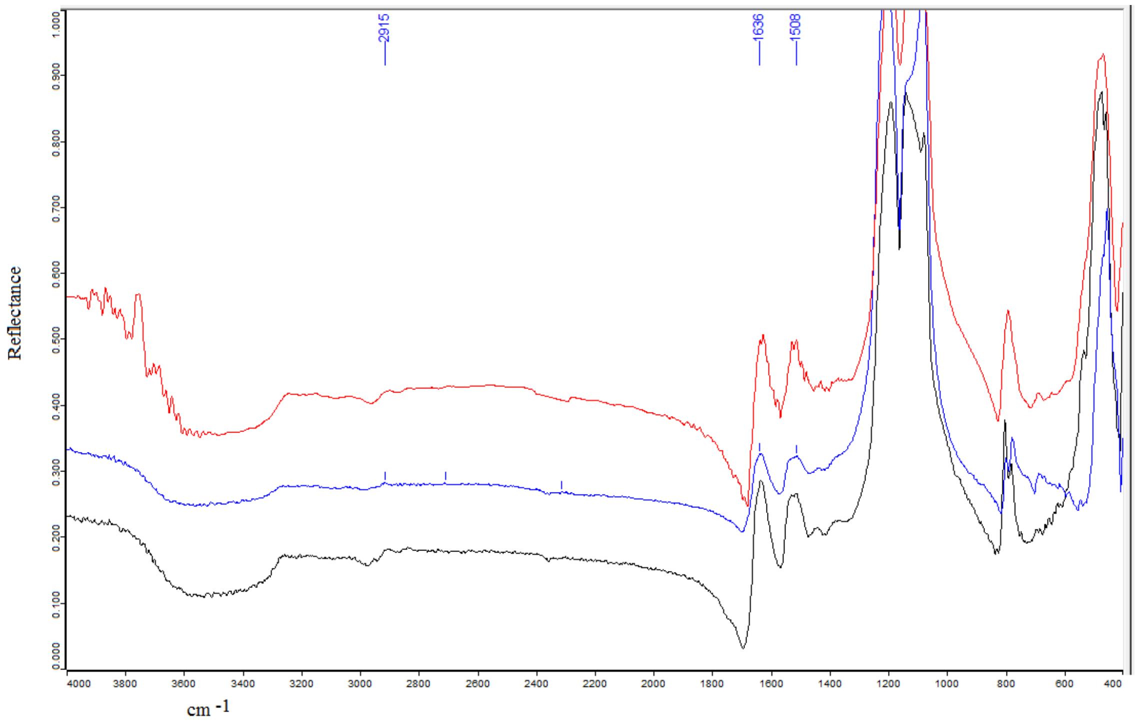


Figure 74: FTIR results after second testing (spectra S. Nunziante Cesaro)

4.3.11. Spleen (*Bos Taurus*)

Flint flake was used for cutting the cow spleen (Fig 75). The total worked time is 21 minutes, and the tool was in contact both with the dorsal and ventral side. Compared to the processing of the liver this activity was more difficult because the spleen had a thick membrane of fat.

Figure 75: Spleen working (photo A. Vinet)

The edge rounding is present on the flake used in the experimentation. However, the traces are not diagnostical and they are represented by some scarce, localized snap shaped scars both on the prehension and use area (Fig. 76). Residues covered most of the micro-wear area, even after the cleaning, and it was not possible to document larger areas of micro traces.

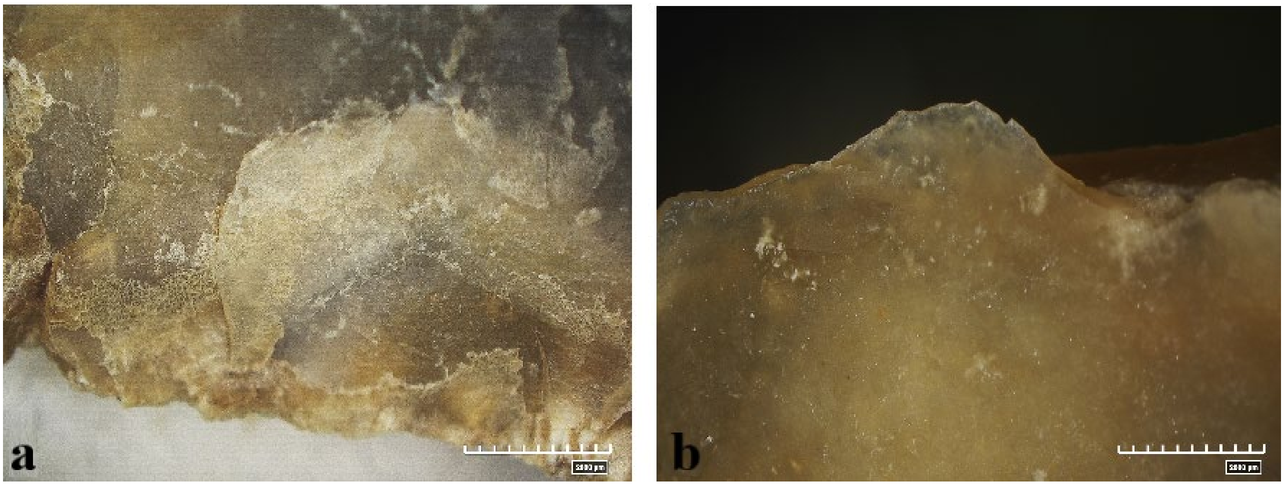
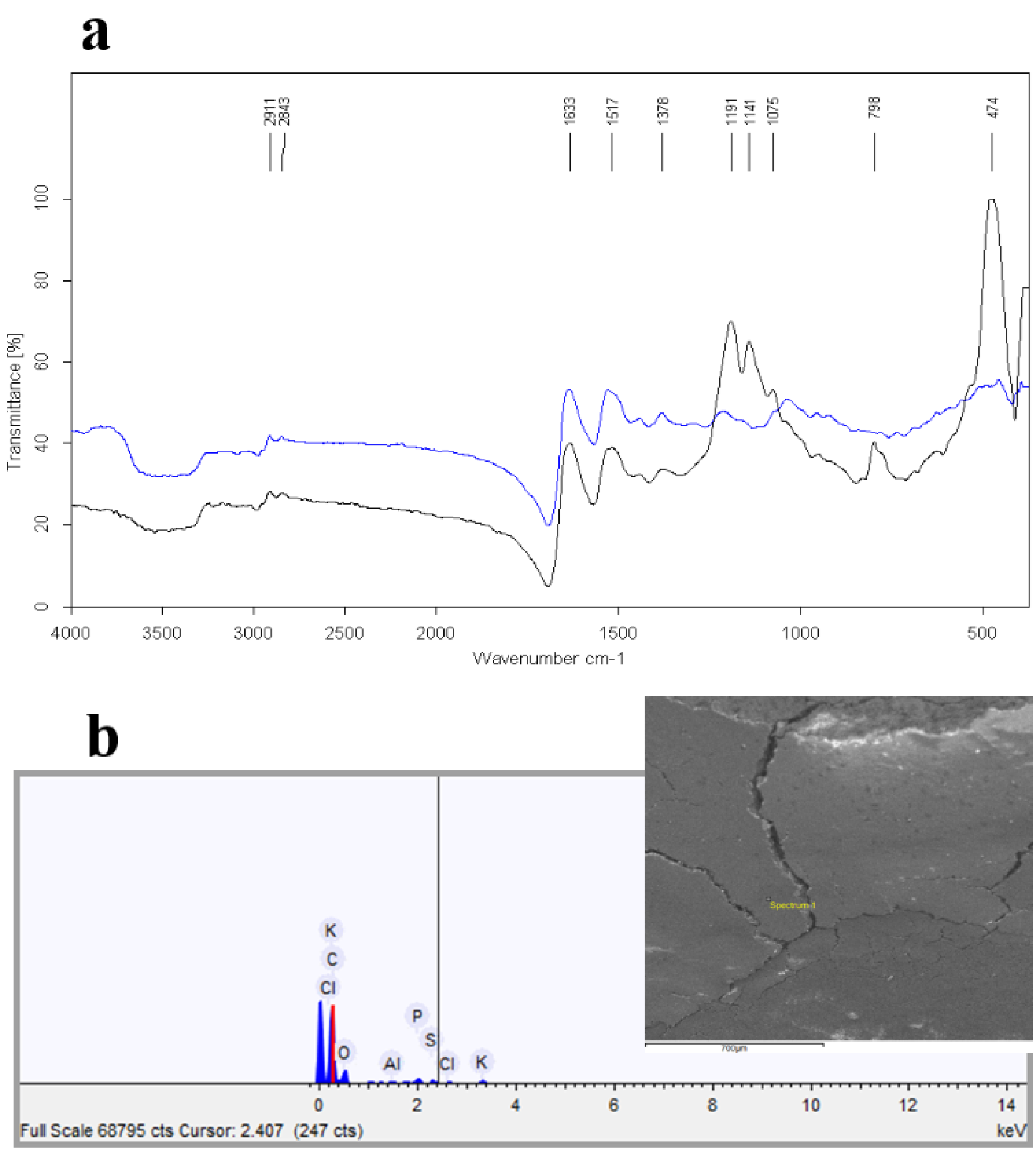


Figure 76: a) Prehension area with residues, b) Used edge (photo A. Petrović)

The first FTIR analysis showed the presence of collagen, observed at ~1630 cm^{-1} (Fig. 77a). Regarding the SEM-EDX results three elements, connected to the animal-based materials were found: Potassium, Sulfur and Phosphorus (Fig. 77b). What should be highlighted is that the second FTIR analysis did not bear any different results compared to the primary ones, hence no adipocere was formed even after 1,4 years between two tests (Fig. 78).



Element	Weight %	Weight % σ	Atomic %
Carbon	43.801	1.493	53.567
Oxygen	45.319	1.231	41.608
Aluminum	1.008	0.060	0.549
Phosphorus	3.613	0.127	1.713
Sulfur	2.048	0.087	0.938
Chlorine	1.105	0.068	0.458
Potassium	3.105	0.112	1.166

Figure 77: a) Results of FTIR analysis, b) SEM-EDX results

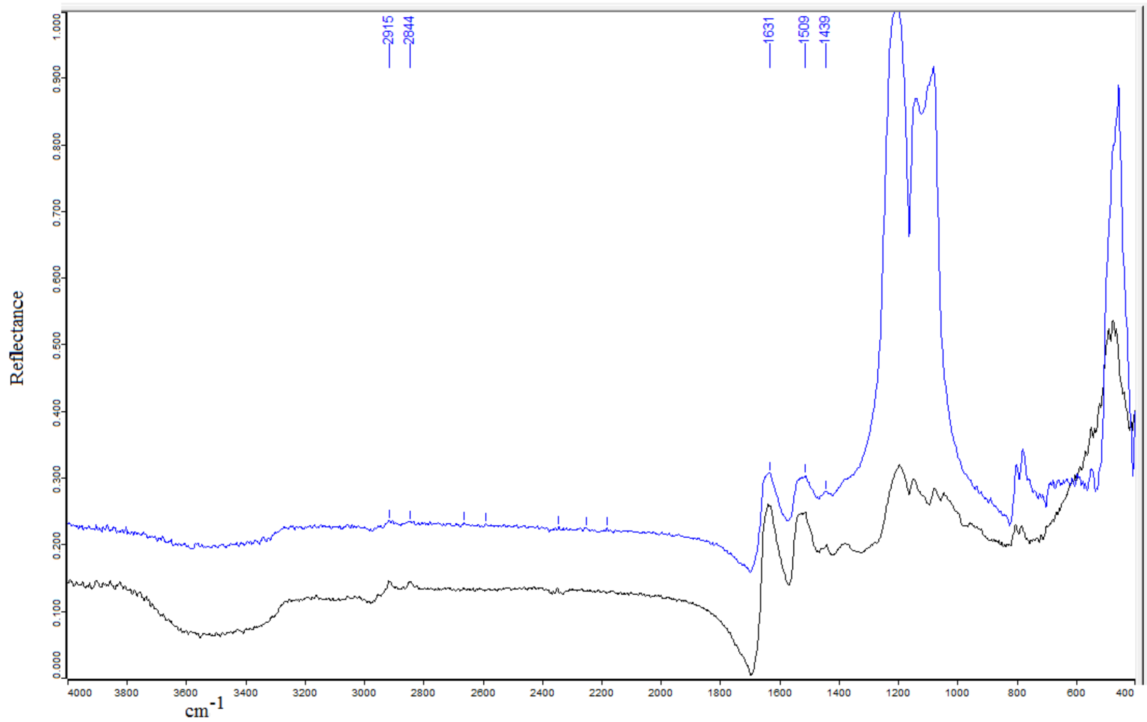


Figure 78: FTIR results after second testing (spectra S. Nunziante Cesaro)

4.3.12. Fish (*Cyprinus carpio*)

Common carp (*Cyprinus carpio*) was used in the fish experiment (Fig. 79) to observe traces occurring after scaling, decapitating, gutting, and filleting. The main reason for this kind of experimental trial is the archaeological data obtained from the preliminary results of the scrapers and flakes from Lepenski Vir site that showed the presence of traces connected to the fish processing (see Chapter 5).

As many fish remains were found at Iron Gates sites (Živaljević 2017) the need to test the possibility of cleaning and preparing the fish with chipped stone tools was obvious. The archeozoological data indicates that during the Transitional period subsistence strategies were based on the consumption of both terrestrial and aquatic resources (Borić and Dimitrijević 2006; Dimitrijević 2000, 2008; Greenfield 2008; Dimitrijević et al. 2016; Živaljević 2017) and the prevalence of use of chipped stone tools for animal materials is very high so we wondered if the fish working could be singled out or any part of the process and visible as specific polish or trace. Additionally, the fishbones from Iron Gates show traces of decapitation connected to the chipped stone tools (Živaljević 2017).

The previous experimental trials done by the colleagues (Moss 1983, Van Gijn 1984/85/86, García Díaz, Clemente-Conte 2011, Clemente-Conte et al. 2020) showed that some specific elements of trace characteristic on chipped stone tools could be noted and that they could help in identifying the fish processing activities in Mesolithic and Neolithic. Also, studies focused on the integration of use-wear analysis and protein residue analysis showed interesting results (Högberg et al. 2009) together with FTIR analysis (Monnier et al. 2018). All these studies gave various and encouraging results, but they still leave their application to the archaeological sample to be proven in the future. This was the main reason also to propose an integrated approach in our study and to examine both use-wear and residue traces.

Figure 79: Common carp (*Cyprinus carpio*), (photo A. Petrović)

Before the description of the experiment and the results of a use-wear analysis it is important to note that specific *fish polish*, as it has been called by colleagues (Clemente et al. 2007) is a consequence of different activities (as head cutting, scaling, gutting, filleting) that produce diverse wear patterns that could be noted after fish working, hence characteristics for all three types of materials could be observed (soft, medium, and hard). The fish processing can be done by various cleaning tasks, but some scholars also propose a hypothesis of use of one tool for all the activities if one needed to work fast, as in the cases where a large number of anadromous fish was caught in a short period (Van Gijn 1984/85/86). We decided to single out scaling and other activities (head cutting, gutting, and filleting) because this way some specific characteristic of fish polish (associated only to the scale contact) could be observed and maybe some of these polish attributes could be noticed in the archaeological sample as well. In this manner, the fish processing could become more traceable in the archaeological context.

Two flint flakes of different size were used, one for scale removal and the other one for head cutting, organ removal and filleting. The first step was scale removal which was done by slightly scraping the scales from their root to the opposite side (Fig. 80a). The hide was cleaned, and all the scales were removed after 30 minutes.

The second step was head cutting (Fig. 80b), followed by opening the fish (Fig. 80c) and removing the organs (gutting), (Fig. 80d). Then the hide was carefully removed by motions of scraping between the hide and fish meat. Finally, the organs were removed, and the meat was cleaned from the bones and filleted (Fig. 47d).

Figure 80: a) Removal of scales, b) Decapitation, c) Opening fish, d) Removal of hide, organs, filleting (photo A. Petrović)

Scaling of the fish was done by an unretouched flake with a convex edge that was used only for this activity. In numerous experimental trials done by colleagues and based on ethnoarchaeological sources, fish scaling was always done opposite to the root of the scale. In our case, that was helpful on the upper part of the fish, near the head, but on the medium part and near the tail it was more convenient to do it by firstly putting pressure on the root of the scale and then sliding it to the tail direction. As mentioned before, it took us 30 minutes to clean the hide and fish from all the scales and during this process tool was in the contact with the working surface on the ventral side. The tool was efficient and still usable even after the activity.

The scaling produced an edge rounding, and snap and halfmoon scars (Fig. 81a-b). The polish that was observed is very rough, dull, with flat topography, sometimes domed in the areas where it was not well developed and greasy on the most pronounced areas (Fig. 81c). The distribution was mostly localised. A similar polish description of the experimental tools was reported by other colleagues (Van Gijn 1984/85/86, Clemente-Conte et al. 2020). Whitish residues were noted even after the cleaning (Fig. 81d).

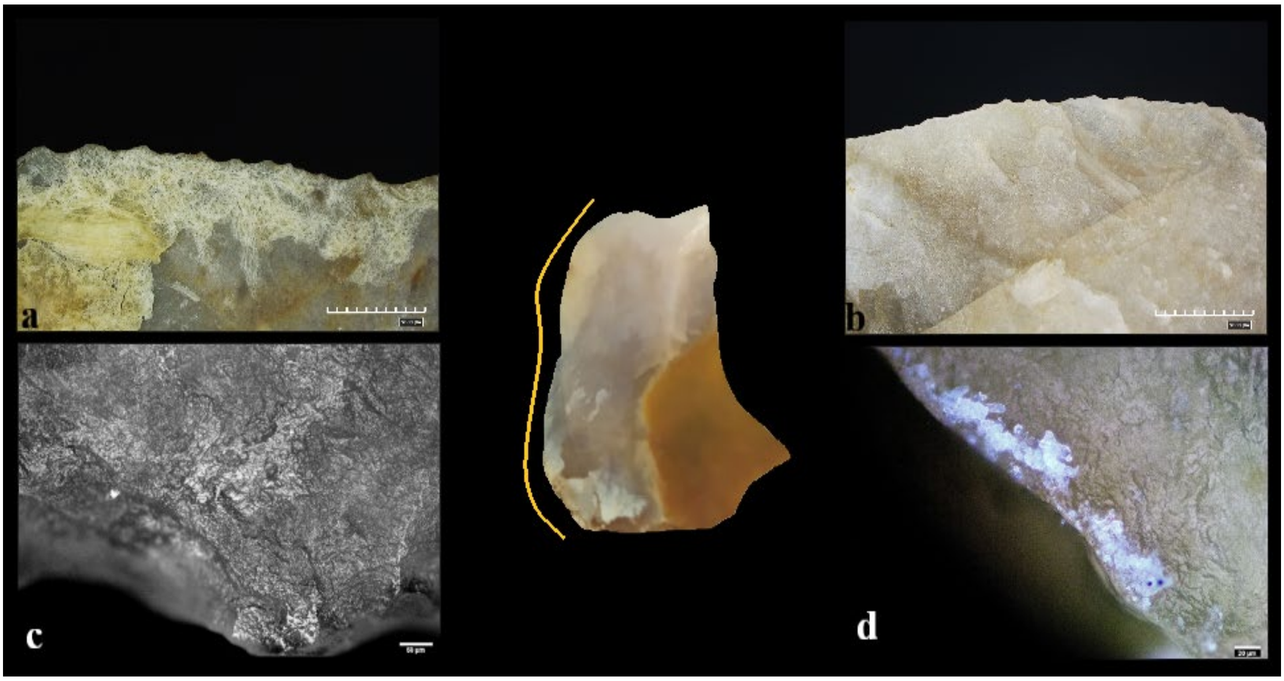


Figure 81: a) Macro traces and residues from scaling, b) Micro snap and halfmoon scars, c) Greasy polish with flat topography, d) Residues, after the cleaning (photo A. Petrović)

The tool was observed by FTIR spectroscopy on two occasions. The first time, just a couple of days after the experimentation, and the second time one year and four months later. The tool was not cleaned.

In both cases, the band of amide I and II are visible everywhere (Fig. 82). They are connected to collagen. On the later spectra, there is a band that is connected to the bone as well at 917 cm^{-1}. This is an expected situation having a mind that scales have both proteinic and bone-like composition.

These results are representing an important indication and the direction in the tracing of the fish activities on the chipped stone tools. The next step is the comparison of the values of chemical residues and trying to follow the details that could differentiate between bone and scale compositions.

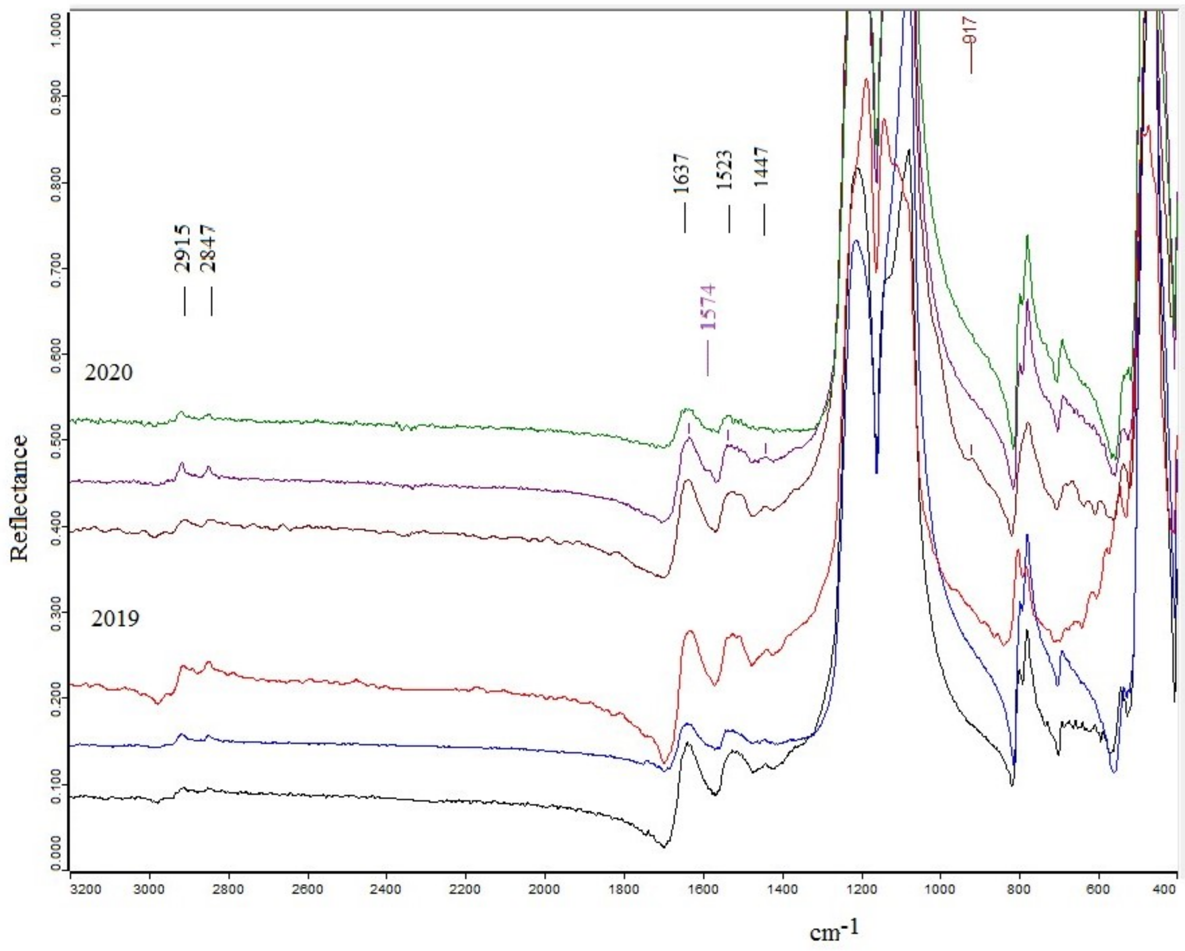
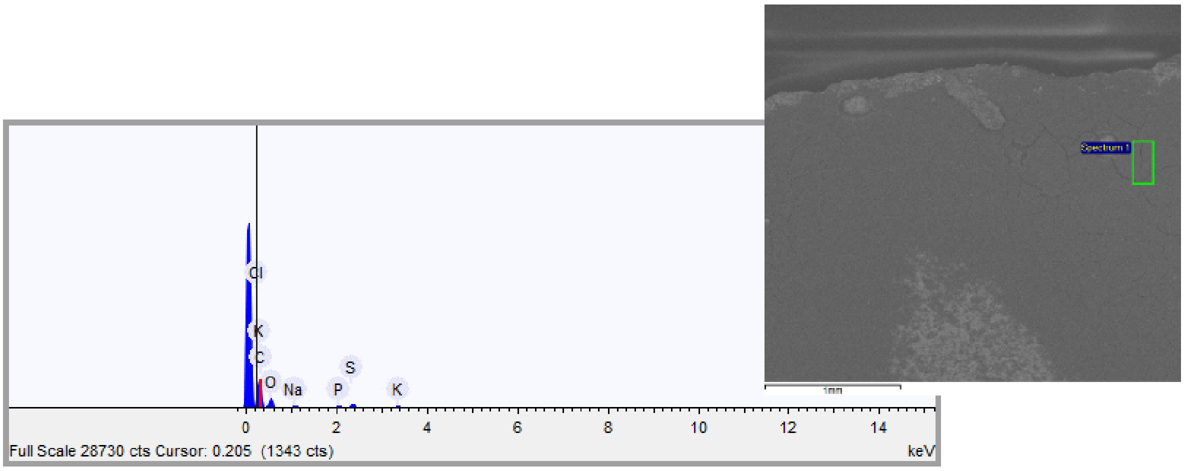


Figure 82: FTIR analysis showing collagen, done 5 days after the experimentation (March 2019), and second analysis, done after 1,4 year (July 2020) – spectra showing AMIDE I and II from collagen and bone (917 cm^{-1}), scaling (spectra S. Nunziante-Cesaro)

SEM-EDX analysis on the tool that was used to remove scales showed, among other elements calcium, sodium, phosphorus, sulfur, potassium and aluminium (Fig. 83). The specimen was tested by three points. The mentioned elements are part of the animal material composition. The sulfur and potassium are the results of contact with hide during the scaling process (Pedergnana and Olle 2018).



Element	Weight %	Weight % σ	Atomic %
Carbon	39.596	2.723	49.647
Oxygen	46.079	2.131	43.374
Sodium	2.893	0.211	1.895
Phosphorus	2.392	0.173	1.163
Sulfur	4.511	0.257	2.119
Chlorine	1.447	0.135	0.615
Potassium	3.082	0.200	1.187

Figure 83: SEM-EDX results, flake used for scaling

A large flake with an unretouched edge was used for all the other activities as head cutting, hide removal, gutting, and filleting. This phase was done in 1 hour and 50 minutes. At first, it was a bit tricky to see what was the easiest way to process the fish that was this large without any previous experience. The head cutting was probably the most challenging task, but it was observed that the easiest way was to cut the meat and everything around the bone and then to break it with the hands.

These activities produced snap and step scars with oblique direction and close regular distribution (Fig. 84a). Polish characterized by granular topography and smooth texture is connected with the bone contact which, in our case, was 60% of the total time (Fig. 84b). The topography is not as flat as it usually is when the tool comes in the contact with the bone. Fishbones are smaller and more fragile compared to other animal bones, and this is the reason the topography is not equally developed. Additionally, the observed trace could mimic the working of any mammal bone in a shorter period. All these attributes are similar to the polish features produced after butchering of any other animal resource-related activity and based on the macro and micro traces no specific characteristics are noted that could be attributed only to fish meat.

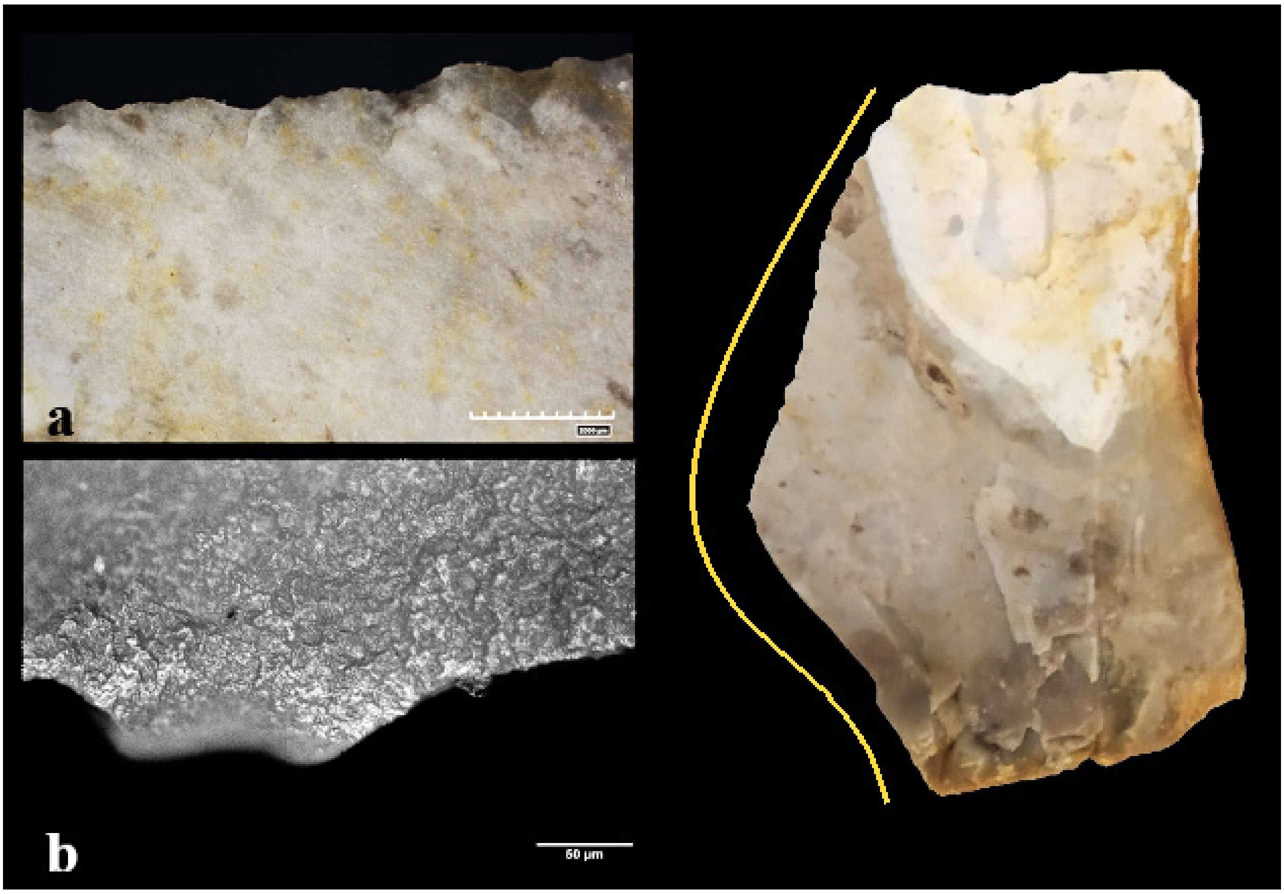


Figure 84: a) Edge rounding and macro traces, b) Granular polish after 1,5 hours of work (photo A. Petrović)

Regarding the FTIR analysis, both spectra measurements showed AMIDE I and II connected to the collagen (Fig. 85). However, no indications of the residues associated with the bone-like composition were observed. This absence, even the tool was in the contact with the fishbone is probably corresponding to their brittleness and to the fact that the quantity of the residue was not large enough to be preserved.

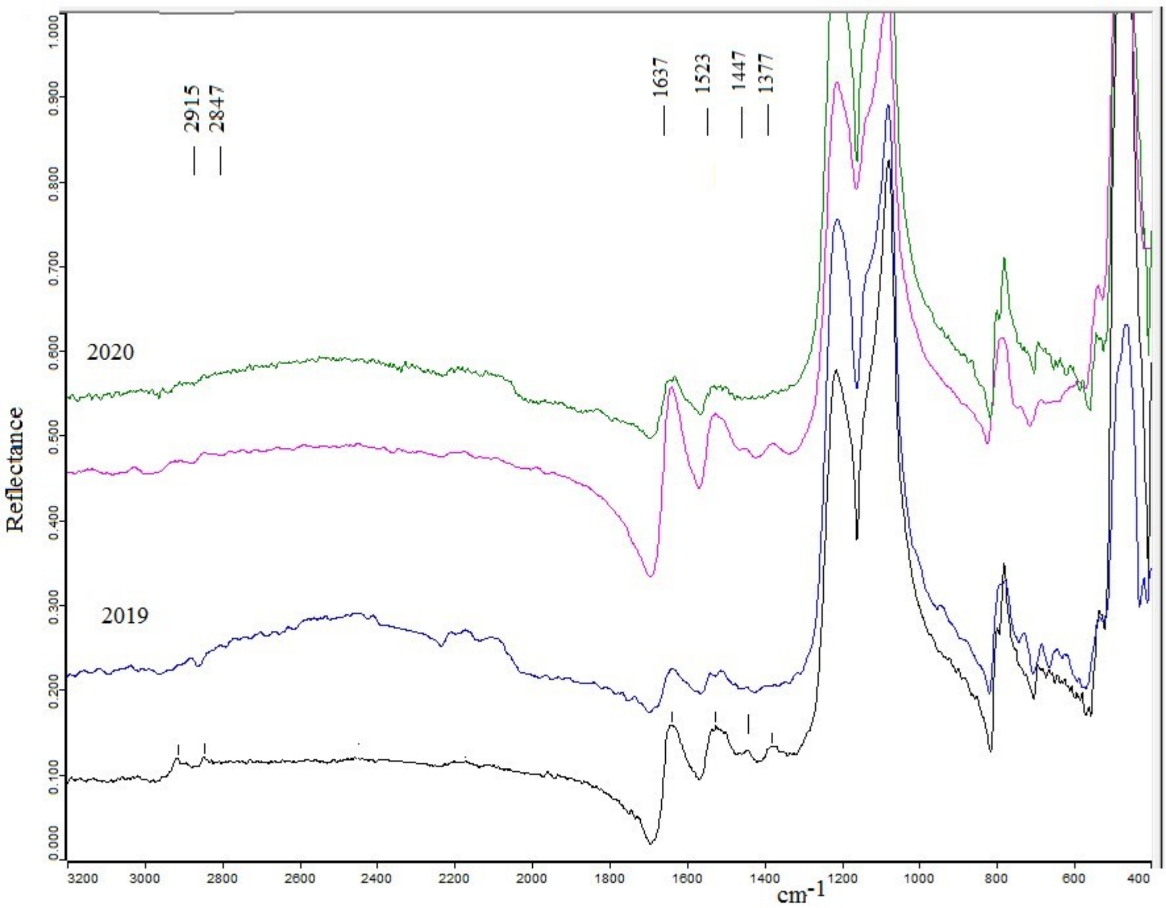
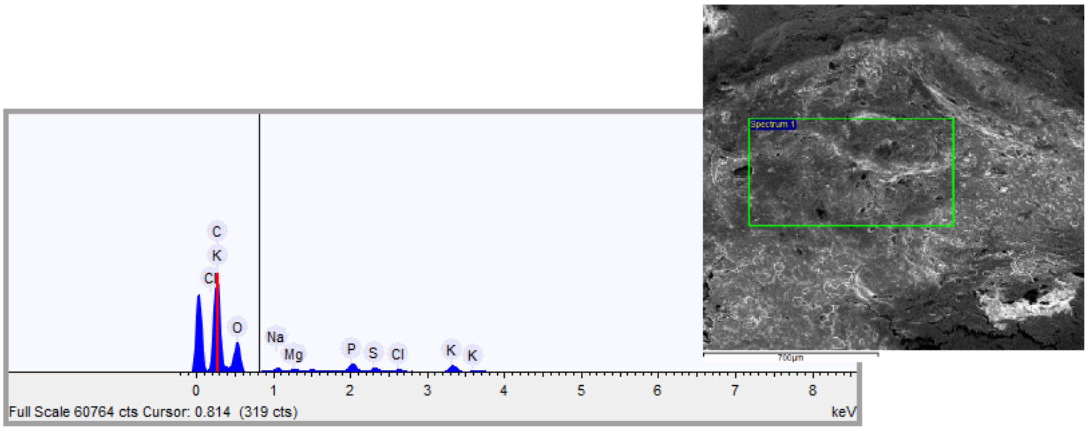


Figure 85: FTIR spectra showing collagen, analysis done 5 days after the experimentation (March 2019), and second analysis, done after 1,4 year (July 2020) - AMIDE I and II from collagen, working of meat and organs (S. Nunziante-Cesaro)

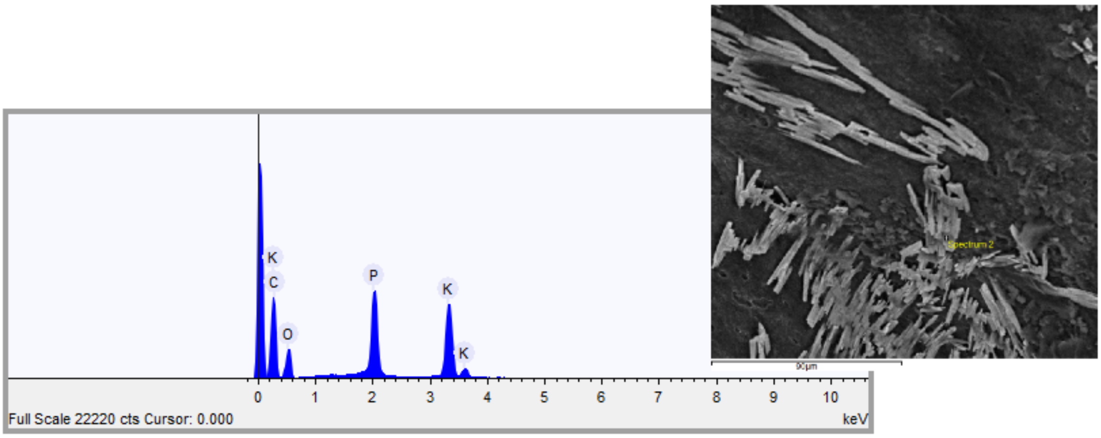
The tools used to remove the organs and for meat cutting and the hide removal showed very similar result to the previous ones with some changes in the quantity of the phosphorus and potassium depending on the test zone. For this reason, two out of three points will be shown for a better understanding of SEM-EDX analysis and how we can utilize the data. The first results are referring to the chosen zone on the dorsal side, right on the area where the residues were preserved, and it showed results very similar to the previous tool (Fig. 86).



Element	Weight %	Weight % σ	Atomic %
Carbon	37.337	1.003	46.730
Oxygen	50.648	0.829	47.589
Sodium	1.487	0.064	0.972
Magnesium	0.693	0.043	0.428
Phosphorus	3.247	0.077	1.576
Sulfur	1.587	0.052	0.744
Chlorine	0.940	0.044	0.399
Potassium	4.063	0.088	1.562

Figure 86: Experiment 36, 1st point

The second point was placed on the group of fibres, also on the dorsal side. This area showed great amounts of potassium and phosphorus (Fig. 87).



Element	Weight %	Weight % σ	Atomic %
Carbon	26.486	1.250	40.207
Oxygen	34.939	0.674	39.817
Phosphorus	16.246	0.303	9.564
Potassium	22.328	0.408	10.412

Figure 87: Experiment 36, 3rd point

SEM-EDX analysis showed no traces of calcium, same as the FTIR spectra. It is very important to note that the chemical analysis of residues can provide additional indications, that later when archaeological material is being tested, we can combine both types of results. This is especially relevant the archaeological samples are altered or when the use-wear traces are not diagnostic.

Besides the flakes, the scales were tested as well (Fig. 88).

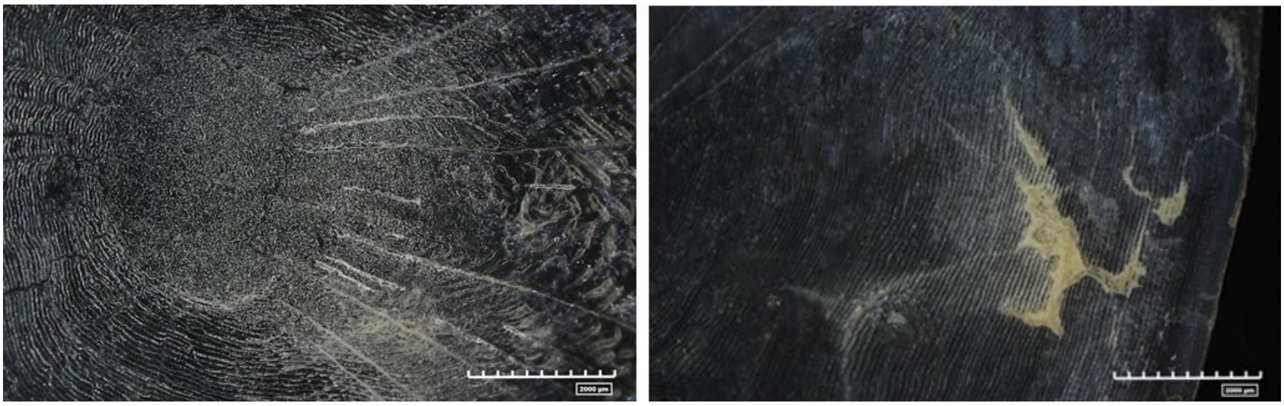


Figure 88: Fish scale under the digital microscope and skin residues (photo A. Petrović)

FTIR analysis showed a composition that is partly made of proteins (red spectra) and calcium phosphate, a bone component (1025 cm-1), and oxidized protein (blue spectra) (Fig. 89).

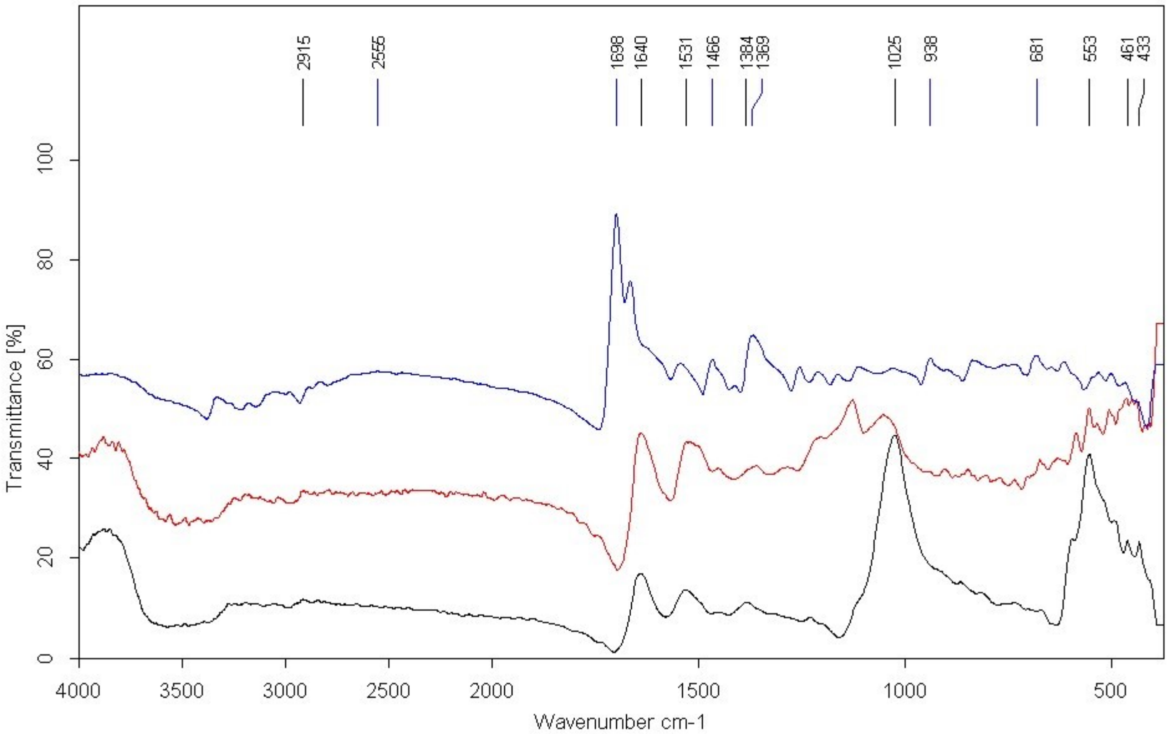
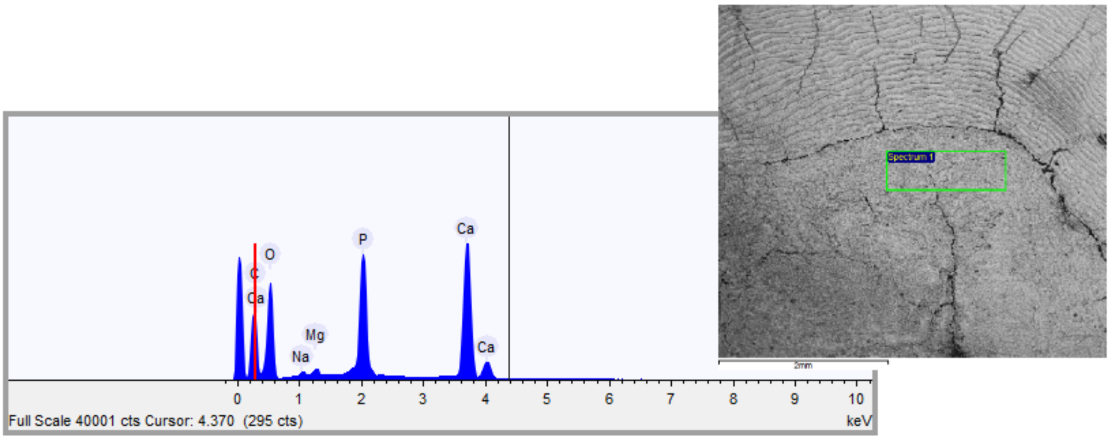


Figure 89: Results of testing the fish scales, apatite (spectra S. Nunziante-Cesaro)

The higher amount and calcium and phosphorous were found as the dominant inorganic matters based on SEM-EDX analysis (Fig. 90). Condensation of those elements might be responsible for the hardness of the external region. The fish scale contains collagen fibrils and calcium phosphates, particularly hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$; HAp) crystals (Okuda et al. 2009) which corresponds with our results. These indications could be very helpful in detecting the residues of scales in the archaeological record. The differentiation between scales and bone viewed by the proposed methods is almost impossible, having in mind that the ratio of calcium and phosphorus found in the scales is 2:1, which is the exact ratio applicable to the bone composition.



Element	Weight %	Weight % σ	Atomic %
Carbon	26.999	0.167	38.668
Oxygen	44.162	0.169	47.483
Sodium	0.401	0.022	0.300
Magnesium	0.468	0.017	0.331
Phosphorus	9.616	0.051	5.341
Calcium	18.353	0.077	7.877

Figure 90: Ratio of phosphorus and calcium, fish scale

4.4. WORKING CERAMICS AND STONE

4.4.1. Ceramics working

Drilling of ceramic spindle whorl (Fig. 91a) was one of the very efficient experiments because it demonstrated two important pieces of information: the scars that are left by the motion of drilling and traces of the ceramics on flint. The experiment lasted 60 minutes. The traces are overlapping, forming two rows of scars that have feather and step endings (Fig. 91b-c). The trend of the scars is oblique bidirectional pointing out to the motion of drilling or perforating (Petrović 2016).

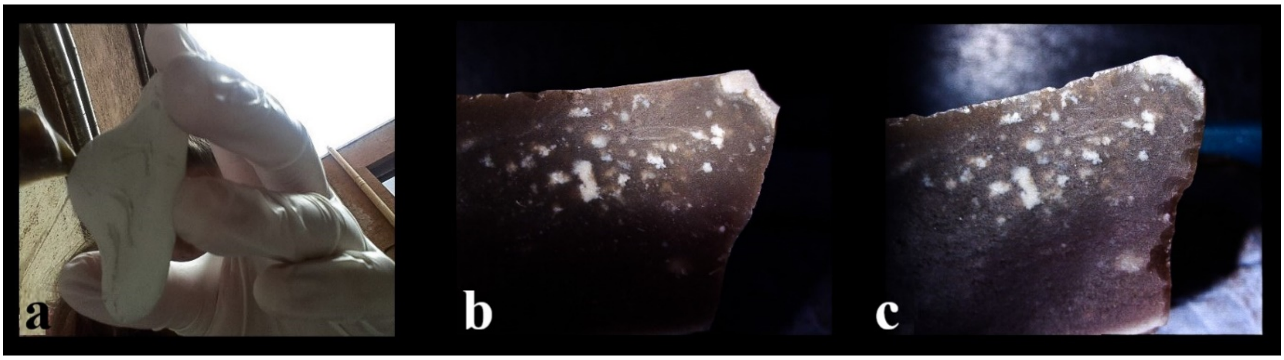


Figure 91: a) Position for drilling of a ceramic spindle whorl, b) Experimental flake before the use, c) Experimental tool after 60 minutes of use (after Petrović 2016)

4.4.2. Soapstone engraving

Figure 92: Soapstone engraving (steatite, origin Liguria, Italy), (photo A. Petrović)

Working on soapstone lasted around 30 minutes and it was a mixture of different movements (Fig. 92). Edge rounding on the ventral side is more pronounced and it consists of a mixture of small step and feather scars (Fig. 93) and smooth polish texture. Since the soapstone is very soft and powdery the traces completely corresponded to contact material and a large number of visible residues, even after cleaning in the ultrasonic tank (Petrović 2016).

Figure 93: a) Step and feather termination, residues, b) Smooth texture (photo A. Petrović)

FTIR analysis showed the presence of silica as well which is directly connected to the soapstone working (Fig. 94). The soapstone usually consists of magnesium, silica, and aqua.

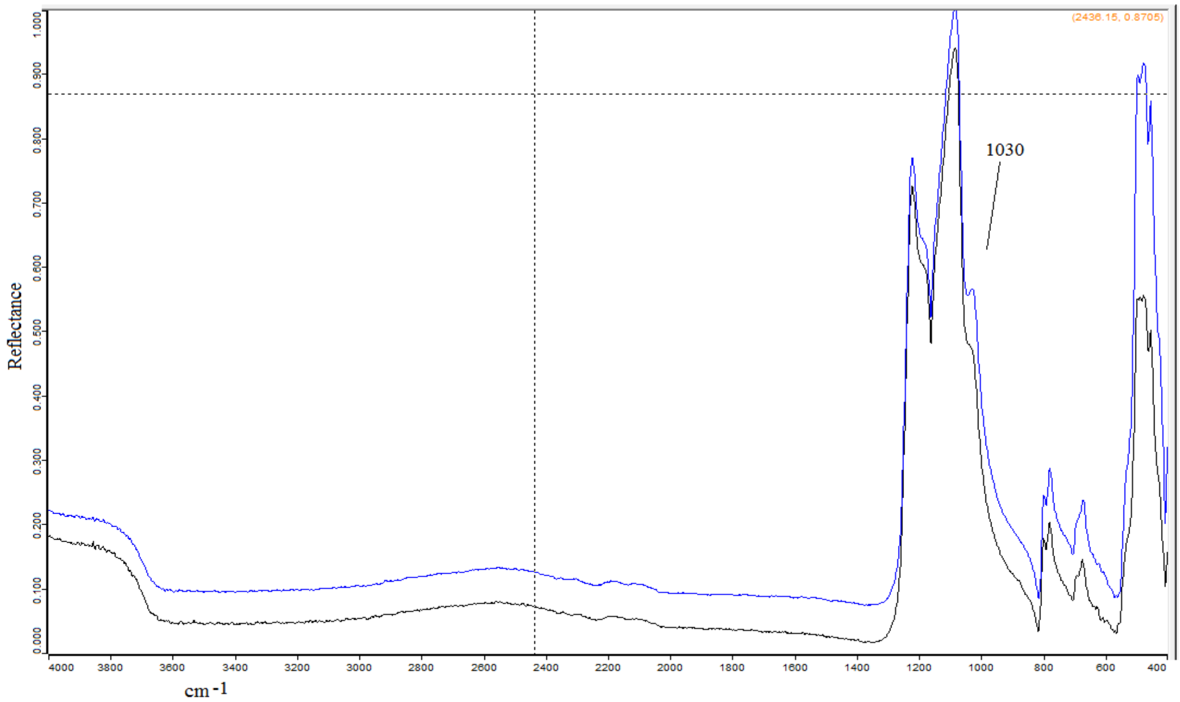


Figure 94: Results of FTIR analysis (spectra S. Nunziante-Cesaro)

4.5. THERMAL STRESS EXPERIMENTAL TRIALS

Numerous studies explored the flint characteristics after heating, presuming that the thermal heating is raising the quality level of flint (Patterson 1995, Marcieca, Hiscock 2008) and in some cases, it was shown that there was no need to preheat the raw materials used for pressure knapping since the flint was already of good quality (Domanski et al. 2009). This testifies that the raw materials, in some cases, were chosen deliberately based on their attributes and performances. However, not so many studies dealt with the use-wear traces and thermal alteration (Olausson 1983, Binder, Gassin 1988, Clemente-Conte 1997). The following experiment was carried out to explore the connection between diverse alterations and heated flint tools. Particularly, the key argument was to test if and how thermal stress affects the macro and micro use-wear traces.

The idea for thermal stress experimentation came from the preliminary analysis of chipped stone tools from house 32 (Lepenski Vir site). Some of the characters connected to the thermal stress were observed, like cracks and change of colour. The artefacts went through (un)intentional fire alteration, but the tools were also used afterwards (Chapter 5). The glossy appearance was observed by higher magnifications that covered completely the micro traces, posing an inquiry – was this alteration induced by thermal stress or other sources.

The knapped tools in the trial were unused, used, and some were utilized after a couple of phases of thermal stress and then burned again. The experimentation was done in the experimental oven at the LTFAPA Laboratory and in the replica on the Neolithic oven at the site of Portonovo (Italy).

4.5.1. Thermal stress trials in experimental oven

The raw materials coming from Serbia, Israel and Italy were knapped by direct percussion (Fig. 95). In total, 13 experimental tools were used in the experimentation (4 flint and 4 quartz tools of which come from Serbia, 2 tools made on raw materials from Gargano (Italy) and 3 produced on the flint from Israel, and 3 tools that were previously used in the previous experiments in 2016 and 2018 (Table 1). The three experiments previously used are exp. 1 – cutting of soaked wood, exp. 6 – scraping of soaked wood, exp. 17 – butchering.

Figure 95: Direct percussion, three different raw materials (photo D. Moscone)

The whole trial consisted of six phases of thermal alteration (Fig. 96 and 97) and two phases of use, phase 0 (before firing), and phase I (after the 5th phase of firing), (Tab. 2, Fig. 100) and it lasted twelve days in total.

Figure 96: Experimental oven at LTFAPA (Sapienza University of Rome) and six phases of heating – the position of the tools inside the oven (photo A. Petrović)

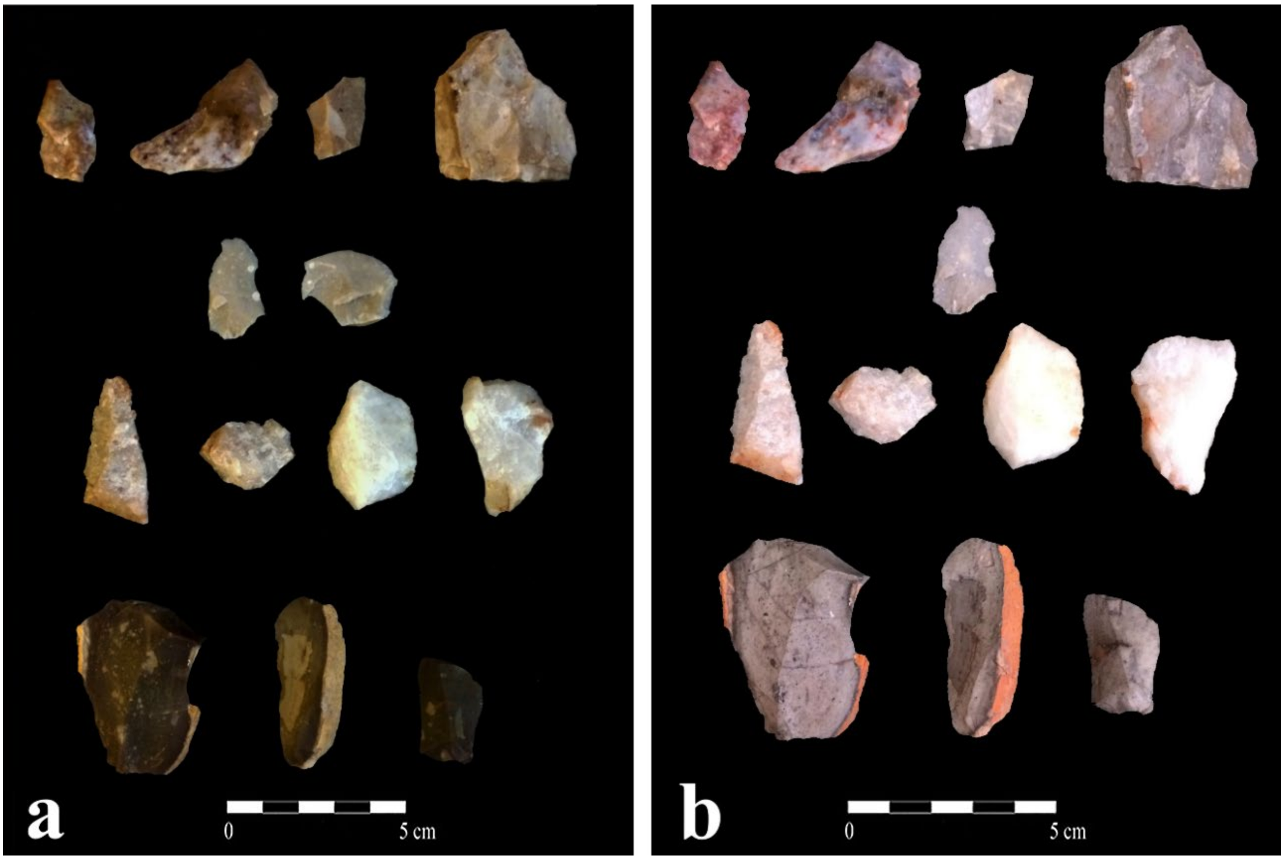


Figure 97: a) Experimental tools before, b) Tools after thermal stress, after the sixth phase (808°C), (photo A. Petrović)

Samples were analysed after each session in the experimental oven. The temperature was increased for 100˚ C after each session and it was constantly on the rise, meaning that there were no periods of stable temperature.

The main changes (Table 2) that were noted after the experimentation are:

- Colour change (CC)
- Patina (P)
- Breakage (complete breakage), (B)
- Widening of lancets (L)
- Scales and fissures (surface crazing), (SC)
- Matt surface (M)
- Thermal extractions (flake splitting), (TE)
- Thermal gloss (TG)
- Jagged fractures (on quartz and quartzite), (J)
- Weight loss (WL)

Table 2: Experimental tools in different phases of fire alteration in the experimental oven with all the noted changes

#	USE 0	I 103°C	II 205°C	III 331°C	IV 478°C	V 607°C	USE I	VI 808°C
37				CC	CC	F, L	Bone scraping (1 hour)	CC
38				CC	CC	F, L	Working tubers (40 minutes)	F, WL, SC, TG
39		CC		CC	CC	F, L, CC		F, CC, TE
40				CC	CC	F, L, CC		F, CC
41		CC		CC				CC. J
42		CC		CC				CC, J
43				CC				CC, J
44				CC				CC, J
45				CC		F		CC
46				CC		B		N/A
EXP 1	Wood cutting (1 hour)			CC	M, F	F, CC		CC, M, TG, TE
EXP 6	Wood scraping (1 hour)			CC	M, F	F, CC		CC, M, TG
EXP 17	Hide scraping (1 hour)			CC	M, F	F, CC		CC, M, TG

During the first phase, the temperature reached 103˚ and the artefacts were left inside the oven during the weekend so they could cool down. The idea came from the previous experiments where it was noted that if the tools are pulled out immediately after the heating they could break due to an extensive temperature variation called thermal shock (Purdy, Brooks 1971, Patterson 1995). In the first phase, the changes were minimum and three tools changed the colour (Table 2). In the next phase, the temperature reached 205˚C and there were no new changes compared to the previous phase. The third phase was a point where all the modification started to appear after reaching 331˚C. All the tools changed colour (Table 2) towards pink, reddish, and yellow. Some pieces changed the colour greatly, while others mildly compared to the natural colour. This difference is not connected to the position of the tools in the oven, having in mind that the pieces were placed in diverse positions in each phase. The fourth phase (478˚C) is when some of the tools showed first signs of breakage, their lancets widened, and surfaces became more matt, moreover, some tools became greyish and whitish (Table 2). On the micro-scale, a light glossy appearance was observed on piece 37 and parts with iron emerged on the surface. In phase five (607˚C) on flint from Israel and Italy fissures emerged on the surface and some of the platforms (created by cracks) on the tool have risen (Table 2). These so-called cracks, scales and fissures are widely known as *surface crazing* (Rick 1878, Patterson 1995) and this phenomenon attributes to the material shrinkage. It is important to highlight that these changes can be noted as appearing isolated or in groups, but also, they can be shallow and not physically dividing the surface or they can be deeper and producing cracks (Clemente-Conte 1997), (Fig. 98).

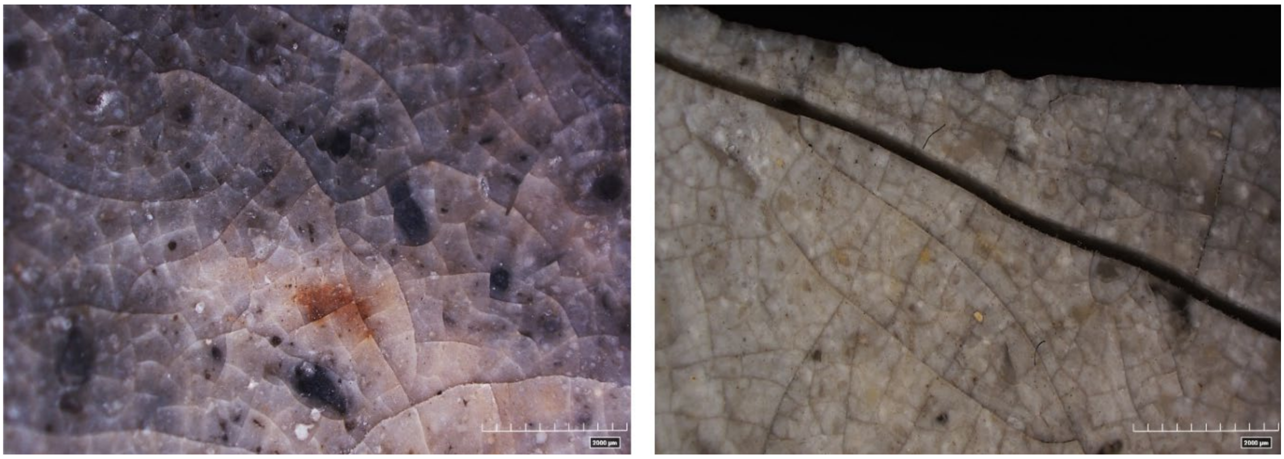


Figure 98: Experiment 6 after 607°C (fifth phase) and 808°C (sixth phase) – surface crazing (photo A. Petrović)

In this phase, tools changed the colour and visible widening of lancets was noted (Fig. 99). Some of the experiment became reddish, which was the iron that emerged to the surface thanks to the thermal stress, while tools 1, 6, and 17 became grey. Other tools showed more scars and the creation of a patina on the cortex. Micro observations showed a very light glossy appearance on tools 45, 46, light on 37, 38 and medium on experiment 1,6. Widening of lancets was visible on tools 39, 40.

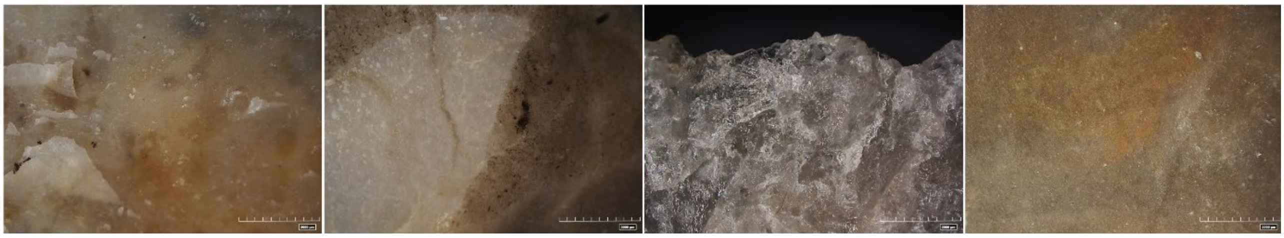


Figure 99: Experimental tools and working edges after thermal stress under 607°C (fifth phase), (photo A. Petrović)

After the fifth phase, two experiments (37 and 38) were singled out and used in different activities (phase use I), (Fig. 100). Tool 37 was used for bone scraping for around 30 minutes and then for cutting for 30 minutes, producing a total of 1 hour of work. Macro observations showed scars both on the dorsal and ventral, but more pronounced on the ventral side. Scars are regular continuous in a snap and step shape with an oblique bidirectional orientation creating a pronounced edge rounding. Micro observations showed that polish had a granular and domed topography and half-tight linkage. Tool 38 was used for peeling off and cutting the tubers for 40 minutes. The macro scars were a small snap, step and feather with an oblique bidirectional orientation, and micro-observations showed domed, flat, and melty topography (very bright).

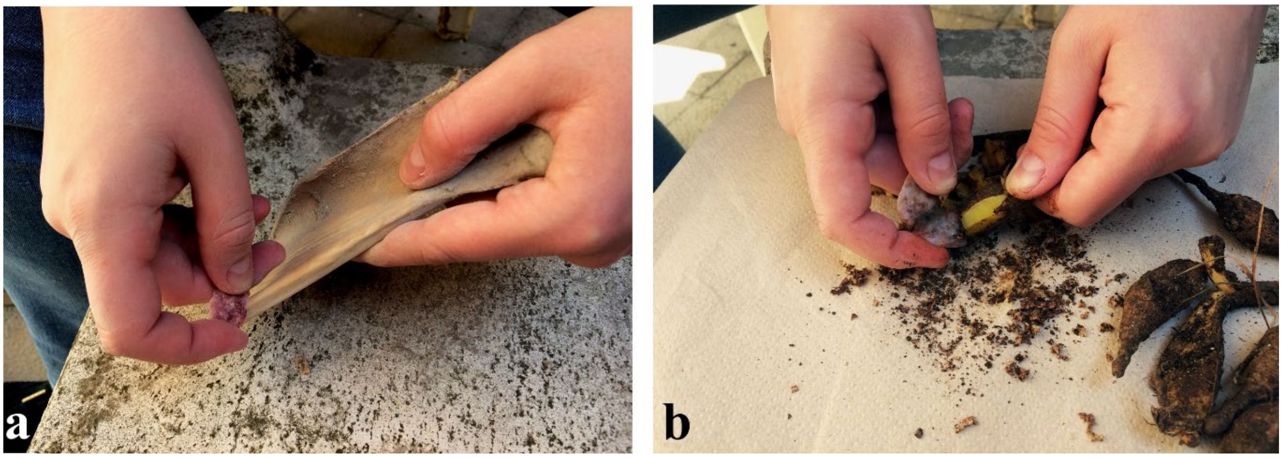


Figure 100: a) Use of experimental tools after the fifth phase (607°C): bone working (1h cutting + scraping), b) Tuber working (40min peeling of + cutting), (photo A. Petrović)

After the interphase of use twelve out of thirteen experimental tools were put again in the oven. One of the tools (46) broke during the observations because it became very porous. The sixth phase (808˚C) was the last phase of the thermal stress experimental trial. Experimental specimen 38 had visible fissures and crack all over the surface and it was the only tool that drastically changed the weight. In a similar way tool 39 cracked and one part of the cortex also became extremely whitish. The tools changed the colour (Fig. 101a-c), as it happened from one phase to another. Gargano flint tools have the presence of black spots on surfaces (Fig. 101c) and their origin is connected to thermal stress. The spots are positioned both on the ventral and dorsal side all over the surface, not indicating any connection to the working area or similar (Clemente-Conte 1997). The cortex of the tools also changed the colour during different phases and it became orange-red in the final session (Fig. 101d).

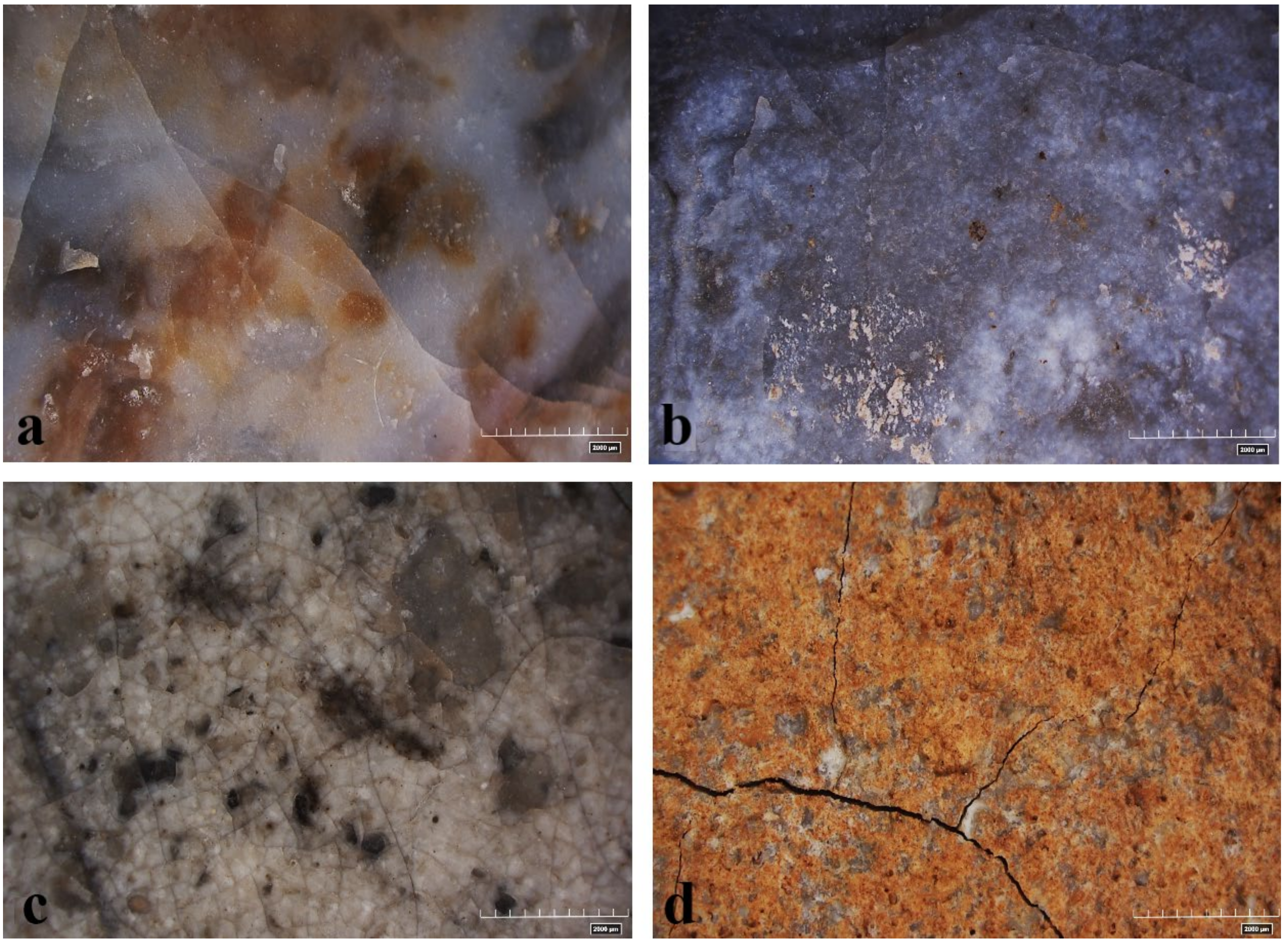


Figure 101: a), b) Colour change on different raw materials, c) black spots, d) change of colour of cortex after thermal stress (photo A. Petrović)

Some tools had parts of the surface missing. These removals are in general called *thermal extractions* (Clemente 1997) that in our case could be described as *flake splitting* (Patterson 1995). In the case of this specific thermal alteration trial tools had small (exp. 1, Fig. 102a) and bigger, flake-like shaped extractions that were noted (exp. 39, Fig. 102b) with a rough negative surface. What defines extractions as flake splitting and not potlid fractures (Patterson 1995) is that they are not in an oval or spherical shape (Patterson 1995). However these typed of potlid fractures were noted in the archaeological sample (see Chapter 5), and in another thermal stress experiment (see Chapter 4.5.2) and most probably are connected to the specific environmental elements and oven types.

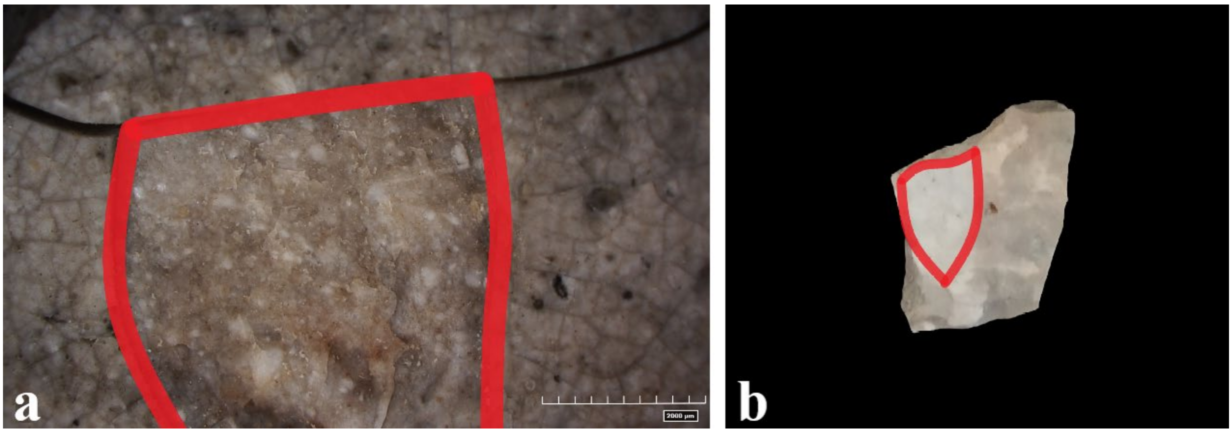


Figure 102: a) Smaller thermal extractions, b) Larger thermal extractions and flake splitting (photo A. Petrović)

The quartzite tools changed the colour, became less transparent and reddish on the edges (Fig. 70a). In the addition, jagged fractures appeared (Fig. 103b).

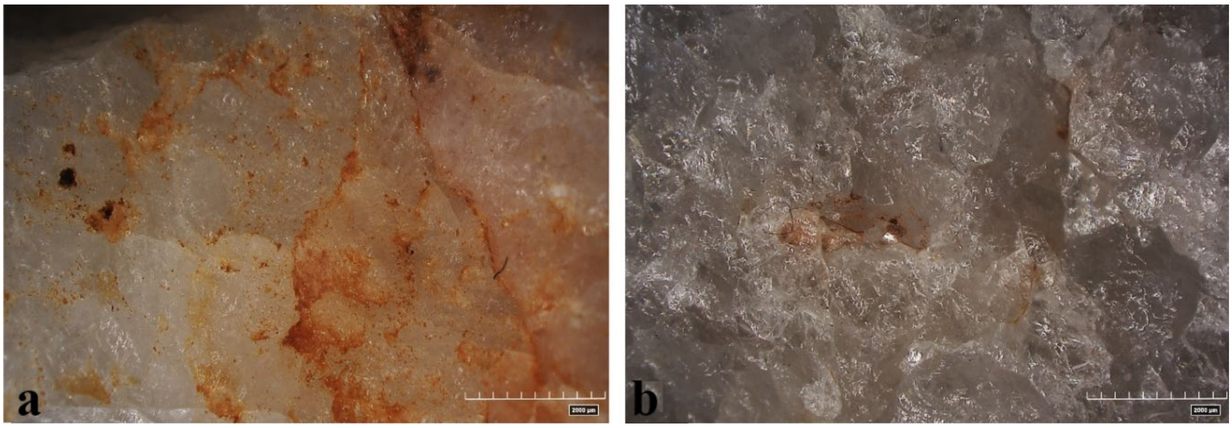


Figure 103: a) Reddish colour change on edges, b) Crystals of quartzite with jagged fractures, after thermal alteration, (photo A. Petrović)

Regarding the tools that have been used in the inter-phase, the macro traces were still diagnostic (Fig. 104).

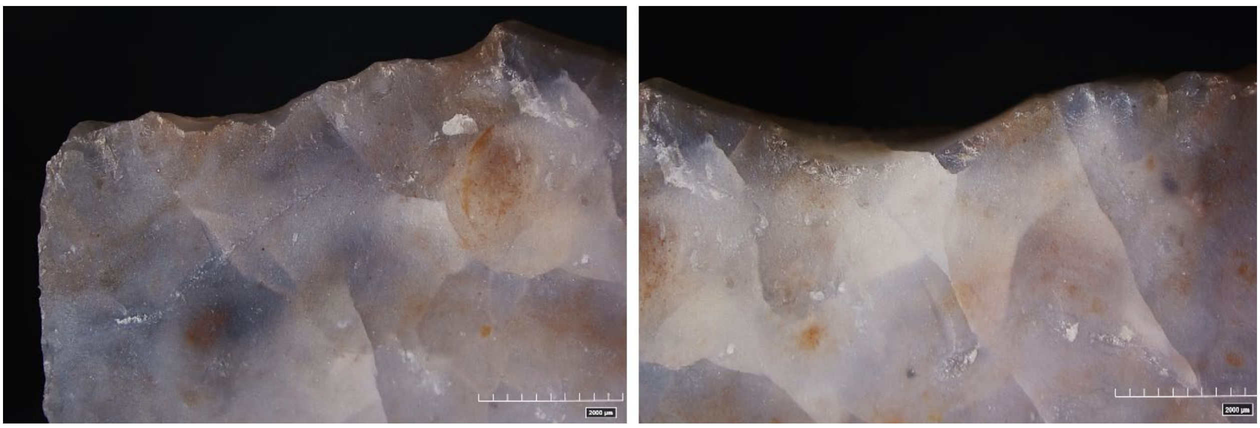


Figure 104: Macro traces, after thermal alteration (photo A. Petrović)

A very similar situation is with micro traces, that have not been covered by glossy appearance. In the case of heating the used tools, until and around 800˚C a glossy appearance did appear, but it did not affect the traces (Fig. 105). It was noted that the brightness of polish is a bit higher, and that experimental tool 37 was used for processing the hard animal material and tool 38 for working the vegetal-based matter.

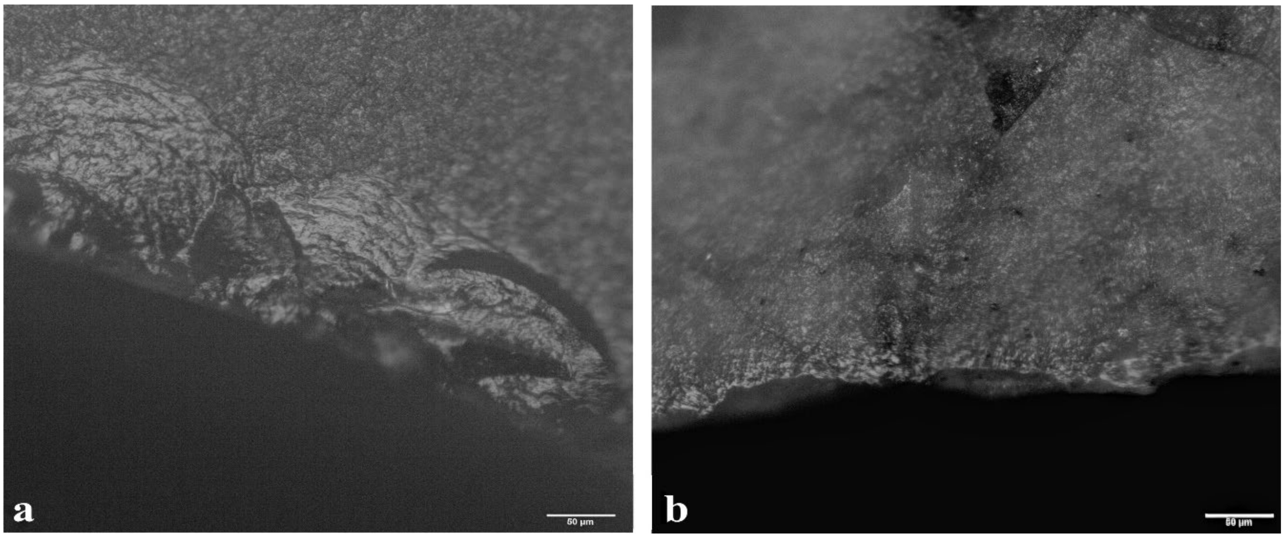


Figure 105: a) Polish on used edge after 808°, tubers, b) Polish on used edge after 808°, wood (photo A. Petrović)

4.5.2. Thermal stress trial, a replica of Neolithic oven at the archaeological site Portonovo (IT)

After the trials in the experimental laboratory oven, six pieces were also tested in the open-air replica of the Early Neolithic oven (Fig. 106 and Fig. 107). The experiment of the underground oven was done according to the archaeological evidence unearthed from the Early Neolithic site of Portonovo-Fosso Fontanaccia (Ancona-Italy) (Conati Barbaro et al. 2020).

Figure 106: Replica of the Neolithic oven at archaeological site Portonovo (Italy), (photo C. Conati Barbaro)

In total, six chipped stone tools were part of the experimental trial at Portonovo. Four pieces were unused, and one tool was used for scraping dry hide (exp. 2) and one was used for scraping and cutting bone for 20 minutes (exp. 47). Same raw materials were used as in the previous thermal stress experiment in the laboratory oven with an idea to track the surface modifications.

Figure 107: The oven chamber after firing experiments and experimental chipped stone tools after the thermal treatment (750°C), (photo C. Conati Barbaro)

The maximum reached temperature was 750℃. The whole experiment took part from 12:26 until 21:30, and various objects, besides the chipped stone tools, were put in the oven chamber as pottery. Some of the knapped tools were placed in the ceramic vessel. After the nine hours of firing the whole structure reminded warm until the next morning[9].

The main changes (Table 3) that were noted after the experimentation are:

- Colour change (CC)
- Patina
- Widening of lancets (L)
- Scales and fissures (surface crazing), (SC)
- Matt surface (M)
- Thermal extractions (flake splitting and potlid fractures), (TE)
- Thermal gloss (TG)
- Jagged fractures (on quartz and quartzite), (J)
- Weight loss (WL)

Table 3: Experimental tools with noted changed after firing (750°C)

#	USE 0	AFTER FIRING (750°C)
47	Bone scraping and cutting (20 minutes)	CC, M, SC, TG
48		CC, M, L, SC
49		CC, M, WL, SC, TE, TG
50		CC, WL
51		
EXP 2	Dry hide scraping (1 hour)	CC, M, WL, SC, TG, TE

The experimental tools were observed after the whole process of burning and all the pieces, except experiment 51 changed the colour (Fig. 108). Widening of lancets (Fig. 108b) together with surface crazing (Fig. 108a, c, d) are some of the most pronounced changes. Macro traces were well

[9] Personal communication with Vanessa Forte, November 2020

preserved, except for some areas that had some fresh fractures that could be correlated to thermal shock (Fig. 108d).

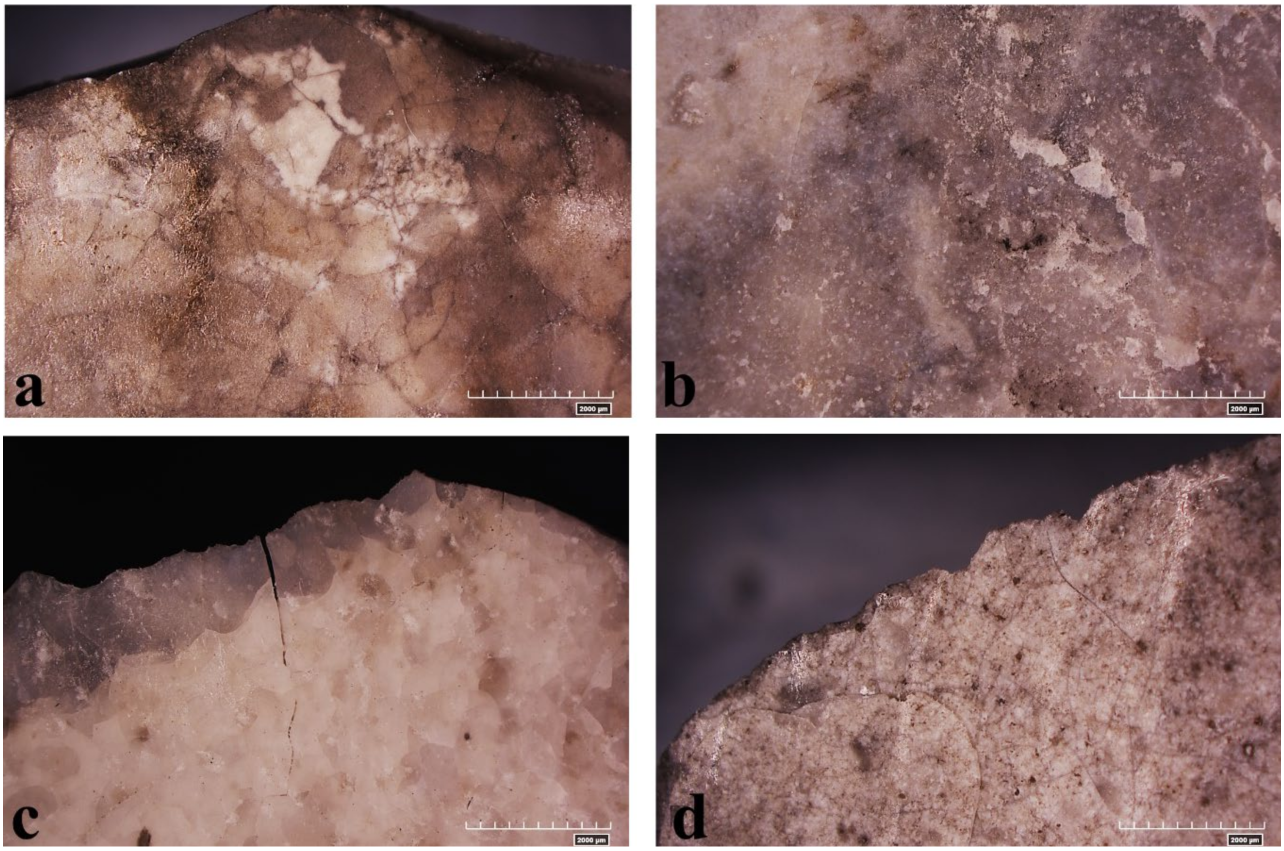


Figure 108: a) Change of colour, b) Widening of the lancets, c) Cracks, d) Pits on experimental tools after thermal stress (photo A. Petrović)

Regarding the polish and its recognition, it was hard to distinguish the used area since the surface was modified (Fig. 109). The polish is still visible in some parts, but it is not possible to connect the polish and exact used material (Fig. 109a-b). In some areas, a light film of thermal gloss is visible (Fig. 109c).

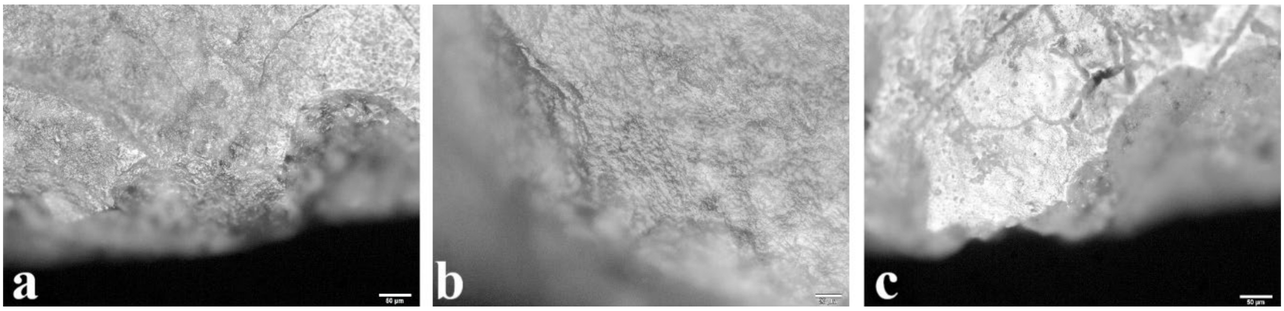


Figure 109: a), b) Area of use, after thermal alteration, c) Light film of thermal gloss (photo A. Petrović)

4.6. TOOL HANDLING MODES

The main reason for tracing this kind of proofs is to gain more insight into the handling modes of chipped stone tools and to be able to recognize the trace characteristics, if present, on the archaeological tools. Most of the tools from the reference collection, presented in this chapter, are hand-held and 5% of the experimental tools were hafted.

4.6.1. Hand-held mode

Prehension on the tools is usually represented by macro traces (Fig. 67b, 71, 76a, 110). The scars are localized, irregular and randomly positioned. Regarding the dispersal of the residues during use, below is an example where most of the residues are positioned on the prehension area (Fig. 110).

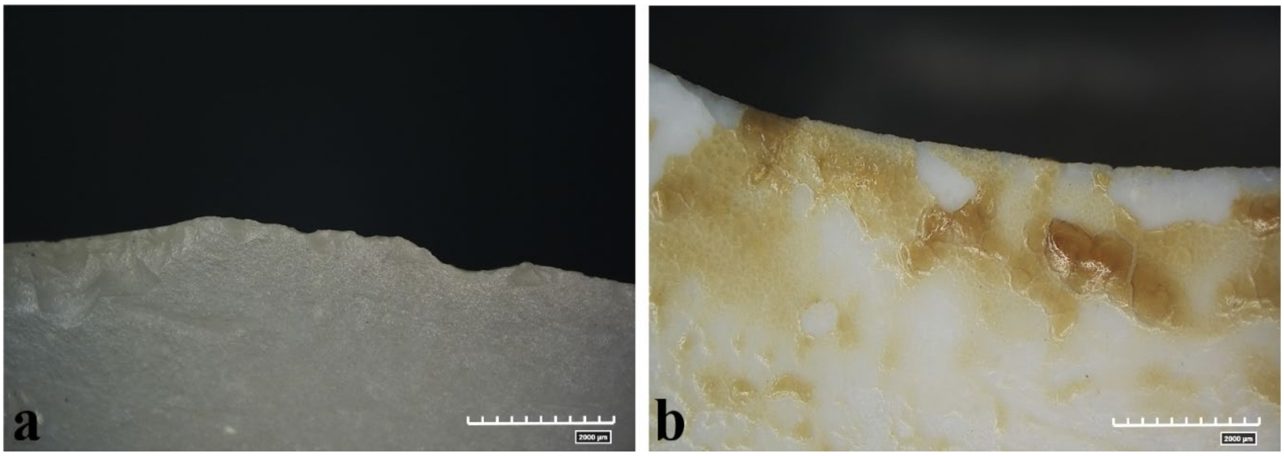


Figure 110: a) Localised, isolated scaring from prehension,
b) Residues accumulated on the prehension area (photo A. Petrović)

On the other hand, micro traces from finger prehension are not always visible and diagnostic when are not well developed. Most of the micro traces are usually localized near the bulb and on the tool's ridges corresponding to the experiences of other colleagues as well (cf. Venditti 2017). A similar pattern of distribution was noted on tools from the archaeological sample (see Chapter 5).

4.6.2. Texture wrapping

The specific need for further experimentation was observed after analysing an archaeological sample from the Padina site (Sector I) where not only polish characteristics connected to the hafting was found, but also the traces of texture wrapping were noted (Chapter 5.2.1.).

The raw material that was used in this experimentation comes from Kanjera South (Kenya) site (Lemorini et al. 2014, Lemorini et al. 2019). The Kanjera flint was chosen with an idea to test the visibility and creation of the polish on the darker raw materials since some of the tools from Iron Gates sites were made on very dark to black chert which source and location were never analysed.

The tool was used for 30 minutes in total. The bone was in the contact with the ventral surface of the tool for 20 minutes and for 10 minutes the tool was in rotation (Fig. 111). The worked bone was in a semi-fresh state.

Figure 111: Bone scraping with tool handled with textile, (photo A. Petrović)

Macro traces are represented by two larger notches. Formation of these notches is normal when the tool is used for processing hard animal materials. The scars are overlapping, they are snap and the direction is obliquely creating a high edge rounding (Fig. 112a). However, the macro traces from prehension are visible but are very undiagnostic – small snap and step scars randomly localized (Fig. 112b). These indications are accurately describing the prehension traces also visible in the archaeological sample (see Chapter 5).

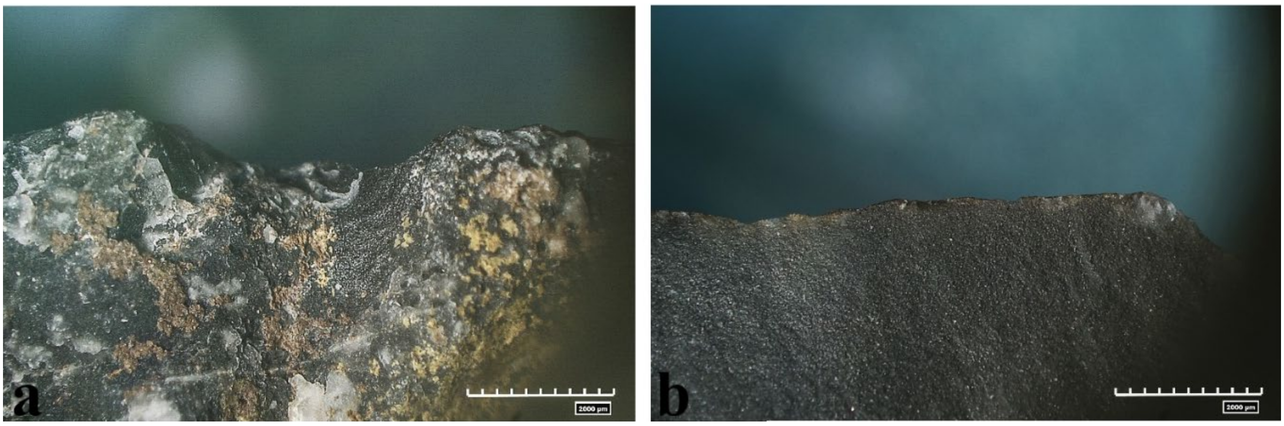


Figure 112: a) Notches and overlapping of the scars, used area, b) Scaring on prehension area, (photo A. Petrović)

Micro traces are visible on the working edge represented by flat and covered polish on the outer edge with visible striations (Fig. 113a). On the ventral side of the prehension area, no specific polish is observed on the edge, but patches and bright spots are visible on the surface (Fig. 113b).

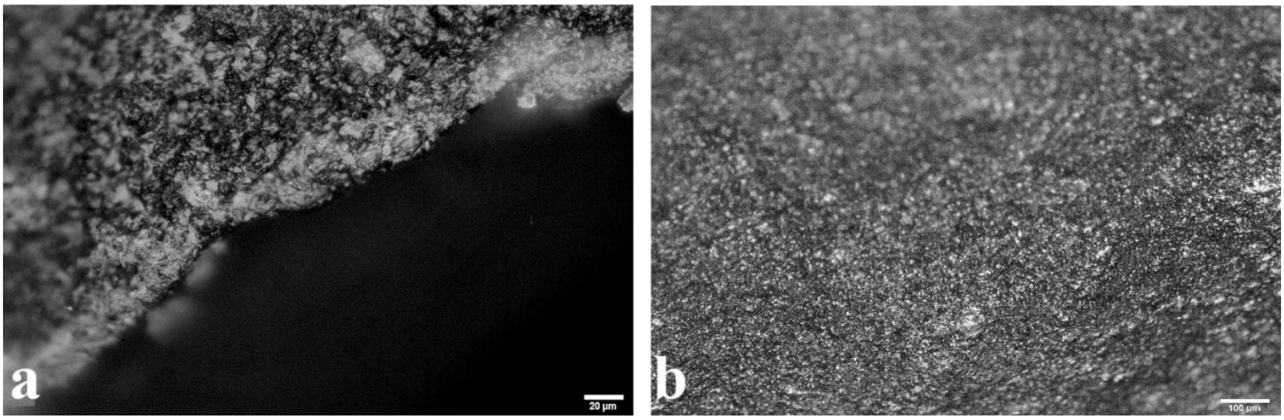


Figure 113: a) Used edge with flat topography and covered linkage,
b) Bright spots and patches distinctive for prehension (photo A. Petrović)

4.6.3. Hafting

As it was mentioned in the Methodology chapter (3.3.6 Hafting), the possibility to identify the hafting traces was discussed for years which resulted in a very extensive experimental program (Rots et al 2001, Rots et al. 2006, Rots 2010).

In our experimental study, one type of hafting arrangement was used – inserting the tool in the wooden handle. A small hole was made on the top of the branches, and the tools were embedded, so 1/3, or 2/3 of the tools was left outside the handle depending on their stability, width and shape (Fig. 114).

Figure 114: Chipped stone tools positioned in hafts (photo A. Petrović)

The haft was secured with a string. The mixture of heated resin and ash (as a thickener) was placed over the haft entrance and the sting area (Fig. 115). Resin is, with tar (Mazza et al. 2006, Ribechini et al. 2011) and bitumen (Boëda et al. 1998, Cârciumaru et al. 2012), among the most used adhesives in prehistory. Hafted tools produced by the presented procedure were used for skin tanning (Chapter 4.3.8) and depilation (Chapter 4.3.9).

Figure 115: Drying of the hafted tools (photo A. Petrović)

There are two stages of trace formation on the hafted products: during the hafting process, but most of the scars and patterns are formed during the use of the hafted tool (Rots 2010). In our case, the traces were observed at the end of the use of hafted tool and differentiation between the two mentioned phases of trace production could not be obtained.

Macro traces are in all the cases of hafted tools present and mostly continuous and irregular (Fig. 116a). The shapes of the scar terminations are very diverse and snap, step traces are observed, while the edge rounding was not noted (Fig. 116b). The same abundancy in scaring and absence of rounding was noted by V. Rots (2008)

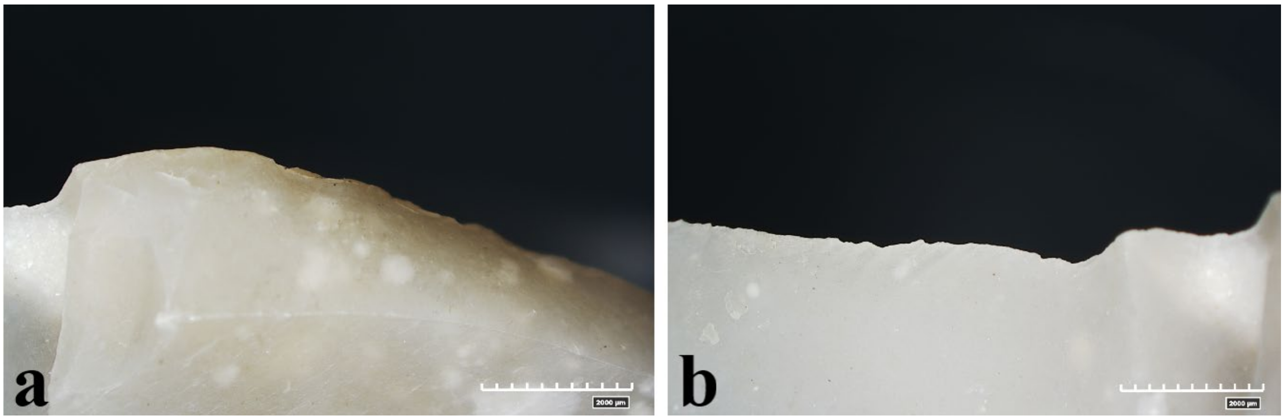


Figure 116: a) Irregular scars, b) Snap and step scar terminations, hafted edge (photo A. Petrović)

Micro traces and polish were noted in all the hafted tools used in experimental trials producing a large variety of different characteristics as linear distribution of domed, flat polish with tight linkage limited to the outer edge of the tool (Fig. 67b). In many cases bright spots and striation lines created by the friction with flint particle(s), (Fig. 117a-c). These types of bright spots can be connected, in specific cases, with antler handle or resin fragments (Rots 2002c). Distribution of bright spots and clear association between them and striations (Fig. 117b) are very common in the hafting under strict conditions and is based on the distribution of the pressure during the use of the tool (Rots 2002c: Fig. 3, Rots 2008: Fig. 3b). Polish from contact with wooden haft produced diagnostic characteristic as domed topography and half tight to tight linkage (Fig. 117d).

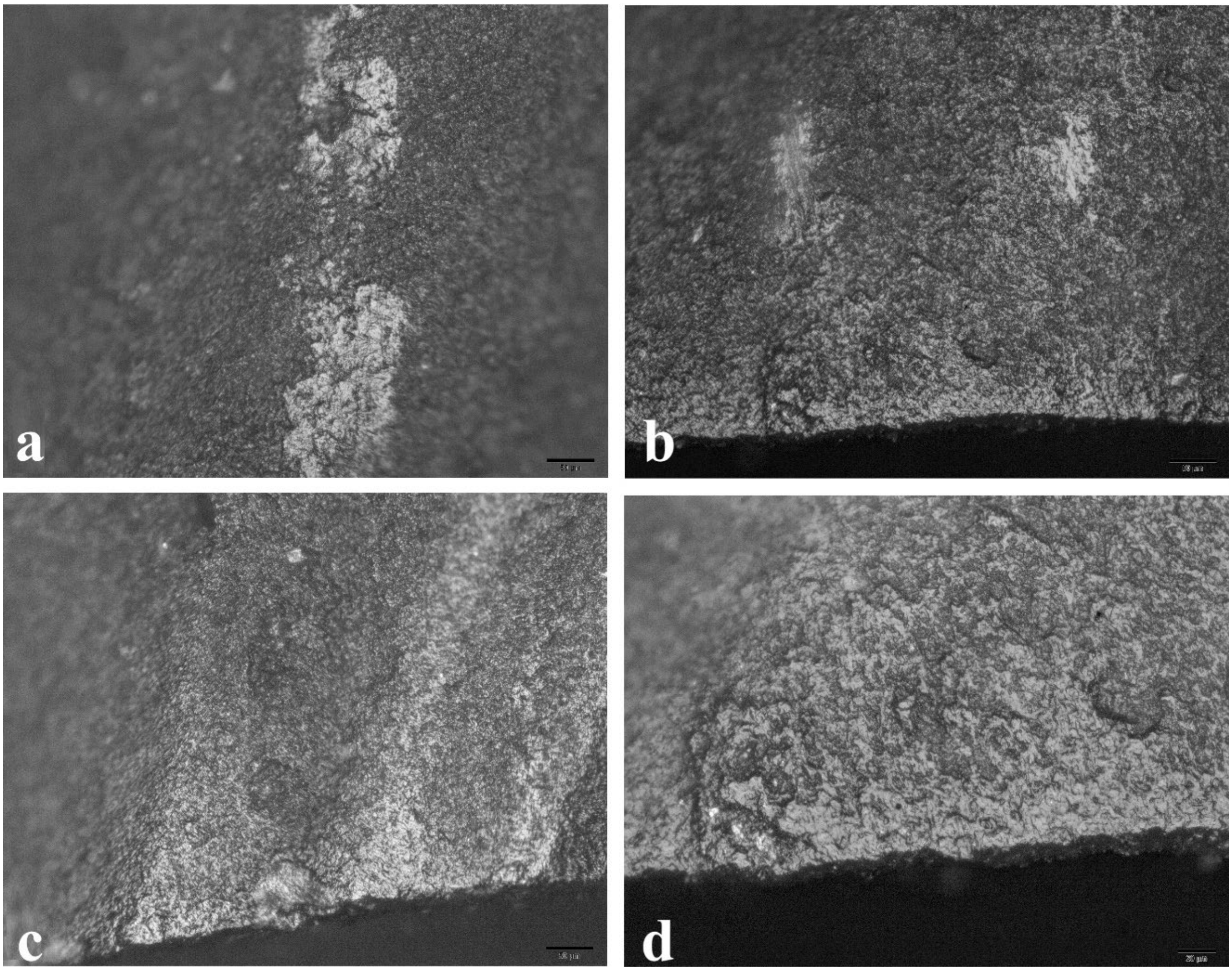


Figure 117: a) Bright spots, b) Bright spots and striations c) Linear distribution and bright spots on the edge, d) Polish as a result of the friction with the wooden haft (photo A. Petrović)

4.7. POST-DEPOSITIONAL SURFACE MODIFICATION EXPERIMENTAL TRIALS

(to be continued)

This experimental trial is still ongoing, and it represents a very extensive study. The idea is to bury in the ground different experimental tools like chipped stone tools and ceramics in diverse geographical areas or soil composition. The experimental chipped stone artefacts and fragments of the pottery are buried in Sicily (San Piero Patti village) (Fig. 118) and the city of Belgrade (Fig. 119). The experimental tools will be uncovered after 3, 5, and 10 years for the analysis. The aim is to trace how the post-deposition modifications affected the surface of the artefacts.

Figure 118: Positions of chipped stone tools in Sicily (photo A. Petrović, S. Taranto)

The experimental tool and piece of ceramics in Belgrade were put into the pit that was 0.60m deep. The pit was dug in the back garden of the building on the address of Zahumska 8. The period for putting the objects in the ground was deliberately chosen after the hard rain, so it would be easier to dig the hole and soil to be of a more natural consistency, having in mind the longer period of drought. In the north-western part of the midden the ceramic fragment, made from secondary clay was positioned. And, in the southern part, three fragments, from quartz, quartzite and flint (Table 1: 56, 57, 58, Fig. 119) were placed. Both types of artefacts were put into the layer of yellow compact soil (probably some lesoid clay layer), which is located under the brownish layer (0.45m depth). The pit was filled in with fresh soil.

Figure 119: Chipped stone tools in Belgrade: left – experimental tools; right – position of the tools (yellow circle) and pottery fragment at the bottom (photo A. Petrović, V. Bogosavljević Petrović)

Provil casts were taken on all the samples and *before* photos were taken (Fig. 120). The idea was to observe the modifications that could alter the surface and to note all the changes and classified them. The first analysis should be done in 2022.

Figure 120: Surfaces of the tools before they were placed in the ground (photo A. Petrović)

4.8. SUMMARY OF THE RESULTS OF THE EXPERIMENTAL PROGRAMME

The experimental programme had a multifold impact on the research:

- Getting familiar with the development of the diverse use-wear patterns
- Getting familiar with the entire process – from the knapping to the utilization of the chipped stone tools
- Formation and increase of the reference collection – great variety of the traces available for the comparison with the archaeological sample
- Formation of FTIR reference collection

Trace formation is a very important element in the trials since it is the only way to observe the changes of the tool's edges. The experimental approach enables researchers to notice and mark the patterns of scars, how, with what speed they developed, and the most important, what contact material produces which kind of edge damage and polish.

The used tools developed compelling traces. Traces found on the tools that were used for cutting showed very pronounced oblique bi-directional movement, and transversal direction in the case of the tools that were used for scraping. Considering the termination of traces left by different activities, scars could easily be defined as used on soft, medium, or hard materials, except for hide scraping. In this case, the results did not directly illustrate medium material, yet the macro traces, in this case, indicated a harder matter. This happened due to the use of ochre as an additive, which produced a denser surface and a more abrasive working edge. As it was mentioned in the introduction to the experimental programme, the time between the multiple microscopical analysis is important, and 30 minutes was enough for the trace development, and it represented an excellent base for the next phase of use.

The probes involving utilization of the experimentally reproduced blades was crucial, having in mind that the blade component is present in all the assemblages that are the subject of the study. Traces on blades usually are less developed than the ones on the flakes and other tools. In the cases of straight standardized blades with a long and broad edge, the scars are not very pronounced, and it takes more time for traces and edge rounding to develop.

The fundamental part of the experimental programme was the creation of problem-oriented trials. As mentioned, the need for these specific experiments came after the observation of the archaeological tool. These results are very encouraging. However, besides the general data these experimentations offered, various explanations and scenarios that could have had happen in the case of the archaeological tools used in the settlement in Iron Gates are now known. Additionally, these experimentations provided a clearer image of the capability of the prehistoric communities that inhabited the region by revealing the actual process behind the activity.

5. RESULTS

5.1. LEPENSKI VIR RESULTS

5.1.1. Building 54

Use-wear analysis

Eleven (11) chipped stone tools from building 54 were analysed (Table 4), (Petrović and Nunziante-Cesaro 2021). Various absolute dates available for this context were published (Quitta 1975, Radovanović 1996:363, Borić 1999:49, fig. 7, Borić, Dimitrijević 2007:21), and dates that are taken as a reference for the *terminus post quem* for the construction of the building are 6393–6116 *cal BC* (Borić 2019:21). The artefacts are labelled as material coming from Layer 1, according to the division made by D. Srejović and accepted by the Polish authors (Kozłowski and Kozłowski 1984). The assemblage is representing the final chapter of building 54 and techno-typologically observed, it is of a mixed character, consisting of both Mesolithic (trapeze) and Neolithic (large, standardized blade) elements, but it also consists of chronologically insensitive components as flakes, cortical and bipolar flakes.

Table 4: Samples from building 54, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 1301	Building 54, building floor	Blade	Cutting	Bone	Hafting	Trampling, Glossy Appearance
LV 1302	Building 54, building floor	flake	Indeterminable	Non-diagnostic	Hafting	Glossy Appearance
LV 1303	Building 54, building floor	Trapeze	Cutting	Bone		Soil sheen
LV 1304	Building 54, building floor	Bladelet	Cutting, incision, engraving	Butchering	Prehension	Glossy Appearance
LV 1014	Building 54, in the ash place	Bipolar cortical flake	Scraping/ Cutting	Fresh hide/butchering	Prehension	Soil sheen
LV 1332	Building 54, building floor	Cortical flake	Indeterminable	Animal material		Soil sheen, abrasion, roots
LV 1328	Building 54, building floor	Flake	Cutting	Vegetal material		Soil sheen
LV 1323	Building 54, building floor	Fragment of a blade	Cutting	Non-diagnostic		Thermal stress, Glossy

LV 1326	Building 54, building floor	Waste	/	Not used		
LV 1002	Building 54, building floor	Retouched flake	Scraping	Dry hide		Glossy Appearance, patina
LV 1004	Building 54, building floor	Bipolar flake	General working	Wood	Prehension	Glossy Appearance

The noted alterations are modern roots (Fig. 121a) and glossy appearance (Fig. 121b) that damaged the surface and cancelled some of the micro traces, hence their interpretation was impossible.

Contact with bone was found on two pieces, including the large, standardized blade (LV 1301). The unique situation regarding the working areas and zones is noted on this blade, accordingly, there are two zones of activities. The exact chronology of use was observed on the right side: zone 2 (medial and proximal part of the blade) was used before the activity on zone 1 (distal end).

Appointed by micro traces, the preserved polish showed that the majority of the samples were working on medium and soft animal materials. A bladelet was used for butchering and a bipolar cortical blade for butchering and working fresh hide, defined by granular topography and half-tight to tight linkage, with smooth texture indicating contact with meat (Fig. 121c-d).

One artefact was used for processing the wood and one for unidentified vegetal based material. The remains of micro polish are indicating vegetal based material as a general category and it is impossible to distinguish the specific plant based on preserved traces (Figure 121e-f).

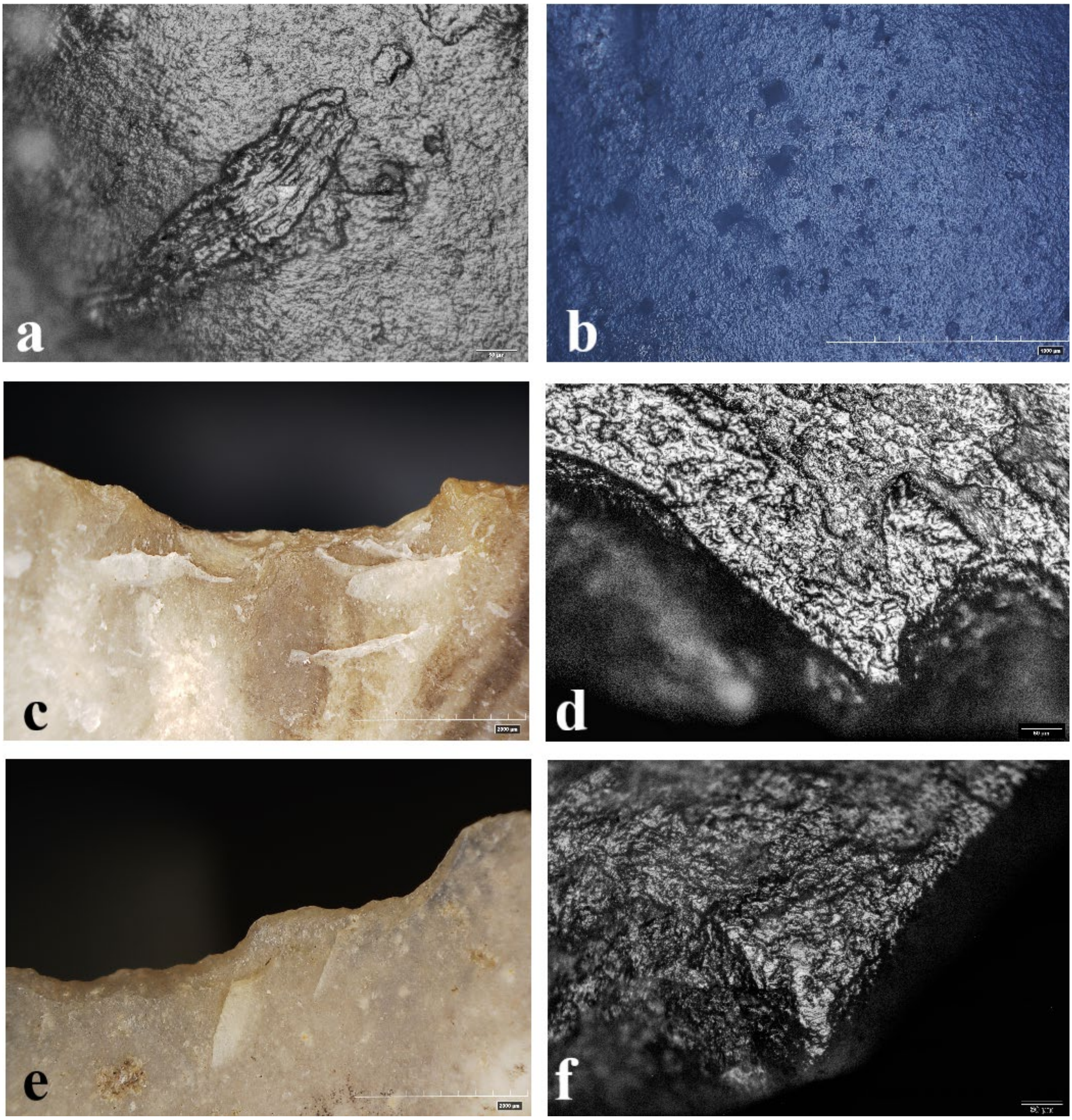


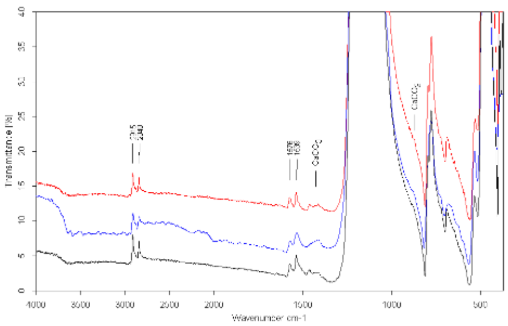
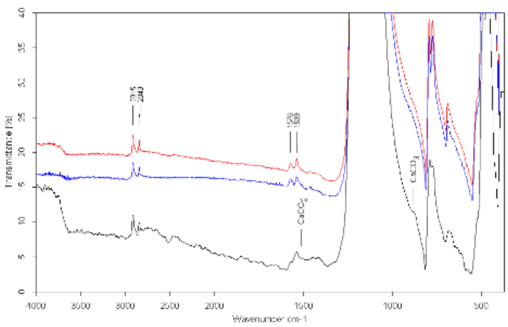
Figure 121: a) Roots, alteration, b) Glossy Appearance, c) Macro traces, medium material, butchering and fresh hide, LV 1014, d) Micro traces, butchering and fresh hide LV 1014, e) Macro traces LV 1328, f) Micro traces, vegetal material, domed to flat topography, LV 1328 (photo A. Petrović)

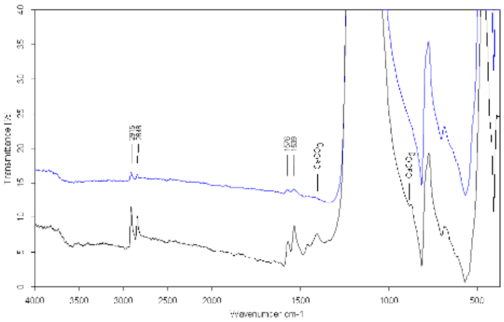
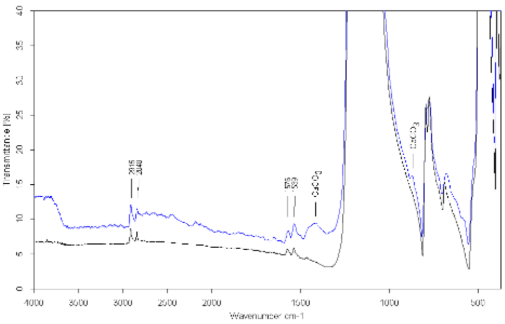
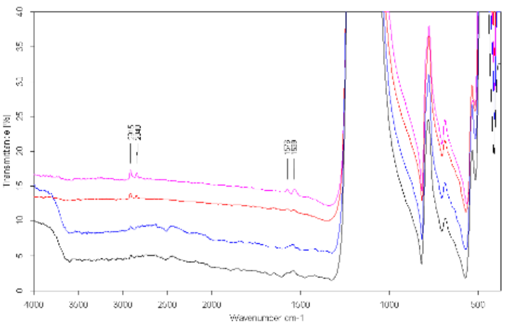
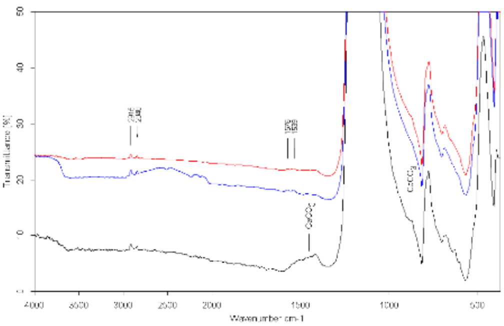
Except for the chipped stone artefacts, one globular vessel (Garašanin, Radovanović 2001) attributed to the Early Neolithic Starčevo culture, dog's lower carnassial tooth, fish remains (mostly teeth) molluscs (Dimitrijević 2008), mallet damaged by fire, broken and reused palette, and adze (Antonović 2006) were found on the floor of the building. This context is very interesting implying large varieties of the activities that took part in house 54, initially considered a core of the settlement, given the central position and its dimensions.

FTIR analysis results

Five artefacts were analysed with FTIR spectroscopy, and in all spectra (Table 5) a very intense absorption band is observed at 1157 cm^{-1}, and two medium intensity bands at 798 and 469 cm^{-1} respectively attributed to Si-O stretching and O-Si-O and\or O-Si-Al bending modes, since cryptocrystalline silica is the principal constituent of the analysed items (Madejová 2003, Vaculíková, Plevová 2005), (Petrović and Nunziante-Cesaro 2021). Doublets at 1575\1536 and 2915\2848 cm^{-1} are observed in all spectra, except the sample LV 1004 where the features are barely visible. They are respectively attributable to the C-O and C-H stretching mode of fatty acids salts (palmitate and or stearate), (Hénichart *et al.* 1982, Gönen *et al*. 2010). These compounds are present both in vegetal (Raíces *et al*. 2003, Woodfield *et al*. 2017), and animal tissues (Petrović and Nunziante-Cesaro 2021). Their presence in the case of the animal-based materials is due to the transformation of animal body fat into a greasy lipid mixture called adipocere (Stuart *et al*. 2000), as already noted in the FTIR results of experimental tools (see Chapter 4).

Table 5: Samples from building 54, Lepenski Vir, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
LV 1301	1576,1540, ~1440	Adipocere, CaCO3	
LV 1302	1540, ~1440, 877, 1576,1540	CaCO3, Adipocere	

LV 1303	1576,1540, ~1440, 877	Adipocere, CaCO3	
LV 1304	1576,1540, ~1440, 877	Adipocere, CaCO3	
LV 1014	1576,1540	Adipocere	
LV 1004	~1440, 877 1576,1540	CaCO3, Adipocere	

5.1.2. Under the level of building XLIV

Use-wear analysis

Building XLIV is the largest structure found on the site and it is also the object with the biggest number of well-known boulders at Lepenski Vir placed around the rectangular hearth. Additionally, no limestone floor was found in the area around the hearth and for this reason, it was assigned by the excavator to phase II, but the limestone flooring was found in the rear of building XLIV, assigned to phase I and named building 57. It is possible that here we are dealing with one building that was marked separately in previous studies (Borić and Dimitrijević 2008, Borić 2002).

There are three dates connected to this context, 6210-6012 cal BC – a stone construction above the floor of the house, 6068-5913 cal BC – on the house floor, 5984-5752 cal BC – burial, level of the floor (Borić and Dimitrijević 2008).

Table 6: Samples from under the level of building XLIV, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 1843	Under the level of building XLIV	Flake	/	Not used		Glossy Appearance
LV 1844	Under the level of building XLIV	Flake	Cutting	Medium material		Glossy Appearance, Roots, Mechanical Alteration

Two flakes were found under the building XLIV (Table 6) and only one had traces of use (LV 1844). Based on the oblique bidirectional trend of the macro scars, it was noted that the tool was used in the cutting motion. However, the exact contact material is not known, since only macro traces were diagnostic enough to conclude that the matter was of medium hardness.

5.1.3. Buildings 40, 41 and space between

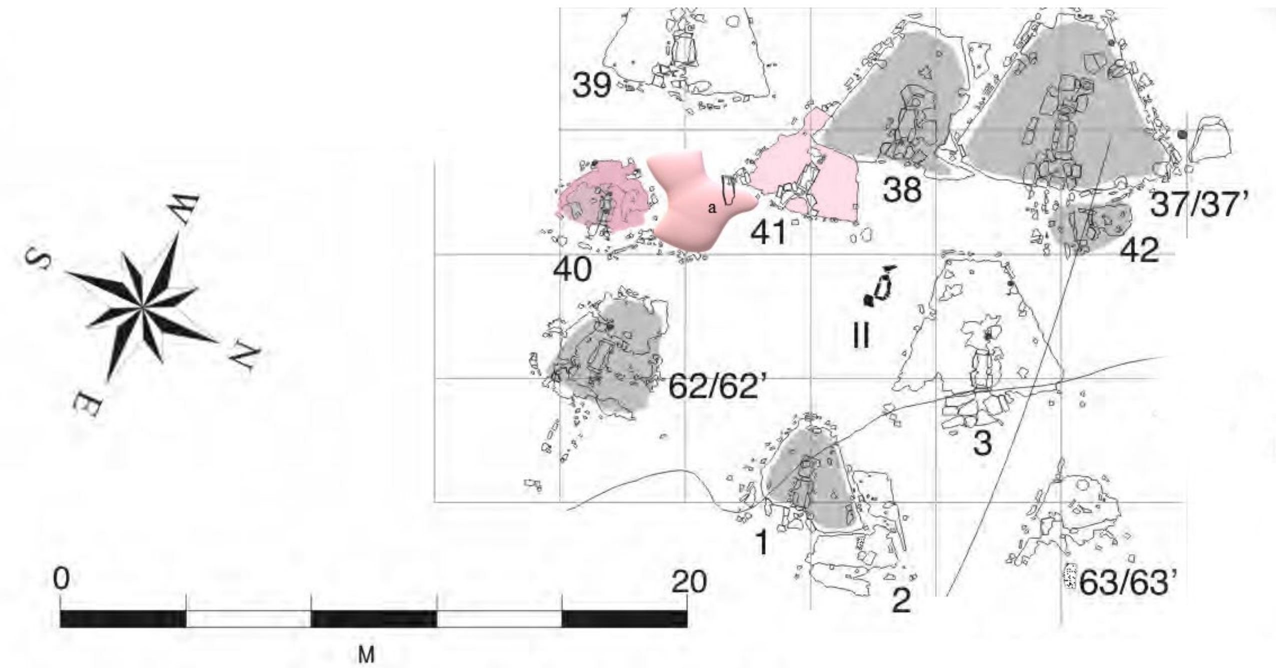


Figure 122: Position of buildings 40, 41 and space between – hearth „a“
(detail from the map from Borić and Dimitrijević 2007, illustration A. Petrović)

Building 40 (Fig. 122) was one of the houses that were most probably transformed into the burial areas, same as building 34, also discussed in this study. One sample of animal bone from the floor of house 40 was selected for dating, but it did not contain enough collagen material (Borić and Dimitrijević 2007). A core was found together with a polisher for pottery and animal bones, with cut marks indicating primary butchering (Dimitrijević 2008), (Table 7).

Hearth „a" dated to the 7740-7587 cal BC is settled between house 40 and 41 (Fig. 122), and associated with the older phase of the settlement (Borić and Dimitrijević 2007). Four (4) tools were found in the space between these two buildings without a specific indication of the exact block or area (Table 7).

There are no absolute dates available for building 41 (Fig. 122), but is it considered that it belongs to the earlier building horizon (6200-6050 cal BC) of the trapezoidal houses (Dimitrijević and Borić 2008). A mallet was found in area A of house 41 (Antonović 2006: 41,62), and regarding the chipped stone tools fifteen (15) artefacts were found on the house floor and three (3) under the floor (Table 7).

Table 7: Samples from building 40, 41 and space between, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 1458	House 40	Core	/	Not used		Glossy Appearance
LV 1792	House 41	Blade	General working	Butchering, meat		Glossy Appearance
LV 1475	House 41	Flake	Cutting, Scraping	Two activities: semi-fresh hide + ash; hide of small dimensions worked with angular movements (refinement of hide)		Glossy Appearance
LV 1476	House 41	Blade	Scraping	Fresh hide		Glossy Appearance
LV 1477	House 41	Flake	Scraping	Dry hide and soft stone		Glossy Appearance
LV 1478	House 41	Flake	Indeterminable	Non-diagnostic		Any
LV 1481	House 41	Flake	Indeterminable	Non-diagnostic		Glossy Appearance

LV 1497	House 41	Flake	Indeterminable	Soft stone	Prehensione	Glossy Appearance
LV 1500	House 41		Scraping	Dry hide		Glossy Appearance
LV 1503	House 41	Flake	Indeterminable	Non-diagnostic		
LV 1499	House 41		Indeterminable	Non-diagnostic		Glossy Appearance
LV 1505	House 41	Flake	General working	Bone + dry hide		Glossy Appearance
LV 1504	House 41	Flake	Indeterminable	Fresh hide		
LV 1507	House 41	Flake		Medium material		Glossy Appearance, Patina
LV 1508	House 41	Flake	Cutting	Non-diagnostic		
LV 1506	House 41	Flake	Indeterminable	Non-diagnostic		Glossy Appearance
LV 1794	Under the floor of house 41	Flake	Cutting	Vegetable		Glossy Appearance
LV 1795	Under the floor of house 41	Flake	/	Not used		Glossy Appearance
LV 1796	Under the floor of house 41	Blade	Indeterminable	Meat + another material		
LV 1026	Between houses 40 and 41	Flake	Indeterminable	Hide, meat		Any
LV 1023	Between houses 40 and 41	Flake	Drilling	Hard material and stone/ceramics working, operated with dirty hands, rotated a lot		
LV 1025	Between houses 40 and 41	Flake	Indeterminable	Soft hide, then dry – refinement	Hafting	
LV 1024	Between houses 40 and 41	Flake	Indeterminable	Dry hide		

A core from house 40, the only artefact from this context, had no traces of use. All the flakes from the space between building 40 and 41 displayed traces of processing the animal-based matters, like the hide in dry and fresh phase and one tool with traces of drilling hard material together with stone or ceramics.

Most of the recovered tools come from house 41 and the area underneath. Polishes connected to the animal-based materials were found on most of the tools coming from this building, as bone, hide and meat. Bone was found in the mixture with dry hide based on the flat polish on the outer edge and granular topography on the inner parts (Fig. 123a). Hide was worked in various phases, from the fresh hide to the final stages of tanning (dry hide). The dry hide is recognizable through rough texture (Fig. 123b), which is in the case of fresh hide smooth (Fig. 123c). Additionally, based on the analysed polish variables, as trace dispersal, more information about the hide dimension is available. The polish on the sample LV 1475 indicates processing (cutting and scraping) of the skins of smaller dimensions, worked by using angular movements and using the morphological shape of the flake.

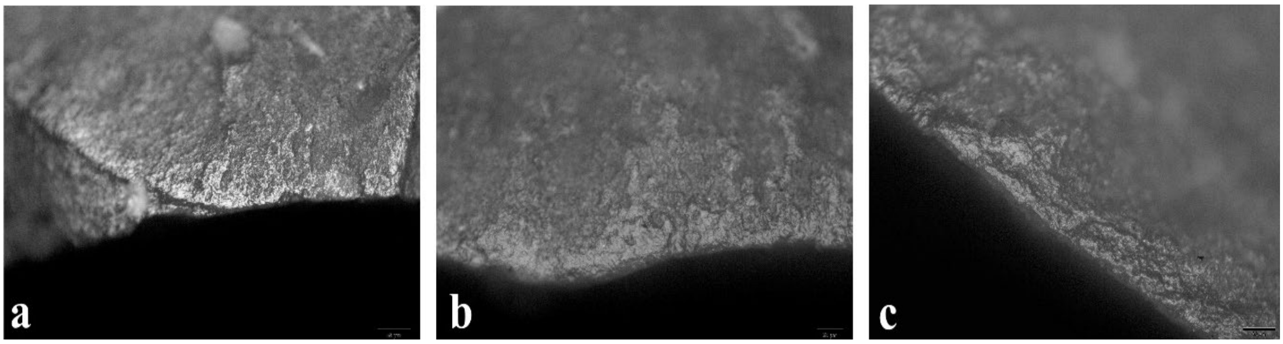


Figure 123: a) Flat topography, rougher texture in the inner parts, bone and dry hide, LV 1505 – bone and dry hide, b) Rough texture, dry hide, LV 1500, c) Smooth texture, higher brightness, fresh hide, LV 1504 (photo A. Petrović)

Regarding the other type of matters whose traces were found on the artefacts from building 41, one tool, sample (LV 1794), was used for processing the vegetal-based material. Five (5) tools were interpreted as utilized for multiple materials and they had traces of superposition, as it is, for example, working of hard materials and stone/ceramic (LV 1023), or dry hide and soft stone (LV 1477).

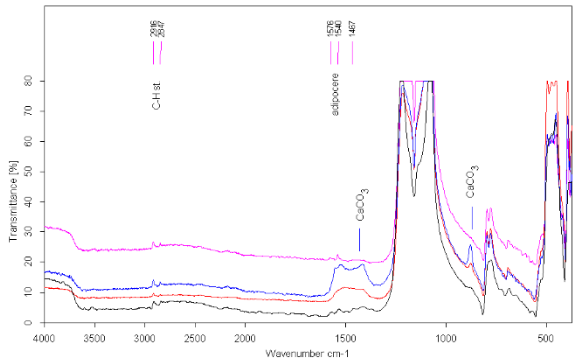
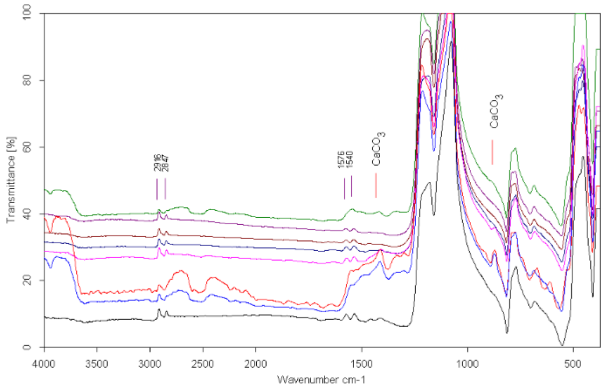
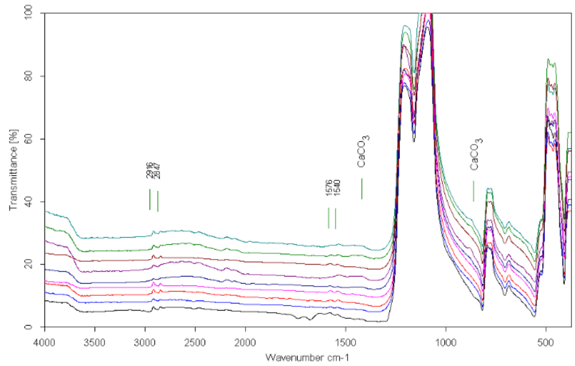
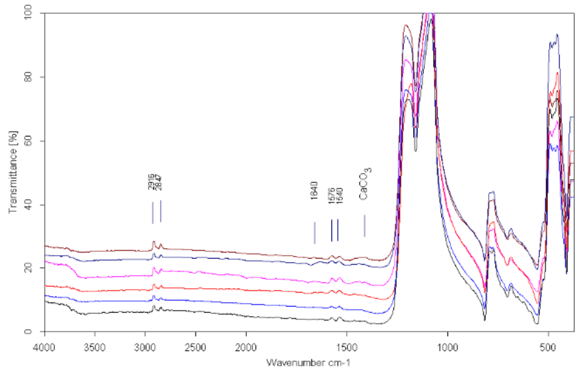
FTIR analysis results

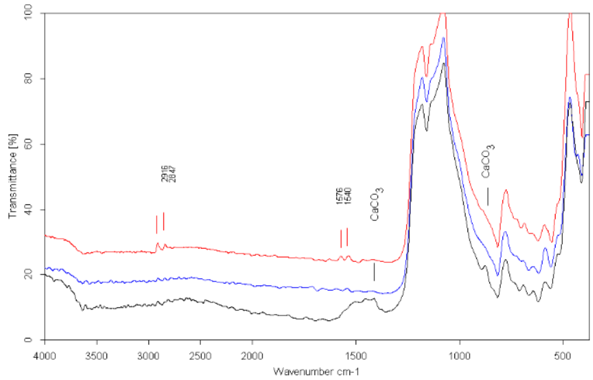
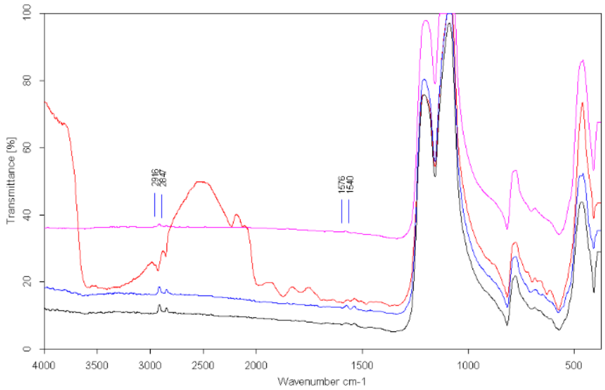
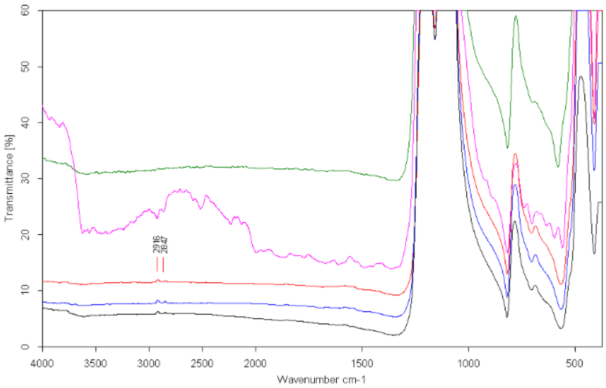
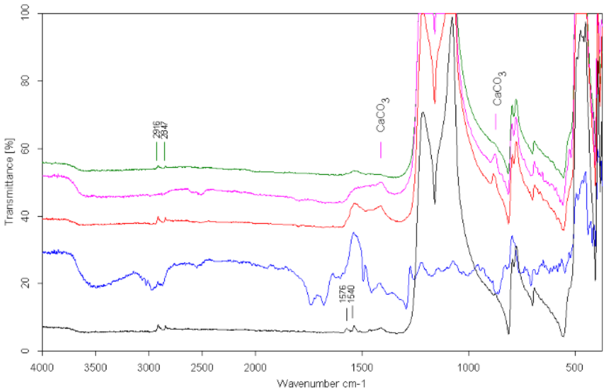
In all the analysed samples (10 artefacts, Table 8), bands at 1576,1540 cm^{-1}, interpreted as adipocere were noted, while calcium carbonate was discovered in 80% of the analysed tools.

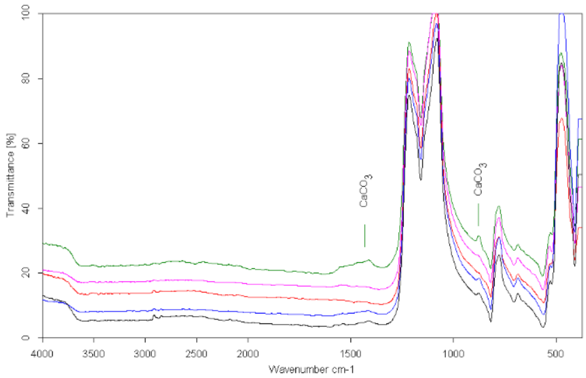
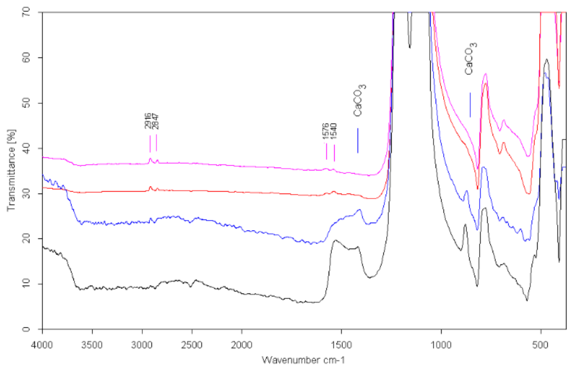
However, the found residues are, in most cases, corresponding to the results of the use-wear analysis. In spectra of the sample LV 1023 traces of adipocere are visible, which offers new insights regarding the unidentified hard material traces that were noted by functional analysis.

Nevertheless, the adipocere was also found in the sample that was used for processing the soft stone (LV 1497) and in the case of cutting vegetal material (LV 1794).

Table 8: Samples from building 40, 41 and space between, Lepenski Vir, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
LV 1475	1576,1540, 1467, 877	Adipocere, CaCO3	
LV 1023	1576,1540, ~1440, 877	Adipocere, CaCO3	
LV 1024	1576,1540 ~ 1550, ~1440, 877	Adipocere, CaCO3	
LV 1025	1576,1540, ~1440	Adipocere, CaCO3	

LV 1026	~1440, 877 1576,1540	CaCO3, Adipocere	
LV 1476	1576,1540	Adipocere	
LV 1497	1576,1540	Adipocere	
LV 1500	1576,1540, ~1440 ~ 1540, ~1420, 877	Adipocere, CaCO3	

LV 1504	1576,1540, ~1440, 877	Adipocere, CaCO3	
LV 1794	1576,1540 ~ 1540, ~1420, 877	Adipocere, CaCO3	

5.1.4. Building 28

Use-wear analysis

A date (6206-5989 cal BC) from the roe deer skull fragment, found on the floor of the house, is dating building 28. This house, according to the new sets of dates, is a part of the early construction horizon of the trapezoidal buildings. This distribution would need more absolute dates and statistical, Bayesian modelling to specify the exact building phase of the objects at Lepenski Vir (Borić and Dimitrijević 2007).

Besides the found fragmented young deer skull, asymmetrical and atypically long (over 50cm) antlers were found together with fish, and molluscs remains were found also (Dimitrijević 2008). In total, one blade was found (Table 9).

Table 9: Samples from building 28, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 1650	Building 28	Blade	Scraping/ Cutting	Left edge: hide or butchering; right edge: bone or antler; distal end: bone and superposition of meat	Prehension	Glossy Appearance

Both oblique and transversal direction of scars were noted indicating a mixed activity of scraping and cutting. The scars are of a smaller dimension, but the edge rounding is high. The blade was used on both sides, and on the left edge there are traces of hide and/or butchering, and on the right edge of a hard animal material like bone or antler, together with the traces of meat above (Fig 124a).

FTIR analysis showed bands at 1576,1540 cm^{-1} interpreted as adipocere, directly connected to the animal-based materials that were processed with this blade, and ~1450 cm^{-1} connected to the calcium carbonate that can be connected to the worked materials, but also the environment (Fig. 124b)

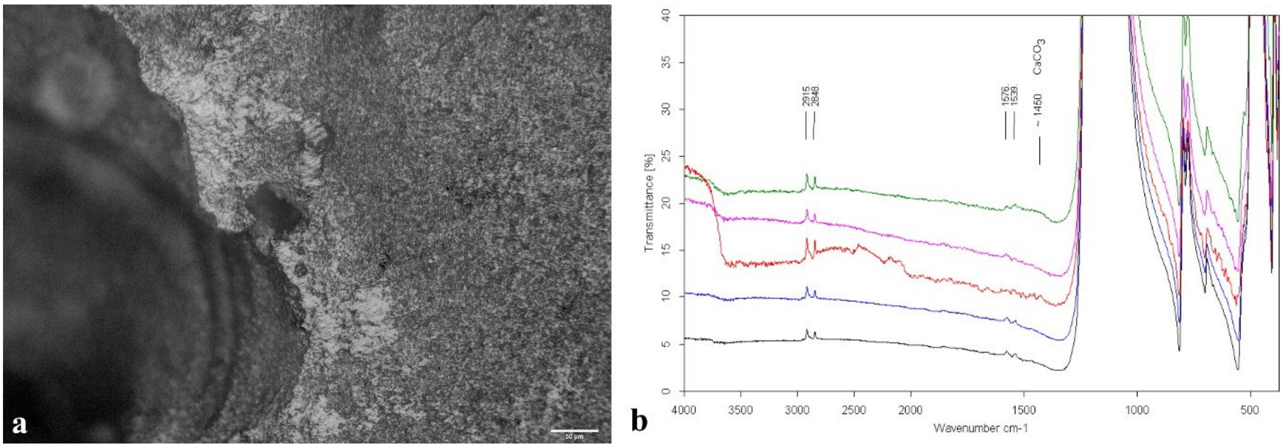


Figure 124: Sample LV 1650 a) Micro traces, flat topography and covered linkage, traces of hard animal material, b) FTIR spectra (photo A. Petrović, spectra by S. Nunziante Cesaro)

5.1.5. Building 34

Use-wear analysis

Building 34 is considered to be one of the features that were transformed to the burial ground. The house is dated to 6100-5925 cal BC, and burial 26, which was dug in behind the hearth to 6078-5880 cal BC, which is thought to be the period of the abandonment of the building (Borić and Dimitrijević 2008). Two flakes were found in house 34 (Table 10). Two lower jaws of dogs were found in house 34 together with a red deer antler fragment, and a metapodial fragment of a small ruminant, that probably represent fragments discarded in the process of tool manufacturing (Dimitrijević 2008).

Table 10: Samples from building 34, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 1664	Building 34	Flake	Cutting	Hide and butchering		
LV 1661	Building 34	Flake	/	Not used		

One flake was showed no traces of use, and another one was used for cutting hide and butchering. The micro traces of the used flake were represented by granular topography, rougher texture, tight linkage, and medium-high brightness, which are diagnostic characteristics for butchering activities (Fig. 125a)

During the FTIR analysis bands at 1576,1540 cm-1 were observed and interpreted as adipocere confirming the use-wear analysis (Fig. 125b).

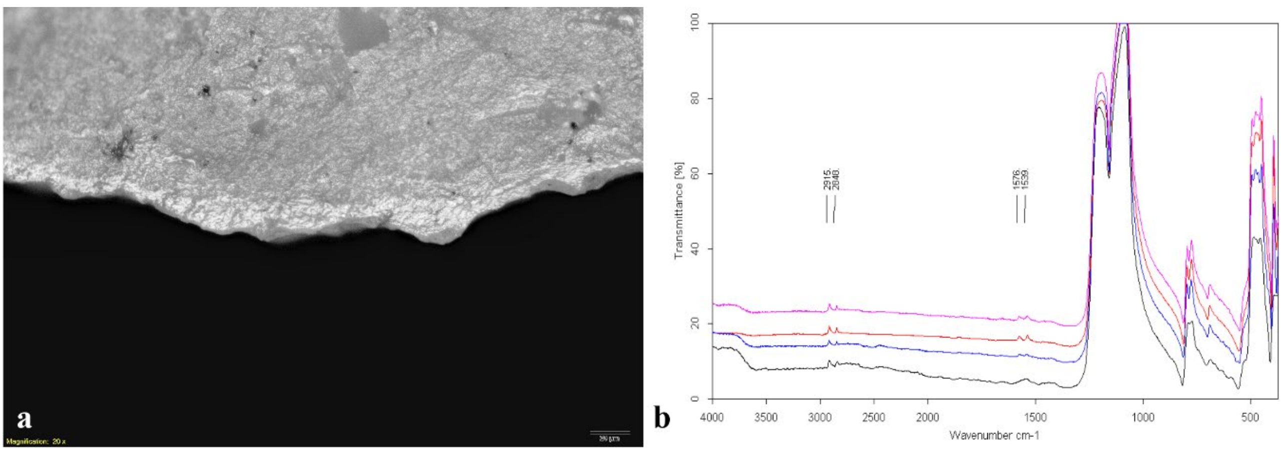


Figure 125: Sample LV 1664 a) Micro traces, granular topography, rough texture, tight linkage, and medium brightness, hide and butchering traces, b) FTIR spectra (photo A. Petrović, spectra by S. Nunziante Cesaro)

5.1.6. Building 37

Use-wear analysis

Five (5) flakes were found in the context of building 37, either in the pit or under the house floor (Table 11). The bone tool from the floor of building 37 is dated to 6071-5992 cal BC. This is the youngest and the largest construction in the stratigraphical sequence of partially overlaying objects (hearth a, building 41, 38 and 37), (Borić and Dimitrijević 2008).

Table 11: Samples from the different areas from building 37, Lepenski Vir, use-wear results

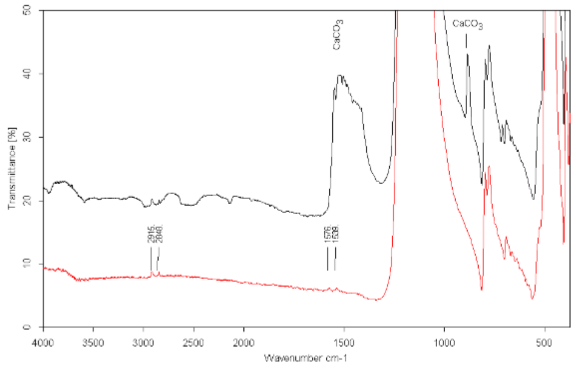
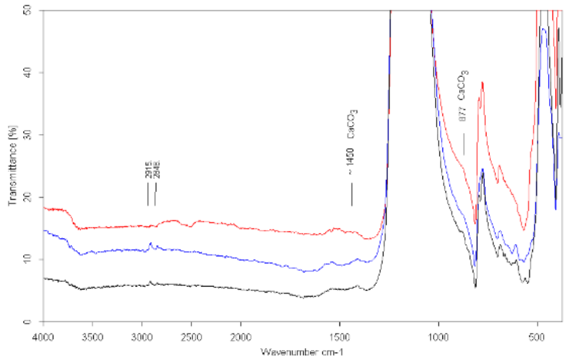
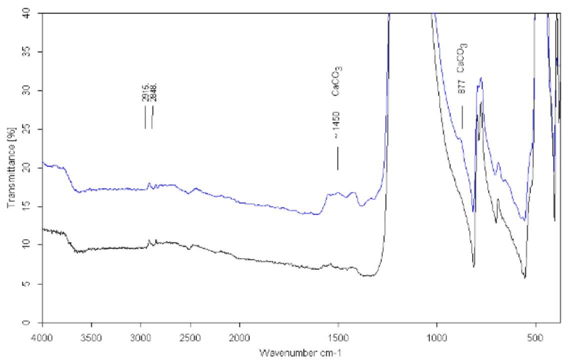
SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 1929	Under the floor of building 37	Flake	Scraping	Dry hide (in the process of drying)		
LV 1931	Under the floor of building 37	Flake	Cutting	Herbaceous plant, worked on the ground		
LV 1928	Under the floor of building 37	Flake	/	Not used		Glossy Appearance
LV 1386	Building 37, from a pit	Flake	General working	Animal tissues		
LV 1384	Building 37, from a pit	Flake	General working	Butchering		

One flake showed no traces of use, while one sample, from the area under the floor of the building, was used for scraping dry hide, or hide in the process of drying (LV 1929), based on the granular topography and rough texture, and for cutting herbaceous plants (LV 1931), based on domed topography. Regarding the tools (LV 1386, 1384) found in the pit inside the house, they were used for processing the animal tissues and butchering.

FTIR analysis results

The four observed samples showed traces of residues that are analogous to the use-wear analysis (Table 12). Traces of adipocere were found only in the sample LV 1929, used for scraping the dry hide. In the case of the flake used for working the vegetal-based materials (LV 1931) only bands of calcium carbonate were found (~ 1520. ~1410, 877 cm^{-1}).

Table 12: Samples from the different areas from building 37, Lepenski Vir, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
LV 1929	~ 1520, 877 1576,1540	CaCO3, Adipocere	
LV 1931	~ 1520, ~1410, 877	CaCO3	
LV 1386	~ 1500, 877	CaCO3	

5.1.7. Building 32

Use-wear analysis

In total 27 artefacts (Table 13) were found in building 32, which is, as it was mentioned, stratigraphically connected to two other houses (20, 33), and is the youngest house in the sequence, dated to 6061-5902 cal BC (Borić and Dimitrijević 2007:24). Three tools, two scrapers and a flake, were found in the ash place of the house. The chipped stone tools were found together with a fine-grained limestone pebble without traces of trimming and use (Antonović 2006 41, 92, Catalogue 113). Regarding the animal remains on the floor, an upper canine of dog, lower second incisor and a proximal metatarsal of red deer and fish were found (Dimitrijević 2008).

Table 13: Samples from building 32, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 1377	Building 32, ash place	Scraper	General working	Bone + ash	Prehension	Thermal stress
LV 1378	Building 32, ash place	Scraper	Scraping	Fish working		
LV 1379	Building 32, ash place	Flake	Cutting	Hide		
LV 1392	Building 32	Blade	Indeterminable	Non-diagnostic		
LV 1393	Building 32	Flake	Cutting General working	Bone + another use (abrasion)		
LV 1394	Building 32	Flake	Cutting	Non-diagnostic		Glossy Appearance
LV 1336	Building 32	Flake	/	Not used		
LV 1380	Building 32	Blade	/	Not used		
LV 1381	Building 32	Blade	Scraping	Soft stone		
LV 1382	Building 32	Flake	Cutting	Non-diagnostic		

LV 1383	Building 32	Flake	General working	Butchering		Glossy Appearance, Bright spots
LV 1347	Building 32	Flake	Indeterminable	Non-diagnostic	Hafting	Any
LV 1348	Building 32	Blade	/	Not used		
LV 1349	Building 32	Flake	Indeterminable	Non-diagnostic		
LV 1344	Building 32	Flake	Cutting	Animal material		Thermal stress, Glossy Appearance
LV 1345	Building 32	Flake	Indeterminable	Non-diagnostic		Glossy Appearance
LV 1340	Building 32	Flake	Cutting	Medium material		Thermal stress
LV 1339	Building 32	Flake	Indeterminable	Non-diagnostic		Glossy Appearance
LV 1341	Building 32	Flake	Cutting	Non-diagnostic		Thermal stress, Glossy Appearance
LV 1343	Building 32	Flake	Indeterminable	Non-diagnostic		Thermal stress
LV 1342	Building 32	Flake	Scraping/Cutting	Medium-hard material		Glossy Appearance
LV 1673	Building 32	Flake	Cutting	Soft material		Roots, chemical alteration
LV 1674	Building 32	Flake	Indeterminable	Medium-hard material		
LV 1676	Building 32	Flake	Indeterminable	Non-diagnostic		Mechanical alterations
LV 1677	Building 32	Flake	Indeterminable	Non-diagnostic		Thermal stress
LV 1672	Building 32	Flake	General working	Hide in processing		Glossy Appearance
LV 1675	Building 32	Flake	Cutting	Non-diagnostic		

Three tools (3) have not been used. Twelve (12) are non-diagnostic, out of which three (3) were employed in cutting activities. The 56% of the sample from the Building 32 has alterations. Among them, glossy appearance (Fig. 126a), abrasion (Fig. 126b), followed by thermal stress are the most common ones. Four (4) tools have only macro traces because micro traces were altered by PDSMs.

Animal-based materials were detected on 7 tools, such as working of bone, bone (with additives), hide in diverse phases and fish processing. One (1) tool was used for scraping soft-stone. Only two tools have traces of hafting and prehension.

Bone and ash were detected as a polish with flat topography, where the ash was noted based on the bright layer of polish (Fig. 126c). As mentioned, hide was noted in various phases from fresh hide to semi-dry, dry hide based on the polish texture (Fig. 126d).

The use of scraper (LV 1378) was confirmed based on the experimental trials and results from previous studies (Clemente-Conte et al. 2020; Van Gijn, 1984/85/86). Macro traces were regular continuous mostly step (Fig. 126e), while the edge rounding is formed and the polish has granular topography with half-tight to the tight linkage, which can be related to meat processing. However, the diffusion of the polish inside the edge fracture is distinctive, previously not observed at Lepenski Vir assemblage (Fig. 126f). The same type of polish dispersal was noted on the experimental tools and archaeological samples from Vale Marim and Vale Pincel (Clemente-Conte et al. 2020), and the same polish penetration is also visible on the experimental flake used for gutting (see Chapter 4).

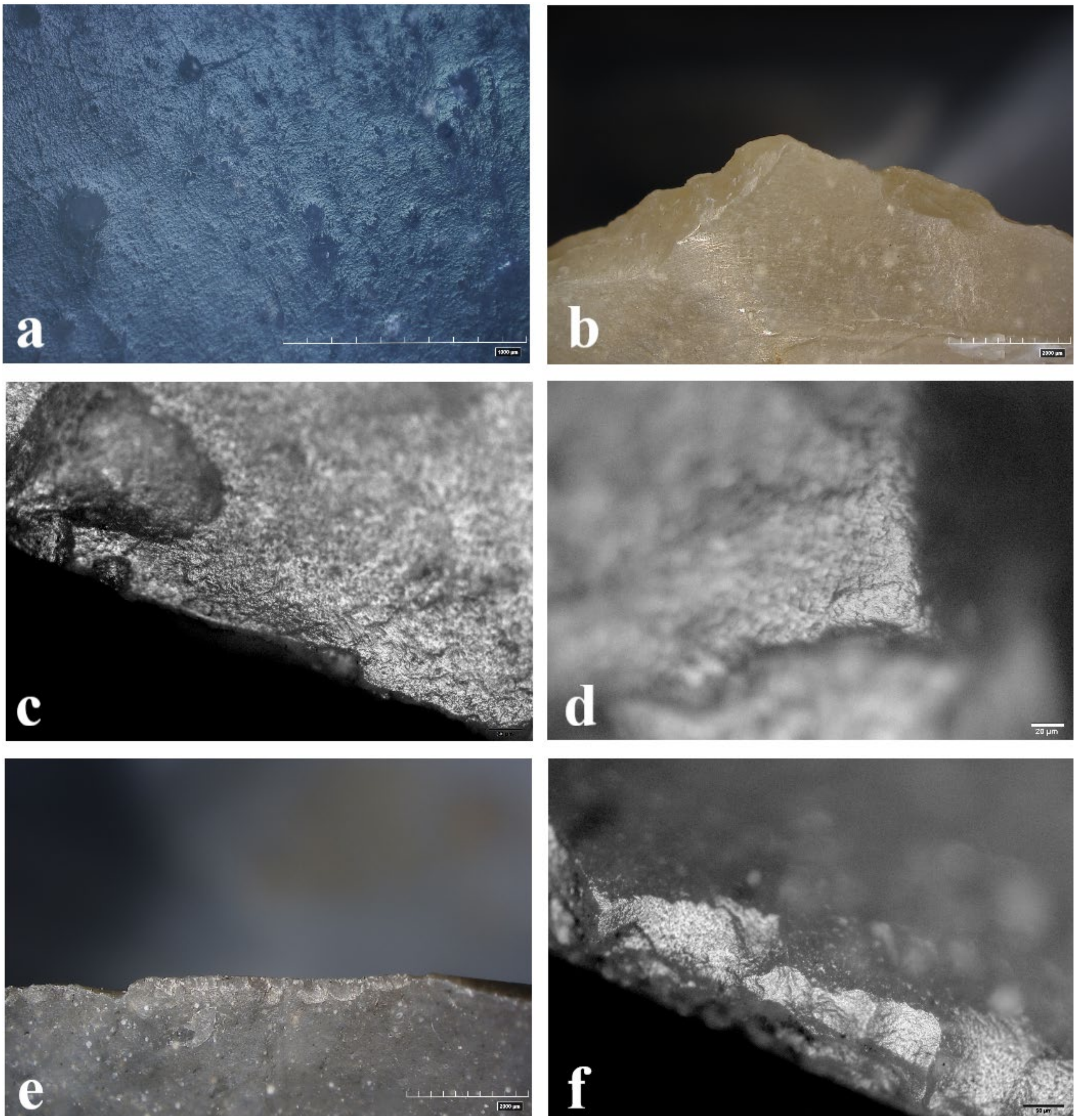
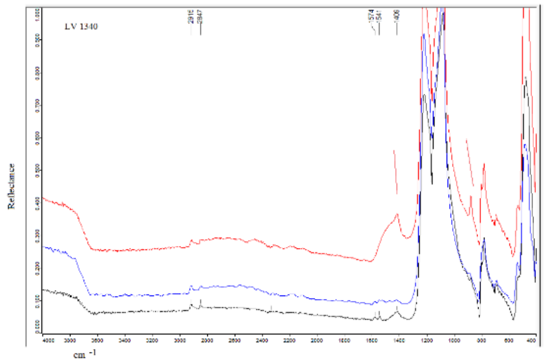
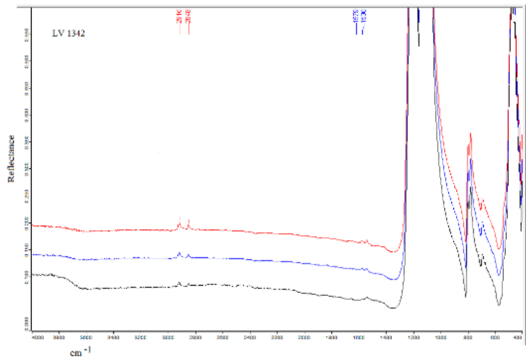
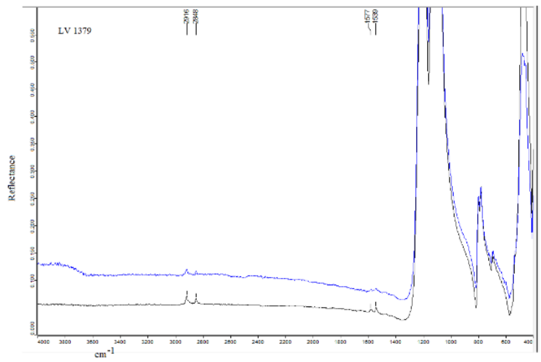


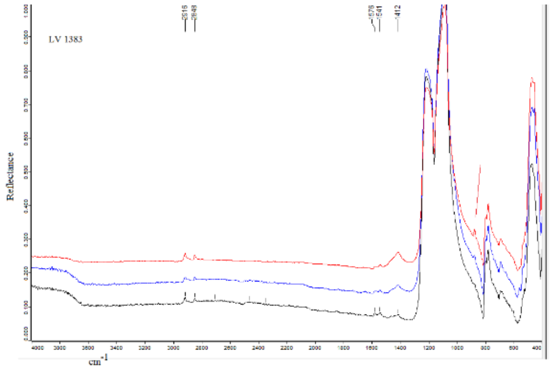
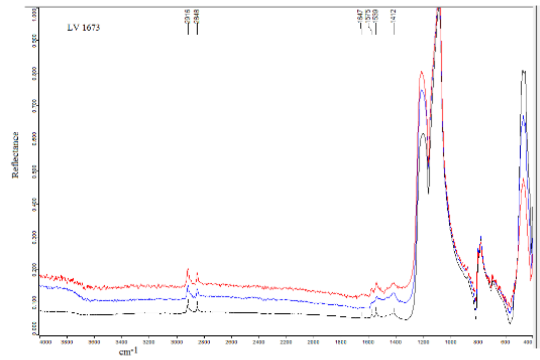
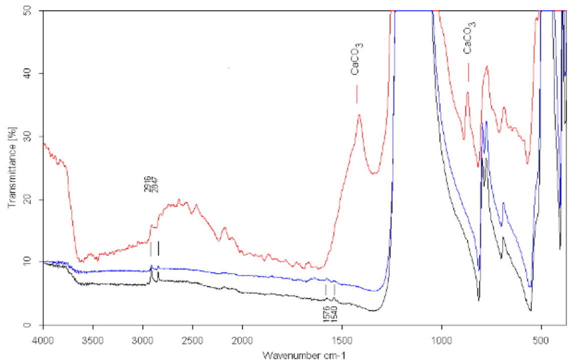
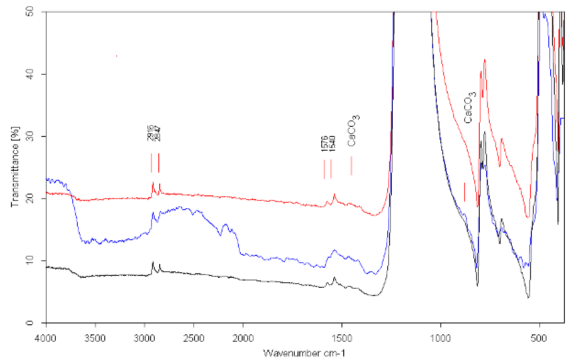
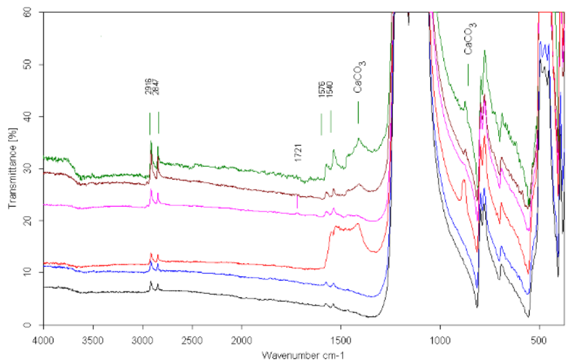
Figure 126: a) Glossy Appearance, b) Surface abrasion, c) Micro traces, bone and ash LV 1377,
d) Micro traces, hide in processing LV 1672, e) Macro traces LV 1378,
f) Micro traces, polish penetration, fish processing, LV 1378 (photo A. Petrović)

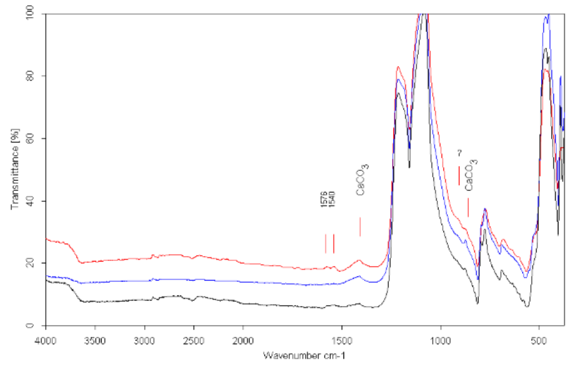
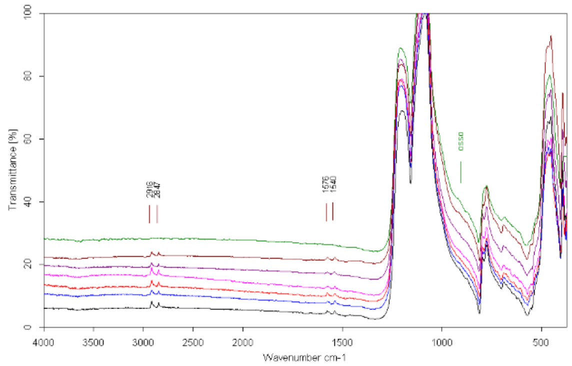
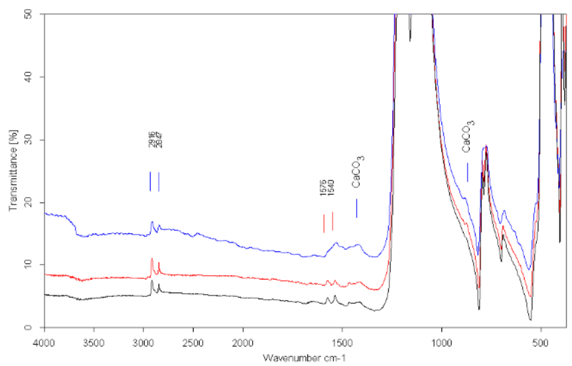
FTIR analysis results

In total eleven (11) artefacts were analysed with FTIR spectrometry (Table 14). In all the samples bands at 1576,1540 cm^{-1} are observed and interpreted as adipocere. As it can be compared with the use-wear analysis (Table 13), the tools analysed with FTIR are either used for processing animal-based materials or their micro characterisation is non-diagnostic, which in some cases can help in further clarification of worked materials. Band partially corresponding to the bone at ~913 cm^{-1} has been noted at the sample LV 1393, which was used for working the bone and some other, unidentified, abrasive material. The presence of chemical indication for the working of the bone are not frequently present at the Iron Gates assemblage, at least not in the quantity confirmed by use-wear analysis, thus this kind of FTIR results represent important indications for production of osseous material that was recovered.

Table 14: Samples from building 32, Lepenski Vir, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
LV 1340	1576,1540, ~1420,877	Adipocere, $CaCO_3$	
LV 1342	1576,1540	Adipocere	
LV 1379	1576,1540	Adipocere	

LV 1383	1576,1540, ~1420,877	Adipocere, CaCO3	
LV 1673	1576,1540, ~1420,877	Adipocere, CaCO3	
LV 1339	1576,1540, ~1410, 877	Adipocere, CaCO3	
LV 1377	1576,1540, ~1410, 877	Adipocere, CaCO3	
LV 1378	1576,1540, ~1510, ~1420,877	Adipocere, CaCO3	

LV 1381	1576,1540, ~1440, 877	Adipocere, CaCO3	
LV 1393	1576,1540, ~913	Adipocere, CaCO3, bone (?)	
LV 1672	1576,1540, ~1440, 877	Adipocere, CaCO3	

5.1.8. Building 8

Use-wear analysis

In building 8, dated to the 6010-5845 cal BC (Borić and Dimitrijević 2006) two tools were found, a flake and a blade (Table 15). A granite hammer was found together with Starčevo pottery, bone tools, amulets and a mass of broken stone overlaying the hearth at the bottom of a layer (Antonović 2006: 39, 81, Catalogue 78).

Table 15: Samples from building 8, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 1486	House 8	Flake	Cutting	Antler		Glossy Appearance
LV 1487	House 8	Blade	Cutting/sawing	Antler		Glossy Appearance

Both tools, flake and a blade, were used for cutting and sawing antlers and were affected by glossy appearance. The edge-rounding is high in both cases and represented with flat to melting topography, and tight to covered linkage (Fig. 127a-b).

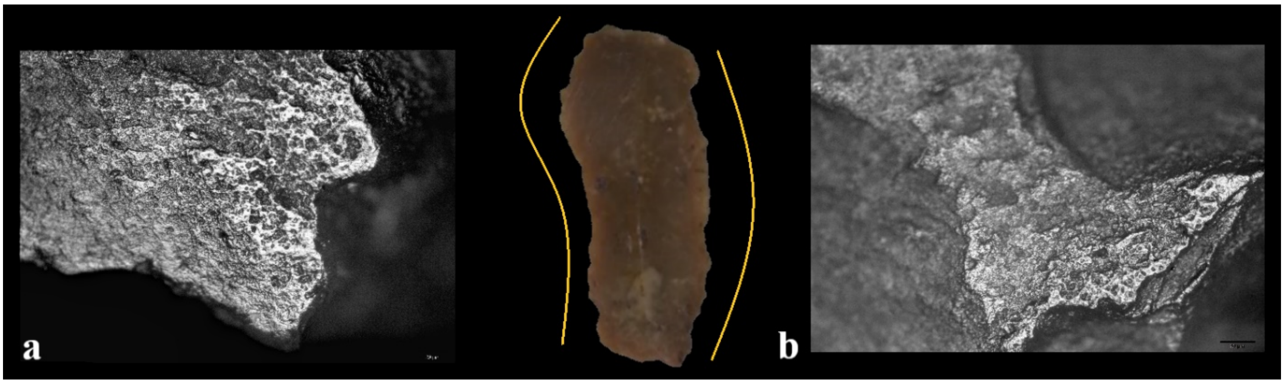
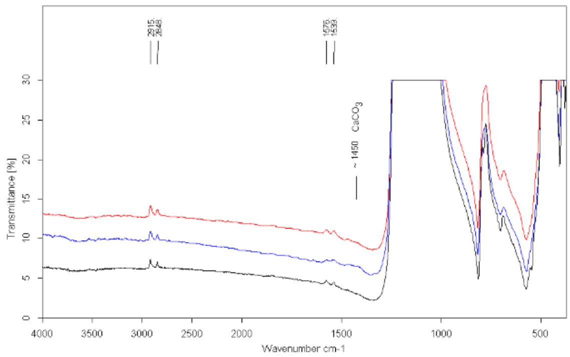
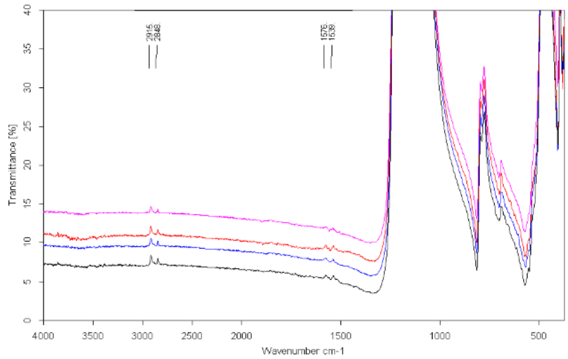


Figure 127: sample LV 1487, processing antler a) Flat and melting topography, b) Tight to covered linkage (photo A. Petrović)

FTIR analysis results

FTIR analysis in both cases showed bands at 1576,1540 cm^{-1} interpreted as adipocere, and a band at ~1450 cm^{-1} in the case of the flake (sample LV 1486) which is attributed to the calcium carbonate (Table 16). However, except for the CaCO3, which could be partially connected to the processing of the antler, no other specific elements, that are usually present, as phosphorus are noted. Having in mind the observed results, it should be highlighted that the tools were cleaned several times and that the residues, in these cases, were probably too scarce to be detected.

Table 16: Samples from building 8, Lepenski Vir, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
LV 1486	1576,1540, ~1540	Adipocere, CaCO3	
LV 1487	1576,1540,	Adipocere	

5.1.9. Buildings 26' and 26

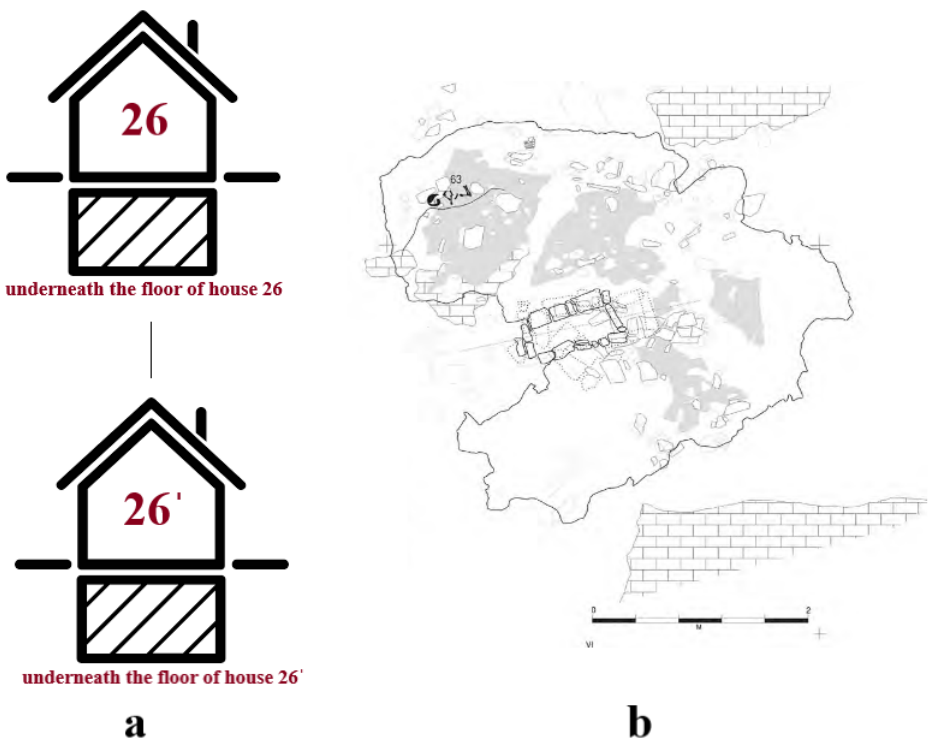


Figure 128: a) Illustration of the overlapping buildings 26' and 26, b) Building 26' overlapped by Building 26 (map of the buildings by Borić and Dimitrijević 2007, illustration by A. Petrović)

Use-wear analysis

Houses 26 and 26' are some of the overlapping buildings found at the Lepenski Vir site (Fig. 128a-b). The oldest date is 8218-7794 cal BC, and it comes from the antler found on the floor of house 26'. However, it is considered to be a case of taphonomic deposition of archaeological material coming from the surrounding layer, which was used for burying the building 26' after it was abandoned. In house 26' the tine of a red deer antler, remains of a dog, fish remains, shells together with many small fragments of unidentifiable mammal bones were collected (Dimitrijević 2008) together with an anvil (Antonović 2006: 40,78, Catalogue 71). Underneath the floor of the building 26' two flakes were found (Table 17).

In the area underneath the building 26 two dates were recovered (6212-6025 cal BC and 6091-5926 cal BC). In this context seventeen (17) pieces of chipped stone tools were found (Table 17).

A date in the range 6023-5849 cal BC is dating the house 26 (Borić and Dimitrijević 2007). On the floor of the building 26 red deer antlers and dog remains were found, and a chisel (Antonović 2006: 40, 114, Catalogue172). Nine (9) chipped stone tools were found on the floor of the house and two flakes outside the building, and they were analysed (Table 17).

Table 17: Samples from buildings 26' and 26, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 1845	Under the floor of house 26'	Flake	Cutting, Scraping	Fresh hide	Prehension	
LV 1846	Under the floor of house 26'	Flake	Indeterminable	Non-diagnostic		Glossy Appearance
LV 1764	Under the floor of house 26	Flake	Indeterminable	Hide	Wooden haft	
LV 1762	Under the floor of house 26	Flake	Indeterminable	Non-diagnostic	Prehension	
LV 1788	Under the floor of house 26	Flake	Cutting	Non-diagnostic		
LV 1776	Under the floor of house 26	Core	Cutting	Medium, abrasive material		Thermal stress
LV 1787	Under the floor of house 26	Flake	Indeterminable	Non-diagnostic		
LV 1767	Under the floor of house 26	Blade	Cutting	Silicious plant		
LV 1784	Under the floor of house 26	Blade	Cutting	Medium material		
LV 1765	Under the floor of house 26	Flake	Cutting	Woody	Prehension	
LV 1778	Under the floor of house 26	Flake	Scraping	Soft material		
LV 1786	Under the floor of house 26	Flake	Cutting, incision	Medium - soft material		
LV 1775	Under the floor of house 26	Flake	Cutting	Medium, abrasive material		
LV 1781	Under the floor of house 26	Flake	Cutting	Meat		

LV 1780	Under the floor of house 26	Flake	Cutting	Hide		
LV 1782	Under the floor of house 26	Flake	Cutting	Non-diagnostic		Trampling
LV 1783	Under the floor of house 26	Blade	Cutting	Soft material		
LV 1766	Under the floor of house 26	Flake	Indeterminable	Medium-hard material		
LV 1785	Under the floor of house 26	Flake	Indeterminable	Hide		
LV 1648	House 26, outside	Flake	Cutting	Vegetal material	Prehension	Glossy Appearance
LV 1649	House 26, outside	Flake	Cutting	Non-diagnostic		Glossy Appearance
LV 1653	House 26	Blade	Cutting	Hide + ash		
LV 1669	House 26	Scraper	Cutting, Scraping	Soft material		Glossy Appearance
LV 1371	House 26	Flake	Indeterminable	Non-diagnostic		Glossy Appearance
LV 1372	House 26	Flake	Indeterminable	Hide		
LV 1373	House 26	Flake	Indeterminable	Soft material	Prehension	
LV 1374	House 26	Flake	Cutting	Hide		Any
LV 1375	House 26	Flake	Cutting	Butchering		Glossy Appearance
LV 1402	House 26	Cortical Flake	/	Not used		
LV 1404	House 26	Flake	/	Not used		

The importance of the assemblages found in the different areas of buildings 26'and 26 is immense since this was one of the overlapping building where more phases of inhabitation were recorded. The oldest dated context (under the floor of house 26') and youngest (house 26) contain tools used for processing the animal-based materials, together with non-diagnostic and not used tool.

The tools found in the context dated to the trapezoidal buildings however indicate various activities with diverse matters, from the animal-based materials, like meat and hide (Fig 129a) to the vegetal matters as silicious plants, wood, and tools where micro traces did not provide enough data (Fig 129b).

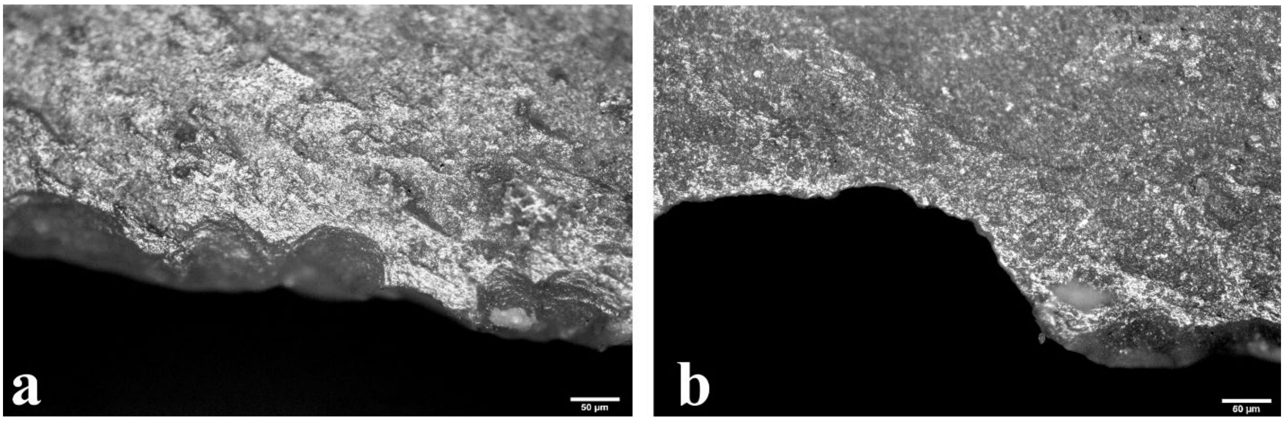
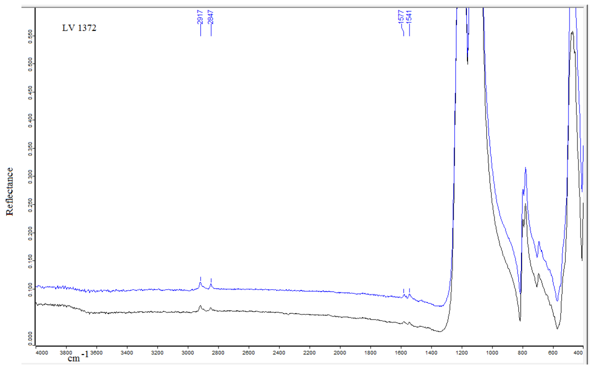
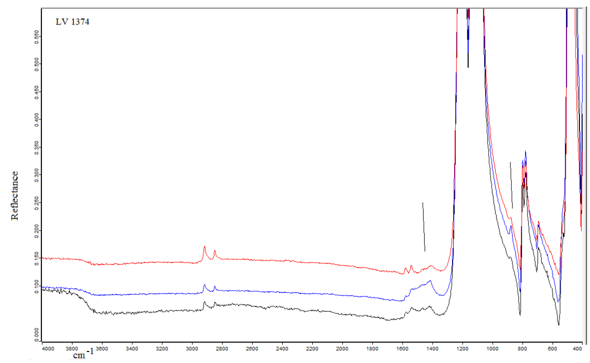
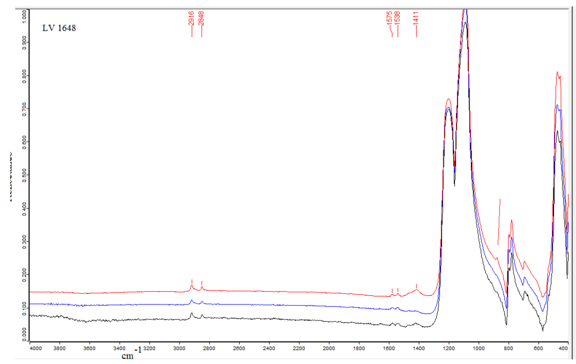
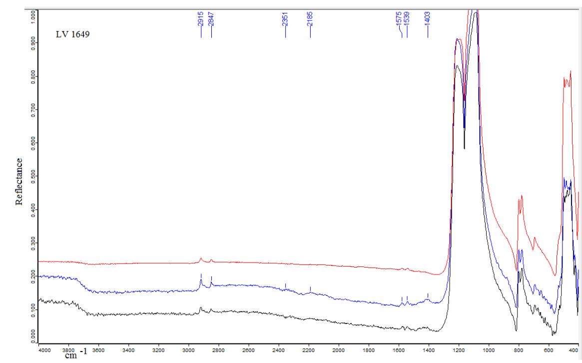


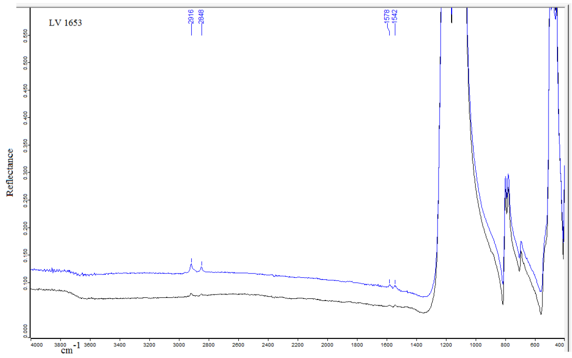
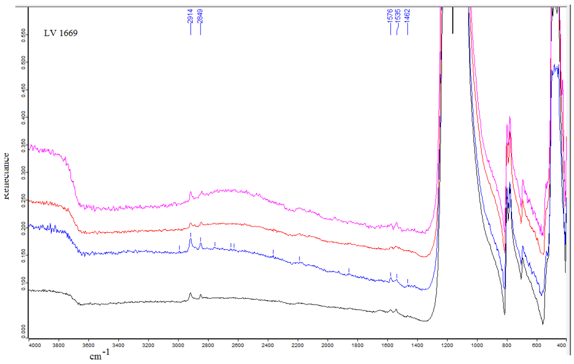
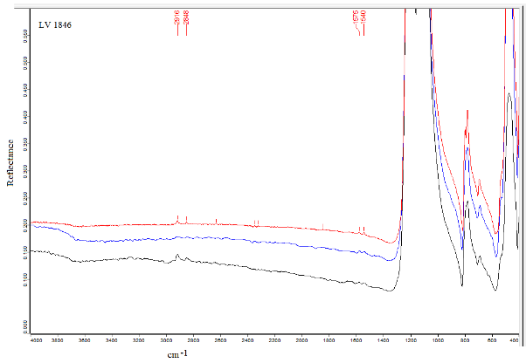
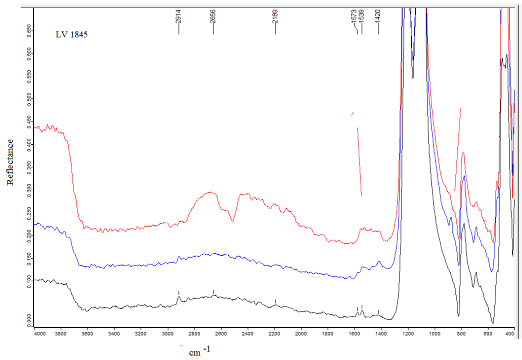
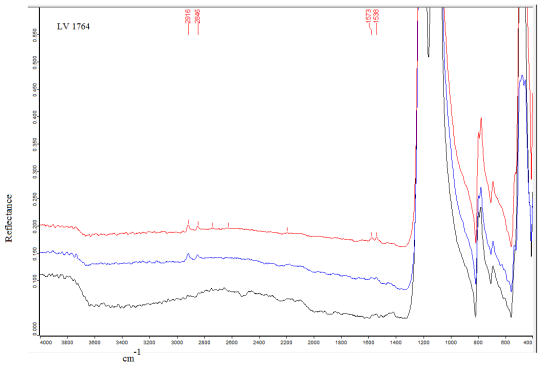
Figure 129: a) Hide processing, LV 1780, under the floor of house 26, b) Cutting medium, abrasive material, LV 1775, under the floor of house 26 (photo A. Petrović)

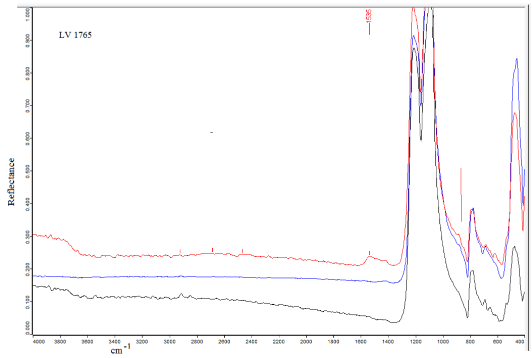
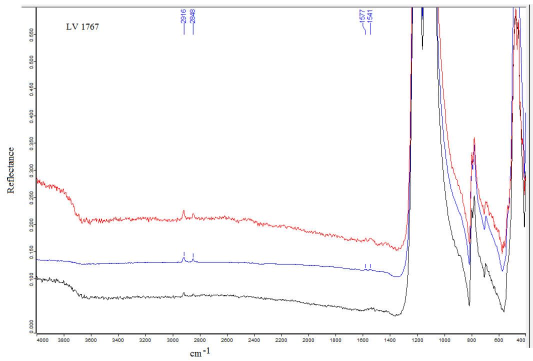
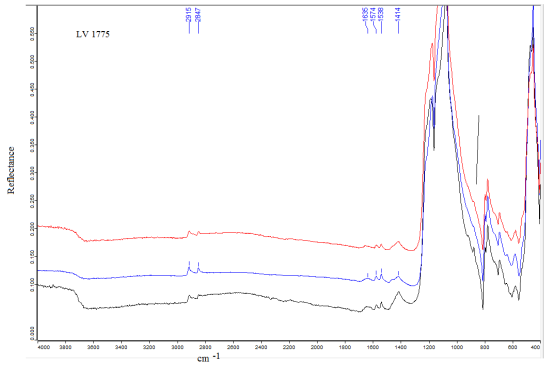
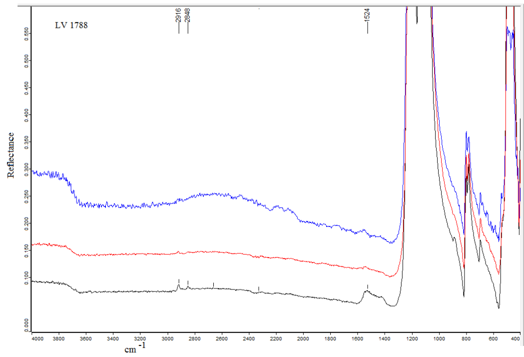
FTIR analysis results

In total thirteen (13) tools were analysed with FTIR spectrometry (Table 18). Bands at 1576, 1540 cm^{-1} are interpreted as adipocere, bands at ~ 1540, ~1420, 877 cm^{-1} as Calcium Carbonate, and in sample LV 1775 the point at 913 cm^{-1} indicated the presence of a bone. This sample was characterised as used for cutting the medium, abrasive material. The residue remains can indicate the possibility that the flake was maybe used for bone processing.

Table 18: Samples from building 26ˈ and 26, Lepenski Vir, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
LV 1372	1576,1540	Adipocere	
LV 1374	1576,1540, ~1420, 877	Adipocere, CaCO3	
LV 1648	1576,1540 ~1420, 877	Adipocere, CaCO3	
LV 1649	1576,1540 ~1420,	Adipocere, CaCO3	

LV 1653	1576,1540	Adipocere	
LV 1669	1576,1540	Adipocere	
LV 1846	1576,1540	Adipocere	
LV 1845	1576,1540 1540 ~1420 877	Adipocere, CaCO3	
LV 1764	1576,1540	Adipocere	

LV 1765	1540 ~1420, 877	$CaCO_3$	
LV 1767	1576,1540	Adipocere	
LV 1775	~1650, 1576,1540 ~1420, 913 877	Adipocere, $CaCO_3$, bone	
LV 1788	1540 ~1420, 877	$CaCO_3$	

5.1.10. Buildings 47' and 47

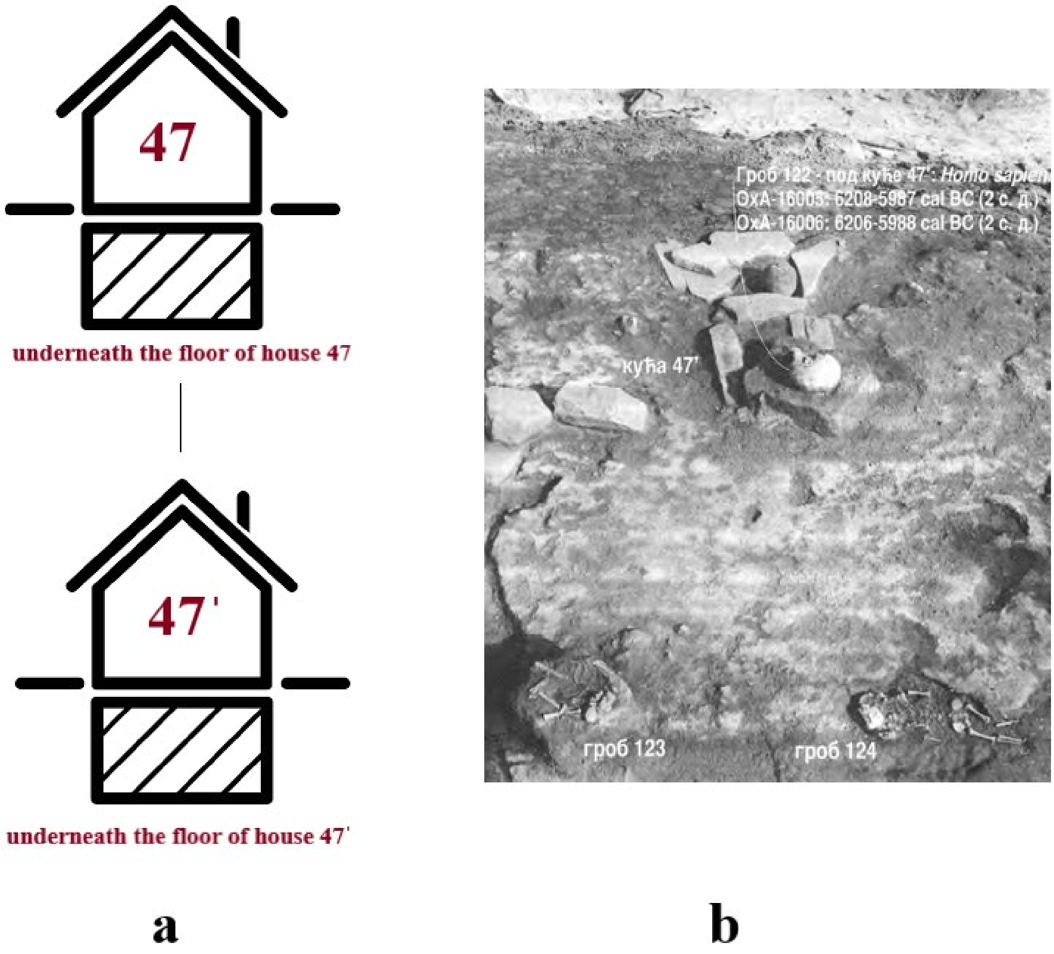


Figure 130: a) Illustration of the overlapping buildings 47' and 47, b) Building 47' (photo from Borić and Dimitrijević 2007, illustration by A. Petrović)

Use-wear analysis

There are a couple of dates that are recovered in the stratigraphically connected buildings 47' and 47 (Fig. 130a-b). The date from underneath the floor of house 47' (9441-9241 cal BC) is the oldest date from Lepenski Vir and it confirmed that this location was inhabited in the Early Mesolithic, similarly to the other sites in the region as Padina and Vlasac (Borić and Dimitrijević 2007). In this context five (5) chipped stone tools were recovered (Table 19).

Two dates are connected to the building 47', an older one (9295-8926 cal BC), which is probably from the secondary deposition of the material that ended up in the soil used for building the house floor, and the second one (the sample was double-dated – 6208-5987/6206-5988 cal BC). Seven chipped stone tools were found in this context (Table 19), together with two anvils and a retoucher.

On the floor of house 47 two flakes and 2 mallets were found. Regarding the animal remains three carbonized and fragmented scapulae (from red deer, wild boar, roe deer) were found, indicating remains of meat consumption (Dimitrijević 2008).

Table 19: Samples from building 47' and 47, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 1490	Under the floor of house 47'	Flake	Cutting	Medium-hard material		
LV 1491	Under the floor of house 47'	Flake	Cutting	Hard, medium material, abrasive material	Prehension	Bright spots, Patina
LV 1494	Under the floor of house 47'	Flake	Scraping	Hard		
LV 1495	Under the floor of house 47'	Flake	Cutting, Scraping	Bone	Prehension	
LV 1496	Under the floor of house 47'	Flake	Cutting, Scraping	Animal tissues, butchering	Prehension	Glossy Appearance
LV 1812	Under the floor of house 47	Blade	Cutting	Hide		
LV 1808	Under the floor of house 47	Flake	/	Not used		
LV 1807	Under the floor of house 47	Flake	Cutting, Scraping	Tribulum		
LV 1809	Under the floor of house 47	Flake	Cutting	Hide		Glossy Appearance
LV 1811	Under the floor of house 47	Flake	Cutting	Soft material		
LV 1814	Under the floor of house 47	Flake	Cutting	Hide, butchering		
LV 1813	Under the floor of house 47	Flake	/	Not used		Glossy Appearance
LV 1040	From the floor of house 47	Flake	Cutting	Medium material	Prehension	Glossy Appearance
LV 1041	From the floor of house 47	Flake	Indeterminable	Non-diagnostic		

Three tools from under the floor of house 47' displayed traces that could be connected to the working of the hard and medium-hard materials. One was used for cutting and scraping of the bone, and one for butchering.

Regarding the small group of tools from under the floor of house 47, besides the traces of animal-based material, as butchering, or hide, distinctive based on the granular topography (Fig. 131a-b), one sample is singled out because it is presumed to be used as a tribulum. The polish texture is smooth, the topography is flat, and the linkage is covered (Fig. 131c). This is the only example that could be viewed as tribulum, and one of the rear tools, in general correlated to the cereal processing. The interpretation was based on the analysis of the experimental pieces from the LTFAPA reference collection.

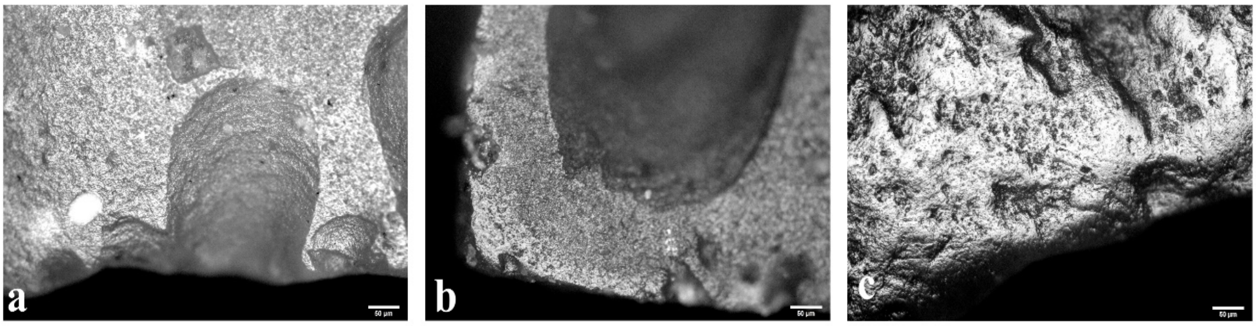
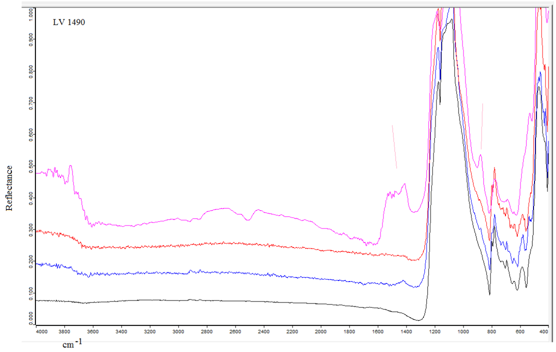
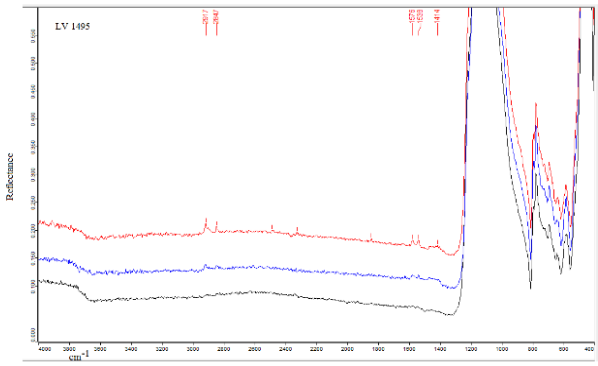
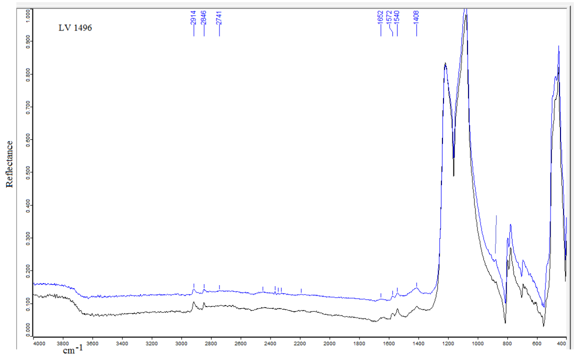
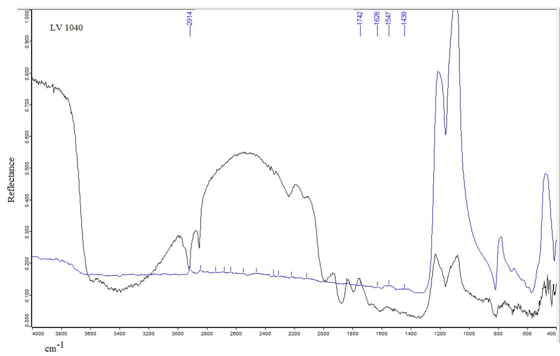


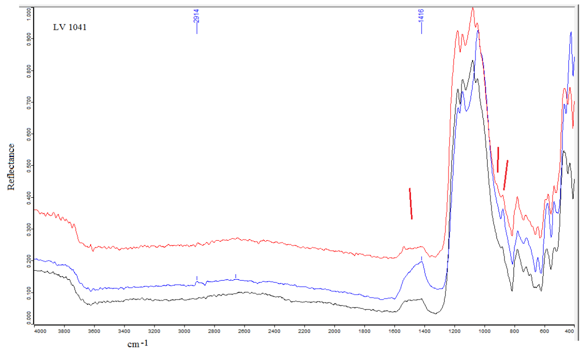
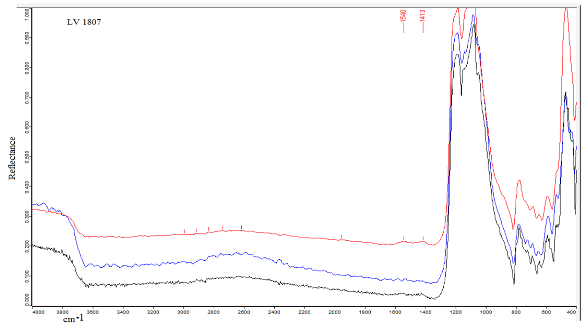
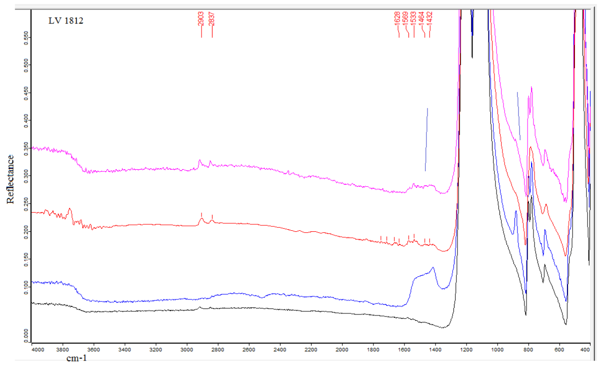
Figure 131: a) Granular topography, hide, LV 1809, b) Granular topography and half-tight linkage, hide, 1812, c) Flat topography, smooth texture LV 1807 (photo A. Petrović)

FTIR analysis results

Two types of residues were found: adipocere, observed at 1576,1540 cm^{-1} and calcium carbonate at ~1540, ~1420, 877 cm^{-1}. Besides the tools used as a tribulum, all the other results of FTIR analysis are corresponding to the use-wear analysis. The tribulum insert has small amounts of adipocere found on the dorsal surface, which leaves this sample in the grey zone since the quantity is tiny.

Table 20: Samples from building 47' and 47, Lepenski Vir, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
LV 1490	~ 1540, ~1420, 877	$CaCO_3$	
LV 1495	1576,1540	Adipocere	
LV 1496	1576,1540 ~1420, 877	Adipocere, $CaCO_3$	
LV 1040	~ 1540, ~1420,	$CaCO_3$	

LV 1041	~ 1540, ~1420, 877	CaCO3	
LV 1807	1576,1540 ~ 1540, ~1420,	Adipocere, CaCO3	
LV 1812	1540~1420, 877	CaCO3	

5.1.11. Building 36

Use-wear analysis

Building 36 is probably belonging to the latter building horizon at Lepenski Vir, and this house is one of the numerous overlapping objects overlayed by building 35. The dating of the object comes from the date of an animal bone from the hearth of the building 36 – 6198-5928 cal BC (Borić and Dimitrijević 2007).

In building 36 thirty (30) chipped stone artefacts were recovered and analysed (Table 21). This house was singled out together with house 32 and 35 because the knapping of the grey flint took part in these buildings (Mitrović 2018). A semi-finished mallet, a granite weight and anvil were found on the almost completely preserved floor of building 36 (Antonović 2006: 41, 63, 68, 78, Catalogue 30, 45, 70), while in the hearth of the house the third phalanx of a wild boar and fish remains were found (Dimitrijević 2008).

Table 21: Samples from building 36, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 1585	House 36	Blade	Cutting	Butchering		
LV 1604	House 36	Flake	Cutting	Fibers		Glossy Appearance
LV 1583	House 36	Blade	Scraping Cutting General working	Hide		Glossy Appearance
LV 1584	House 36	Blade	Cutting	Tubers		White patina
LV 1610	House 36	Core	/	Not used		
LV 1595	House 36	Blade	Cutting	Non-diagnostic		
LV 1590	House 36	Flake	Cutting	Fresh Wood + hard animal material		Glossy Appearance, Thermal stress
LV 1582	House 36	Blade	Indeterminable	Non-diagnostic		
LV 1588	House 36	Core	/	Not used		
LV 1587	House 36	Flake	Cutting	Non-diagnostic		Thermal stress, Glossy Appearance
LV 1601	House 36	Flake	Cutting	Herbaceous plant, worked on the ground		
LV 1589	House 36	Flake	Cutting	Medium-hard material	Prehension	Glossy Appearance, Bright spots
LV 1599	House 36	Flake	Cutting	Wood + another use		Glossy Appearance
LV 1598	House 36	Flake	Cutting/Scraping	Hide		
LV 1606	House 36	Flake	Cutting	Hide		Thermal stress, Glossy Appearance

LV 1608	House 36	Blade	Cutting	Medium-soft material		Glossy Appearance
LV 1602	House 36	Flake	/	Not used		
LV 1603	House 36	Flake	Cutting	Hide		Glossy Appearance
LV 1597	House 36	Flake	Indeterminable	Soft material		
LV 1591	House 36	Blade	Cutting	Woody material, tubers		Glossy Appearance
LV 1611	House 36	Flake	Cutting	Non-diagnostic		Glossy Appearance
LV 1600	House 36	Flake	General working	Butchering		Glossy Appearance
LV 1593	House 36	Flake	/	Not used		
LV 1607	House 36	Flake	Cutting General working	Fresh Hide		
LV 1609	House 36	Flake	Indeterminable	Hard, mineral material		Soil sheen
LV 1594	House 36	Flake	Cutting	Animal material		
LV 1592	House 36	Flake	Indeterminable	Non-diagnostic		Glossy Appearance
LV 1596	House 36	Blade	Cutting	Medium material		Glossy Appearance
LV 1586	House 36	Flake	Cutting	Hide, towards dry		
LV 1605	House 36	Flake	Indeterminable	Hide		

In total four (4) tools were not used, while 50% of the assemblage from the building 32 exhibited alterations, such as glossy appearance, thermal stress. Cutting is the most represented motion and 53% of the tools showed an oblique bidirectional trend of the traces. Clear traces of tool handling modes were observed only in the case of sample LV 1589 where the micro traces indicated that the flake was hand-held.

Animal-based contact materials were noted at the 28% of the sample found in the house, and the results are indicating hide in various stages of processing, from general working of skin represented by granular topography (Fig. 132a-b), through the examples showing utilization of the fresh hide with smoother texture (Fig. 132c), to the cutting of the hide in a semi-dry state characterized by rougher texture (Fig. 132d). The tools were utilized for specific processing of skins, based on the state and hide dimension, with the focus on working the hide of smaller dimensions, hence the details in the processes of making the leather goods.

Vegetal-based activities (18% of the tool assemblage) were noted in building 36. The most prominent are the traces of woodworking, represented both by polishes of fresh and dry wood. However, the superposition of traces is present in this assemblage since the domed topography and woodworking in the example of LV 1599 was covered with the use of hard animal material, represented with the flat and covered linkage of polish (Fig. 132e-f). A flake (LV 1601) was used for cutting the herbaceous plants, indicated by tight, flat polish on the outer edge, with a light abrasive layer indicating the vicinity of the tool to the terrain during the activity – on/near the ground (Fig. 132g). However, the most peculiar specimen was flake LV 1604 used for cutting of some kind of fibres (Fig. 132h), and according to the analysed archaeological material, it is the only tool that has been used for either production or cutting of some kind of filaments.

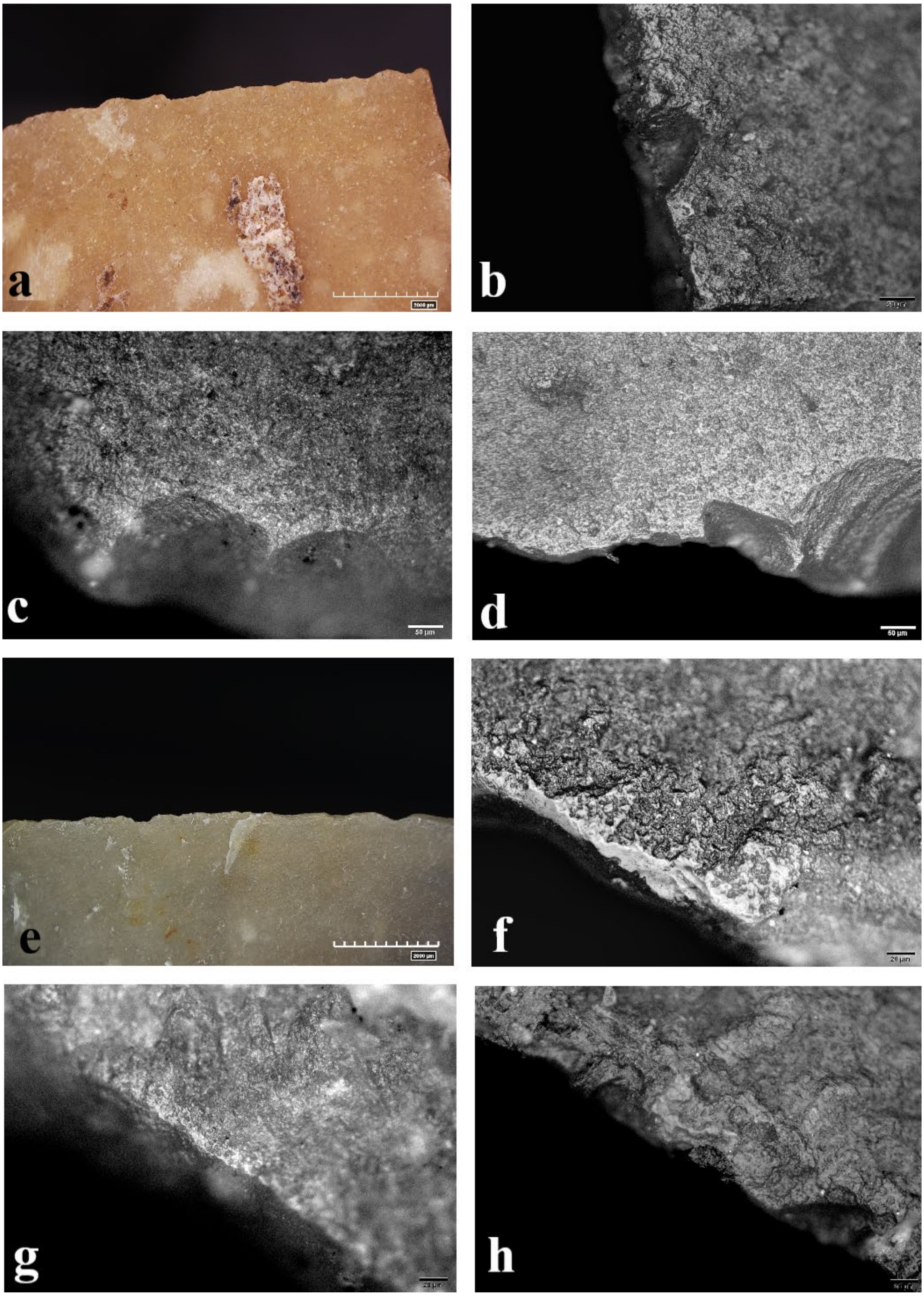


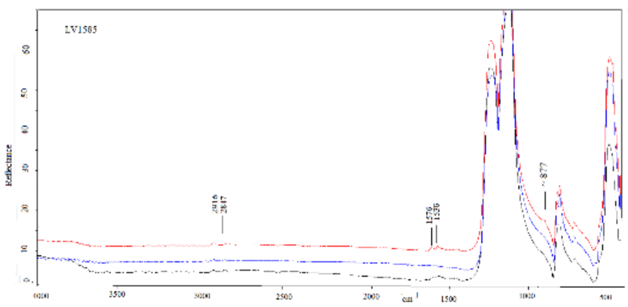
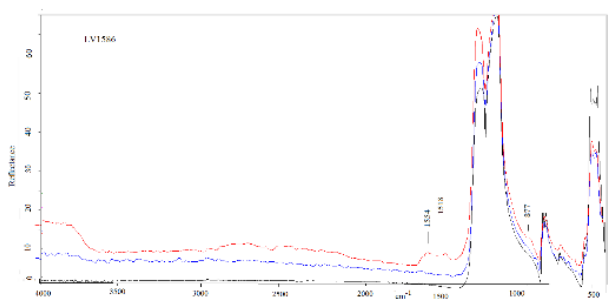
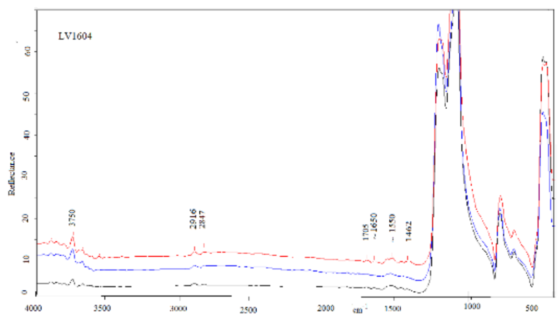
Figure 132: a) Macro traces, snap, step scars, oblique and transversal trend, LV 1583,
b) Micro traces, granular topography, hide processing, LV 1583, c) Micro traces, fresh hide, LV 1607,
d) Micro traces, semi-dry hide, LV 1586, e) Macro traces, snap, oblique scars, LV 1590,
f) Micro traces, flat polish, fresh wood and hard animal material, LV 1590,
g) Flat topography, rough texture, herbaceous plant, LV 1601,
f) Flat/domed topography, fibres processing, LV 1604 (photo A. Petrović)

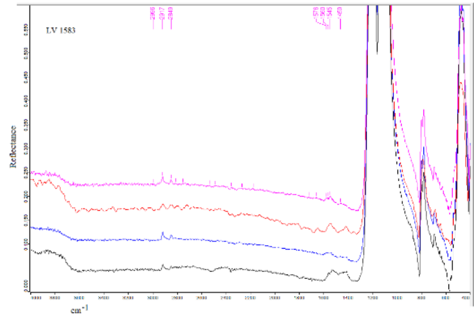
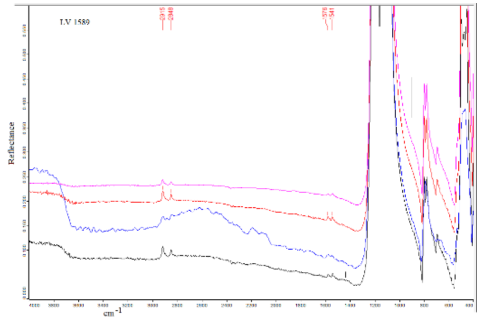
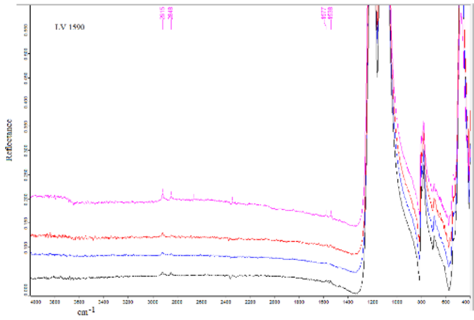
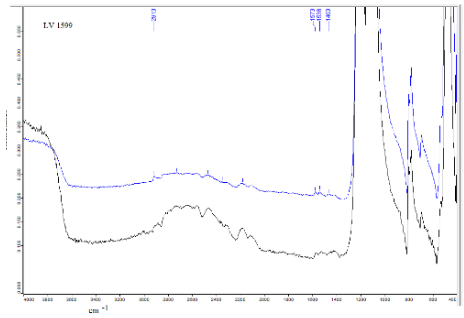
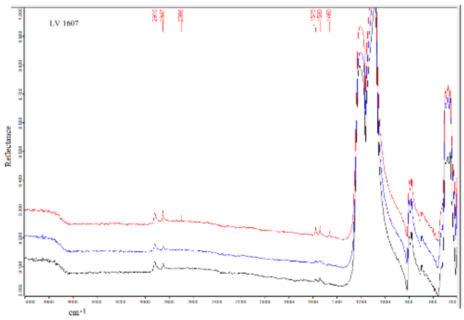
FTIR analysis results

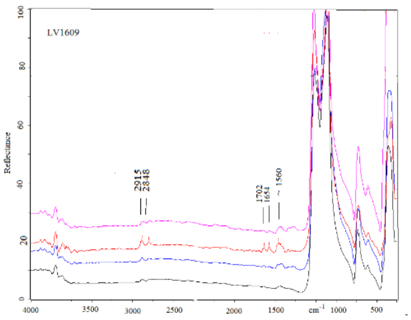
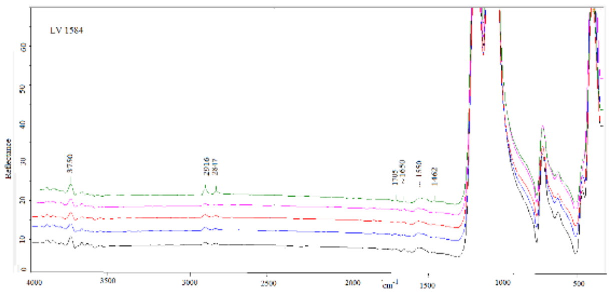
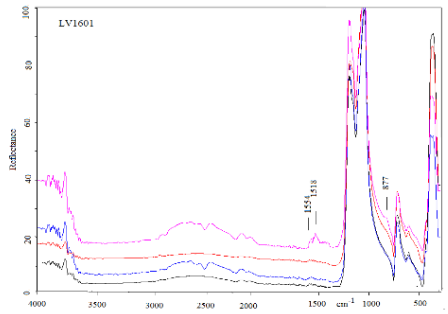
In total eleven (11) artefacts were analysed by FTIR spectrometry (Table 22). Bands observed at 1576,1540 cm^{-1} are interpreted as adipocere and are completely comparable to the results of use-wear analysis (see Table 21), except for the sample LV 1589, which did not have diagnostic micro traces. In this case, it is possible to assume that the tool was used for processing some kind of animal-based material, having in mind traces of adipocere found on both dorsal and ventral surface.

Bands 1710, 1650, ~1540, 1430 cm^{-1} are observed in the sample LV 1604 and LV 1609 and these residues are connected to the woody matters.

Table 22: Samples from building 36, Lepenski Vir, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
LV 1585	1576,1540, 877	Adipocere, CaCO3	
LV 1586	~ 1540, ~1420, 877	CaCO3	
LV 1604	1710, 1650, ~1540, 1430	Wood	

LV 1583	1540, ~1420 877	$CaCO_3$	
LV 1589	1576,1540	Adipocere	
LV 1590	1576,1540	Adipocere	
LV 1599	1576,1540 ~1420, 877	Adipocere, $CaCO_3$	
LV 1607	1576,1540	Adipocere	

LV 1609	1710, 1650, ~1540, 1430	Wood	
LV 1584	~ 1560	?	
LV 1601	~ 1540, ~1420, 877	CaCO3	

5.1.12. Building 35

Use-wear analysis

Building 35 is overlapping house 36 and it is the object where the biggest quantity of chipped stone tools was found, out of which 224 artefacts have been analysed (Table 23). Besides a large amount of knapped artefacts, a massive, stationary grinding stone and a chisel were found on the building floor (Antonović 2006: 35,73, 112, Catalogue 57, 168). Regarding the animal remains, a large sample of mammal bones was collected, consisting of 96 fragments of various skeletal parts. Additionally, bird, fish and mollusc remains were collected as well (Dimitrijević 2008).

The house itself is marked as the place where grey and Balkan flint were knapped (Mitrović 2018). An extensive number of small flakes (around 84%) was noted as “chips” or “waste”, as it was written on the bags in which material was preserved. Around 8% of the assemblage is represented by blades, and 4% as cores and core fragments.

Table 23: Samples from building 35, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 1275	House 35	Flake	/	Not used		
LV 1278	House 35	Flake	/	Not used		Glossy Appearance, Mechanical Alteration
LV 1282	House 35	Flake	/	Not used		Mechanical Alteration
LV 1271	House 35	Cortical Flake	/	Not used		Mechanical Alteration
LV 1274	House 35	Flake	/	Not used		Mechanical Alteration, Glossy Appearance
LV 1279	House 35	Flake	/	Not used		Glossy Appearance
LV 1276	House 35	Flake	/	Not used		Glossy Appearance
LV 1277	House 35	Flake	Indeterminable	Non-diagnostic		Glossy Appearance
LV 1281	House 35	Flake	/	Not used		
LV 1272	House 35	Flake	/	Not used		Mechanical Alteration, Glossy Appearance
LV 1273	House 35	Flake	/	Not used		Any Mechanical Alteration
LV 1283	House 35	Flake	/	Not used		Glossy Appearance, Thermal stress
LV 1280	House 35	Flake	Indeterminable	Non-diagnostic		Glossy Appearance, Mechanical Alteration
LV 1260	House 35	Flake	/	Not used		Bright Spots
LV 1265	House 35	Flake	/	Not used		Mechanical Alteration
LV 1269	House 35	Flake	/	Not used		Mechanical Alteration

LV 1267	House 35	Flake	/	Not used		Mechanical Alteration
LV 1262	House 35	Flake	/	Not used		Mechanical Alteration
LV 1270	House 35	Flake	/	Not used		Mechanical Alteration
LV 1264	House 35	Flake	/	Not used		Glossy Appearance, Mechanical Alteration
LV 1261	House 35	Flake	/	Not used		Mechanical Alteration
LV 1263	House 35	Flake	/	Not used		Mechanical Alteration
LV 1266	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1255	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1257	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1259	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1268	House 35	Flake	Indeterminable	Non diangostic		Mechanical Alteration
LV 1178	House 35	Scraper	Cutting, Scraping	Two zones of activity: scraping of medium-hard material, and cutting hard material		Mechanical Alteration
LV 1177	House 35	Flake	Scraping	Medium-hard material		Glossy Appearance
LV 1190	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1209	House 35	Flake	/	Not used		Mechanical Alteration
LV 1211	House 35	Flake	/	Not used		Mechanical Alteration
LV 1183	House 35	Blade	Cutting, Scraping	Medium-soft material		
LV 1201	House 35	Flake	/	Not used		Mechanical Alteration

LV 1192	House 35	Flake	/	Not used		Mechanical Alteration
LV 1186	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1184	House 35	Flake	/	Not used		Mechanical Alteration
LV 1185	House 35	Flake	/	Not used		
LV 1193	House 35	Flake		Not used		Mechanical Alteration
LV 1182	House 35	Core	/	Not used		Mechanical Alteration
LV 1194	House 35	Flake	/	Not used		Mechanical Alteration
LV 1202	House 35	Flake	/	Not used		Mechanical Alteration
LV 1197	House 35	Flake	/	Not used		Mechanical Alteration
LV 1210	House 35	Flake	/	Not used		Mechanical Alteration
LV 1212	House 35	Flake	/	Not used		Mechanical Alteration
LV 1206	House 35	Flake	/	Not used		Mechanical Alteration
LV 1191	House 35	Flake	/	Not used		Mechanical Alteration
LV 1188	House 35	Flake	/	Not used		
LV 1200	House 35	Flake	/	Not used		Mechanical Alteration
LV 1196	House 35	Flake	/	Not used		
LV 1195	House 35	Flake	/	Not used		Mechanical Alteration
LV 1187	House 35	Flake	/	Not used		Mechanical Alteration
LV 1198	House 35	Flake	/	Not used		Mechanical Alteration
LV 1207	House 35	Flake	/	Not used		Mechanical Alteration

LV 1180	House 35	Flake	Cutting	Non-diagnostic		Mechanical Alteration
LV 1220	House 35	Core	/	Not used		
LV 1236	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1234	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1230	House 35	Blade	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1243	House 35	Flake	/	Not used		
LV 1225	House 35	Blade	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1231	House 35	Flake	Cutting	Soft material		Glossy Appearance, Mechanical Alteration
LV 1253	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1238	House 35	Flake	Cutting	Animal Tissues	Prehension	Mechanical Alteration, Glossy Appearance
LV 1245	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1229	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1228	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1221	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1254	House 35	Flake	Cutting	Fish		
LV 1250	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1227	House 35	Flake	/	Not used		Soil sheen
LV 1249	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1239	House 35	Flake	/	Not used		Mechanical Alteration

LV 1242	House 35	Flake	Cutting	Medium material		Glossy Appearance, Mechanical Alteration
LV 1224	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1233	House 35	Flake	/	Not used		Mechanical Alteration
LV 1248	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1252	House 35	Flake	/	Not used		
LV 1226	House 35	Flake	/	Not used		Abrasion
LV 1232	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1251	House 35	Flake	/	Not used		Mechanical Alteration
LV 1244	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1246	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1241	House 35	Flake	Cutting	Non-diagnostic		Mechanical Alteration
LV 1223	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1240	House 35	Flake	/	Not used		Mechanical Alteration
LV 1222	House 35	Flake	/	Not used		Mechanical Alteration
LV 1155	House 35	Flake	Cutting	Medium-hard materials		Mechanical Alteration
LV 1153	House 35	Flake	/	Not used		Mechanical Alteration
LV 1167	House 35	Flake	/	Not used		Mechanical Alteration
LV 1156	House 35	Flake	/	Not used		Mechanical Alteration
LV 1150	House 35	Flake	/	Not used		Mechanical Alteration

LV 1157	House 35	Cortical Flake	/	Not used		Mechanical Alteration
LV 1160	House 35	Flake	/	Not used		Mechanical Alteration
LV 1166	House 35	Flake	/	Not used		Mechanical Alteration
LV 1169	House 35	Flake	/	Not used		
LV 1170	House 35	Flake	/	Not used		
LV 1148	House 35	Polished flake				
LV 1165	House 35	Flake	/	Not used		
LV 1175	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1146	House 35	Flake	/	Not used		Mechanical Alteration
LV 1172	House 35	Flake	/	Not used		
LV 1116	House 35	Core fragment	/	Not used		
LV 1112	House 35	Core fragment	/	Not used		
LV 1117	House 35	Core	/	Not used		
LV 1118	House 35	Flake	/	Not used		Roots, Abrasion
LV 1111	House 35	Flake	General working	Animal material		Roots
LV 1135	House 35	Flake	/	Not used		Soil sheen
LV 1106	House 35	Flake	/	Not used		Mechanical Alteration
LV 1128	House 35	Core	Indeterminable	Non-diagnostic		Glossy Appearance
LV 1136	House 35	Flake	/	Not used		Mechanical Alteration

LV 1138	House 35	Flake	/	Not used		Mechanical Alteration, Thermal stress
LV 1145	House 35	Flake	/	Not used		
LV 1161	House 35	Flake	/	Not used		Mechanical Alteration
LV 1143	House 35	Flake	Scraping, Cutting	Animal material		Glossy Appearance, Mechanical Alteration
LV 1141	House 35	Flake	Indeterminable	Non-diagnostic		Roots
LV 1110	House 35	Flake	Cutting	Hard material		Abrasion
LV 1107	House 35	Flake	Cutting			Mechanical Alteration
LV 1114	House 35	Flake	Cutting	Animal material		
LV 1129	House 35	Flake	Cutting	Vegetable		
LV 1122	House 35	Flake	Indeterminable	Medium-hard material		Mechanical Alteration
LV 1144	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1142	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1105	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1120	House 35	Flake	Cutting	Non-diagnostic		Mechanical Alteration
LV 1113	House 35	Flake	Cutting	Medium-hard material		
LV 1139	House 35	Flake	Cutting	Non-diagnostic		Mechanical Alteration
LV 1133	House 35	Flake	/	Not used		
LV 1126	House 35	Flake	Cutting	Soft material		Mechanical Alteration
LV 1108	House 35	Flake	Scraping	Medium-hard material		Glossy Appearance

LV 1109	House 35	Flake	Indeterminable	Medium material		Mechanical Alteration
LV 1115	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1119	House 35	Flake	Indeterminable	Non-diagnostic		Glossy Appearance, Mechanical Alteration
LV 1121	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1131	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1134	House 35	Flake	Indeterminable	Non-diagnostic		Glossy Appearance
LV 1125	House 35	Flake	Indeterminable	Herbaceous plant, worked on the ground		
LV 1124	House 35	Flake	Cutting	Medium material		
LV 1078	House 35	Flake	Cutting, Scraping	Medium material		Mechanical Alteration
LV 1050	House 35	Blade	Cutting	Non-diagnostic		Mechanical Alteration
LV 1055	House 35	Blade	Cutting, Scraping	Medium material		Mechanical Alteration
LV 1046	House 35	Flake	/	Not used		
LV 1079	House 35	Flake	/	Not used		
LV 1076	House 35	Flake	/	Not used		
LV 1081	House 35	Flake	/	Not used		Mechanical Alteration
LV 1089	House 35	Flake	Cutting	Soft material		Glossy Appearance
LV 1085	House 35	Flake	Indeterminable	Woody		
LV 1065	House 35	Flake	Indeterminable	Non-diagnostic		Glossy Appearance
LV 1051	House 35	Flake	Cutting	Medium-hard material		Mechanical Alteration

LV 1059	House 35	Flake	Cutting	Medium-hard material		Mechanical Alteration
LV 1066	House 35	Flake	Cutting	Disarticulation of the bone, butchering		
LV 1060	House 35	Flake	/	Not used		
LV 1056	House 35	Flake	Indeterminable	Non-diagnostic		Glossy Appearance
LV 1071	House 35	Flake	General working	Butchering		Glossy Appearance
LV 1052	House 35	Flake	Cutting	Medium material		
LV 1063	House 35	Blade	/	Not used		Glossy Appearance
LV 1104	House 35	Flake	/	Not used		
LV 1049	House 35	Scraper	/	Not used		Mechanical Alteration
LV 1092	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1090	House 35	Core fragment	Indeterminable	Non-diagnostic		Glossy Appearance
LV 1086	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1100	House 35	Flake	/	Not used		
LV 1093	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1091	House 35	Flake	Indeterminable	Non-diagnostic		Mechanical Alteration
LV 1088	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1103	House 35	Flake	Indeterminable	Non-diagnostic		Abrasion
LV 1097	House 35	Flake	/	Not used		
LV 1102	House 35	Flake	/	Not used		
LV 1101	House 35	Flake	/	Not used		Mechanical Alteration

LV 1075	House 35	Flake	Indeterminable	Soft-medium material		
LV 1070	House 35	Flake	Cutting	Soft-medium material		Any
LV 1074	House 35	Flake	Cutting	Soft-medium material		
LV 1062	House 35	Flake	Cutting	Medium material		Abrasion
LV 1069	House 35	Flake	Indeterminable	Medium material		Any
LV 1054	House 35	Flake	Indeterminable	Medium, Animal Tissues		Glossy Appearance
LV 1058	House 35	Bipolar flake	Indeterminable	Animal material		
LV 1083	House 35	Flake	Cutting	Soft material		Glossy Appearance
LV 1042	House 35	Flake	Cutting	Soft material		Glossy Appearance
LV 1072	House 35	Flake	Cutting	Medium material		
LV 1073	House 35	Flake	/	Not used		Mechanical Alteration
LV 1064	House 35	Flake	/	Not used		Mechanical Alteration
LV 1077	House 35	Flake	Indeterminable	Soft material		Mechanical Alteration
LV 1082	House 35	Flake	Cutting	Soft material		Glossy Appearance
LV 1067	House 35	Flake	Cutting	Medium material		Mechanical Alteration
LV 1094	House 35	Flake	Indeterminable	Animal Tissues, Meat		
LV 1096	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1256	House 35	Flake	/	Not used		Mechanical Alteration
LV 1258	House 35	Blade	Indeterminable	Dry Hide Fresh Hide		Soil sheen

LV 1208	House 35	Flake	/	Not used		Soil sheen, Thermal stress
LV 1203	House 35	Flake	/	Not used		Soil sheen
LV 1204	House 35	Flake	/	Not used		
LV 1189	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1181	House 35	Blade	/	Not used		Thermal stress
LV 1205	House 35	Flake	/	Not used		
LV 1164	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1168	House 35	Flake	Indeterminable	Non-diagnostic		
LV 1053	House 35	Core fragment	Indeterminable	Non-diagnostic		
LV 1235	House 35	Burin	General working	Butchering with frequent bone contact		
LV 1123	House 35	Geometric	Cutting	Semi-dry Hide		
LV 1127	House 35	Flake	Cutting	Fresh Hide		
LV 1132	House 35	Geometric	Scraping	Soft-medium material, worked on the ground		
LV 1137	House 35	Flake	Cutting	Animal material		
LV 1171	House 35	Burin	Indeterminable	Non-diagnostic		
LV 1095	House 35	Flake	Indeterminable	Soft material and soft-medial		
LV 1084	House 35	Flake	Cutting	Dry Hide		Glossy Appearance
LV 1068	House 35	Blade	Cutting	Non-diagnostic		Glossy Appearance
LV 1057	House 35	Blade	Cutting	Medium material		Glossy Appearance

LV 1047	House 35	Flake	Cutting	Non-diagnostic		
LV 1080	House 35	Splinter	Indeterminable	Woody		
LV 1685	House 35	Flake	Cutting, Scraping	Medium material		
LV 1692	House 35	Flake	Indeterminable	Dry Hide		Glossy Appearance
LV 1683	House 35	Blade	Scraping, Cutting	Antler		
LV 1689	House 35	Blade	Indeterminable	Bone or antler		
LV 1687	House 35	Blade	Scraping, Cutting	Antler		
LV 1688	House 35	Flake	Cutting	Bone, mineral		
LV 1686	House 35	Blade	Scraping	Medium, Vegetable, abrasive		
LV 1691	House 35	Flake	Indeterminable	Hide		
LV 1684	House 35	Blade	Cutting	Medium material		
LV 1690	House 35	Blade	Indeterminable	Bone		
LV 1215	House 35	Blade	Indeterminable	Animal material		Glossy Appearance
LV 1217	House 35	Blade	Cutting	Bone or antler + hide		
LV 1218	House 35	Scraper	Indeterminable	Woody	Hafting	
LV 1219	House 35	Blade	Cutting	Animal material		
LV 1173	House 35	Flake	Indeterminable	Non-diagnostic		

From the total of the analysed samples from building 35, ninety-five (95) or the 42% were not used, and 66% of the tools were affected by alterations. Among them, the most common is the mechanical alteration (Fig. 133), followed by glossy appearance, thermal stress, soil sheen, abrasion and bright spots.

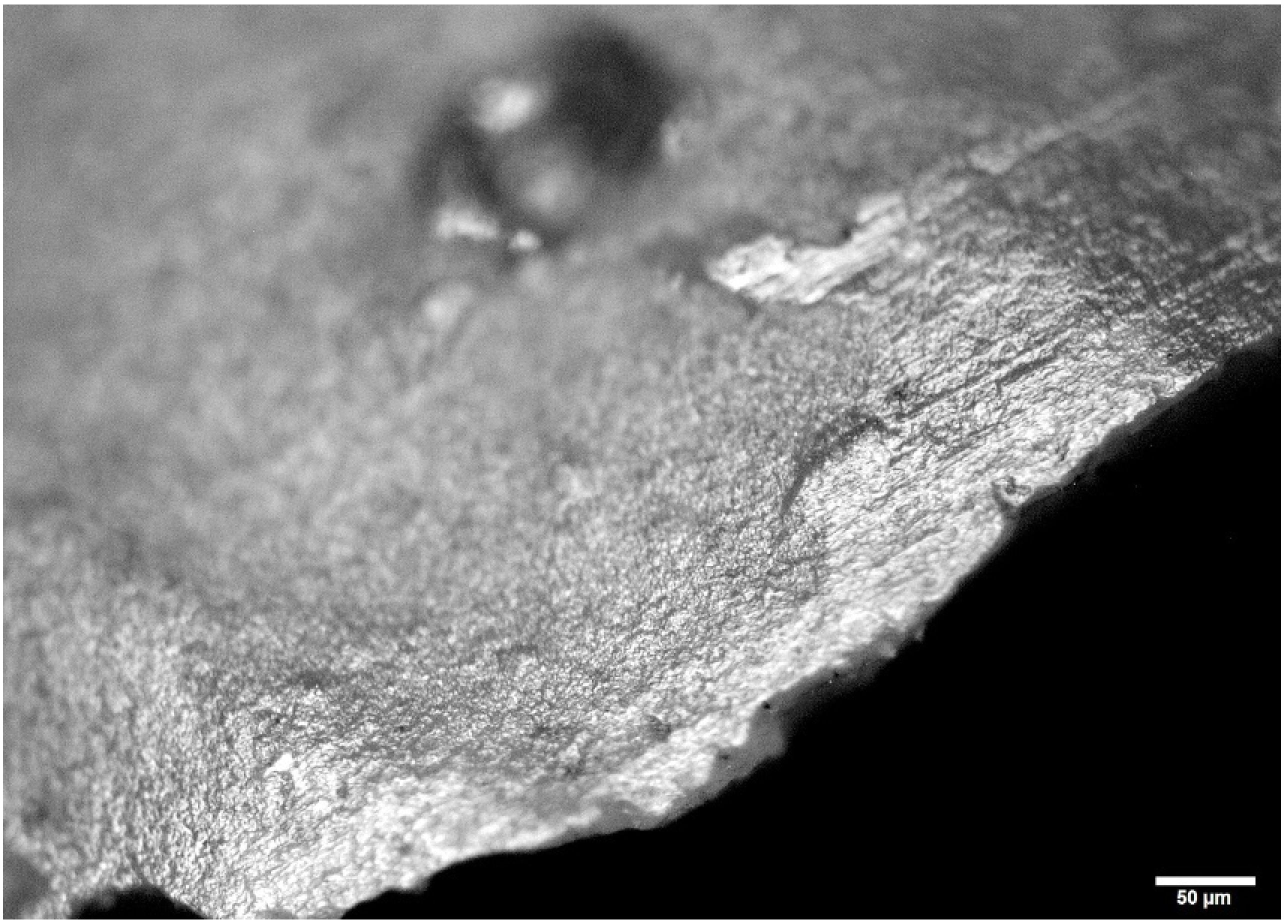


Figure 133: Mechanical alteration, LV 1051, house 35 (photo A. Petrović)

Of the remaining used tools, 44% were non-diagnostic and the contact material could not be identified based on the trace and tool preservation. Diagnostic traces were found on 72 tools, but only 33 tools had polishes that could be attributed either to the animal/vegetal category or to the exact worked material.

Polish connected to the animal-based materials were found on 27 tools. The tools were used for processing antler, visible in flat to melting topography, and covered linkage (Fig. 134a). For example, one flake (LV 1066) was used for disarticulation of bone and butchering (Fig. 134b-c), while the processing of hide is present in various phases, as fresh hide (Fig. 134d), to semi-dry hide (Fig. 134e). Two bruins were found in house 35, and only one had diagnostic traces of butchering with frequent bone contact. Besides the example from house 32, sample LV 1254 is the second tool where polish connected to fish working was observed. The greasy polish is present on the outer edge and edge, with flat and domed topography of tight polish and striae (Fig. 134f). Domed topography is present in the zones where the polish did not develop due to insufficient contact with the scales. The same observations are noted on the experimental flake used in the scaling trial (see Chapter 4.3.12.).

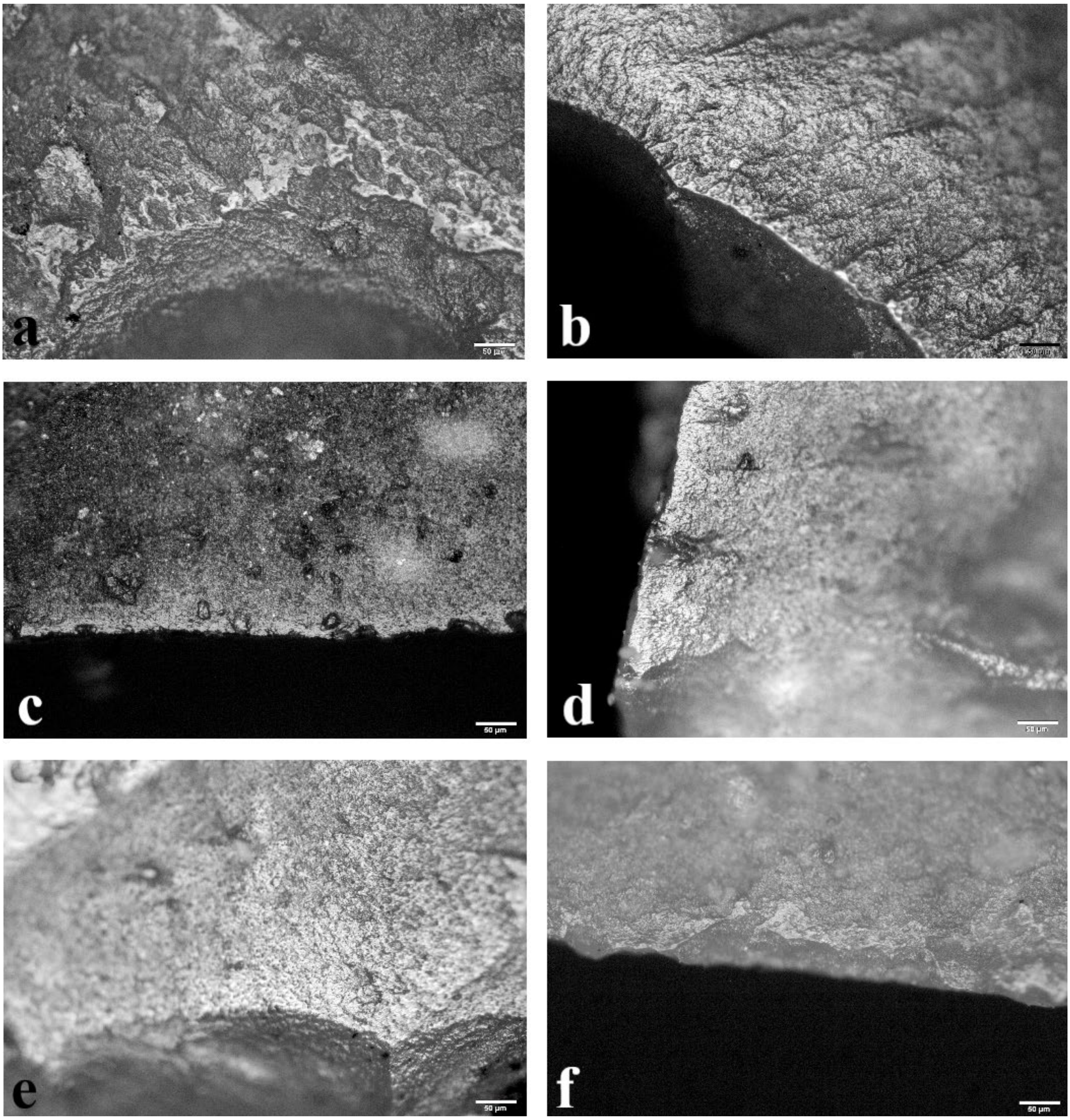


Figure 134: a) Flat and melting topography, antler working, LV 1683, b) Disarticulation of the bone, LV 1066, c) Butchering with frequent bone contact, LV 1235, d) Fresh hide, LV 1127, e) Semi-dry hide, LV 1123, f) Processing fish, scaling, LV 1254 (photo A. Petrović)

Traces of vegetal resources were found on only six (6) tools, from building 35, which included the working of wood and herbaceous plants. Woodworking is the most common and it is represented by domed topography on higher areas penetrating the edge (Fig. 135a-b).

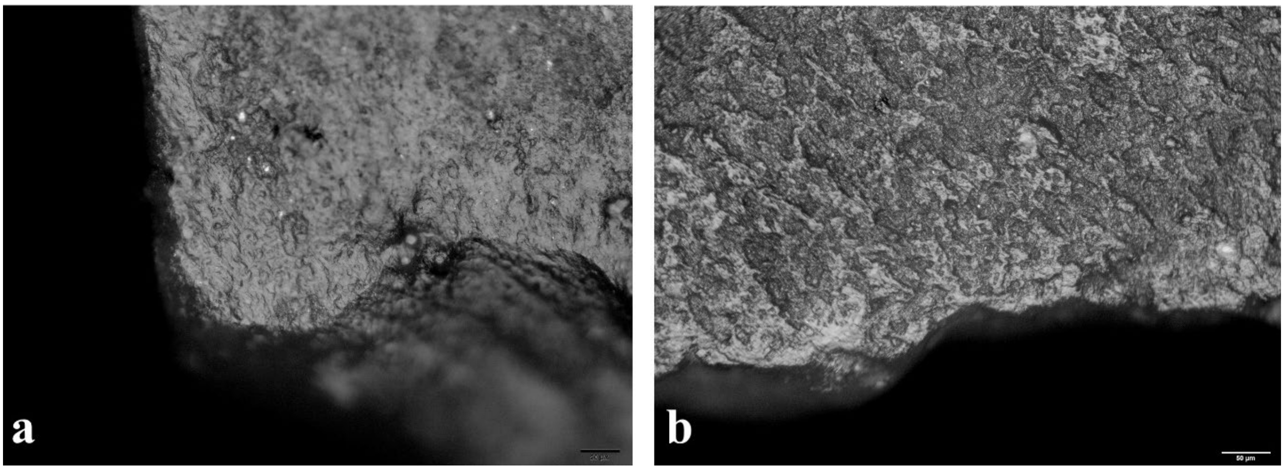
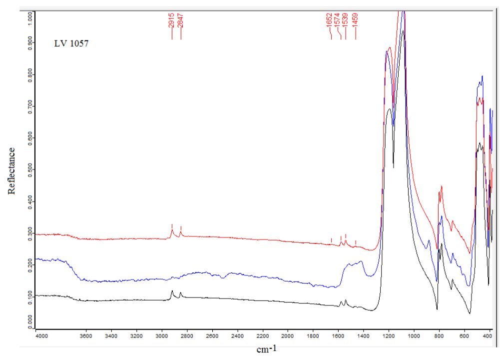


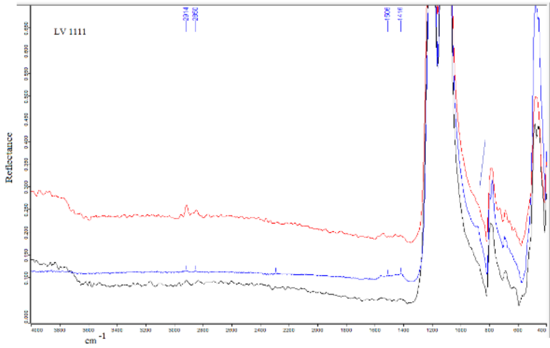
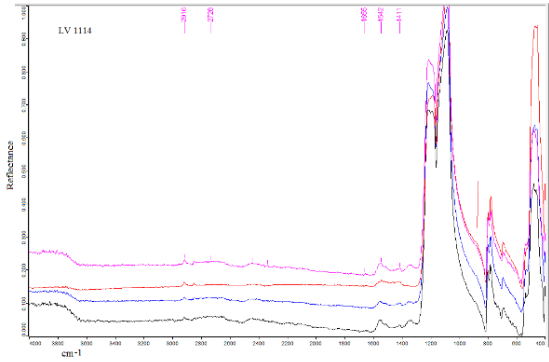
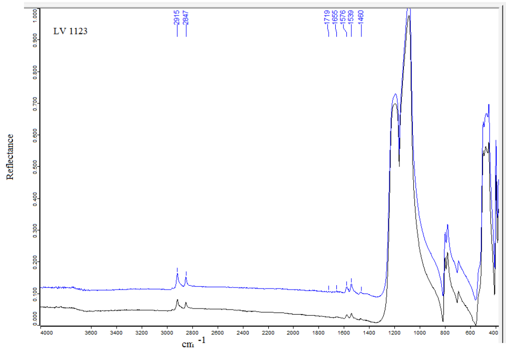
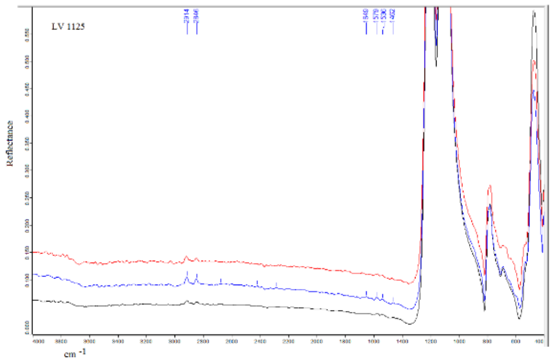
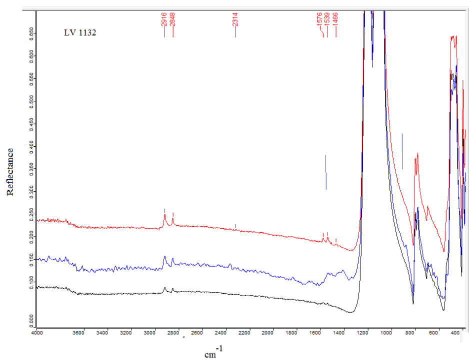
Figure 135: a) Woodworking, LV 1080, b) Woodworking, domed topography, LV 1085 (photo A. Petrović)

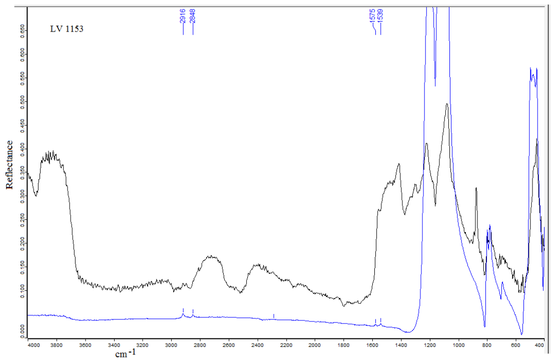
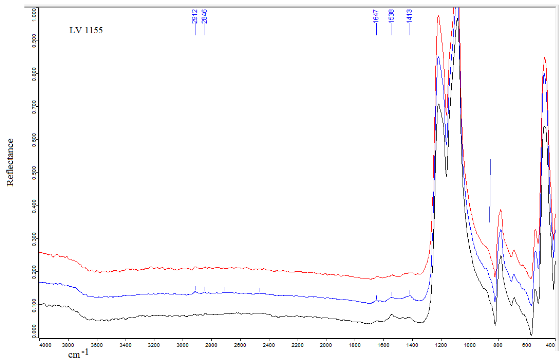
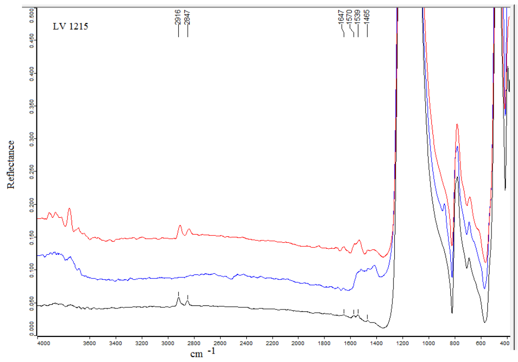
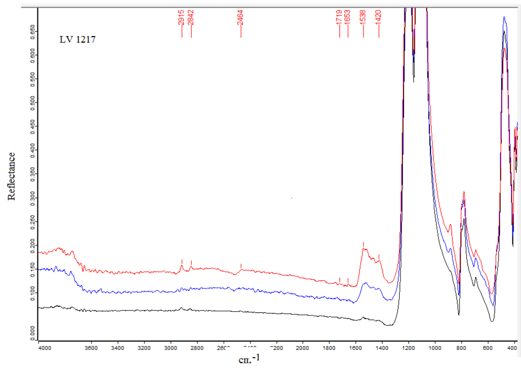
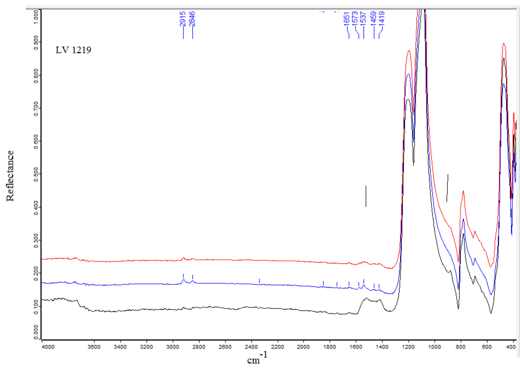
FTIR analysis results

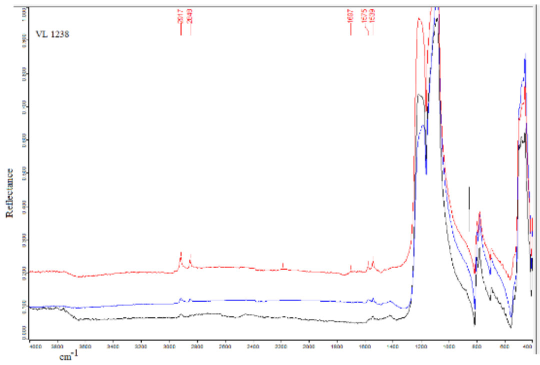
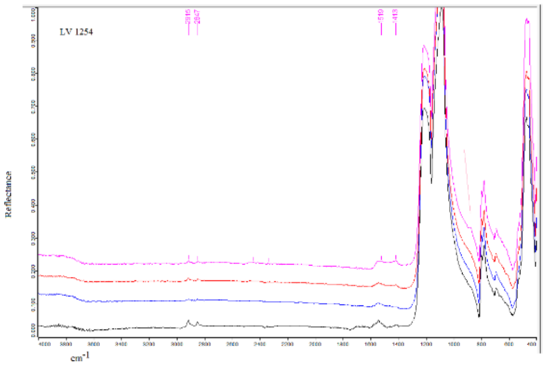
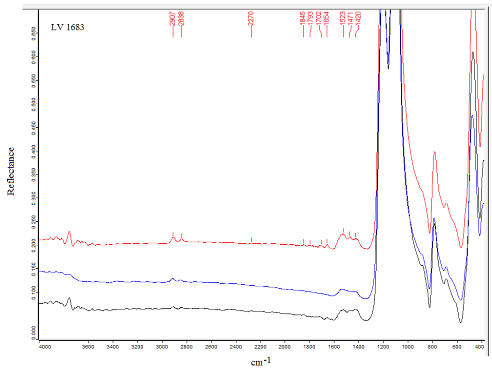
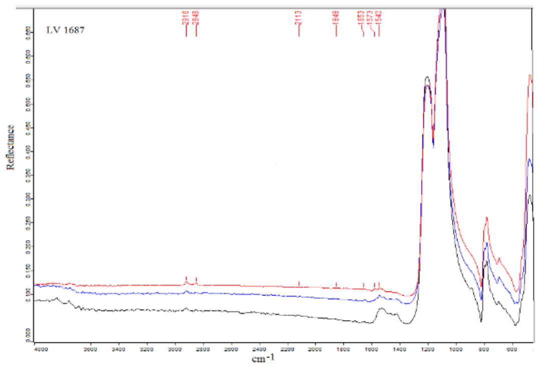
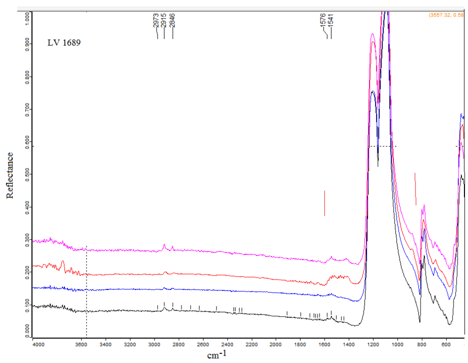
In total seventeen (17) artefacts were analysed by FTIR spectrometry (Table 23). Bands observed at 1576,1540 cm-1 are interpreted as adipocere, and bands at ~ 1540, ~1420, 877 cm^{-1} as calcium carbonate. The results are in most cases corresponding to the results of the use-wear analysis. The two samples (LV 1057 and LV 1132) have only macro traces and in these cases, the FTIR analysis and the residues of adipocere and calcium carbonate can indicate the processing of animal-based material. The only two samples with ambiguous results are sample LV 1125, used for processing of the herbaceous plants on the ground, which can be partially an explanation for the traces of the found residues, and sample LV 1153, which was heavily altered and did not have any indicative traces of use but displayed remains of residues. Additionally, it should be emphasised that in the cases of tools used for antler and bone processing (LV 1217, 1683, 1687, 1689, 1690), except for the one band of calcium carbonate, no other direct indications were found.

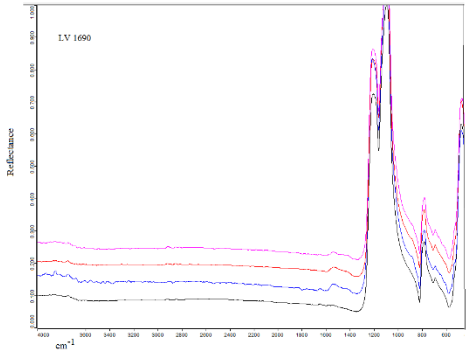
Table 24: Samples from building 35, Lepenski Vir, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
LV 1057	1576,1540 ~ 1540, ~1420, 877	Adipocere, $CaCO_3$	

LV 1111	1540~1420, 877	CaCO3	
LV 1114	1540~1420, 877 ~1540 1380	CaCO3, ?	
LV 1123	1576,1540	Adipocere	
LV 1125	1576,1540 1540~1420, 877	Adipocere, CaCO3	
LV 1132	1576,1540 ~ 1540, ~1420, 877	Adipocere, CaCO3	

LV 1153	1540 ~1420, 877 1576,1540	$CaCO_3$. Adipocere,	
LV 1155	1650, 1540~1420, 877	$CaCO_3$, ?	
LV 1215	1576,1540 ~ 1540, ~1420, 877	Adipocere, $CaCO_3$	
LV 1217	~ 1540, ~1420, 877	$CaCO_3$	
LV 1219	~ 1540, ~1420, 877	$CaCO_3$	

LV 1238	1576,1540, ~1420, 877	Adipocere, CaCO3	
LV 1254	1650, 1540~1420, 877	CaCO3	
LV 1683	~ 1540, ~1420, 877	CaCO3	
LV 1687	~ 1540, ~1420, 877, 1576,1540	CaCO3, Adipocere	
LV 1689	1576,1540 ~ 1540, ~1420, 877	Adipocere, CaCO3	

LV 1690	~ 1540, ~1420, 877	CaCO3	

5.1.13. Nearby the hearth of building XXXIII

Use-wear analysis

Two blades were found in the vicinity of the hearth of house XXXIII (Table 25). One blade (LV 1670) displayed no traces of use, and on the second one (LV 1671), based on the analysed micro-wear, it was discovered that it was utilized for scraping and cutting fresh hide. Both blades have various post-depositional surface modification as bright spots, trampling and soil sheen.

Table 25: Samples found nearby the hearth of building XXXIII, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 1670	Nearby the hearth of building XXXIII	Blade	/	Not used		Bright spots
LV 1671	Nearby the hearth of building XXXIII	Blade	Cutting/Scraping	Fresh hide		Trampling, Soil sheen

5.1.14. Hearth 70

Use-wear analysis

In total thirteen (13) artefacts found in the hearth 70 were analysed (Table 26). Only three (3) flakes displayed traces of use. Two flakes were used for processing the dry hide and one for cutting unidentified vegetal-based matter. Seven tools (7) were not used at all, and three (3) were non-diagnostic. The variety of alterations noted on the tools from the small assemblage, found in the hearth 70, is high, and modifications as glossy appearance, thermal stress, bright spots, trampling and roots are present.

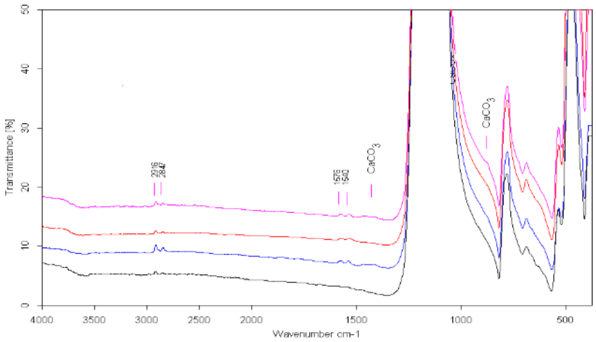
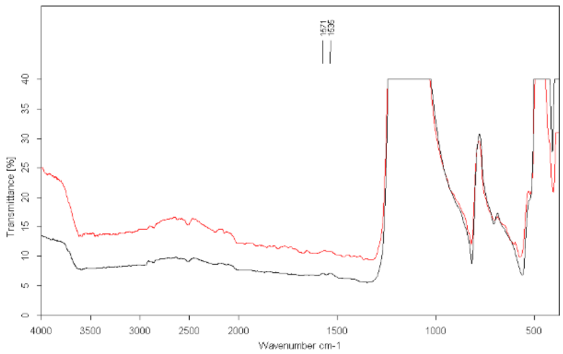
Table 26: Samples from hearth 70, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 208	Hearth 70	Flake	General working	Dry hide		Roots
LV 209	Hearth 70	Flake	Cutting	Vegetal material		Glossy Appearance, Roots
LV 210	Hearth 70	Flake	Indeterminable	Non-diagnostic		Roots, Mechanical Alteration
LV 207	Hearth 70	Flake	/	Not used		
LV 213	Hearth 70	Flake	/	Not used		
LV 218	Hearth 70	Flake	Indeterminable	Non-diagnostic		
LV 222	Hearth 70	Scraper	Indeterminable	Non-diagnostic		Glossy Appearance, Thermal stress, Bright spots
LV 224	Hearth 70	Flake	/	Not used		
LV 221	Hearth 70	Core	/	Not used		
LV 215	Hearth 70	Flake	Cutting	Dry hide		Thermal stress, Trampling, Abrasion, Bright spots
LV 223	Hearth 70	Flake	/	Not used		
LV 216	Hearth 70	Flake	/	Not used		
LV 217	Hearth 70	Flake	/	Not used		Thermal stress

FTIR analysis results

Bands at 1576, 1540 cm^{-1} are observed at spectra of both analysed samples (Table 27). In the case of LV 222, the results are offering some new indications, having in mind that observed use-wear traces were not diagnostic enough to offer a more detailed interpretation. However, in the case of the LV 209 used for vegetal material, the compounds of fatty acid salts can imply the processing of plants rich in fat.

Table 27: Samples from hearth 70, Lepenski Vir, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
LV 209	1576, 1540	Adipocere	
LV 222	1576, 1540	Adipocere	

5.1.15. Pits

Use-wear analysis

Usually, the pits are used to deposit domestic waste from the households, like animal bones, shell mollusc, but also pottery and lithics. In total, five chipped stones from three different pits were analysed for the study (Table 28). Additionally, two flakes from the pit from building 37 were analysed, but these results are being discussed separately (see Chapter 5.1.6.).

Table 28: Samples from pits, Lepenski Vir, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
LV 142	Pit, C/X, XI	Flake	General working	Butchering/animal tissues		
LV 143	Pit, C/X, XI	Flake	Cutting	Animal tissues, worked in open space		Glossy Appearance
LV 122	a/VI	Flake	Cutting	Fresh hide		
LV 23	c/II	Scraper	General working	Very fresh bone or antler, butchering		
LV 24	c/II	Flake	Cutting	butchering		

C/X, XI, spit III

In the Neolithic midden, located in the quadrants X and XI, burial 66 was found in the zone where a Neolithic pit was documented (Field Journal entries for 25–27/08/1968).

In the pit, besides Early Neolithic fragments of Starčevo pottery, two flakes of fine-grained chert were found. One of the artefacts was not altered (LV 142) and another flake has traces of light glossy appearance (LV 143). Both flakes have indications that they were utilized for processing animal materials. Artefact LV 142 is more connected to the soft material and activity of butchering, based on the granular topography and smooth to the rough texture (Fig. 136a). Sample LV 142 has small patches, most probably from working in the open space. The micro-wear is connected to the working on the fresh hide with an edge that could be interpreted as a prehension zone that was used afterwards, hence the tool was rotated when needed. Striations are present both on the dorsal and ventral edge.

a/VI

The sample LV 122 was found in the pit in block a/VI, positioned above building 26/26'. The flake was used for cutting fresh hide based on the granular topography, which in some areas is becoming more domed and melted.

C/II

This pit is spatially oriented between house 8 and house 16. There is not much information about this midden and two chipped stone finds showed very interesting animal traces. The sample LV 23 was used for processing hard animal material as bone or antler, and it was involved in the general activity of butchering (Fig. 136b), while artefacts LV 24 was used in the butchering with less frequent contact with the bone. The bright spots were noted as well near the working edge (Fig. 136c).

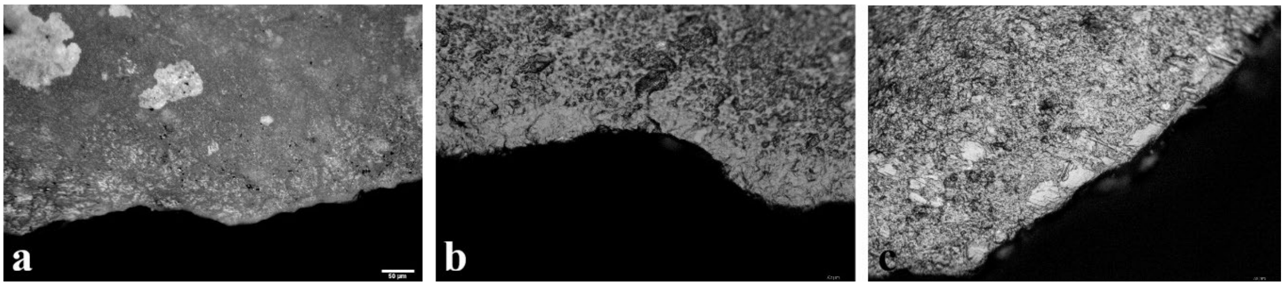
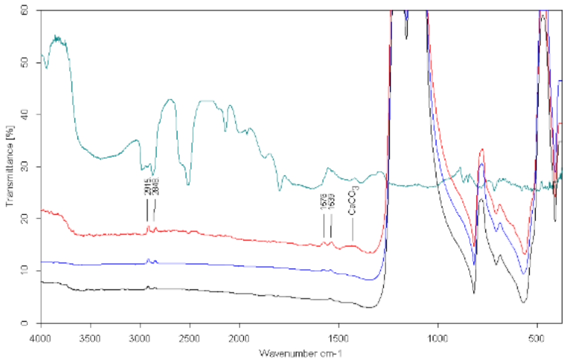
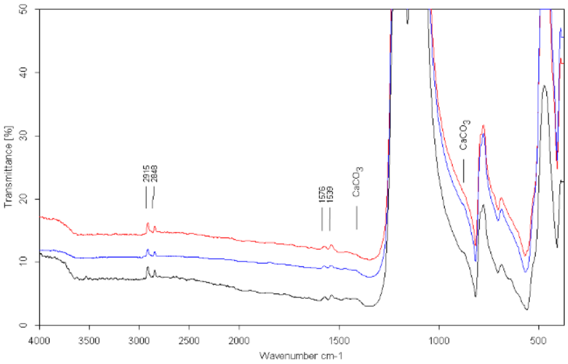
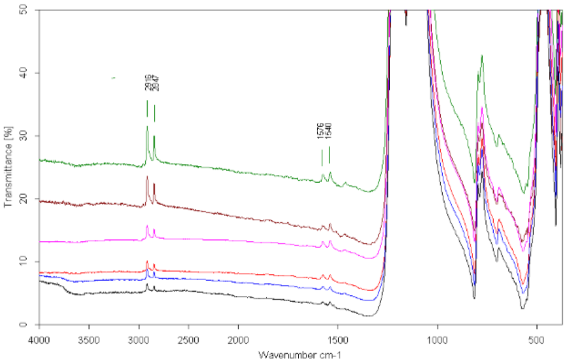
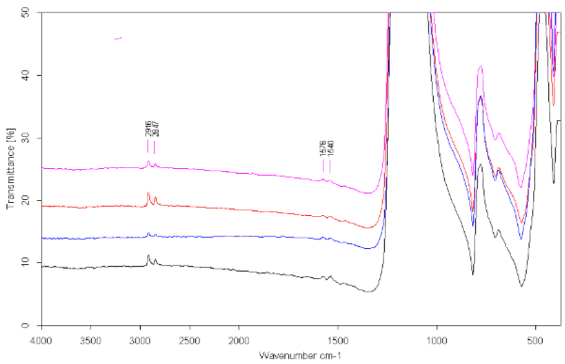


Figure 136: pits, micro-wear: a) Sample LV 142, butchering, contact with animal tissues, soft texture and granular topography, b) Sample LV 23, butchering with frequent bone contact, flat topography, covered linkage, c) Sample LV 24, butchering with bone contact, bright spots (photo A. Petrović)

FTIR analysis results

In all observed spectra of analysed samples, the bands at 1576,1540 cm^{-1} were observed (Table 29). The spectra were interpreted as adipocere, which is corresponding to the use-wear analysis which indicated the utilization of the chipped stone tools for processing the animal-based materials, as animal tissues, hard animal materials or butchering in general. Calcium carbonate (~1440, 877 cm^{-1}) was noted in the case of the flakes found in the Neolithic pit C/X, XI, which can indicate both the residues from activity or it can be part of the environmental aspect where the activity took place.

Table 29: Samples from pits, Lepenski Vir, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
LV 142	1576,1540, ~1440	Adipocere, $CaCO_3$	
LV 143	1576,1540, ~1440, 877	Adipocere, $CaCO_3$	
LV 23	1576,1540	Adipocere	
LV 24	1576,1540	Adipocere	

5.1.16. Summary of the results of the chipped stone tools from Lepenski Vir site

In total 393 artefacts from Lepenski Vir have been analysed with low and high power approach, and eighty-eight (88) tools were additionally analysed with FTIR spectroscopy. One hundred and nineteen (119) tools did not bear any traces of use.

Around 44% of the tools have indeterminable trace direction, while cutting is the most represented activity observed (Fig. 137). The combination of cutting and scraping is in the second place, followed by general working and scraping. One tool was used for a combined activity of incision, cutting and engraving, and one for drilling.

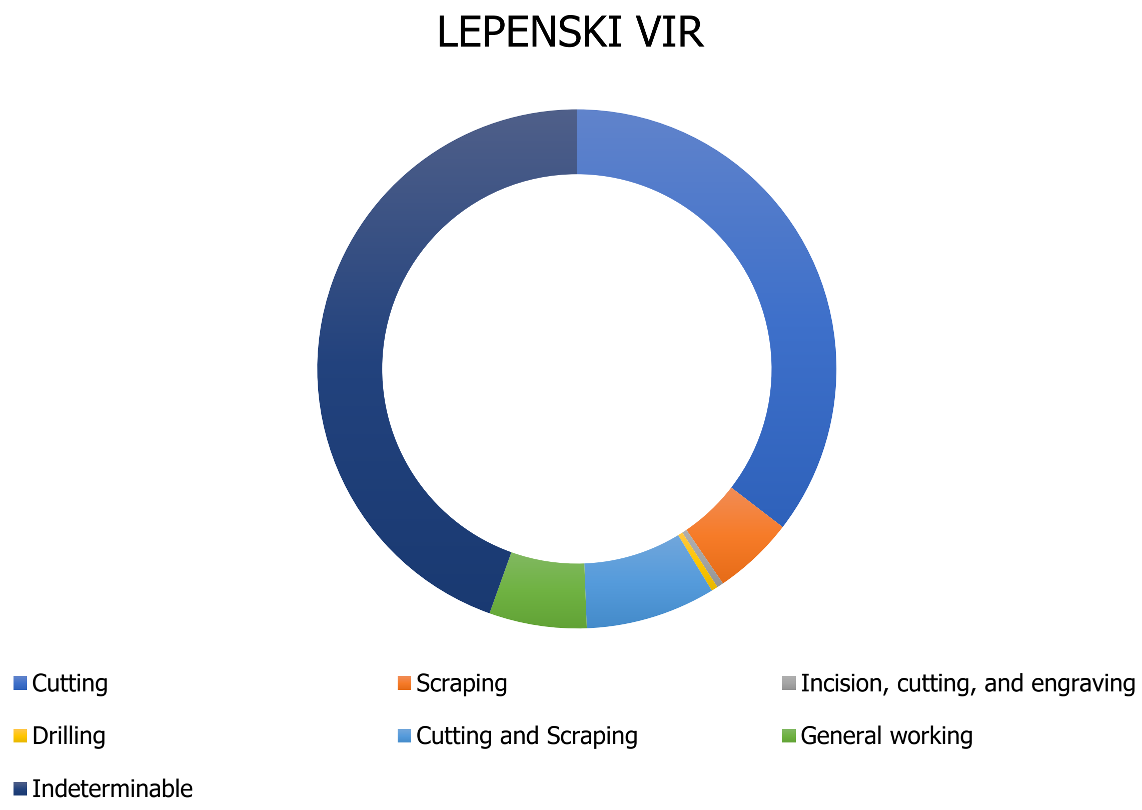


Figure 137: Activties, Lepenski Vir

If we observe the worked matters, in general, around 34% of the tools have non-diagnostic traces, while around 23% have only macro traces that could be interpreted due to trace preservation and alterations (Fig. 138). The animal-based materials were processed most frequently by the analysed tools from all the contexts of Lepenski Vir, while the quantity used for working vegetal materials is low (around 8%). Five tools were used in processing the mineral materials, as soft stone. There were no indications for use of both animal and vegetal matters on the tools, although there is a frequent superposition of animal materials. However, these episodes could not be singled out chronologically, so it is not clear were these activities part of one task or the tools were circulating.

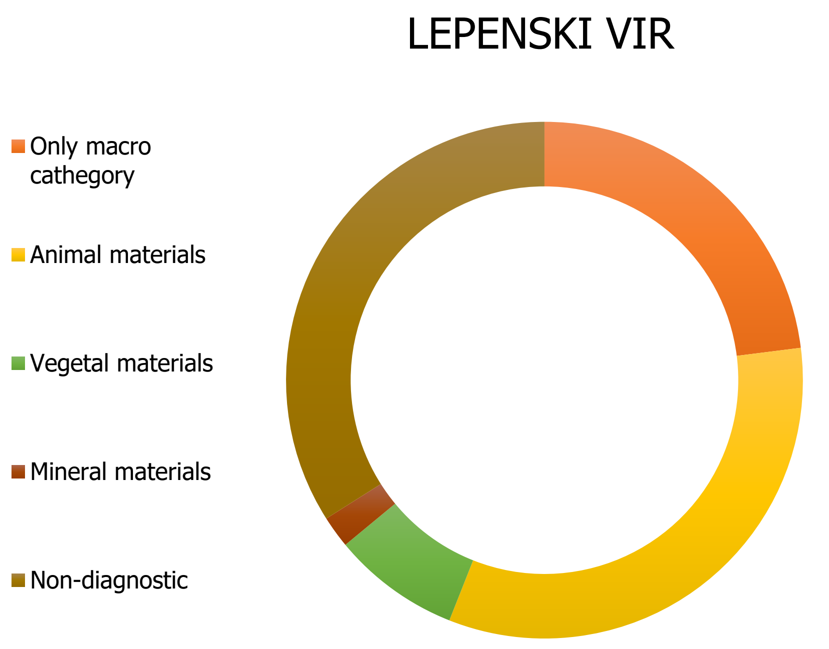


Figure 138: Worked materials, Lepenski Vir

The animal materials that were worked on the Lepenski Vir site are diverse, with hide as the most common material. Hard animal materials are present and their differentiation has been made on bone and antler, and a group of hard animal materials that displayed characteristics of hard materials, like snap, step, overlapping scars with high edge rounding and micro-wear that is indicating animal-based polish. Regarding the hide, which is based on the macro observations usually connected to the medium matters diverse phases of processing of the skins were noted from fresh, to semi-dry and dry or hide with additives. Soft animal materials are usually detected based on the feather macro traces and granular texture of polish with smooth texture. Two more general categories were found at the Lepenski Vir – meat and animal tissues. The second material however is usually indicating the mixture of meat and some polish characteristics that could be a result of contact with the ligaments and tendons. These activities can be phases of the butchering process, but ulterior indications of hide and bone contact were not found. It should be emphasised that some contexts, for example, pits, contained tools used only for the processing of animal matters.

Vegetal matters were treated at Lepenski Vir but in a very low quantity. The variety of vegetal materials processed at Lepenski Vir is represented by wood (in diverse phases, both fresh and dry), tubers, herbaceous, silicious plants. The highest amount of tools utilized by vegetals is found in houses 36 and 26.

5.2. PADINA RESULTS

5.2.1. Sector I

Use-wear analysis

Majority of the tools found in Sector I are coming from block 1b, marked as house 2, which is dated to 6650-6460 cal BC, the transitional period of Iron Gates (Borić and Miracle 2004: 348). Blade PA 6 is coming from block 2b, marked as house 3, together with house 2 belonging to the Padina B horizon (Radovanović 1996). Artefacts that came from profile 3, segment 2 were found with Starčevo pottery placing them in the Early Neolithic period. Nineteen (19) chipped stone tools were analysed from Sector I (Table 30). Out of nineteen pieces, eighteen were made on chert and one blade was made of obsidian, whose sourcing is not known. It is assumed that it came from the Carpathian 1 source, based on the existing results of obsidian characterisation from Central Balkans (Milić and Tripković 2008).

Table 30: Samples from Sector I, Padina, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
PA 1	Trench 1, block 1b, under the hearth 1614	Blade	Scraping/cutting	Butchering and skinning (maybe superposition of a couple of episodes)	Wrapped	Roots, Bright Spots
PA 2	Trench 1	Blade	Cutting	Antler	Hafted (superposition of use, then retouched and then hafted)	Roots
PA 3	Profile 3, segment 2	Flake	Cutting	Butchering	Prehension (superposition of use and prehension traces on both edges): hand-held	
PA 4	Profile 3, segment 2	Flake	Cutting	Superposition of wood and animal material	Prehension: hand-held	
PA 5	Trench 1, block 1b	Blade	Cutting/Scraping	Dry Hide	Hafted (superposition of use and then hafted)	Glossy Appearance

PA 6	Trench 1, block 2b	Blade	Cutting/Scraping	Medium material		Chemical alteration
PA 7	Trench 1, block 1b	Flake	Scraping	Wood	Prehension: hand-held	Any
PA 8	Trench 1, block 1b	Flake	Cutting	Medium-hard material		
PA 10	Trench 1, block 1b	Flake	Scraping	Soft-medium material		
PA 11	Trench 1, block 1b	Flake	Cutting	Soft material		Thermal stress
PA 12	Trench 1, block 1b	Flake	Indeterminable	Animal material		
PA 13	Trench 1, block 1b	Flake	Indeterminable	Medium material		Glossy Appearance
PA 14	Trench 1, block 1b	Flake	Cutting	Soft material		Soil sheen
PA 15	Trench 1, block 1b		/	Not used		
PA 16	Trench 1, block 1b	Flake	Indeterminable	Animal Tissues		Glossy Appearance, Bright Spots
PA 17	Trench 1, block 1b	Flake	Scraping	Soft-medium material		Glossy Appearance, Thermal stress
PA 18	Trench 1, block 1b	Flake	Indeterminable	Non-diagnostic		
PA 19	Trench 1, block 1b	Flake	Indeterminable	Non-diagnostic		
PA 20	Trench 1, block 1b	Flake	Indeterminable	Non-diagnostic		Thermic Alteration

Regarding the general results considering the tools that were found in Sector I, all tools except one were used. Three flakes have indeterminable traces due to the alterations. As already mentioned many tools were affected by the presence of modern roots (Fig. 139a), which altered the surface both mechanically and chemically. Post-depositional surface modifications (PDSM) are present at 53% of the chert assemblage from Sector I and bright spots (Fig. 139b), roots, soil sheen, glossy appearance, thermal stress and various chemical and physical alteration are present (Fig. 139).

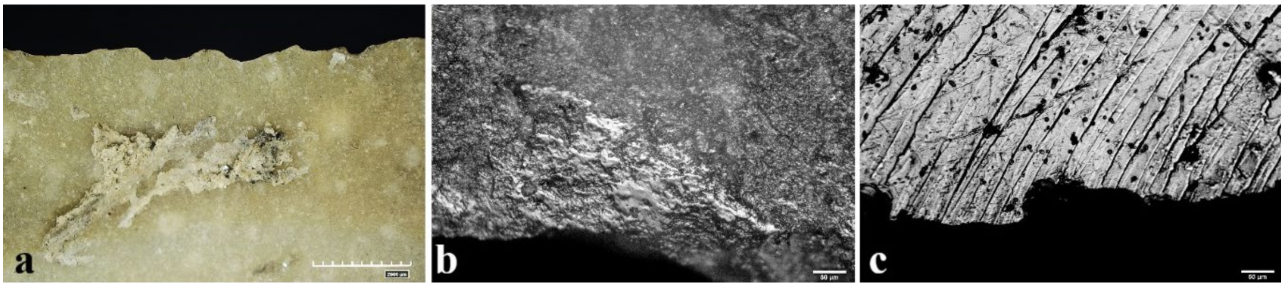


Figure 139: Alterations: a) Roots, PA 1 b) Bright spot, PA 1 c) Chemical and physical alteration on the obsidian blade, PA 6 (photo A. Petrović)

From the total number of tools that were used and diagnostic 53% were possible to be determined to the exact used materials, meaning that micro traces were preserved. Animal materials were processed with 32% of the tools, and only one tool was used for vegetable materials like wood, and one was both used for working animal and vegetal materials. Out of the total number of the utilized artefacts, six tools had indeterminable characteristics for revealing the motion, six tools were used for cutting, three for scraping and three for mixed activities of cutting and scraping.

Regarding the hard animal material, only one tool was used for cutting antler (Fig. 140a). These tools had traces of granular and domed topography and a tight linkage. Other tools were used for processing the animal materials, dived into the ones used for butchering (Fig. 140b), working of dry hide and animal tissues, leaving two tools in the general category. The tools used for butchering were covered with prehension traces and in the case of the blade, wrapping patches indicating shifting of the working zone.

One flake was used for scraping wood, and another had overlapping traces of wood and animal material in general (Fig. 140c). Wood traces are represented with pronounced domed topography and in the case of PA 7, rough texture (Fig. 140d).

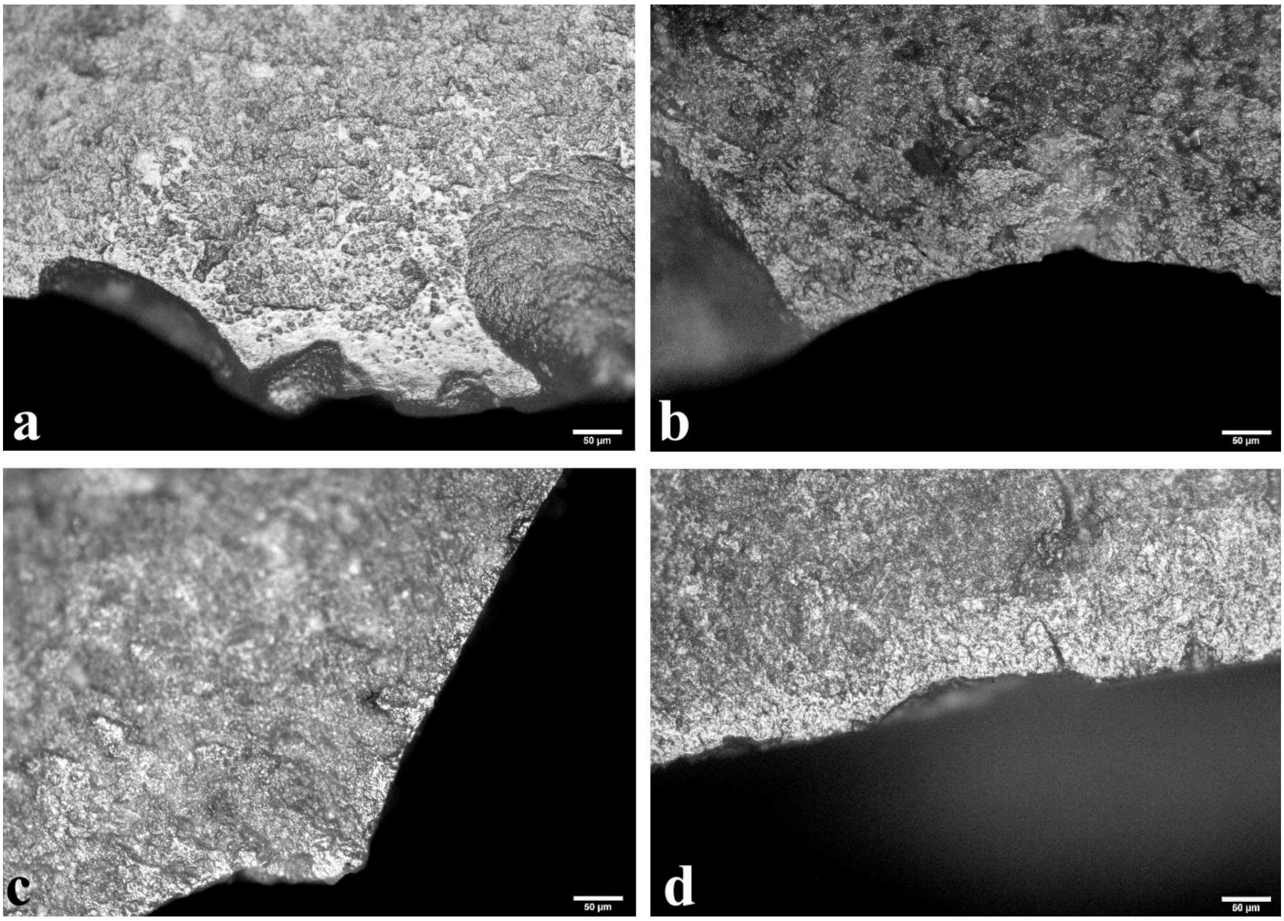


Figure 140: Micro use-wear traces: a) Antler, PA 2, b) Butchering, PA 1, c) Woodworking and animal material, PA 4, d) Wood, PA 7 (photo A. Petrović)

The presence of both hafted and wrapped tools is highlighting the importance of the area of Sector I. Hafting traces were found on two blades (Fig. 141a-b). Scar morphology, in the case of PA 2, is scalar while distribution is uneven and run-together. The trace pattern is represented by larger scars with smaller ones inside them, followed by smooth morphology.

Traces of wrapping were found on one blade (Fig. 141c). The binding was probably done with some kind of texture or even with beeswax. These traces were mimicked with experiments and observed traces are corresponding. This is, so far, based on the analysed samples from all three sites, the only tool that has wrapping traces, leaving indications that this was not a usual procedure in Iron Gates. The wrapping polish is noted on the edge and the ridges, and there is a possibility that bright spots (Fig. 139b) occurred as a result of the friction between the wrapping texture or beeswax and particles of the ground or worked material.

Prehension traces were found on three flakes and they were held by a hand (Fig. 141d), other analysed tools from Sector I did not have any diagnostic tool handling traces.

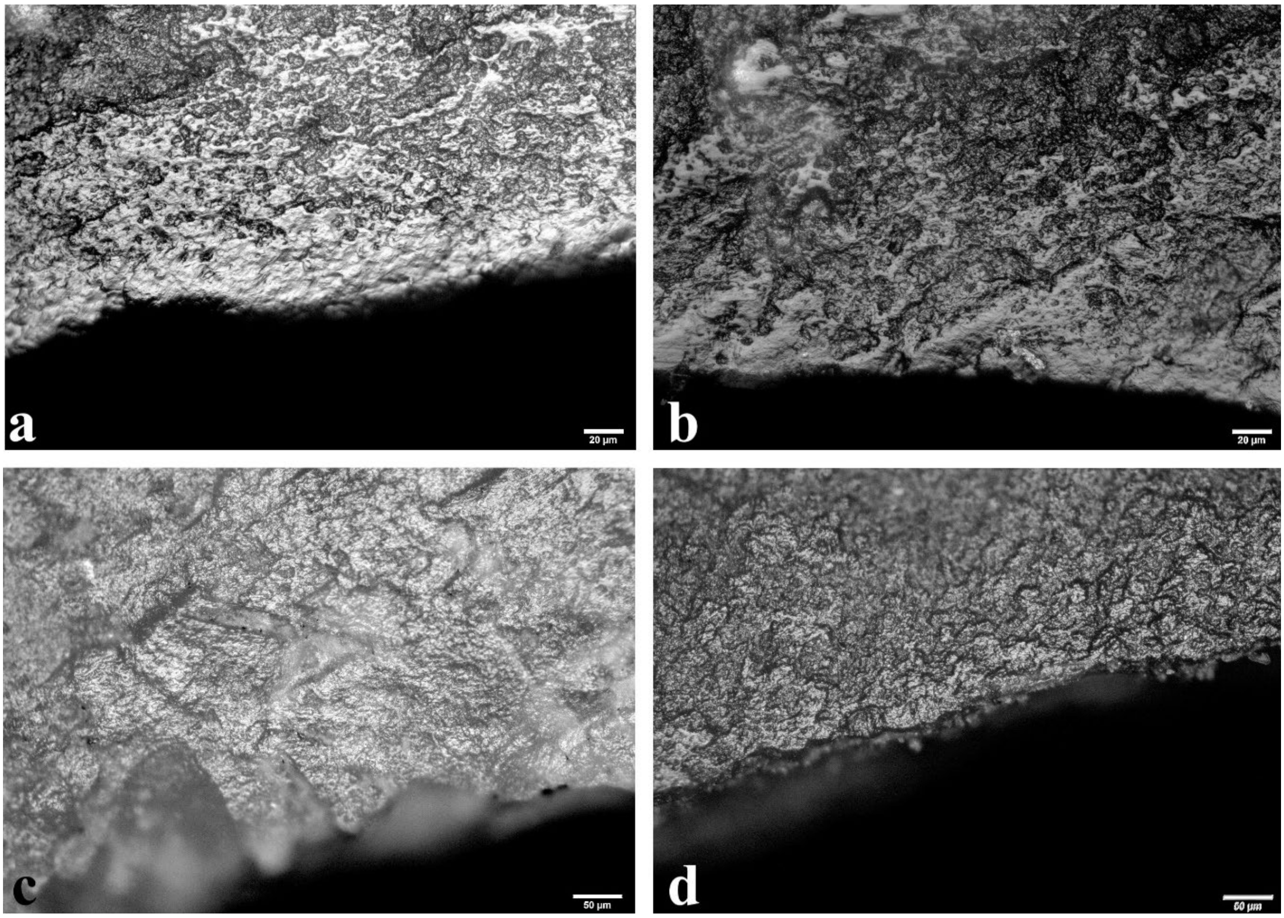


Figure 141: Tool handling modes: a) Hafting, PA 5, b) Hafting, PA 2, c) Wrapping, PA 1, d) Hand-held, PA 7 (photo A. Petrović)

Superposition of traces was found on one tool where there is a clear depiction of wood traces and animal material in general. Also, the blade from the hearth (PA 1) indicates more activities laying over each other. However, there is also overlapping of use and wrapping and hafting on both edges of the tools in three cases (PA 2, 3 and 5).

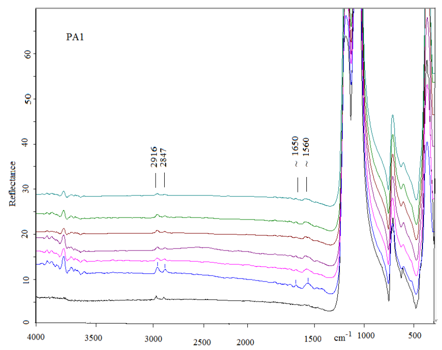
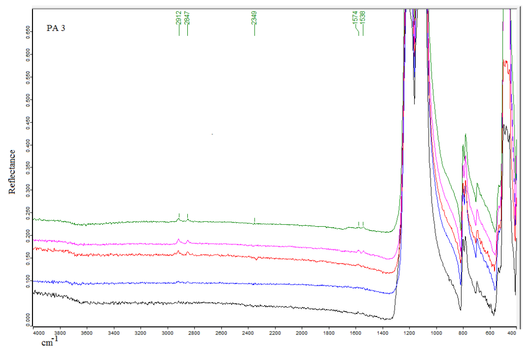
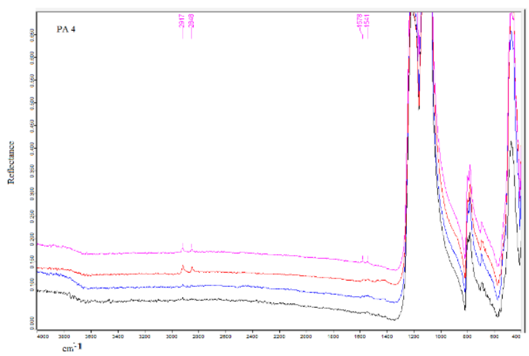
These results, from Sector I and block 1b and profile 3 are very important since they belong to the context dated to the transitional period, therefore they represent a clear picture of various activities from butchering to woodworking. The presence of tools with superpositioned traces as noted on the tool PA 4 are peculiar and they testify about the maximum utilization of the tools.

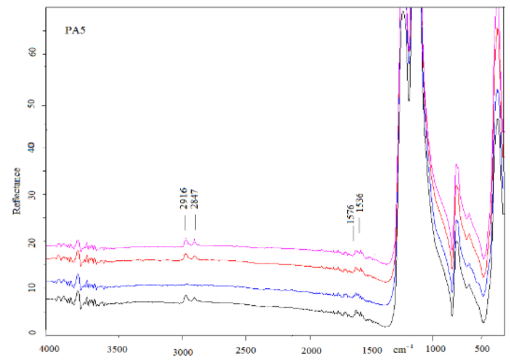
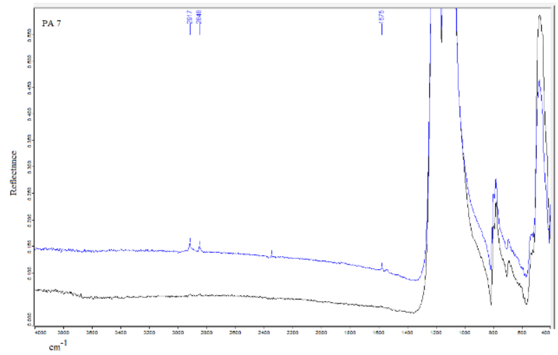
FTIR analysis results

Five samples, from Sector I were analysed with FTIR spectroscopy (Table 31). They all showed the existence of a greasy lipid mixture, known as adipocere (1576, 1540 bands), which is most representative of animal-based materials.

The presence of collagen (~1650) is very important, having in mind that it is found on the PA 3 used for butchering activities, completely supporting the use-wear traces. Calcium carbonate (~1420) is usually present in rocks, as the minerals calcite and aragonite, most notably as limestone, and is found in the shells as well. It can also be an indication of an environmental element considering the possibility of worked materials and prehistoric processes. Lignin (1710, 1660, 1550), which provides structural support within plants and is a major component of woody tissue, is present on the PA 1, which was used for butchering, but it can be attributed to the wrapping process since traces were found all over the tool's surface.

Table 31: Samples from Sector I, Padina, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
PA 1	1576,1540 1710, 1660, 1550, ~1420	Adipocere, Lignin, CaCO3	
PA 3	1576,1540, ~1650	Adipocere, Collagen	
PA 4	1576,1540, ~1420	Adipocere, CaCO3	

PA 5	1576,1540	Adipocere	
PA 7	1576,1540	Adipocere	

5.2.2. Sector II

Use-wear analysis

The majority of the tools found in Sector II originates from block 2a. Since many artefacts were found in this block, the most important categories were chosen from each excavation layer. As already stated, there are no absolute dates from this block, but according to the found material and constructions this block belongs to Padina A horizon which is settled in the second half of the ninth millennium cal BC (Radovanović 1996). The only date (8250-7600 cal BC) from Sector II is from burial 7, found in block 1b (Borić and Miracle 2004). In total, 97 artefacts were sampled from this context from II, IV, V, VII excavation layers (Table 32). All sampled tools, except for the PA 68, which is very rounded and alternated in the way that raw material is not recognizable, are made of chert.

Table 32: Samples from Sector II, Padina, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
PA 27	Block 2a	Flake	Cutting	Woody material	Wooden haft (superposition of use and hafting)	Roots
PA 28	Block 2a	Flake	Engraving	Wood, abrasive		Roots
PA 29	Block 2a	Flake	Cutting	Humid hide, abrasive materials (superposition)		Roots
PA 30	Block 2a	Flake	Cutting	Medium material		
PA 31	Block 2a	Flake	Cutting	Vegetable (woody or tubers), soil (superposition)	Prehension: hand-held (superposition of use and prehension)	
PA 32	Block 2a	Flake	Scraping, Cutting	Medium material		Bright Spots, Glossy Appearance
PA 33	Block 2a	Flake	Indeterminable	Non-diagnostic		Any
PA 34	Block 2a	Flake	Cutting	Bone and hide + ash (?), superposition	Gripping	Glossy Appearance
PA 35	Block 2a	Flake	Cutting	Tubers	Prehension: hand-held	Roots
PA 36	Block 2a	Flake	Cutting	Hide of a smaller animal (possibly fish)		
PA 37	Block 2a	Flake	Incision	Wood		
PA 38	Block 2a	Flake	Cutting	Wood		
PA 40	Block 2a	Flake	Cutting	Butchering, hide, meat	Prehension: hand-held	Glossy Appearance

PA 41	Block 2a	Blade	Cutting	Animal Material		Glossy Appearance, Roots
PA 42	Block 2a	Flake	Indeterminable	Semi-dry hide		Glossy Appearance, Roots
PA 43	Block 2a	Flake	Cutting	Medium-hard material		Any
PA 44	Block 2a	Flake	Cutting	Animal material		Roots
PA 45	Block 2a	Flake	Cutting and Scraping	Medium-hard material		
PA 46	Block 2a	Flake	Cutting	Woody material		Roots
PA 47	Block 2a	Flake	Cutting	Hard material		
PA 48	Block 2a	Flake	Cutting	Animal material		Glossy Appearance
PA 49	Block 2a	Flake	Indeterminable	Animal material		
PA 53	Block 2a	Flake	Cutting	Hide		
PA 55	Block 2a	Blade	Cutting	Vegetable		Glossy Appearance
PA 56	Block 2a	Flake	General working	Vegetable		Any
PA 57	Block 2a	Blade	Cutting	Medium material		Glossy Appearance
PA 58	Block 2a	Flake	Cutting	Tubers		Roots
PA 59	Block 2a	Blade	Cutting	Hard animal material	Prehension: hand-held, hafting	Roots
PA 60	Block 2a	Flake	Scraping, Cutting	Medium material		

PA 61	Block 2a	Flake	Cutting	Hard animal material		Any, roots
PA 62	Block 2a	Flake	Cutting	Fresh Hide and other material		
PA 63	Block 2a	Flake	Cutting	Soft-medium material	Prehension	Roots
PA 64	Block 2a	Flake	Cutting	Dry Hide		
PA 65	Block 2a	Flake	Incision	Soft stone		Roots
PA 66	Block 2a	Flake	Cutting	Vegetable (tubers or wood)		Roots
PA 67	Block 2a	Flake	Cutting	Medium		Glossy Appearance
PA 68	Block 2a	Non-diagnostic	Non-diagnostic	Non-diagnostic		
PA 69	Block 2a	Flake	Cutting	Butchering, meat		
PA 70	Block 2a	Flake	Cutting	Woody material on one edge, meat and hide on another (superposition)		
PA 71	Block 2a	Flake	Cutting	Fresh antler (greasy), superposition		Roots
PA 72	Block 2a	Flake	Cutting, scraping	Antler and hide with minerals (superposition)		
PA 73	Block 2a	Blade	Cutting	Tubers	Wooden haft	Roots
PA 74	Block 2a	Flake	Cutting	Hide		
PA 75	Block 2a	Flake	Cutting	Hide with additives		
PA 76	Block 2a	Blade	Cutting, Scraping	Woody material, worked near the ground		

PA 77	Block 2a	Flake	Cutting, Scraping	Woody material		
PA 78	Block 2a	Scraper	Non-diagnostic	Abrasive material		
PA 79	Block 2a	Flake	Cutting, Scraping	Hard animal material	Prehension: hand-held	
PA 80	Block 2a	Flake	Incision	Hide, worked on the ground	Wooden haft	
PA 81	Block 2a	Flake	Cutting	Bone		
PA 82	Block 2a	Flake	Cutting	Hard material, abrasive		
PA 83	Block 2a	Flake	Incision	Hide and mineral	Prehension: hand-held	
PA 84	Block 2a	Flake	Indeterminable	Non-diagnostic		
PA 85	Block 2a	Flake	Indeterminable	Wood		
PA 86	Block 2a	Flake	General working	Hide with additives and bone		Any
PA 87	Block 2a	Flake	Indeterminable	Soft material		
PA 88	Block 2a	Flake	Indeterminable	Hard animal material		
PA 89	Block 2a	Flake	Cutting	Medium material		Any
PA 90	Block 2a	Flake	Cutting	Medium material		Glossy Appearance
PA 91	Block 2a	Flake	Cutting	Bone	Prehension: hand-held	
PA 92	Block 2a	Flake	Cutting	Medium material		Glossy Appearance

PA 93	Block 2a	Flake	Scraping	Mineral material		Glossy Appearance
PA 94	Block 2a	Flake	Indeterminable	Non-diagnostic		Any
PA 95	Block 2a	Flake	Indeterminable	Woody material		
PA 96	Block 2a	Flake	Indeterminable	Mineral material		
PA 97	Block 2a	Flake	Indeterminable	Non-diagnostic		
PA 98	Block 2a	Flake	Cutting	Medium material		
PA 99	Block 2a	Flake	Cutting	Non-diagnostic		Glossy Appearance
PA 100	Block 2a	Flake	Cutting, Incision	Wood		
PA 101	Block 2a	Scraper	Scraping	Vegetable material		Glossy Appearance (light)
PA 102	Block 2a	Flake	Cutting	Bone		
PA 103	Block 2a	Flake	Cutting	Bone, mineral material		
PA 104	Block 2a	Flake	Cutting	Medium material		Glossy Appearance
PA 105	Block 2a	Flake	General working	Butchering		Any, roots
PA 106	Block 2a	Core	Not used	Not used		
PA 107	Block 2a	Core	Not used	Not used		
PA 108	Block 2a	Core	Not used	Not used		

PA 109	Block 2a	Flake	Scraping, cutting	Medium, abrasive material, animal		
PA 110	Block 2a	Flake	Cutting	Woody material		
PA 111	Block 2a	Flake	Cutting	Soft-medium, abrasive material		
PA 112	Block 2a	Flake	Cutting	Butchering		
PA 113	Block 2a	Flake	Cutting	Butchering, dry hide	Hafting	Roots
PA 114	Block 2a	Flake	Cutting	Woody material		Roots
PA 115	Block 2a	Flake	Indeterminable	Non-diagnostic		
PA 116	Block 2a	Flake	Cutting	Non-diagnostic		
PA 117	Block 2a	Flake	Indeterminable	Medium, abraded material		
PA 118	Block 2a	Flake	Cutting, scraping	Butchering		
PA 119	Block 2a	Blade	Indeterminable	Soft material	Prehension: hand-held	Glossy Appearance
PA 120	Block 2a	Flake	Cutting	Woody and abrasive material on one side, on another hide		
PA 121	Block 2a	Flake	Cutting	Medium material		Glossy Appearance
PA 122	Block 2a	Flake	Indeterminable	Woody material		Glossy Appearance
PA 123	Block 2a	Flake	Cutting	Woody material		
PA 124	Block 2a	Blade	Indeterminable	Tubers		

PA 125	Block 2a	Flake	General working	Semi-dry hide on one edge, woody material on another	Prehension: hand-held	
PA 126	Block 2a	Flake	Cutting	Woody, mineral material		
PA 127	Block 2a	Flake	Cutting	Medium, mineral material	Hafting/ Prehension	
PA 128	Block 2a	Flake	Indeterminable	Medium material		

Regarding the general overview of Sector II, only three cores (PA 106, PA 107 and PA 108) were not used. The 41% of the analysed tools were affected by various alterations as roots (Fig. 142a-c), glossy appearance, bright spots, and other, alterations that could not be determined in detail.

Figure 142: Root alterations on samples from Sector II a) PA 28, b) PA 42, c) PA 58) (photo A. Petrović)

In total 6 samples were non-diagnostic and their traces could not be analysed, all the other samples could be determined from at least one variable, such as either activity or worked material. From all the analysed tools 20% of the artefacts have been used but the exact motion is not possible to be determined. Cutting, present at 57%, is by far the most pronounced activity in Sector II, followed by tools with two motions as cutting and scraping (9%), incision (4%), and general working (4%). In smaller amounts scraping is also present at 2%, and a dual activity of animal and incision (1%).

From the used tools, 25% of the tools could not be determined as animal and vegetable worked materials, and their analysis is solely based on macro traces putting them in categories as hard, medium, soft materials, sometimes abraded, and in mixed categories as a hard medium, and soft medium materials.

Regarding the animal materials they were worked by 35% of the tools from this assemblage, while 28% of the tools were used for processing the vegetable-based resources, 4% for mineral materials and 8% were completely non-diagnostic.

Animal resources are present in the most diverse shapes and combinations in Sector II. Among traces of hard animal materials bone was confirmed and in one case antler. However, some tools did not show enough characteristics and are left as generic conclusions. Bone traces gave very tight to the covered linkage, smooth texture and flat topography (Fig. 143a), and it depends on the angle of work and bone size, usually localized on the edge and the edge and surface. In some cases, the presence of additives such as ash is visible in the brightness (Fig. 143a). Antler working was found only on one flake in Sector II. Antler processing is represented with flat and melted topography, and it is mixed with some hide and mineral working defined by some abrasive characteristics and granular topography (Fig. 143b). The tools that were used for hard animal materials processing have certain unique characteristic as tight linkage and flat topography, sometimes varying as a rougher texture on the tools PA 59 (Fig. 143c), or smoother texture and covered linkage on the edge as in case of PA 61 (Fig. 143d)

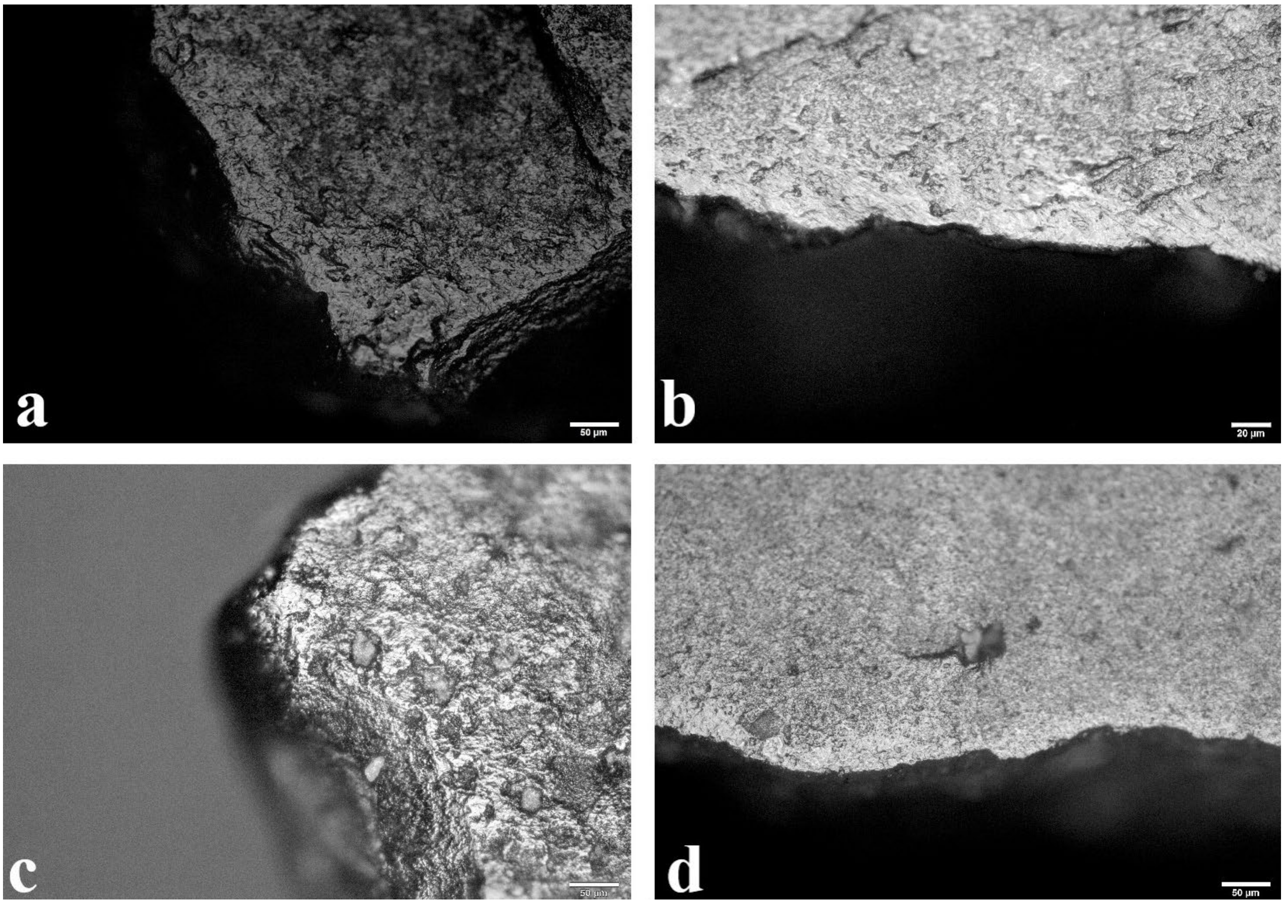


Figure 143: a) Bone working with ash, PA 34 b) Antler PA 72 c) General hard animal material, PA 5
d) General hard animal material, PA 61 (photo A. Petrović)

Around 1/3 of the total tools used for processing the animal resources was used to work hide in various phases and with additives. The diversity of the hide phases is very important for understanding the everyday dynamics of the Padina settlement in the specific period, but also complements the overall hide processing treatment in the Iron Gates, already visible at the Lepenski Vir.

Processing of hide is usually visible in the granular topography on the outer edge (Fig. 144a). The texture of the traces is depending on the state of the hide varying from the smooth, but rougher on the semi-dry hide (Fig. 144b) to the rough polish on the dry hide (Fig. 144c). What is specific is the working of the smaller portion of skin, visible in the light but very localised traces on the sample PA 36, testifying that the animal that was process was of more compact dimensions (Fig. 144d).

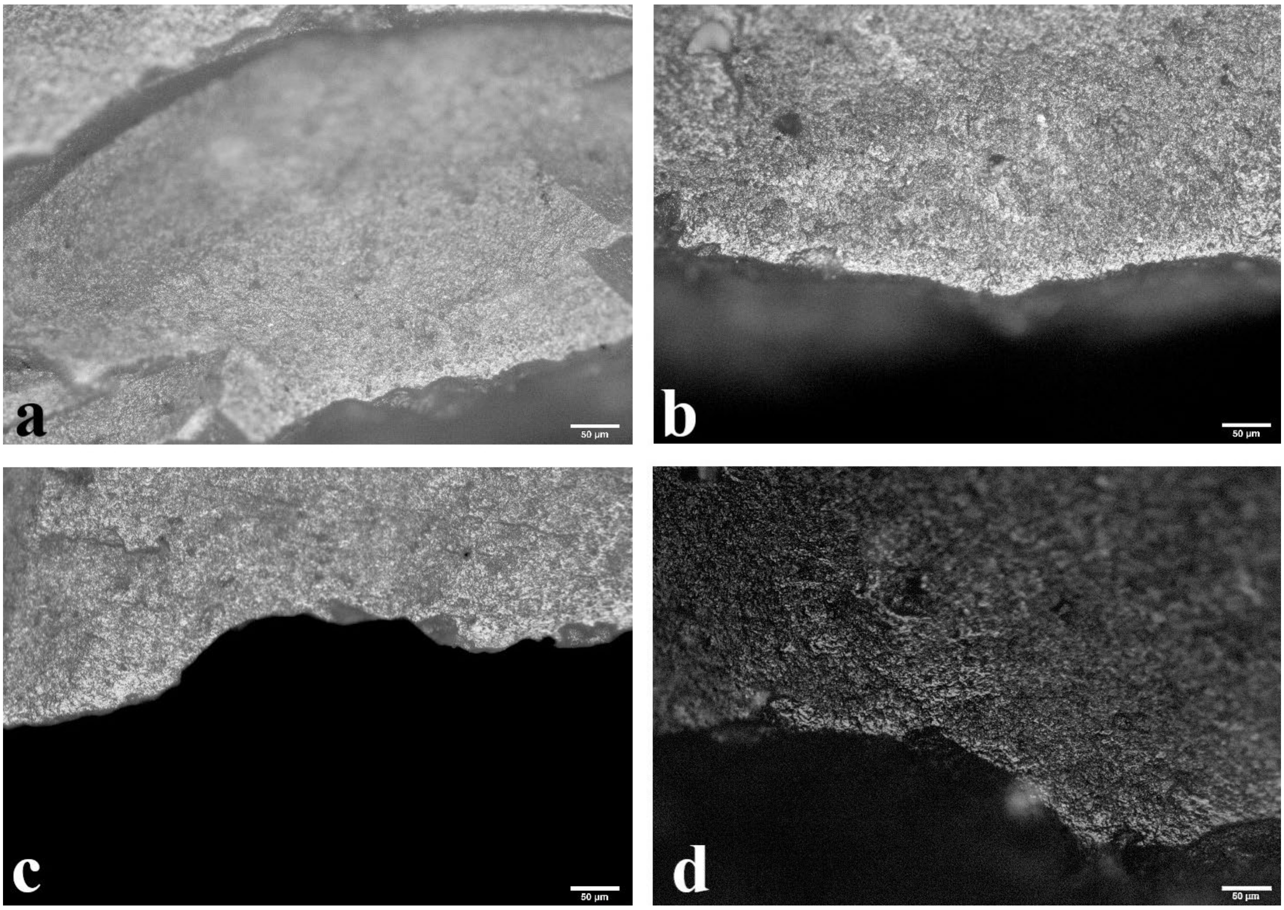


Figure 144: a) Hide working, PA 53, b) Semi-dry hide, PA 42, c) Dry hide, PA 64, d) Working of small-sized animal skins, PA 36 (photo A. Petrović)

Some of the tools were used for more activities and materials, and in the case of the combination in the hide, one flake was used for working of humid hide and unidentified material (Fig. 145a). Another flake was used for processing fresh hide and another unrecognized material (Fig. 145b). In both cases, the traces are concentrated on the outer edge and edge area.

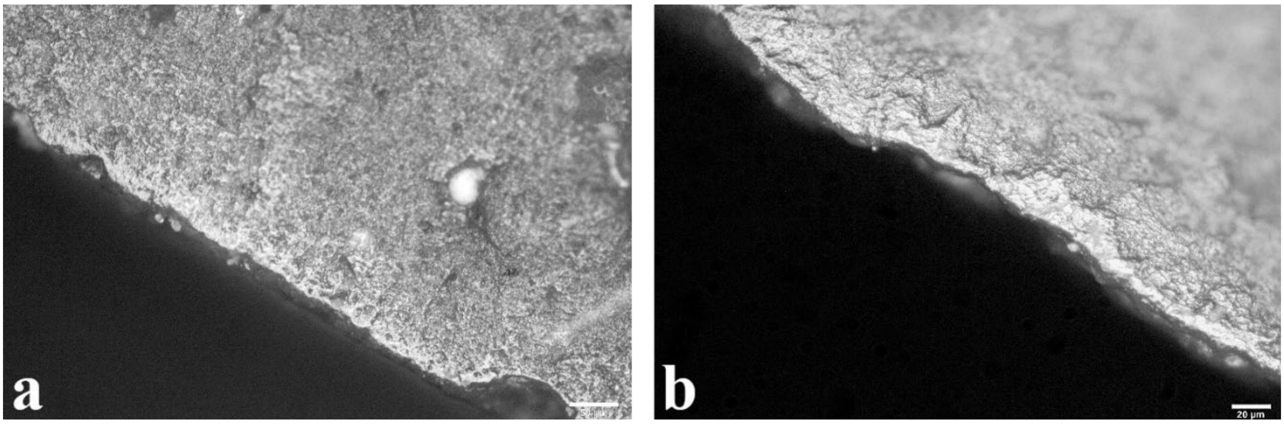


Figure 145: a) Working of humid hide and another material, PA 29, b) Fresh hide processing and another material, PA 62 (photo A. Petrović)

Butchering traces were found on 6% of the tools from Sector II. Clear traces of mixed contact materials as granular topography for the hide, flat and tight areas of the bone contact were found on the outer edges of the tools (Fig. 146a-b). However, no isolated meat traces and animal tissues were found.

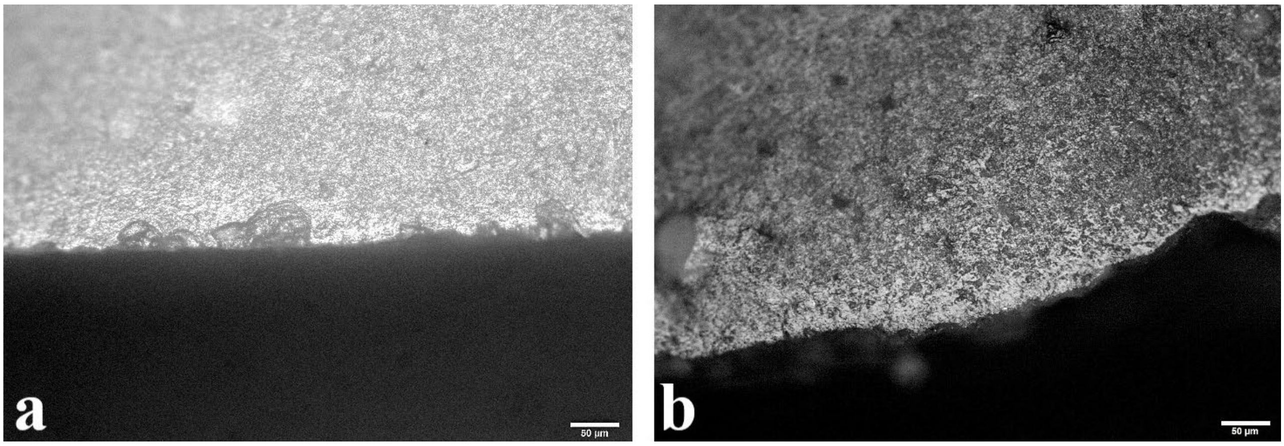


Figure 146: polish on the outer edge a) Butchering traces, PA 69, b) Butchering and dry hide, PA 113 (photo A. Petrović)

Regarding the vegetable base resources that were worked a couple of categories were made: vegetable material in general, woody materials, wood-working, and tubers. These results were encouraging since the vegetable base processes are outnumbered in the entire region, so the concentration we have in Sector II is very important for the comparison with other contexts but also indicating, once again, no cereal processing.

Vegetable base materials are recognized with domed topography. The linkage is depending on the working time, but also the amount of lignin and other mineral components in the plant-based materials. The linkage can be looser as in the case of the tools that generally worked some kind of the plant (Fig. 147a), but they can also penetrate more into the surface as the PA 120, which worked a woody material mixed with mineral component (Fig. 147b). This flake was used for working skin on the other edge. Wood is usually recognized as domed topography with closed higher parts of the polish, and more half-tight linkage on the lower parts (Fig. 147c-d). Tubers have tight linkage on the outer edge but they can be located on the ridges more inside the surface of the tool (Fig. 147e-f).

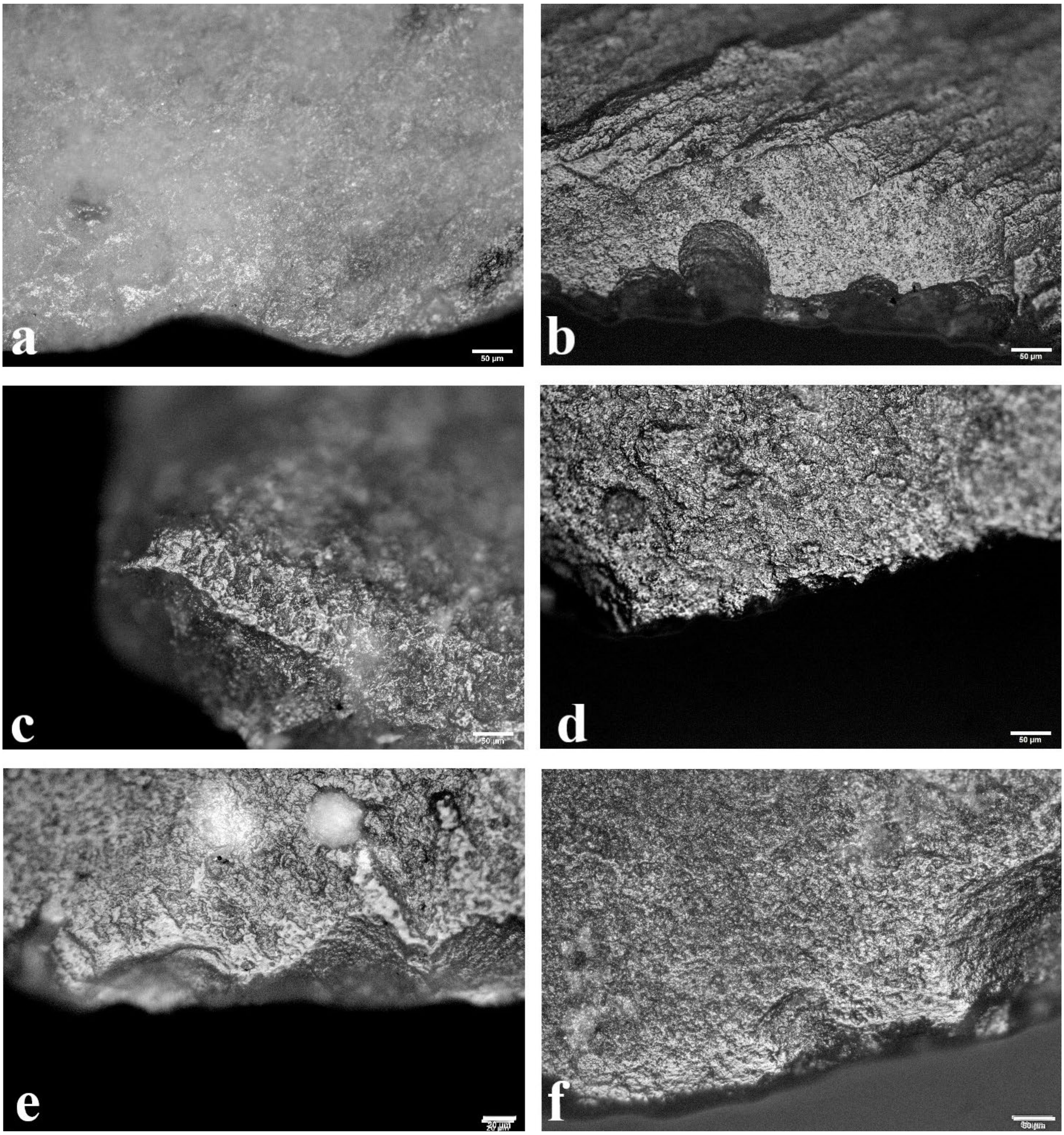


Figure 147: a) General working of vegetable-based material, PA 56, b) Cutting of woody material, PA 120, c) Engraving of wood with the abrasive component, PA 28, d) Cutting and incision of wood, PA 100, e) Cutting tubers, PA 35, f) Cutting tubers, PA 58 (photo A. Petrović)

One scraper (PA 78) was used for working of the abraded material and it left smooth and flat polish, and two flakes (PA 93, and PA 96) for working of the mineral material which left domed and granular polish characteristics. One tool was used for incision of the soft stone and left domed and covered traces on the higher parts of the polish and more granular on the lower part, leaving an abraded layer in some areas and striation visible on the flat and smooth zones of the outer edge (Fig. 148).

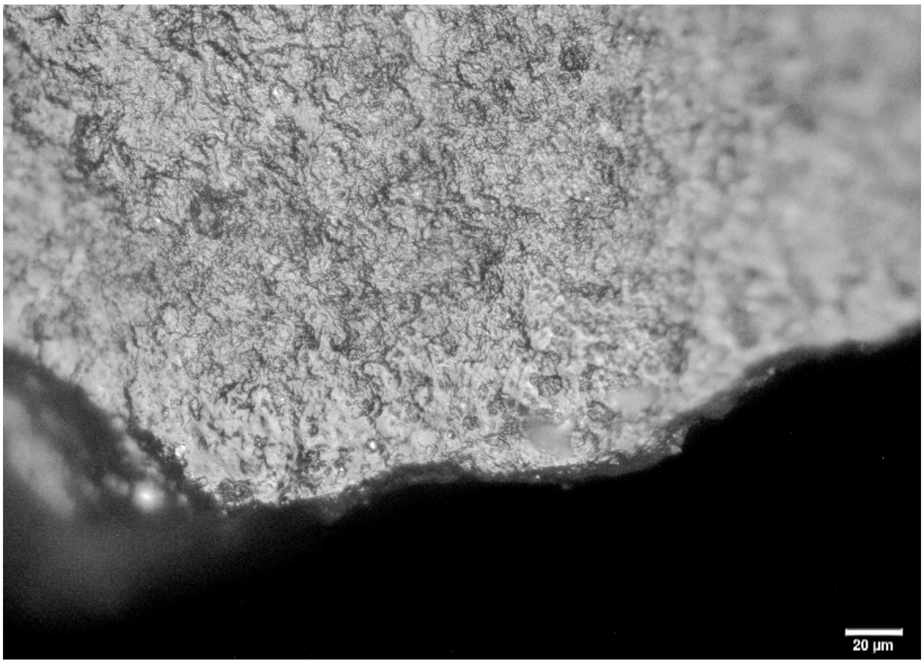


Figure 148: Soft-stone incision, PA 65 (photo A. Petrović)

On the 17% of the used tools from Sector II various traces of handling were found, as hand-held prehension (4%), (Fig. 149a), hafting (12%) and one tool (1%) was used within both modes. The haft was in three cases recognized as wooden haft (Fig. 149b). Two flakes (PA 27 and PA 31) were had the superposition of use traces and prehension traces on the same edge.

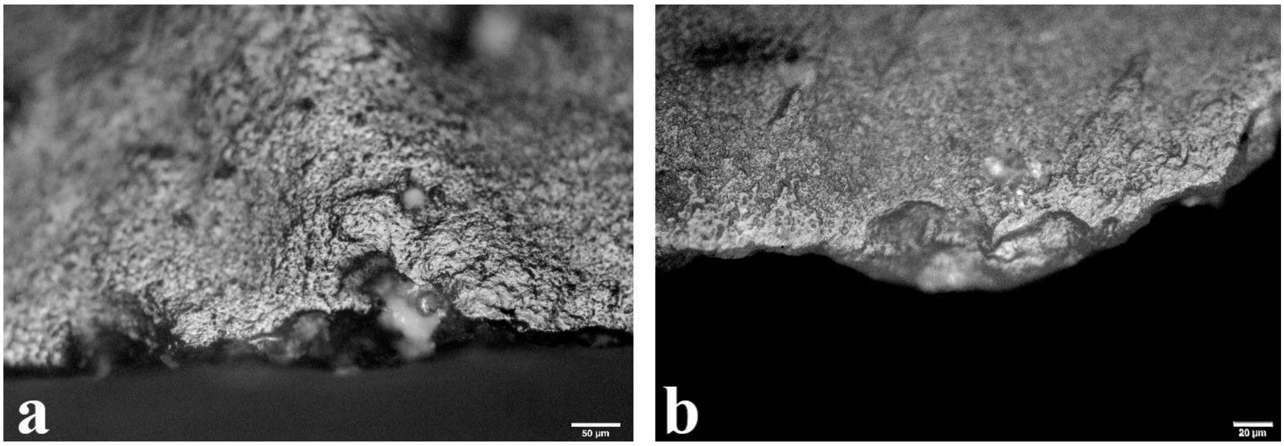


Figure 149: a) hand-held, PA 35, b) hafting with a wooden haft, PA 27 (photo A. Petrović)

Except for the tools with superposition traces from Sector I, the tools found in block 2a of Sector II were in similar condition, where different use traces were layered on each other (6%). Some of the artefacts (2%) had both edges employed in the diverse or same activities, and as already stated in a couple of cases prehension covered the used edge. This expedient usage of the tools testifies about human routine at the Padina site and indicates the extensive need for use of the tools for various activities, not preselecting them for specific materials in certain cases.

The predominance of working of animal materials is very notable, but what is more important is the number of diverse materials as harder animal materials as bone and antler, diverse types of hides and butchering. In the contrast, there are almost no tools that were solely used for meat and animal tissues. On the other side, the presence of vegetable base traces is crucial, since not many contexts in the analysed sites from Iron Gates have shown a high percentage of wood and tuber processing presence.

FTIR analysis

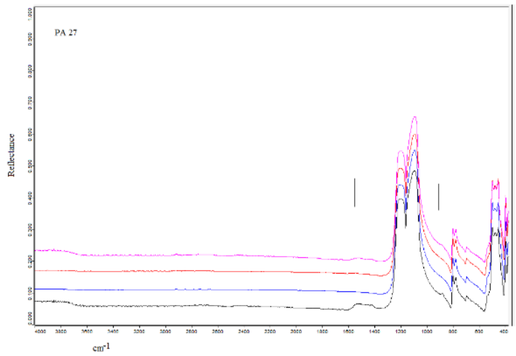
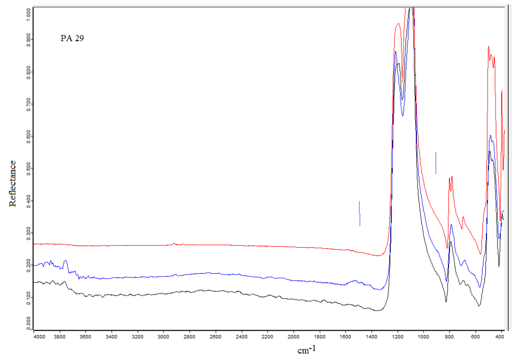
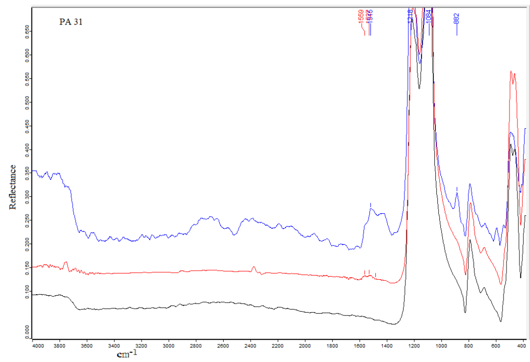
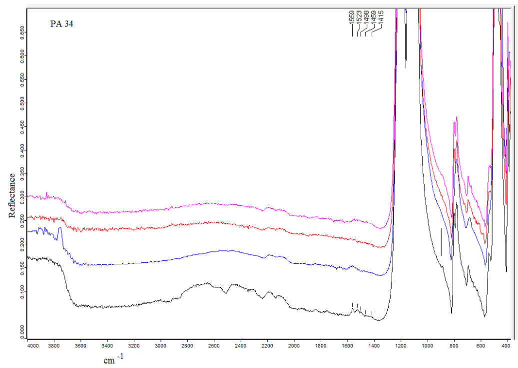
In total 20 samples were analysed with FTIR spectroscopy (Table 33).

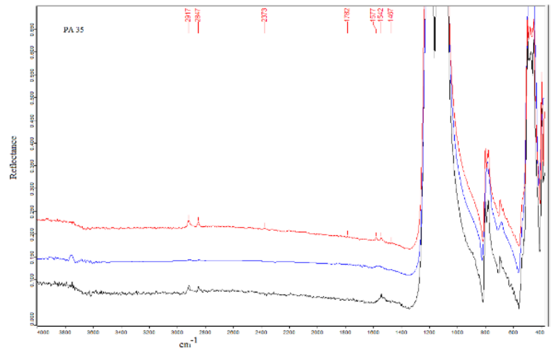
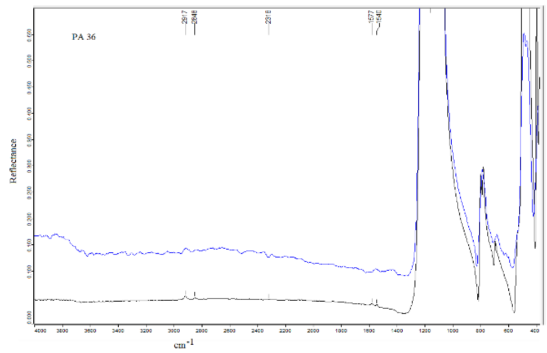
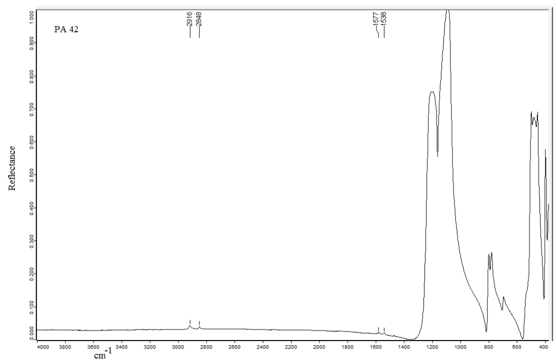
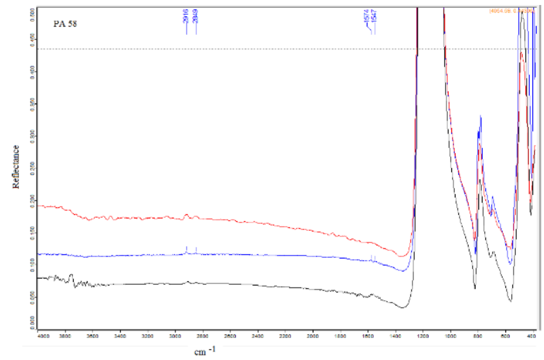
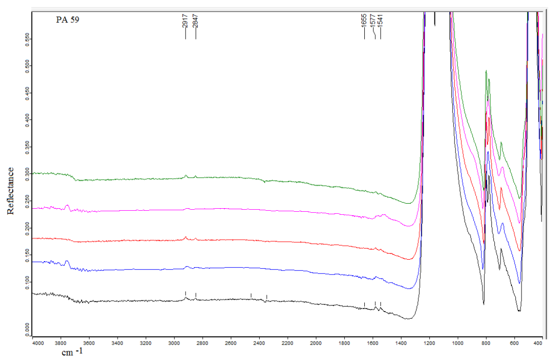
Adipocere is present in 80% (1576,1540 bands) of the analysed samples, even in the tools used for working the woody materials and tubers (for example PA 31 and PA 58). The position of adipocere on the vegetable-based material is present on either dorsal or ventral or on both surfaces.

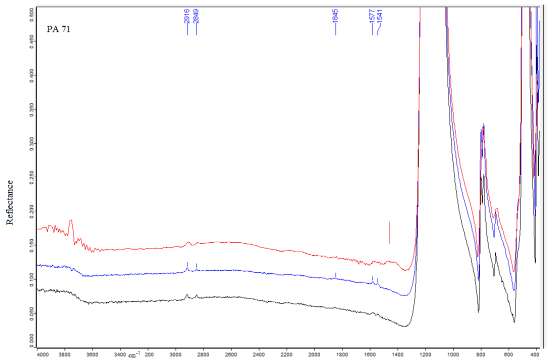
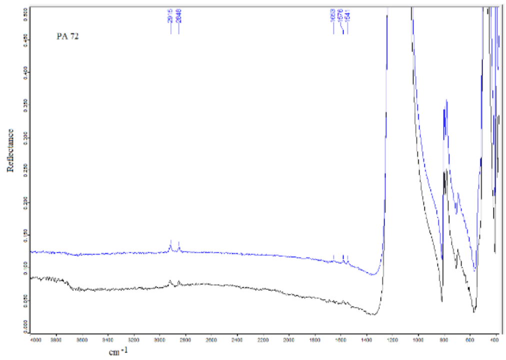
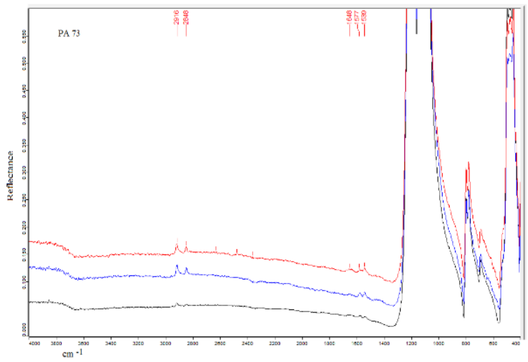
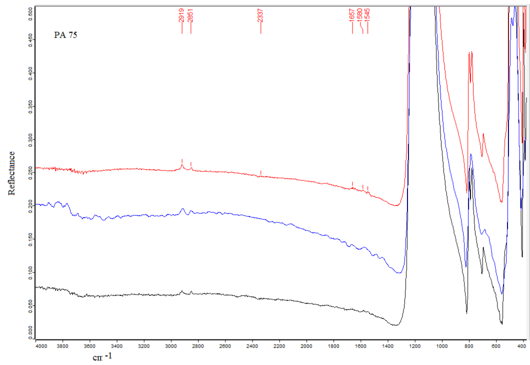
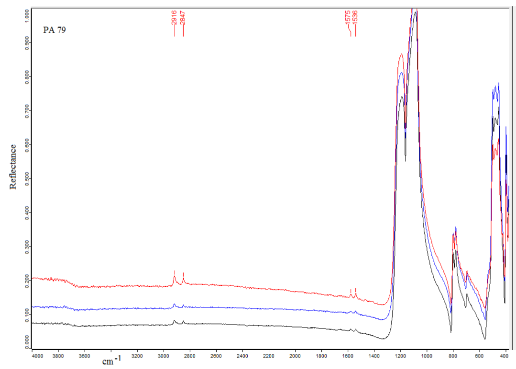
Traces of collagen (~1650) and adipocere are present at the sample PA 73 are the only ambiguous data concerning the observed tools. What is interesting is that the sample was used for cutting tubers and it was handled with a wooden haft. However, the bands connected to the vegetable-based material, as lignin, are not visible. This discrepancy between the use-wear and residue analysis can be caused by many factors, as due to the alterations or contamination that came from environmental factors. Simply, the tool could have been left with skins or animal products during its time of use, or when it was discarded. Unfortunately, there are no clear indications of the context where the blade was found.

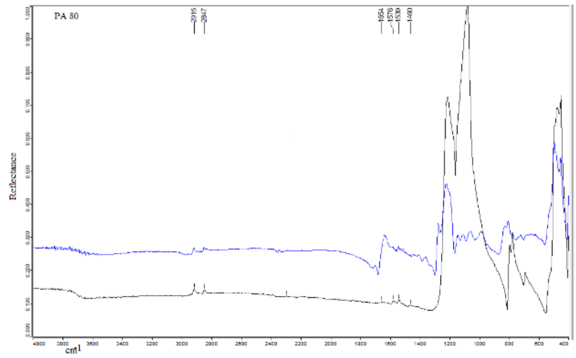
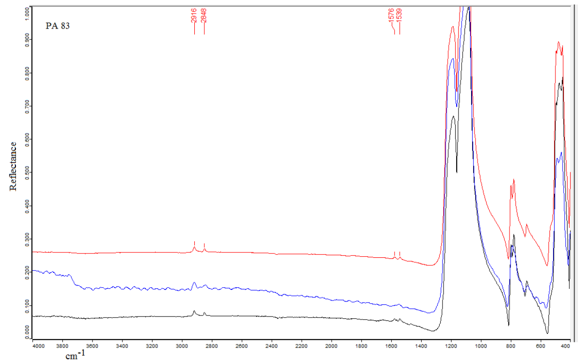
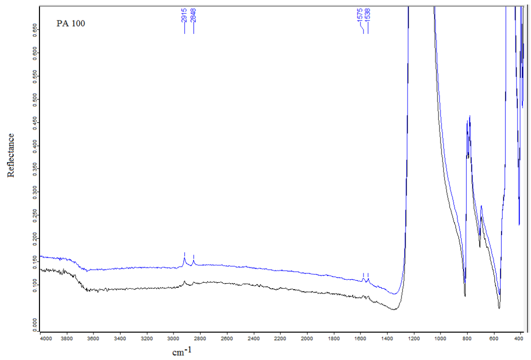
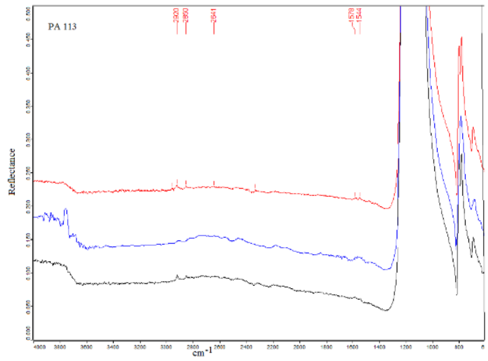
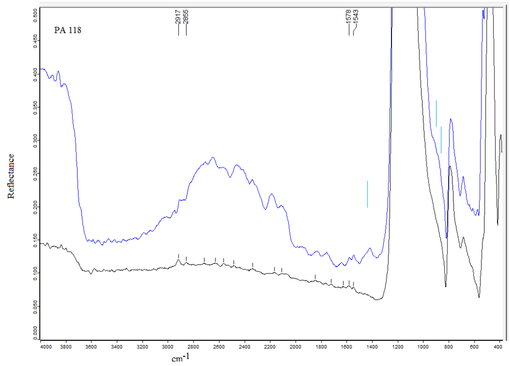
The observed bands at ~ 1540, ~1420, 877, present at the 25% of the analysed assemblage, are connected to the calcium carbonate, which could be connected either to the worked material or to the environmental aspect.

Table 33: Samples from Sector II, Padina, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
PA 27	~ 1540, ~1420, 877	CaCO3	
PA 29	1576,1540	Adipocere	
PA 31	1576, 1540, ~ 1540, ~1420, 877	Adipocere, CaCO3	
PA 34	~ 1540, ~1420, 877	CaCO3	

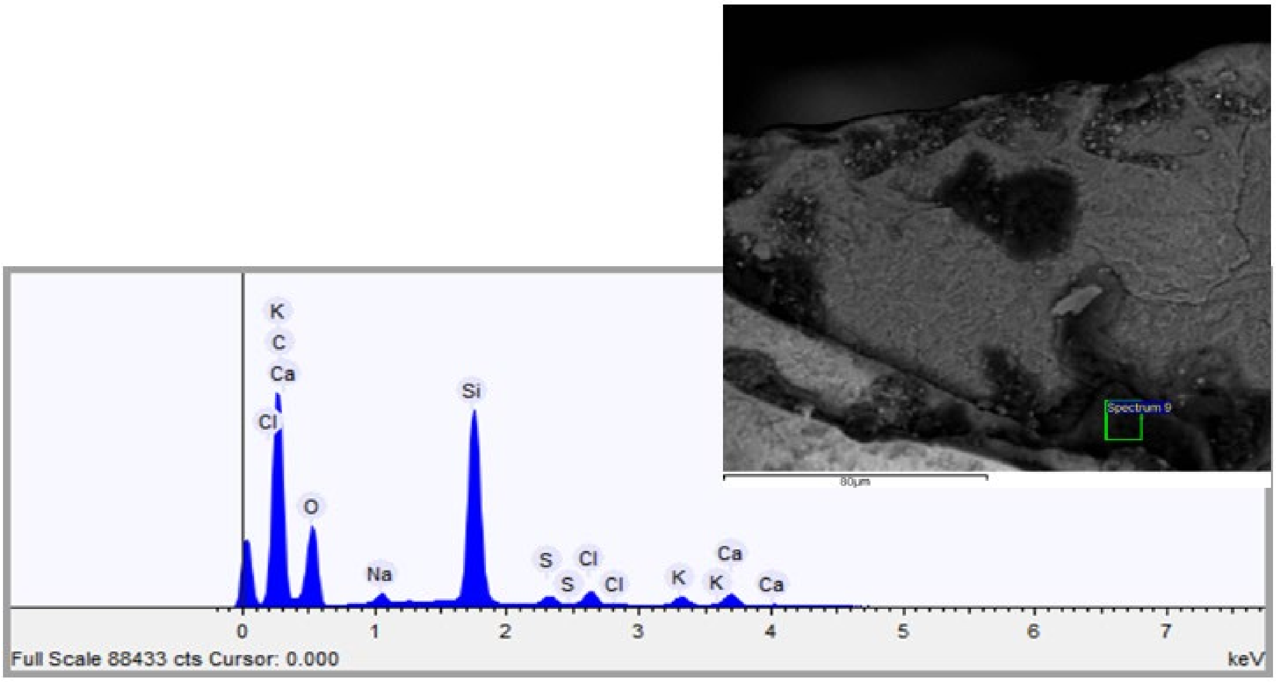
PA 35	~ 1540	CaCO3	
PA 36	1576, 1540	Adipocere	
PA 42	1576, 1540	Adipocere	
PA 58	1576, 1540	Adipocere	
PA 59	1576,1540,	Adipocere	

PA 71	1576, 1540	Adipocere	
PA 72	1576, 1540	Adipocere	
PA 73	~1650, 1576, 1540	Collagen (?), Adipocere	
PA 75	1576, 1540	Adipocere	
PA 79	1576, 1540	Adipocere	

PA 80	1576, 1540	Adipocere	
PA 83	1576, 1540	Adipocere	
PA 100	1576, 1540	Adipocere	
PA 113	1576, 1540	Adipocere	
PA 118	1576, 1540, ~1420,	Adipocere, CaCO3	

SEM-EDX analysis

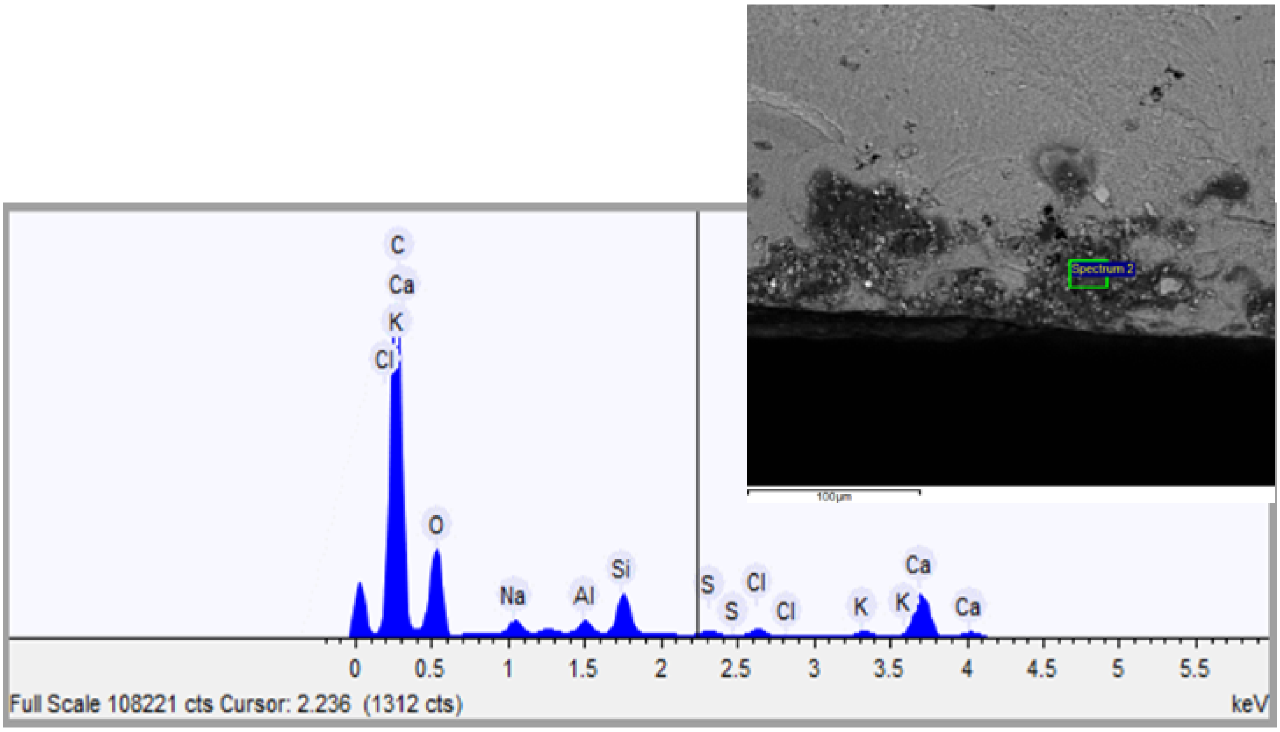
Two tools were chosen for further residue testing (PA 63, PA 72), and both are originating from block 2a, from Sector II. The flake PA 63 was used for cutting the soft to medium materials without further indication of the exact resource. The dark residues observed at 5Kv along the working edge showed higher values of calcium, chlorine, and potassium, typical for hide/meat chemical composition (Fig. 150).



Element	Weight %	Weight % σ	Atomic %
Carbon	37.356	0.757	49.063
Oxygen	38.788	0.481	38.245
Sodium	1.089	0.026	0.748
Silicon	16.579	0.205	9.312
Sulfur	0.964	0.022	0.474
Chlorine	1.739	0.030	0.774
Potassium	1.391	0.026	0.561
Calcium	2.094	0.034	0.824

Figure 150: PA 63, SEM-EDX results

The second observed flake (PA 72), which was used for processing antler and hide with minerals, was observed by FTIR spectroscopy and bands connected to adipocere were found, while the dark and whitish residues were observed at SEM-EDX together with sodium, aluminium, and calcium. In smaller amount sulfur, chlorine and potassium were discovered, all indicating the animal-based matter (Fig. 151).



Element	Weight %	Weight % σ	Atomic %
Carbon	37.943	0.535	48.644
Oxygen	45.082	0.404	43.389
Sodium	1.718	0.032	1.150
Aluminum	1.221	0.021	0.697
Silicon	3.776	0.041	2.070
Sulfur	0.581	0.017	0.279
Chlorine	0.847	0.019	0.368
Potassium	0.953	0.020	0.375
Calcium	7.880	0.078	3.027

Figure 151: PA 72, Sem-EDX results

5.2.3. Sector III

Use-wear analysis

The total of 93 analysed tools (Table 34), from sector III, come from trenches 3, 5, 6, 7. The samples originate from blocks in which the remains of houses, hearths and stone structures were found together with artefacts from profile III, segments 1, 2, 3, between segments 1 and 2, and from the level of the construction (segment 2).

Trench 6 has dates indicating the Early Mesolithic utilization of the site as an area for burial practices (burial 15 – 8450-7960 cal BC, burial 14 – 8690-8230 cal BC, burial 12 – 8750-83330 cal BC), (Borić and Miracle 2004). Similar chronological scope backing the aforementioned use of the zone as the funerary ground was noted in the sample from burial 21 in trench 7 (9250-8790 cal BC), (Borić and Miracle 2004).

In block 1 of trench 5 three houses were recovered (house 16, 17, 18). A date in the range 6250-6025 cal BC indicated the occupation or abandonment of the house 17, and two animal bones, one found on the floor of the house was dated to 5990-5720 cal BC and dog ulna found underneath (6440-6210 cal BC), are connected to the inhabitation of house 18 (Borić and Miracle 2004). From the material deposited beneath house 15 (block 2) one date was recovered from the burial 9360-8920 cal BC, and another one from used bone 5780-5560 cal BC (Borić and Miracle 2004). The later phase of the Early Neolithic occupation of the site was confirmed by the dates from house 15 (5990-5720 cal BC) and 18 (5780-5560 cal BC).

Regarding the AMS dates from profile III, segment 1, in the area near house 6, a lower date (7600-7340 cal BC) and higher from beneath house 14 (9965-9275 cal BC) are available. The gap could be explained with an idea that the place was used continuously over the different periods of the Mesolithic period, where only the broad number of new dates from single features can confirm this hypothesis (Borić and Miracle 2004).

No dates are available for trench 3, which is situated in the coastal belt of the Danube. The material found in this context will be presented based on the data about the stone construction found in block 1.

Table 34: Samples from Sector III, Padina, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
PA 130	Profile 3, segment 2	Flake	General working	Hide		Any
PA 131	Profie 3, segment b, near point 4'	Flake	Cutting, Scraping	Mineral material		
PA 132	Profile 3, border of segment 1 and 2, house near point B'	Blade	Cutting	Woody material		
PA 133	Profile 3, segment 1, level with houses	Flake	Cutting	Soft material		
PA 134	Profile 3, segment 1	Flake	Non-diagnostic	Vegetal		Any
PA 135	Profile 3, segment 1	Flake	Non-diagnostic	Non-diagnostic		Roots
PA 136	Profile 3, segment 1 and 2, level of the house at point B	Flake	General working	Meat		
PA 137	Along the profile 3, segment 1	Flake	Cutting	Medium		
PA 138	Along profile 3, segment 1-2	Flake	Cutting, Scraping	Woody material		
PA 139	Along profile 3, segment 1-2	Flake	Cutting	Medium		
PA 140	Along profile 3, segment 1-2	Flake	Cutting	Woody material		
PA 141	Along profile 3, segment 1-2	Blade	Cutting	Meat		
PA 142	Along profile 3, segment 1-2	Flake	Cutting	Woody material		Glossy Appearance

PA 143	Along profile 3, segment 1-2	Flake	Cutting	Medium material		
PA 144	Along profile 3, segment 1-2	Flake	Cutting	Cereal		
PA 145	Along profile 3, segment 1-2	Blade	Cutting	Meat	Hafting	
PA 146	Along profile 3, segment 1-2	Flake	Cutting	Animal material		
PA 147	Along profile 3, segment 1-2	Flake	Non-diagnostic	Soft-medium material		Glossy Appearance
PA 148	Along profile 3, segment 1-2	Flake	Cutting	Medium material		Any
PA 149	Profile 3, border of segment 1 and 2	Blade	Non-diagnostic	Soft material	Hafting	
PA 159	Profile 3, segment 1	Scraper	Non-diagnostic	Medium-hard material		
PA 160	Profile 3, segment 1	Flake	General working	Woody material + bone	Prehension	
PA 161	Profile 3, segment 1	Flake	Non-diagnostic	Non-diagnostic		Roots, Patina, Mechanical alteration
PA 162	Profile 3, segment 1	Flake	Cutting	Non-diagnostic		
PA 163	Profile 3, segment 1	Flake	Cutting	Hide		
PA 164	Profile 3, segment 1	Point	Non-diagnostic	Hard-medium to medium material		White patina, Glossy Appearance
PA 165	Profile 3, segment 1	Flake	Incision, Carving	Stone		
PA 166	Profile 3, segment 1	Flake	Cutting, Scraping	Animal Tissues		

PA 167	Profile 3, segment 1	Flake	Scraping, Cutting	Hide in processing		
PA 168	Profile 3, segment 1	Flake	Non-diagnostic	Non-diagnostic		Any
PA 169	Profile 3, segment 1	Flake	Non-diagnostic	Non-diagnostic		Roots
PA 170	Profile 3, segment 1	Flake	Non-diagnostic	Dry Hide		
PA 173	Profile 3, segment 2, from hearth of the house (point 5)	Flake	Non-diagnostic	Animal material		Any
PA 174	Profile 3, segment 2, from hearth of the house	Flake	Non-diagnostic	Non-diagnostic		Roots
PA 175	Profile 3, segment 2, from hearth of the house (point 5)	Flake	Non-diagnostic	Medium		Any
PA 176	Profile 3, segment 2, from hearth of the house (point 5)	Flake	/	Not used		
PA 188	Profile 3, segment 2, level of construction	Flake	Scraping	Fresh hide		Glossy Appearance
PA 189	Profile 3, segment 2, level of construction	Blade	Non-diagnostic	Animal Tissues		Roots
PA 190	Profile 3, segment 2, level of construction	Flake	Non-diagnostic	Non-diagnostic		Roots
PA 191	Profile 3, segment 2, level of construction	Flake	Cutting	Woody material		Roots
PA 192	Profile 3, segment 2, level of construction	Flake	Scraping	Humid bone		

PA 193	Profile 3, segment 2, level of construction	Flake	Cutting	Dry hide + abrasive material		
PA 194	Profile 3, segment 2, level of construction	Flake	Non-diagnostic	Meat	Hafting	Glossy Appearance
PA 195	Profile 3, segment 2, level of construction	Flake	Cutting	Meat		
PA 196	Profile 3, segment 2, level of construction	Flake	Cutting	Animal material		Glossy Appearance
PA 211	Trench 5, block 1	Flake	Cutting, Scraping	Dry hide		
PA 212	Trench 5, block 1	Flake	Cutting	Animal Tissues	Prehension	Glossy Appearance
PA 213	Trench 5, block 1	Blade	Scraping	Hide		
PA 215	Trench 5, block 1	Blade	Cutting	Hard material		Glossy Appearance
PA 216	Trench 5, block 1, hearth in the central part of the block	Blade	Non-diagnostic	Herbaceous plant (lightly silicious)		
PA 217	Trench 5, block 2	Blade	Non-diagnostic	Silicious plant		Glossy Appearance
PA 218	Trench 5, block 1, profile 7-9	Blade	Cutting	Mineral material		
PA 219	Trench 5, block 2, under the floor house at point 9	Flake	Non-diagnostic	Meat		Glossy Appearance
PA 220	Trench 5, block 2, under the floor house at point 9	Blade	Non-diagnostic	Non-diagnostic		

PA 221	Trench 5, block 2, under the floor house at point 9	Flake	Cutting	Soft material	Prehension/ hafting	
PA 222	Trench 5, block 2, under the floor house at point 9	Blade	Non-diagnostic	Soft material		Any
PA 223	Trench 5, block 1, profile 19-10	Flake	Non-diagnostic	Animal material		Any
PA 224	Trench 5, block 2, above the house	Flake	Cutting	Woody material		Thermic Alteration, Roots
PA 225	Trench 5, block 1, hearth in the centre of the block	Flake	Cutting	Hard material		Any
PA 226	Trench 5, block 1, hearth in the centre of the block	Flake	Cutting	Soft-medium, abrasive material		Roots
PA 227	Trench 5	Flake	Cutting	Hide		
PA 228	Trench 5	Flake	Non-diagnostic	Hide		
PA 229	Trench 3, block 1-4	Flake	Cutting	Antler	Prehension/ha fting	Glossy Appearance
PA 230	Trench 3, block 1-4	Blade	Cutting	Bone	Hafting	Thermic Alteration
PA 231	Trench 3, block 1-4	Blade	Non-diagnostic	Antler		
PA 232	Trench 3, block 1, under the stone construction	Flake	Scraping, Cutting	Soft-medium material	Prehension	
PA 233	Trench 3, block 1, on stone construction	Blade	Cutting	Hide		

PA 234	Trench 6, block 2	Blade	Cutting	Hide, meat		
PA 235	Trench 6, block 1,2	Flake	Cutting	Medium material		
PA 236	Trench 6, block 1	Blade	General working	Herbaceous plant (lightly silicious)	Prehension	Glossy Appearance
PA 237	Profile 3, under the level with human remains	Blade	Non-diagnostic	Animal material	Prehension	
PA 238	Profile 1-3	Blade	Scraping, cutting	Herbaceous plant		
PA 239	Segment 1-2, house near point 4	Flake	Non-diagnostic	Non-diagnostic		
PA 241	Trench 7, block 3	Flake	Cutting, Scraping	Animal material		
PA 242	Trench 7, block 3	Flake	Non-diagnostic	Animal material		
PA 243	Trench 7, block 3	Flake	Non-diagnostic	Mineral material		Glossy Appearance
PA 244	Trench 7, block 3	Flake	Cutting	Hide		
PA 245	Trench 7, block 3	Blade	Cutting	Animal material		Glossy Appearance
PA 246	Trench 7, block 3	Flake	Cutting, Scraping	Animal material		
PA 247	Trench 7, block 3	Flake	Cutting, Scraping	Woody on one edge and Animal material on another		
PA 248	Trench 7, block 3	Flake	Cutting	Medium-soft material		

PA 249	Trench 7, block 3, III level of stone construction	Flake	Cutting	Animal material		
PA 250	Trench 7, block 3, IV level of stone construction	Flake	Cutting	Animal material, abrasive		
PA 251	Trench 7, block 3, III level of stone construction	Flake	Non-diagnostic	Medium material		
PA 252	Trench 7, block 3	Blade	Non-diagnostic	Medium		
PA 253	Trench 7, block 3, III level of stone construction	Flake	Non-diagnostic	Animal material		Glossy Appearance
PA 254	Trench 7, block 3, III level of stone construction	Flake	Non-diagnostic	Non-diagnostic		Glossy Appearance
PA 255	Trench 7, block 5, IV level	Flake	/	Not used		
PA 256	Trench 7, block 5, IV level	Flake	Non-diagnostic	Hide		
PA 257	Trench 7, block 5, IV level	Flake	Non-diagnostic	Animal material		Thermic Alteration Glossy Appearance
PA 258	Trench 7, block 3, II level of stone construction	Flake	Cutting	Hard-medium material		
PA 259	Trench 7, block 3, II level of stone construction	Core	/	Not used		
PA 260	Trench 7, block 3, II level of construction	Flake	Cutting	Medium material		

Out of the total of the analysed tools from Sector III, only two flakes and one core did not have any traces of use (3%), and 39% of the assemblage has various alterations which in some cases aggravated the identification of motions or contact material.

The most often alteration noted is the glossy appearance (Fig. 152a), followed by roots (Fig. 152b), while thermal stress is only observed at three pieces.

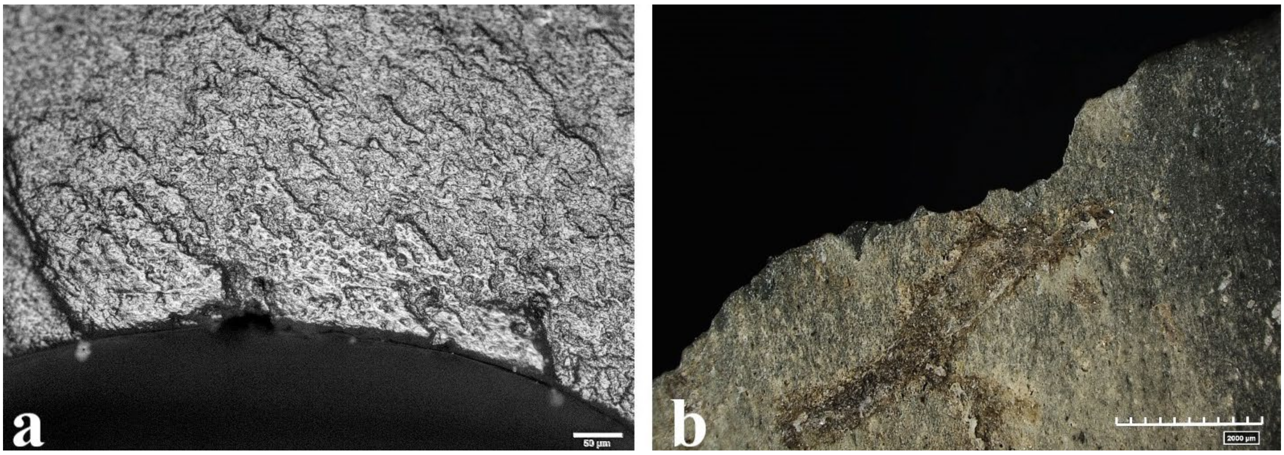


Figure 152: Alterations: a) Glossy Appearance, PA 217, b) Root alteration, PA 191 (photo A. Petrović)

Tools found in Sector III were used for diverse activities, as cutting (42%), followed by 11% of the tools used for mixed motion of cutting and scraping, that are sometimes superpositioned, while 4% were used for general working, 3% only for scraping, and 1% for the incision. The 38% of the tools had traces that were noted as non-diagnostic, meaning that observed variables both macro and micro were not enough convincing to determine the exact motion.

From the total number of analysed tools, 44% were utilized in the activities with animal-based materials, and 13% for the vegetable-based processes, only 2% for mixed contact materials and 3% for mineral-based materials, and one flake was used for the incision of soft stone.

Hard animal materials are present in the shape of the flat topography, smooth texture and covered linkage. Bone traces are developed on the outer edge and the polish is dispersing towards the inside of the surface of the tool (Fig. 153a-b). While antler traces have similar polish characterisations, it is noted that they have domed and melting topography in some of the higher areas (Fig. 153c-d).

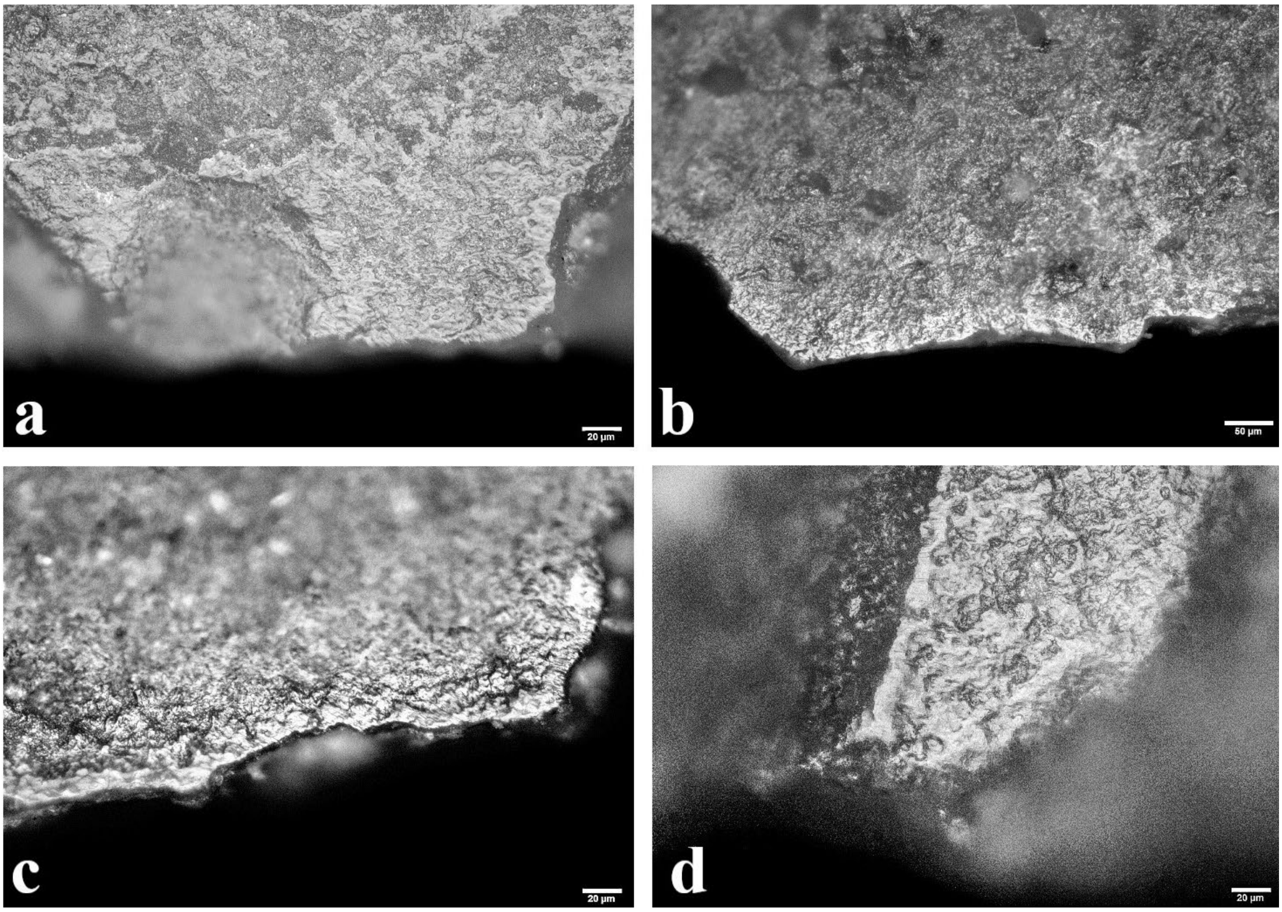


Figure 153: Hard animal materials: a) Humid bone, PA 192, b) Bone PA 230,
c) Antler 229, d) Antler 231 (photo A. Petrović)

Regarding the other animal materials, the most pronounced are traces of hide (Fig. 14a), hide and meat (Fig. 14b) and animal tissues (Fig 14c). The hide is characterised by granular topography and rough texture. The small differences between the smooth and rough texture are indicating the actual state of the hide, as already indicated. These materials have a smooth texture and a very open to half-tight linkage, since the meat and animal tissues are characterised as soft materials and they do not provide compelling traces as much harder and denser materials.

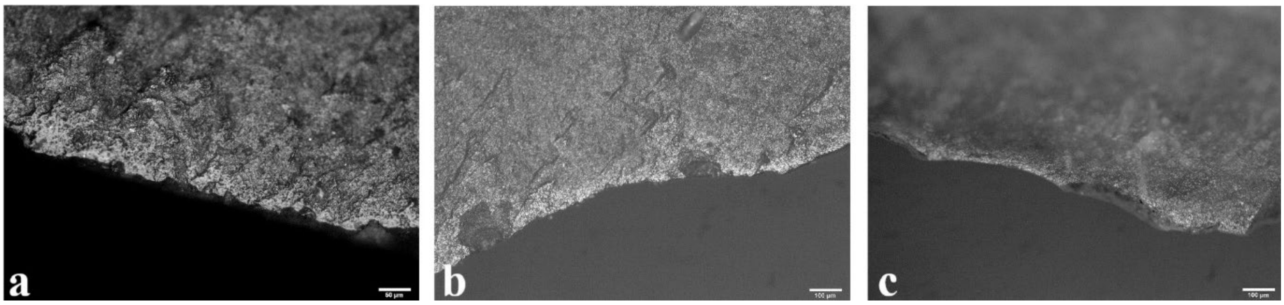


Figure 154: a) Hide working, PA 233, b) Hide and meat PA 234, c) Animal tissues PA 212

The variety of vegetable-based contact materials present in the assemblage of Sector III of the Padina site is remarkable since other contexts do not provide detailed data on the plant processing, as is the case with Sector II and III.

The processing of the woody material is described as domed topography with tight linkage on higher parts and the polish penetrated the working edge, developed in the surface area as well (Fig. 155a). Herbaceous plants have similar characteristics, but the polish is more developed on the outer edge and edge, creating a tight to covered linkage with a smooth texture, sometimes with an abrasive element that could be a result of the area or position (inside, outside, on the ground, etc) where the activity was done (Fig. 155b). The silicious plant however has more bright polish, which is more domed on higher parts creating more levels of polish (Fig. 155c). The processing of cereals is rare among the analysed tools from Iron Gates, and one tool connected to this activity was found in the Sector III. The topography of the flakes used for processing cereals is flat, smooth and covered penetrating beyond the edge of the use with diagnostic pits all over the working area (Fig. 155d).

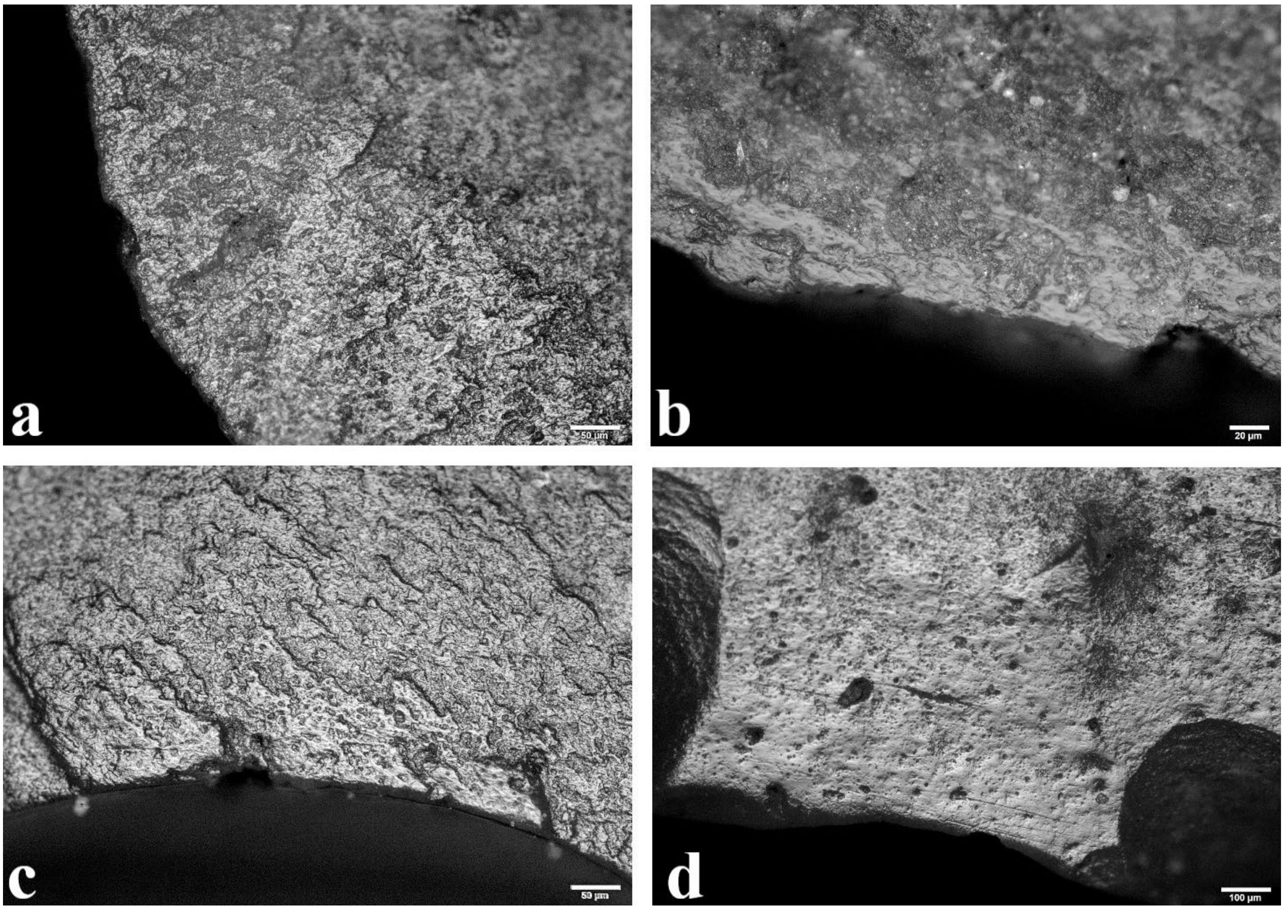


Figure 155: a) Hide, PA 142, b) Herbaceous plant, PA 236, c) Silicious plant, PA 217, d) Cereal, PA 144 (photo A. Petrović)

Besides the animal and vegetable matters, tools were used for processing the stone and mineral materials. This is usually recognizable by the abrasive layer near the edge and rough texture with striation visible under higher magnifications.

Around 12% of the tools have diagnostic prehension or hafting traces. Four tools have hafting traces, while five prehension and two tools have polish which could not be attributed in detail to the exact handling mode. The prehension traces are the most pronounced and could be easily detected, as they are represented by flat patches of polish, sometimes created on the edge (Fig. 156a), and sometimes on the surface of the tool (Fig. 156b).

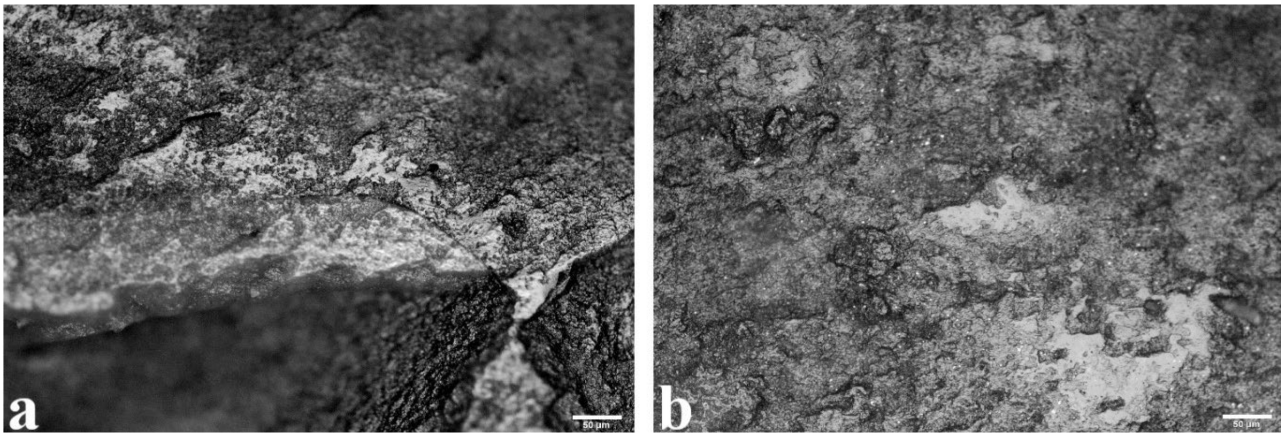


Figure 156: a) Prehension patches along the edge, PA 232,
b) Prehension patches in the surface, PA 236 (photo A. Petrović)

FTIR analysis results

In total 30 artefacts from Padina III assemblage were analysed with FTIR spectroscopy (Table 35). From this number 13% (4 artefacts) showed no presence of residues on both surfaces.

Regarding the residues associated with bone composition, the observed band at ~913 cm^{-1} is indicating the bone residues. However, the correlation to the use-wear traces found on these two samples is only partial. One flake (PA 257) does not have indicative micro traces, except that it was confirmed to be used for processing animal materials in general. In this case, the FTIR analysis reveals possible evidence for broadening the interpretation, having in mind the presence of adipocere and calcium carbonate that confirm the animal component of the contact material and offer the possibility of using the flake for activities as butchering or bone working. Blade (PA 238), accordingly to the use-wear analysis, was used for scraping and cutting the herbaceous plants on both edges, with the traces of prehension superpositioned indicating the need for extensive use of the tool. Even though the FTIR analysis does not correspond to the function in this case, the explanation lies within the context. The blade was found in the same layer as human sceletons. The accumulation of the human remains and the position of the blade were probably the reasons why the chemical analysis showed interpretation diverse from the use-wear analysis.

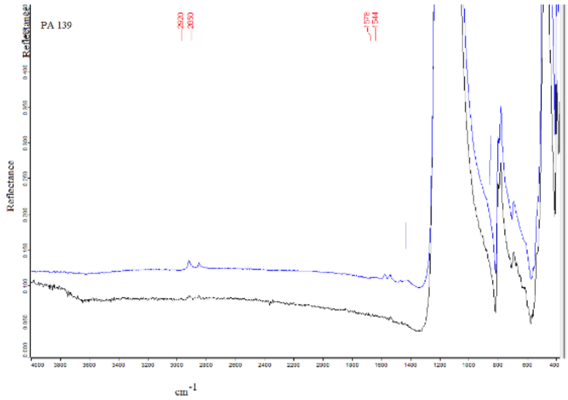
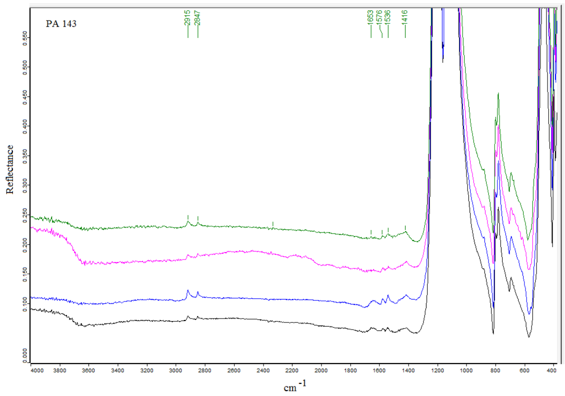
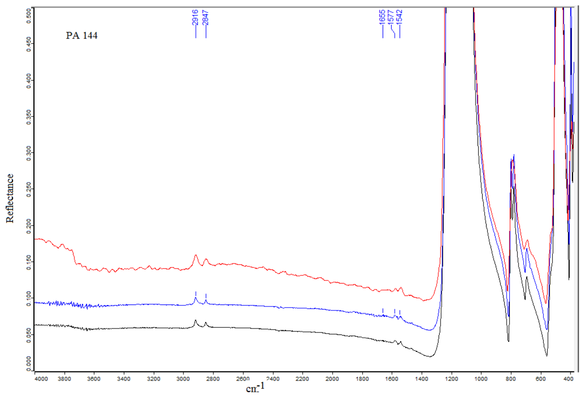
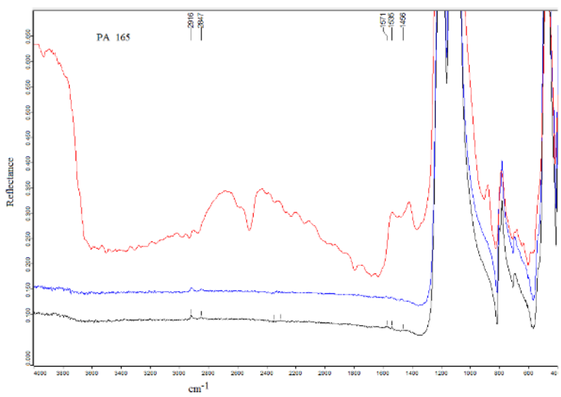
Bands observed at 1576,1540 connected to the adipocere are present at 70% (21 tools) of the analysed tools. Out of this number 13 tools have solely traces of adipocere, and no other residues were observed.

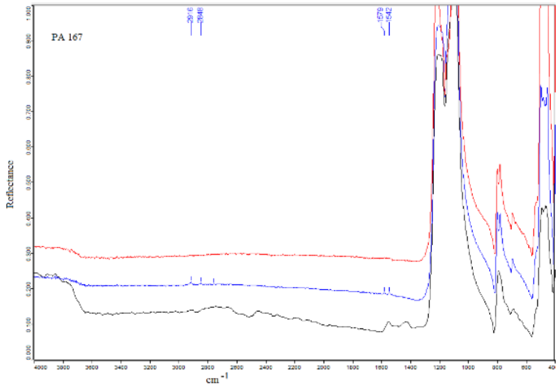
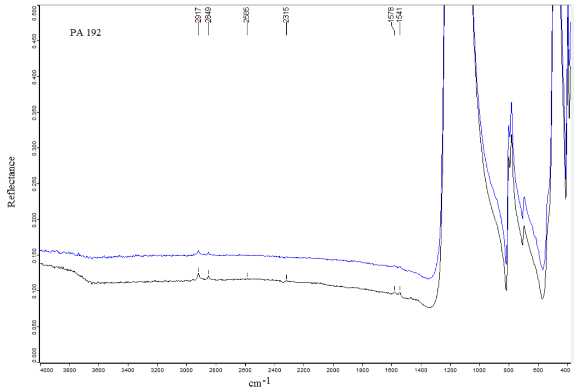
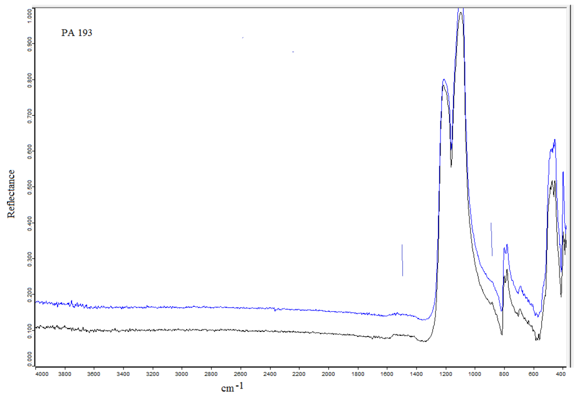
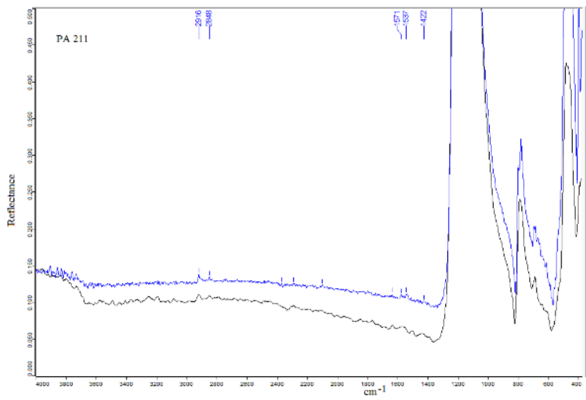
Collagen bands (~1650) were observed in the results of already discussed blade PA 238 and a flake, PA 143, used for processing medium material, in which case traces of collagen could enhance the interpretation towards animal material, having in mind adipocere bands were observed at the same sample.

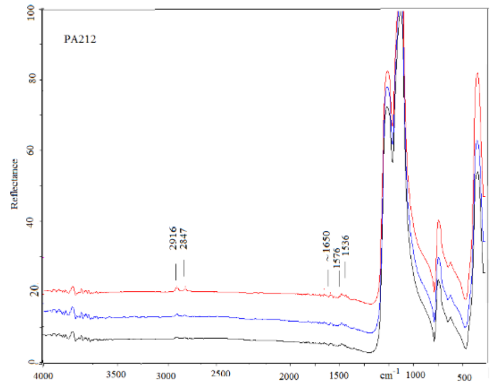
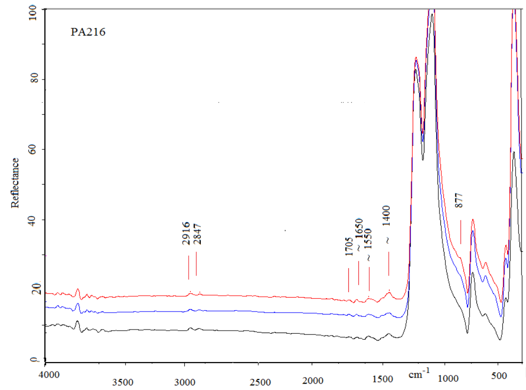
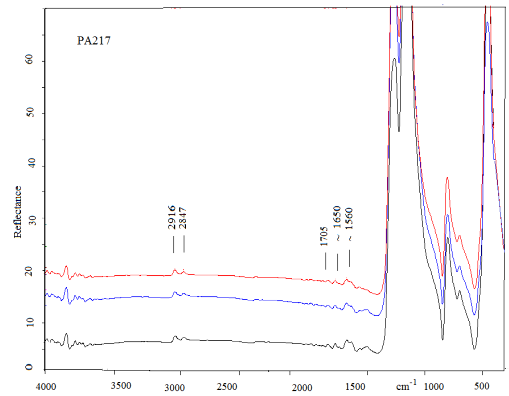
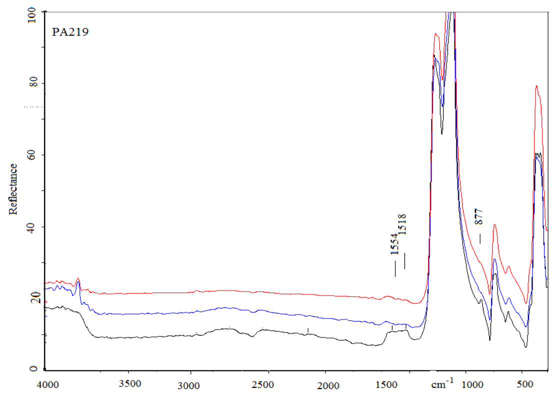
Calcium carbonate (~1420) was observed at 30% of the analysed tools. In the case of the FTIR analysis, it can either be connected to the worked material, or it can be taphonomic.

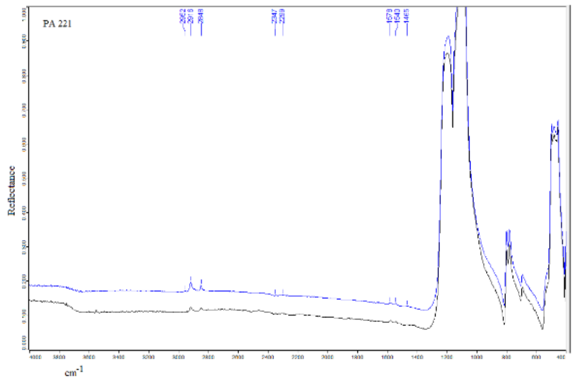
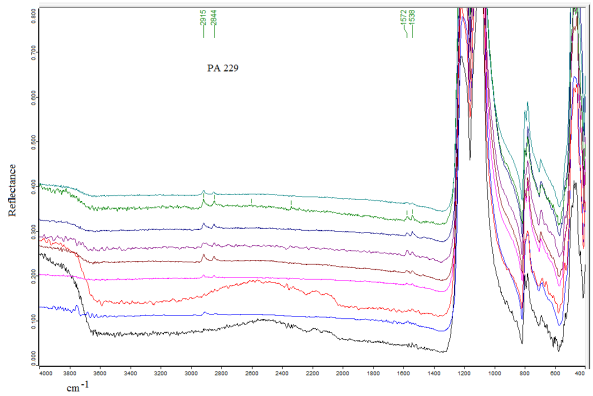
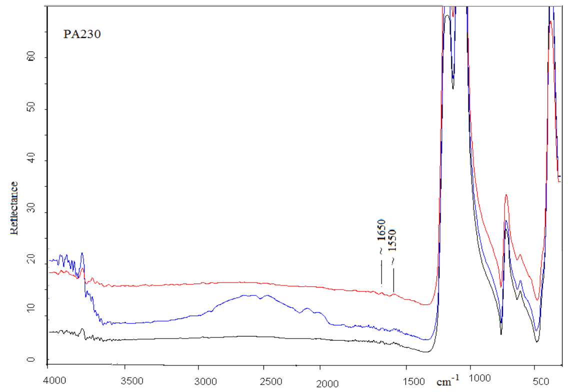
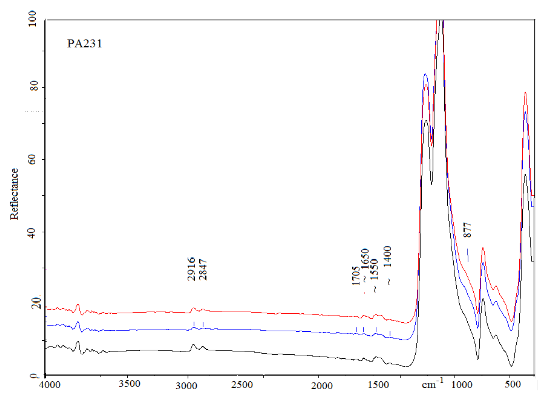
Lignin (bands 1710, 1660, 1550) was noted on 17% of the studied assemblage. Three tools (PA 216, PA 217, PA 236) were used for working herbaceous and silicious plants, which is confirmed by FTIR analysis. But two remaining samples (PA 230 and PA 231) are connected to the animal materials. However, the discrepancy between the results in these two cases could easily be explained. The blade PA 230 was used for working bone, but it was also hafted. The wooden haft could leave enough residues to be detected with FTIR. Regarding the blade PA 231 used for working antler, there is overlapping with adipocere residues, that could be connected to the activity itself. The antler traces, as already stated, together with other hard animal material leave very flat and smooth polish that has covered linkage. It can easily cancel all the previous work of the tool, that could have taken place.

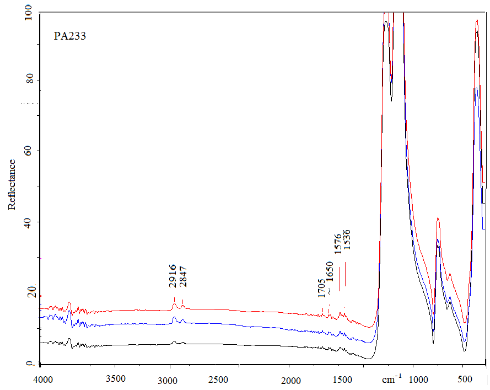
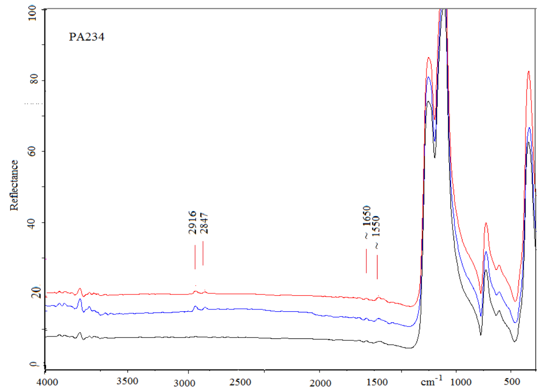
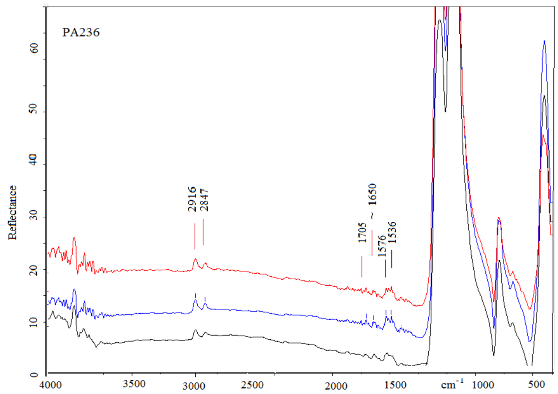
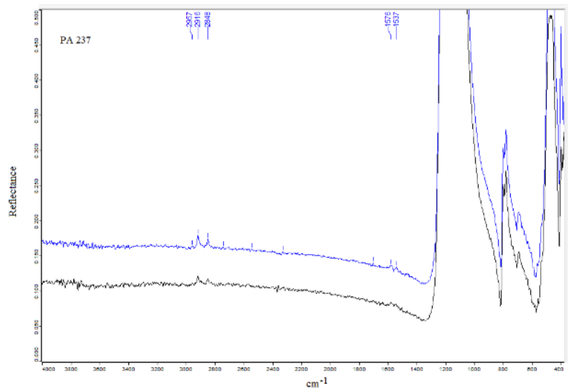
Table 35: Samples from Sector III, Padina, FTIR analysis results (spectra by S. Nunziante Cesaro)

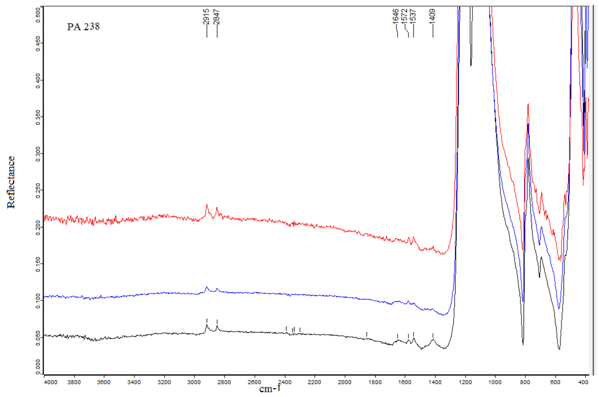
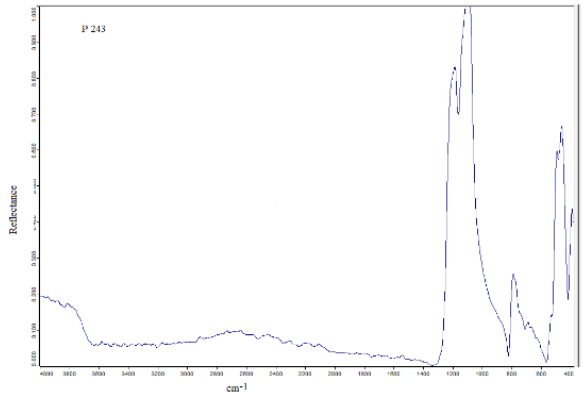
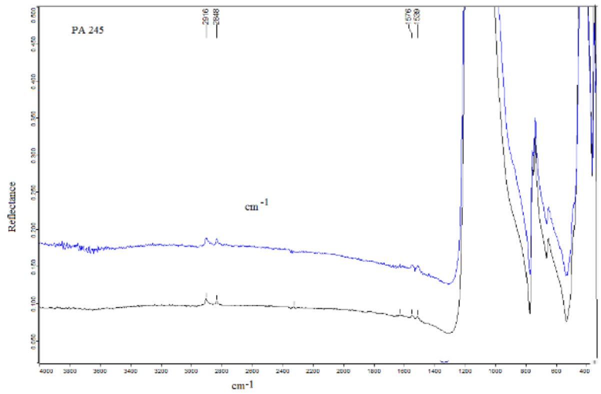
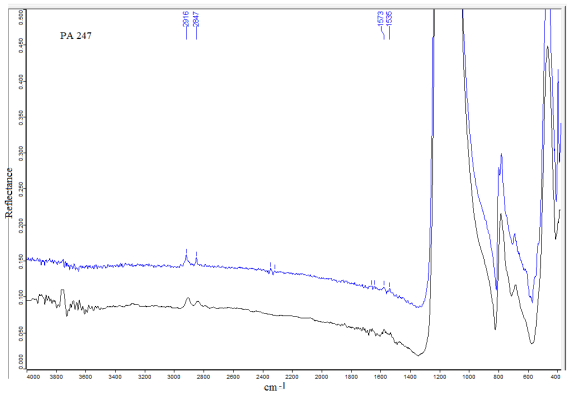
SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
PA 139	1576,1540	Adipocere	
PA 143	~1650, 1576,1540 ~1420 877	Collagen, Adipocere, CaCO3	
PA 144	1576,1540	Adipocere	
PA 165	1576,1540 ~ 1540, ~1420, 877	Adipocere, CaCO3	

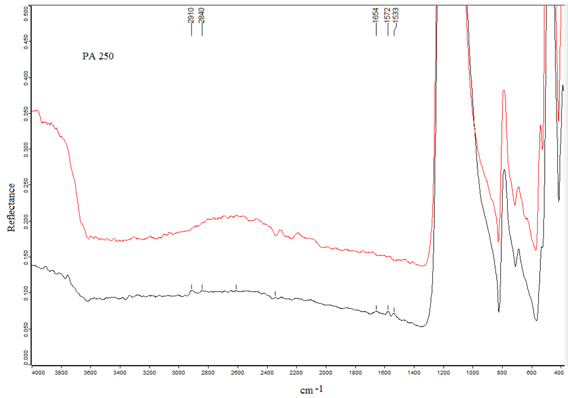
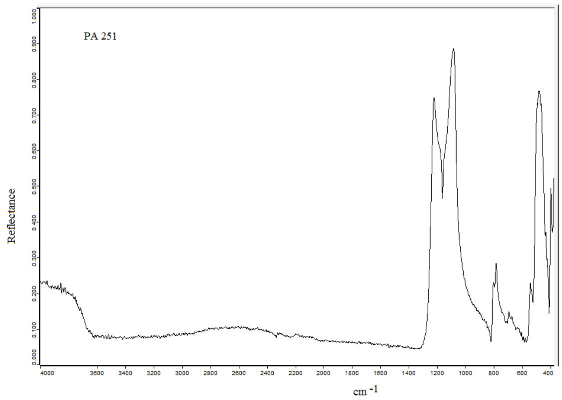
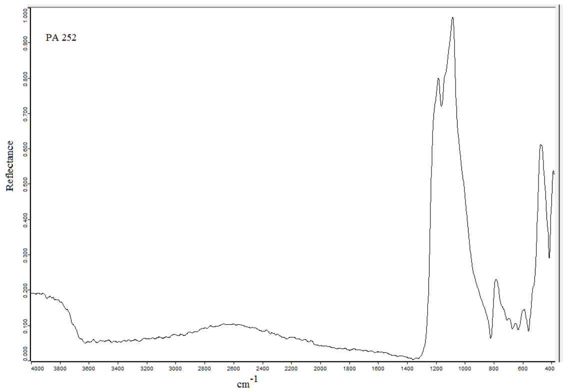
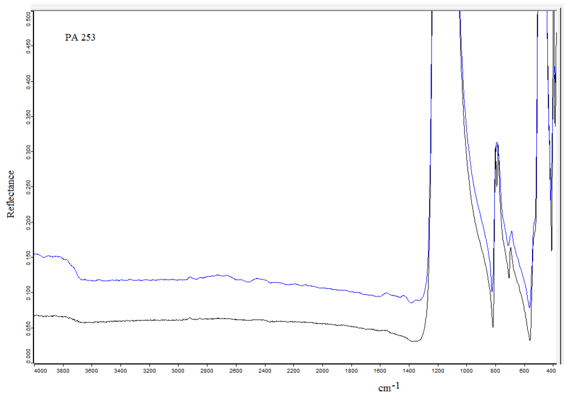
PA 167	~ 1540, ~1420, 877 1576,1540	CaCO3, Adipocere	
PA 192	1576,1540	Adipocere	
PA 193	~ 1540, ~1420, 877	CaCO3	
PA 211	1576,1540	Adipocere	

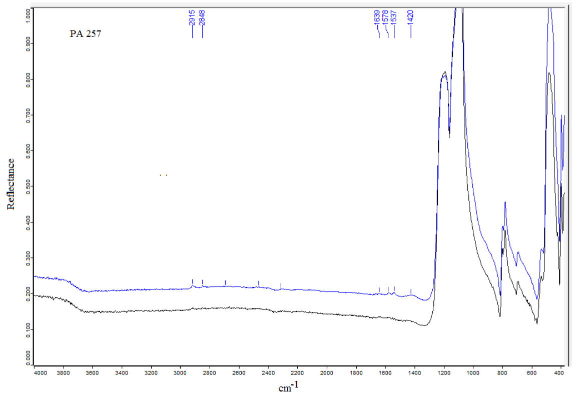
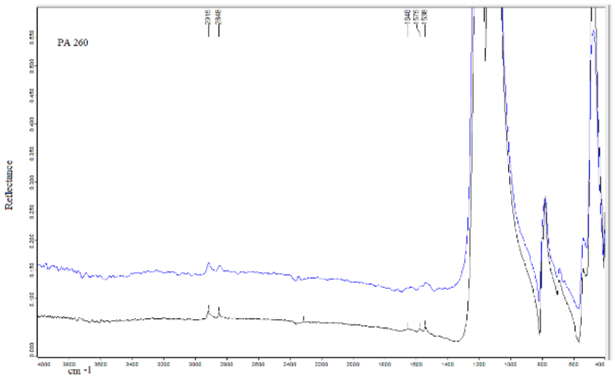
PA 212	1660, 1570	Adipocere	
PA 216	1710, 1660, 1550, ~1420, 877	Lignin, CaCO3	
PA 217	1710, 1660, 1550, ~1420	Lignin, CaCO3	
PA 219	~1530, ~1420, 877 ~1650	CaCO3, H2O	

PA 221	1576,1540	Adipocere	
PA 229	1576,1540	Adipocere	
PA 230	1710, 1660, 1550,	Lignin	
PA 231	1660, 1550	Lignin, Adipocere, overlapping?	

PA 233	1576,1540	Adipocere	
PA 234	~1570	Adipocere, overlapping	
PA 236	1710, ~1660, ~1570,	Lignin, Adipocere, overlapping?	
PA 237	1576,1540	Adipocere	

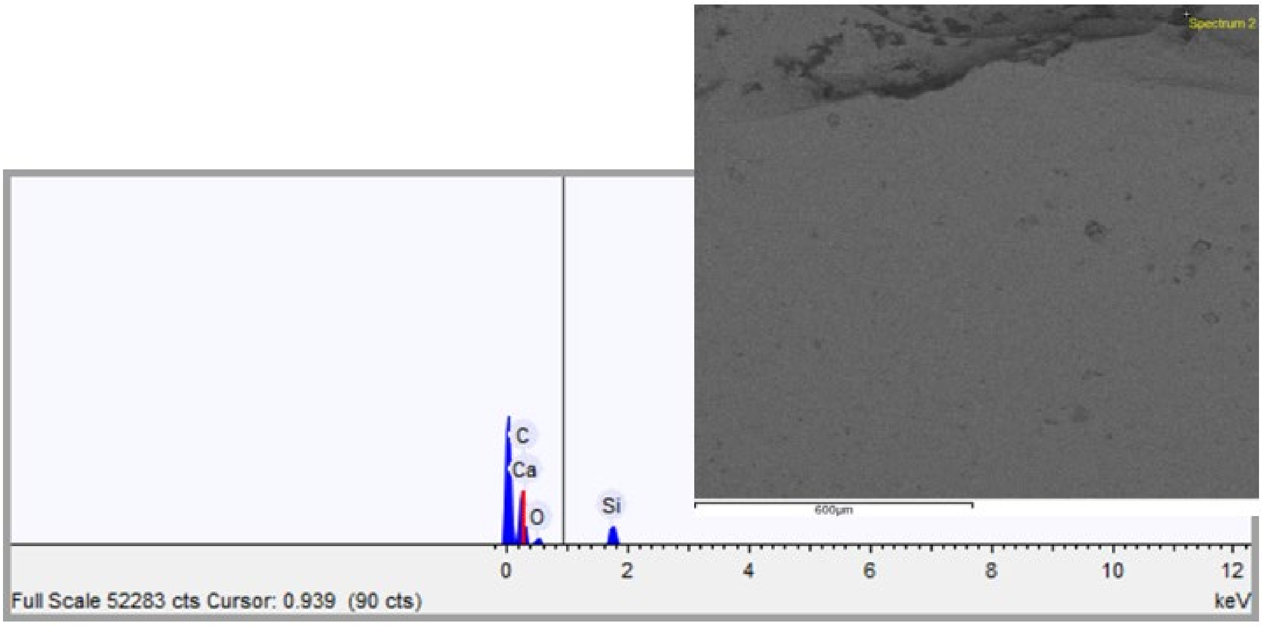
PA 238	~1650, 1576,1540 ~1420 ~913 877	Collagen, Adipocere, $CaCO_3$, Bone	
PA 243	/	/	
PA 245	1576,1540	Adipocere	
PA 247	1576,1540	Adipocere	

PA 250	1576,1540	Adipocere	
PA 251	/	/	
PA 252	/	/	
PA 253	/	/	

PA 257	1576,1540, ~1420 ~913	Adipocere, CaCO3, Bone	
PA 260	1576,1540, ~1640, ~1550,	Adipocere, ??	

SEM-EDX analysis

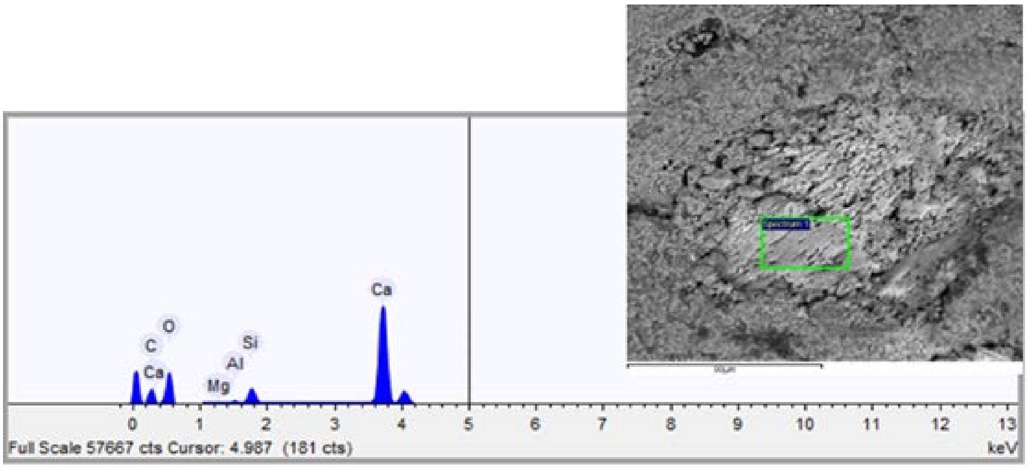
On the tools from Padina III assemblage, the SEM-EDX was used to further identify the morphologically observed residues. In the case of PA 144, which is one of the few tools used for processing cereals, no specific indications, based on the detected chemical elements, could be noted (Fig. 157).



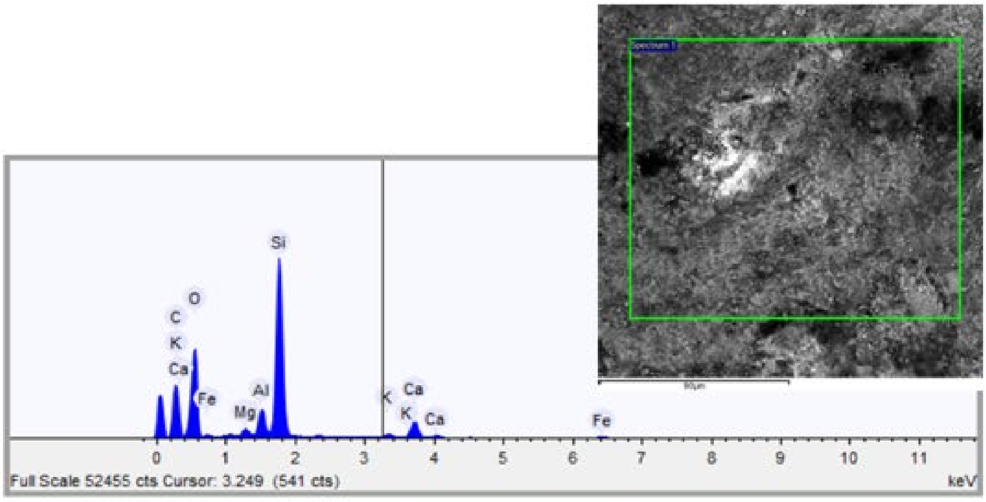
Element	Weight %	Weight % σ	Atomic %
Carbon	70.638	0.368	78.726
Oxygen	20.949	0.372	17.528
Magnesium	0.118	0.028	0.065
Aluminum	0.219	0.029	0.109
Silicon	6.237	0.080	2.973
Sulfur	0.465	0.034	0.194
Calcium	0.965	0.043	0.322
Zinc	0.408	0.076	0.084

Figure 157: PA 144, SEM-EDX results

The second observed sample was used for processing antler, and the SEM-EDX analysis discovered lighter residues inside the surface with larger amounts of calcium and smaller quantities of aluminium and magnesium. However, no traces of phosphorus were found (Fig. 158).



Element	Weight %	Weight % σ	Atomic %
Carbon	11.394	0.165	19.047
Oxygen	47.528	0.245	59.644
Magnesium	0.226	0.026	0.186
Aluminum	0.185	0.023	0.138
Silicon	2.866	0.039	2.049
Calcium	37.801	0.190	18.936



Element	Weight %	Weight % σ	Atomic %
Carbon	9.834	1.531	15.410
Oxygen	50.908	0.878	59.889
Magnesium	0.994	0.034	0.769
Aluminum	3.454	0.070	2.409
Silicon	27.164	0.472	18.204
Potassium	0.789	0.032	0.380
Calcium	4.735	0.093	2.223
Iron	2.123	0.074	0.716

Figure 158: PA 229, two points

5.2.4. Summary of the results of the chipped stone tools from Padina site

In total 209 artefacts from all three sectors of the Padina site have been analysed with low and high power approach, and 55 tools were additionally analysed with FTIR spectroscopy. Seven (7) tools in total have not been used at all.

Regarding the activities, cutting is the most present motions in all three sectors, followed by the mixed activities of cutting and scraping (159). Engraving and incision are not very represented in the observed sample, and only two tools have characteristics of these specific motions.

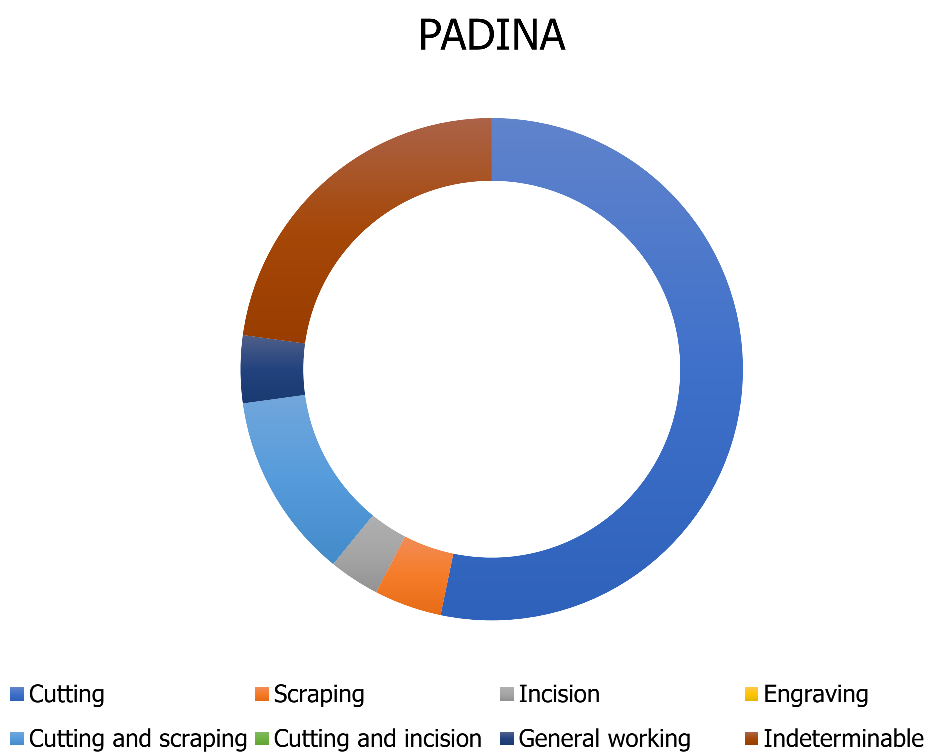


Figure 159: Activities, Padina

Various contact materials are present at the Padina site in the Transitional period (Fig. 160). The tools were, mostly, used for processing animal-based matters, followed by vegetals. A high percentage of working animal materials is observed at all the analysed sites from Iron Gates. However, it is important to note the presence of tools used for vegetable contact materials at the Padina. This is very important having in mind the low percentage on the other sites. Another fundamental observation is the presence of herbaceous, silicious plants and tubers together with the wood, which is recorded frequently at all three sites.

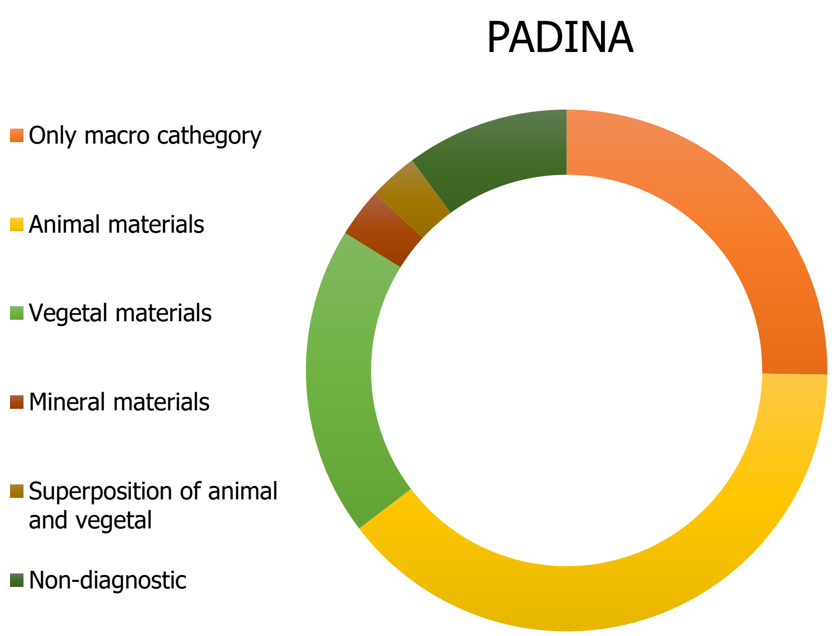


Figure 160: Worked materials, Padina

To conclude, the results of Padina assemblage have their particular fingerprint which is visible as we process the data statistically, hence as we dive into the details. The most important impression is the amount of the tools used for processing the vegetal contact materials, but also their diversity as well. The importance of these traces, data and gathered information is even greater compared to the results of the use of the chipped stone tools from the other sites in the region.

5.3. VLASAC RESULTS

5.3.1. Vlasac I, burials and houses, 1970

Table 36: Samples from Vlasac I, burials and houses, 1970, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
VL 1	B/IV-C/IV-XVI (3)	Flake	Cutting	Animal material (underneath) and hard material (above)	Hafted	
VL 2	B/IV-C/IV-XVI (3)	Flake	Cutting	Hide		
VL 3	C.A XXII	Blade	Cutting	Stone		
VL 4	C.A XXII	Blade	Indeterminable	Woody; change of activity or something on the top of the traces		Glossy Appearance
VL 5	S.A. III, IV	Flake	Indeterminable	Hide, worked near the ground		
VL 6	B/IV, C/IV-XII(3)	Flake	Cutting	Hide		
VL 7	XIX	Flake	Cutting	Non-diagnostic		Any
VL 8	B/IV, C/IV, XI(2)	Point	Cutting	Woody		
VL 9	C/I XX	Scraper	Cutting	Woody and something abrasive (dust/dirt)		
VL 10	A XXV	Scraper	Indeterminable	Stone		Any
VL 11	CA-XXII	Flake	Cutting	Left: hide and meat; right: abrasive		
VL 12	CA-XXII	Flake	General working	Bone		

VL 13	CA-XXII	Flake	Indeterminable	Wood		
VL 14	S.A. I. II	Flake	Indeterminable	Non-diagnostic		
VL 15	S.A. I. II	Flake	Indeterminable	Vegetal, on the ground		
VL 16	S.A. I. II	Flake	Scraping	Scraping dry and semi-dry hide, small sizes of skins		

Use-wear analysis

Use-wear traces found on sixteen (16) tools originating from miscellaneous contexts have revealed a variety of the exploited contact materials, from bone, hide to the vegetal matters and stoneworking (Table 36). The only context with the same type of the processed material is B/IV-C/IV-XVI.

The tools, in general, are well preserved and only three artefacts are affected by PDSMs, while only two tools have non-diagnostic traces. Hard materials as bone working have developed polish with flat topography near the outer edge (Fig. 161a), while the granular topography is the key characteristic of hide processing (Fig. 161b). The nuances in the polish texture and linkage are important since they are defining the exact state of hide, as, for example, the rougher texture in the cases of semi-dry to dry hide (Fig. 161c). Vegetal matters are detected by domed topography and half-tight linkage. The superposition of different contact materials is quite common on the analysed tools. For example, the sample VL 4 has areas of polish indictive for the woodworking, after which they either changed the material or the activity (Fig. 161d).

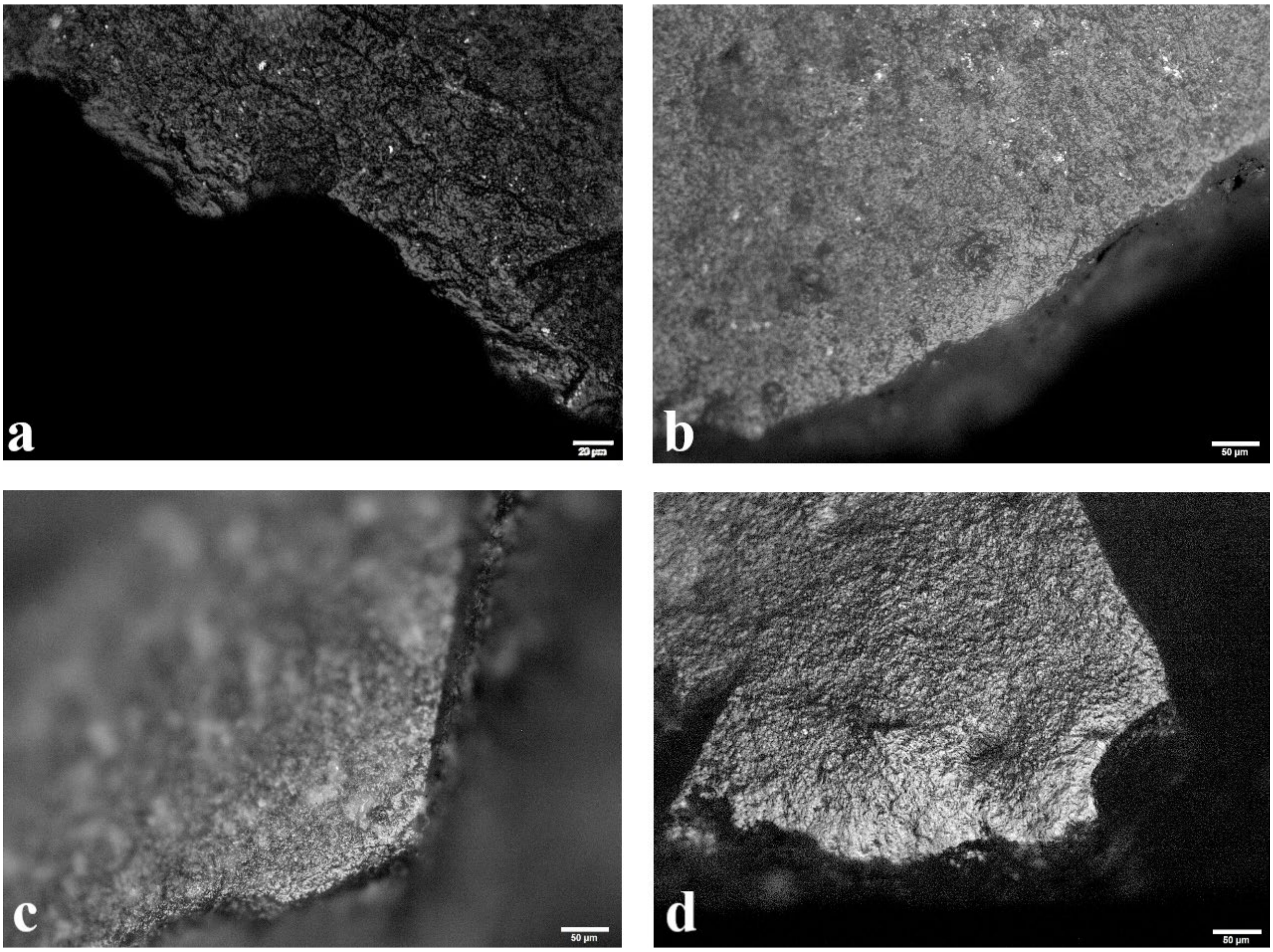
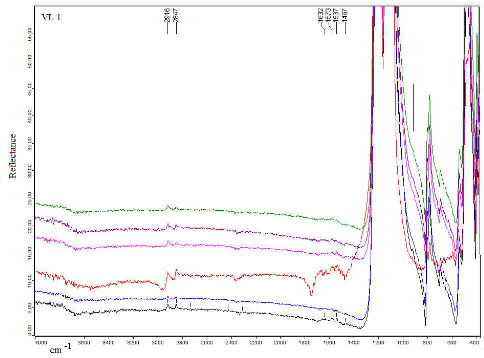
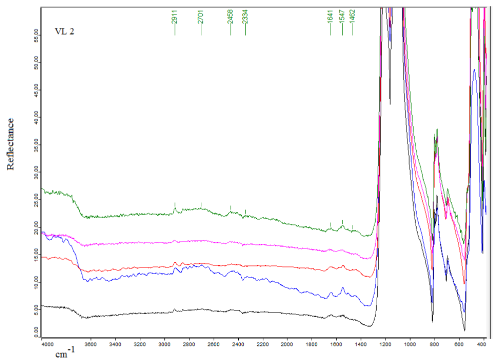
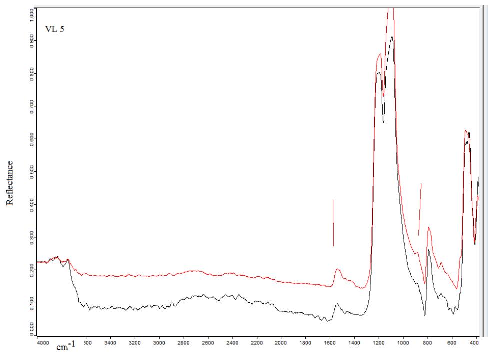
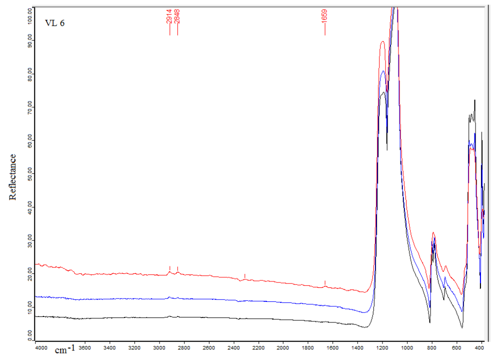


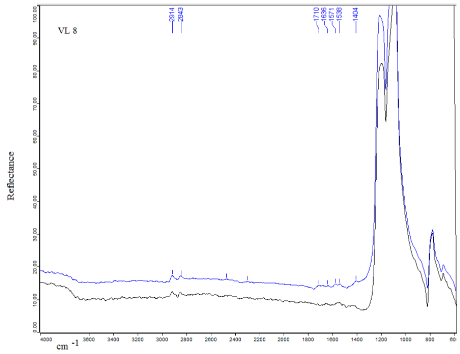
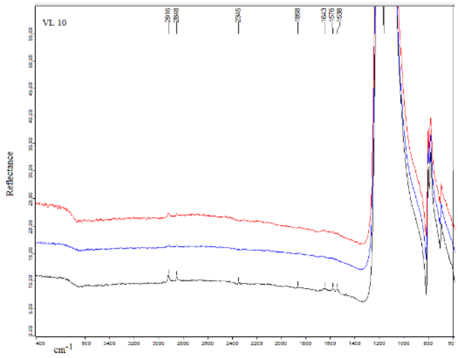
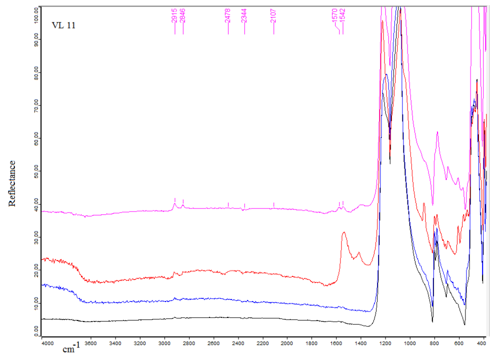
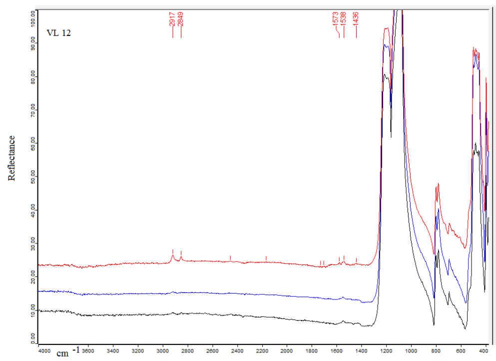
Figure 161: Samples from Vlasac I, burials and houses, 1970 a) Flat topography, smooth texture, bone working, VL 12, b) Granular topography, outer edge, hide VL 2, c) Granular topography, rough texture, tight linkage, dry and semi-dry hide, VL 16, d) Flat and tough topography, rough to smooth texture, superposition of wood and other materials or change of activity, VL 4 (photo A. Petrović)

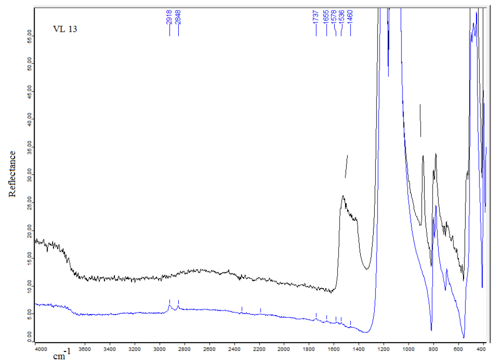
FTIR analysis results

Nine (9) tools were analysed with FTIR spectroscopy (Table 37). The results are encouraging and constructive, especially in the cases where use-wear analysis could not provide clear identification of the worked material. For example, a band at ~913 cm^{-1} displayed the presence of bone residues, and in the case of the VL 1, where the functional analysis (of the second layer of use) was based only on the macro traces (hard material), the interpretation is facilitated. Except for the bone and calcium carbonate (~1420 cm-1) residues, collagen (~1650 cm-1) was noted in 56% of the analysed artefacts. Regarding the residues of collagen, in two cases its presence is demanding some further explanations since the worked materials are of mineral and vegetal origin.

Table 37: Samples from Vlasac I, burials and houses, 1970, FTIR analysis results (spectra by S. Nunziante Cesaro)

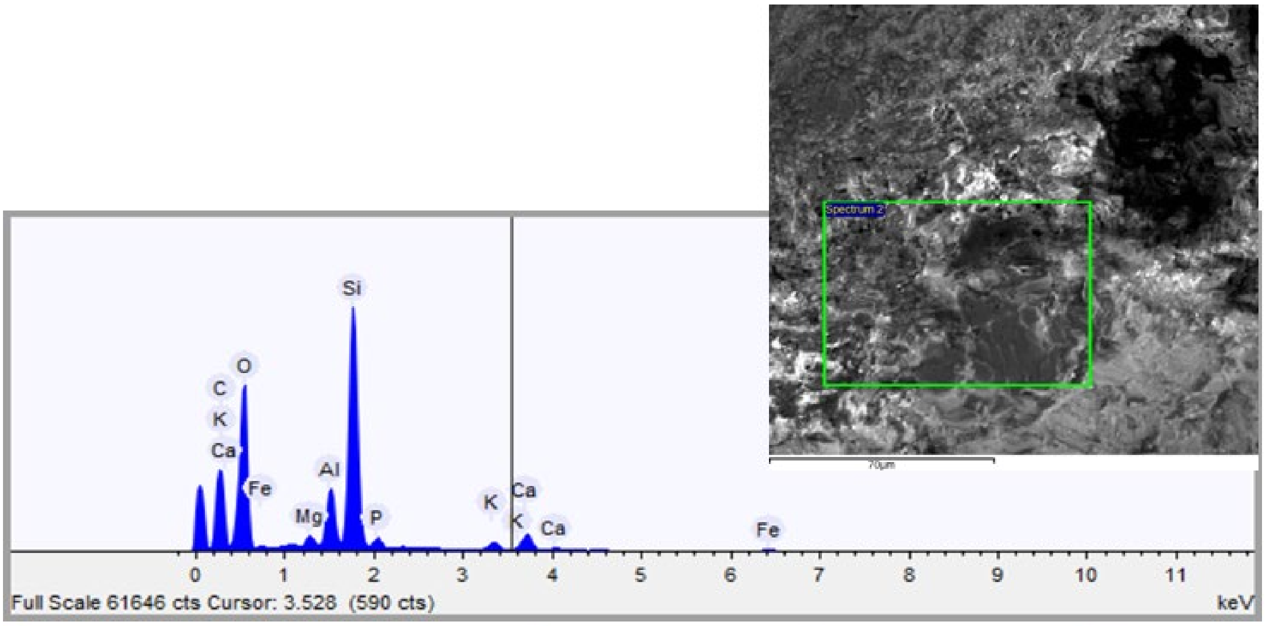
SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
VL 1	~1650, ~1530, ~1650, ~1530, ~913	Collagen, H2O Collagen, Bone	
VL 2	~1650, ~1530, ~1650, ~1530, ~913	Collagen, H2O Collagen, Bone	
VL 5	~1540 ~1420, 877	CaCO3	
VL 6	~1650, ~1530, ~1420	Collagen, H2O	

VL 8	~1650, ~1530, ~1420	Collagen, $H2O$	
VL 10	~1650, ~1530,	Collagen, $H2O$	
VL 11	~1540 ~1420, 877	Collagen	
VL 12	~1650, ~1530	Collagen, $H2O$	

VL 13	~1540 ~1420, 877	CaCO3	

SEM-EDX analysis

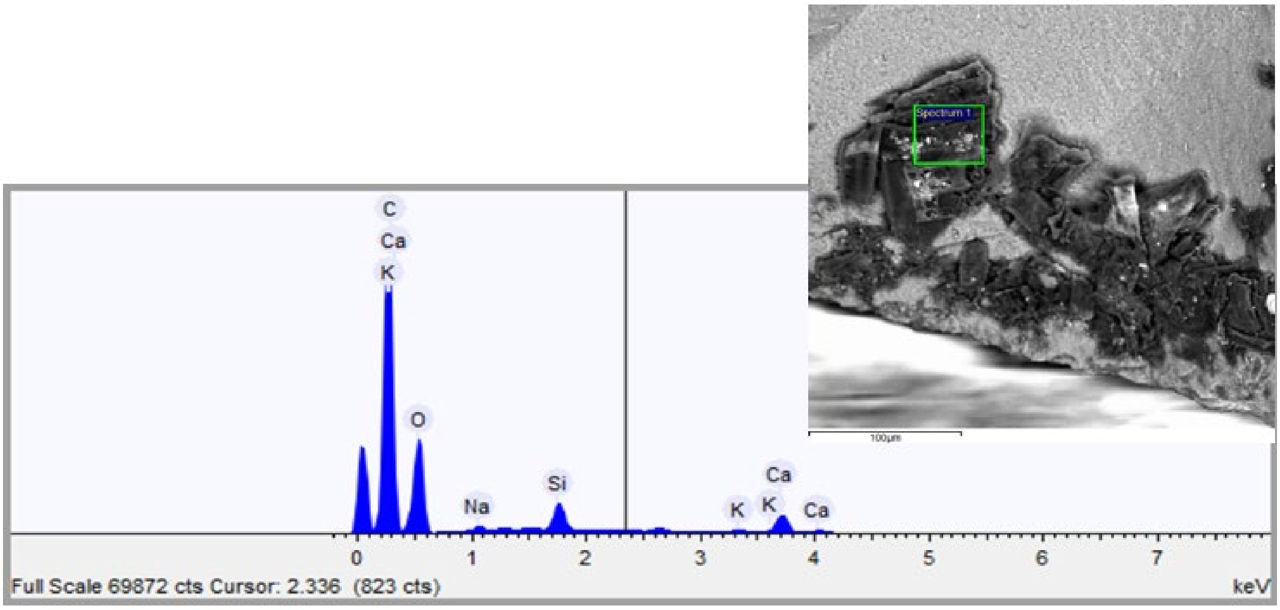
A flake (VL 1) was used for cutting unidentified animal material and hard material afterwards, according to the use-wear analysis. The same tool was analysed with FTIR and the results showed the presence of hydroxyapatite, a bone mineral component (PO3) represented, in the FTIR spectrum, by a peak at the frequency of ~913 cm^{-1}. In the addition, SEM-EDX analysis noted smeared like whitish, dense residues and the presence of Phosphorous and Calcium in the ratio 3:1, with smaller contributions of magnesium (Fig. 162), which is corresponding to the bone/antler (Hayes and Rots 2019).



Element	Weight %	Weight % σ	Atomic %
Carbon	7.851	1.327	12.248
Oxygen	54.630	0.795	63.980
Magnesium	0.959	0.028	0.739
Aluminum	4.945	0.080	3.434
Silicon	24.133	0.356	16.100
Phosphorus	1.470	0.038	0.889
Potassium	1.314	0.032	0.630
Calcium	3.052	0.055	1.427
Iron	1.646	0.054	0.552

Figure 162: VL 1, SEM-EDX results

A flake (VL 13) was used for processing wood. Both dark and lighter fibres near the used edge were observed together with calcium and sodium (Fig. 163). In some cases, calcium can be embedded within the wood fibres and derived from the plant, rather than as a result of contamination (Hayes and Rots 2019).



Element	Weight %	Weight % σ	Atomic %
Carbon	20.865	1.344	27.898
Oxygen	64.671	1.105	64.914
Sodium	1.588	0.060	1.109
Silicon	5.338	0.103	3.052
Potassium	0.705	0.037	0.290
Calcium	6.832	0.131	2.737

Figure 163: VL 13, SEM-EDX results

5.3.2. Dwellings

Use-wear analysis

Fifty-nine (59) tools coming from areas above and from the house floors of Vlasasc were analysed (Table 38). Dwelling 2 is connected to the first phase of the occupation of the Vlasac Ia and it was only partially recovered. The chipped stone tools were found together with the animal and fish bones, a fragment of the human cranium, antler and bone tools. The roe deer antler was dated and the sample is in the range 7047 to 6699 cal BC. Dwelling 4 is belonging to the later phase of occupation – Vlasac Ib, and the charcoal dates this dwelling in the range 7036 to 6496 cal BC. Dwelling 5, also, belongs to the Vlasac Ib, and one date is connected to this structure (7034 to 6693 cal BC).

Table 38: Samples from houses, and above the house floors, Vlasac, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
VL 17	b-18, House 2, from the floor	Core fragments	Indeterminable	Soft material		Any
VL 18	b-18, House 2, from the floor	Flake	Indeterminable	Stone		Any
VL 19	b-18, House 2	Splinter	Scraping	Woody material		
VL 20	b-18, House 2	Splinter	Indeterminable	Medium material		
VL 21	b-18, House 2	Flake	Indeterminable	Woody material		Any
VL 22	b-18, House 2	Flake	Indeterminable	Silicious plant	Prehension	
VL 23	b-18, House 2	Core fragment	Indeterminable	Non-diagnostic		
VL 52	House 4	Scraper	Indeterminable	Non-diagnostic		Any
VL 53	House 5	Flake	Cutting	Left: hide + ash, right: hard material		
VL 54	House 2	Flake	Indeterminable	Medium material		
VL 55	House 6	Scraper	Cutting	Medium material	Prehension	
VL 56	House 6	Point	Cutting	Non-diagnostic		
VL 57	House 6	Scraper	Cutting	Hard-medium material		
VL 58	House 6	Flake	Cutting	Soft material	Prehension	
VL 59	House 2	Flake	Cutting	Vegetal material	Hafted	
VL 60	House 2	Flake	Cutting	Soft material		
VL 61	House 4	Flake	Indeterminable	Hide	Prehension	

VL 62	House 4	Flake	Cutting	Woody material		
VL 63	House 6	Scraper	Indeterminable	Wood		
VL 64	House 6	Scraper	Indeterminable	Woody		
VL 65	House 6	Flake	Scraping, Cutting	Woody		Any
VL 66	House 2, a/18	Flake	Cutting, Scraping	Woody		
VL 67	House 2	Core	Cutting, Scraping	Medium material		
VL 68	House 5	Flake	Scraping	Hide		Any
VL 69	a/18, above the floor of house 2	Flake	Cutting	Medium material		
VL 70	a/18 above the floor of house 2	Flake	Cutting	Medium material		
VL 71	a/18 above the floor of house 2	Flake	Cutting	Hide		
VL 72	a/18, from floor of the house 2	Flake	Indeterminable	Medium-soft material		Glossy Appearance
VL 73	a/18, from floor of the house 2	Flake	Indeterminable	Non-diagnostic		Any Glossy Appearance
VL 74	a/18, from floor of the house 2	Splinter	General working	Dry hide		
VL 75	a/18, from floor of the house 2	Splinter	Cutting, Scraping	Animal + vegetal		
VL 76	a/18, from floor of the house 2	Splinter	Cutting	Medium material		
VL 77	a/18, from floor of the house 2	Flake	Indeterminable	Non-diagnostic	Prehension	
VL 78	a/18, from floor of the house 2	Flake	Cutting	Medium material		
VL 79	a/18, from floor of the house 2	Blade	Indeterminable	Medium material		
VL 80	a/18, from floor of the house 2	Flake	Indeterminable	Medium material		

VL 81	a/18, from floor of the house 2	Flake	Indeterminable	Non-diagnostical		
VL 82	Vlasac I, above the floor of house 2	Flake	Indeterminable	Tubers	Prehension	
VL 83	above the floor of house 2	Flake	Cutting	Dry Hide		
VL 84	above the floor of house 2	Flake	Cutting	Medium material		
VL 85	above the floor of house 2	Flake	/	Not used		
VL 86	above the floor of house 2	Flake	Indeterminable	Non-diagnostic		
VL 88	above the floor of house 2	Splinter	Cutting	Soft-medium material	Prehension/ Hafted	
VL 89	above the floor of house 2	Splinter	Scraping	Soft material		
VL 90	above the floor of house 2	Flake	Indeterminable	Tubers		
VL 91	above the floor of house 2	Flake	Cutting	Vegetal		Any
VL 92	above the floor of house 2	Core	/	Not used		
VL 93	above the floor of house 2	Blade	Cutting	Woody		
VL 94	above the floor of house 2	Flake	Cutting	Medium-soft material		Any
VL 95	above the floor of house 2	Flake	Scraping	Non-diagnostic		
VL 96	above the floor of house 2	Flake	Cutting	Medium-Hard material		
VL 97	above the floor of house 2	Flake	Cutting	Woody		
VL 98	above the floor of house 2	Flake	Cutting, Scraping	Soft, soft-medium material		
VL 99	above the floor of house 2	Flake	Drilling	Wood + something else		
VL 100	above the floor of house 2	Flake	Cutting	Medium-hard material		

VL 101	above the floor of house 2	Flake	Cutting	Animal material		Glossy Appearance
VL 102	above the floor of house 2	Flake	Indeterminable	Hide		Any
VL 103	above the floor of house 2	Flake	Indeterminable	Medium material		Any
VL 104	above the floor of house 2	Flake	Indeterminable	Medium material		

Polishes connected to the processing of animal-based matters confirmed that the tools were mainly utilized for hide working, represented mainly by granular topography (Fig. 164a-b).

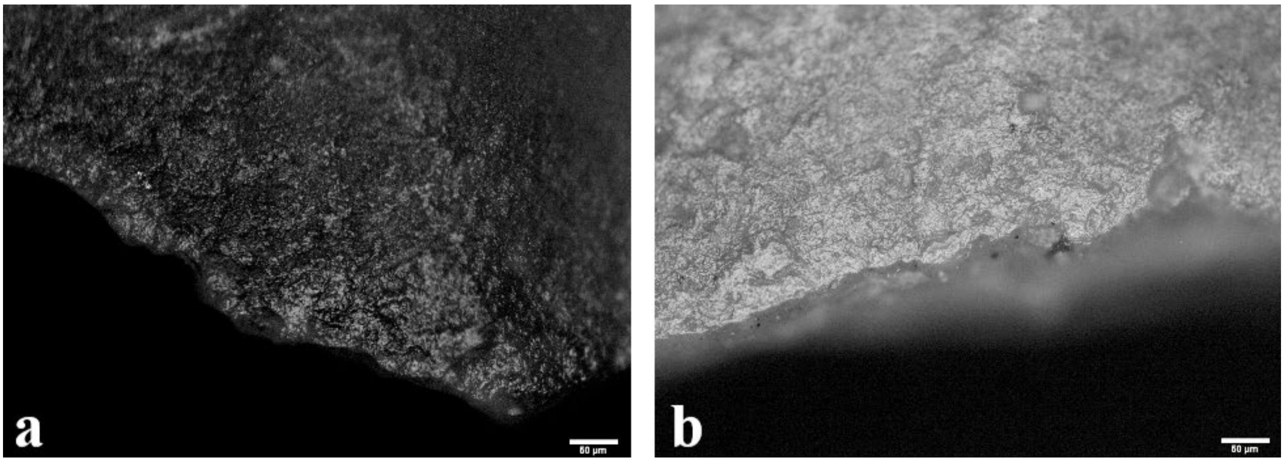


Figure 164: a) Granular topography, hide processing, VL 68, b) Granular topography, rough texture, VL 61 (photo A. Petrović)

The processing of the vegetal-based matters is observed on 61% of the diagnostic tools. Besides the scraping and cutting of the wood and woody material (Fig. 165a-c), traces of silicious plants (Fig. 165d) and tubers were noted.

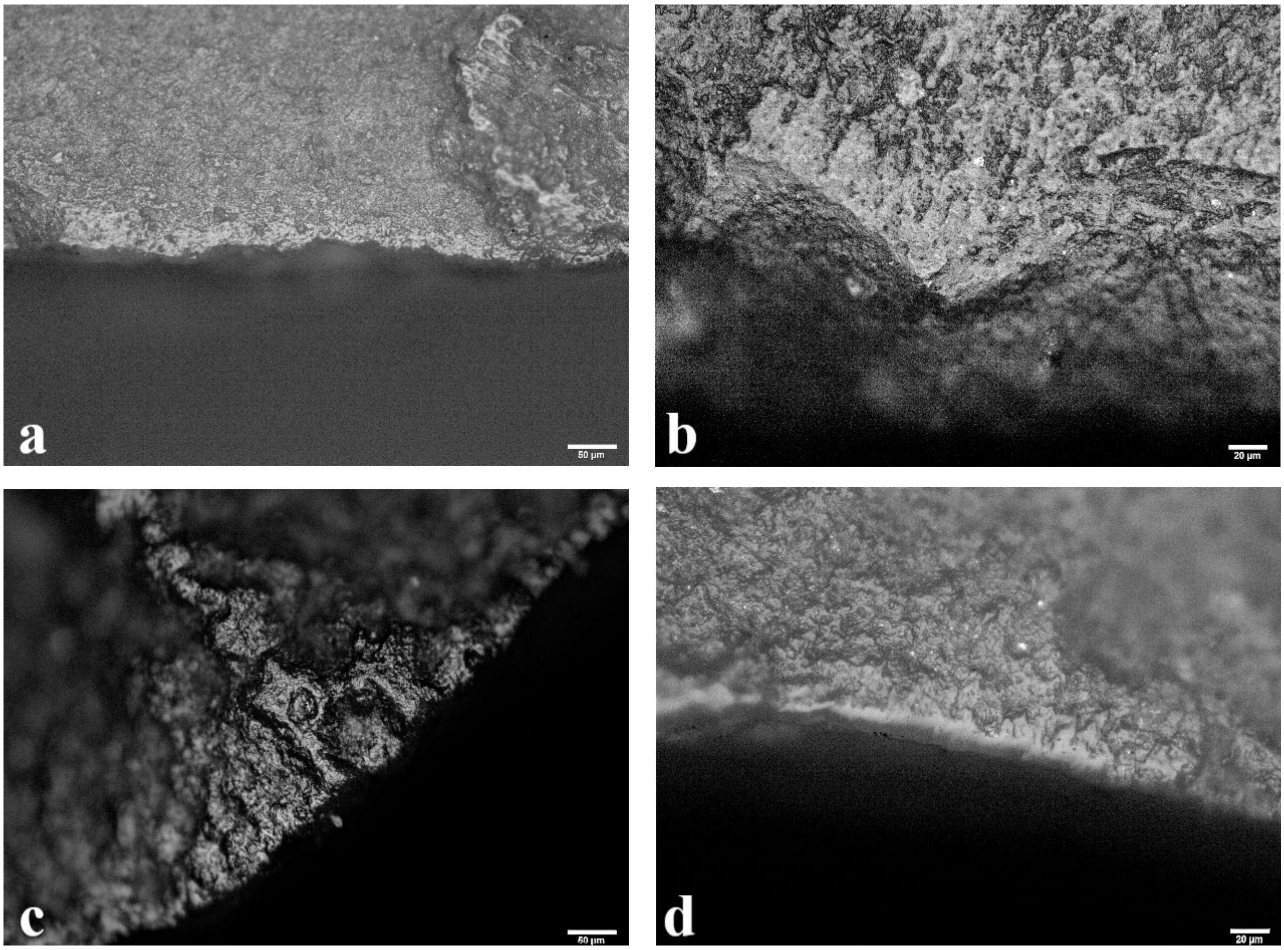


Figure 165: a) Woody material, VL 21, b) Woody material, VL 62, c) Woody material, VL 63, d) Silicious plant VL 22 (photo A. Petrović)

One flake (VL 18) was used for processing the stone, visible by the striation formed inside the polish with flat topography and rougher texture in the less developed areas (Fig. 166).

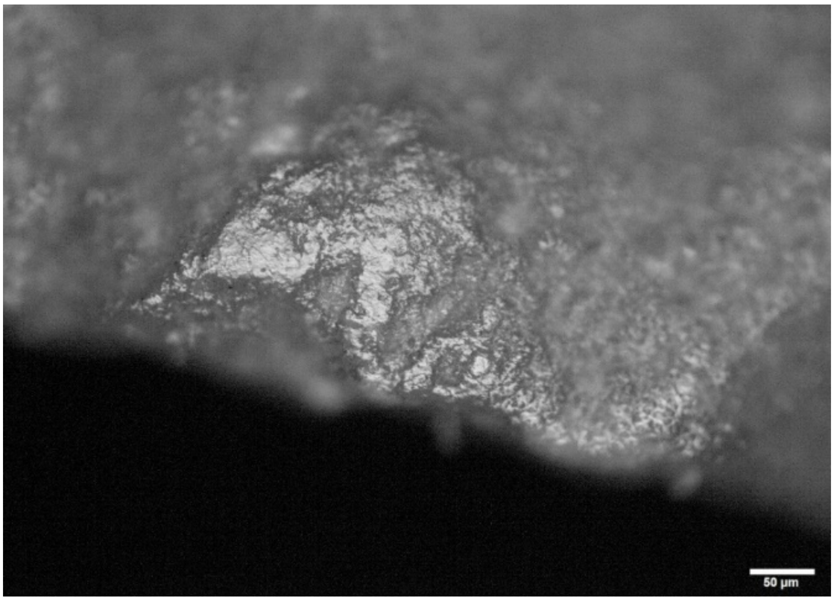


Figure 166: Stone working, VL 18 (photo A. Petrović)

The superposition of a couple of diverse activities was noted on the two tools from and above the floor of house 2. In the case of the sample VL 75 domed topography and rough texture are indicating both the processing of the animal and vegetal matters (Fig. 167a), while the sample VL 99 has clear traces of woodworking, based on the domed topography and half-tight to tight linkage on the lower parts, and another level of utilization in the contact with unidentified matter (Fig. 167b).

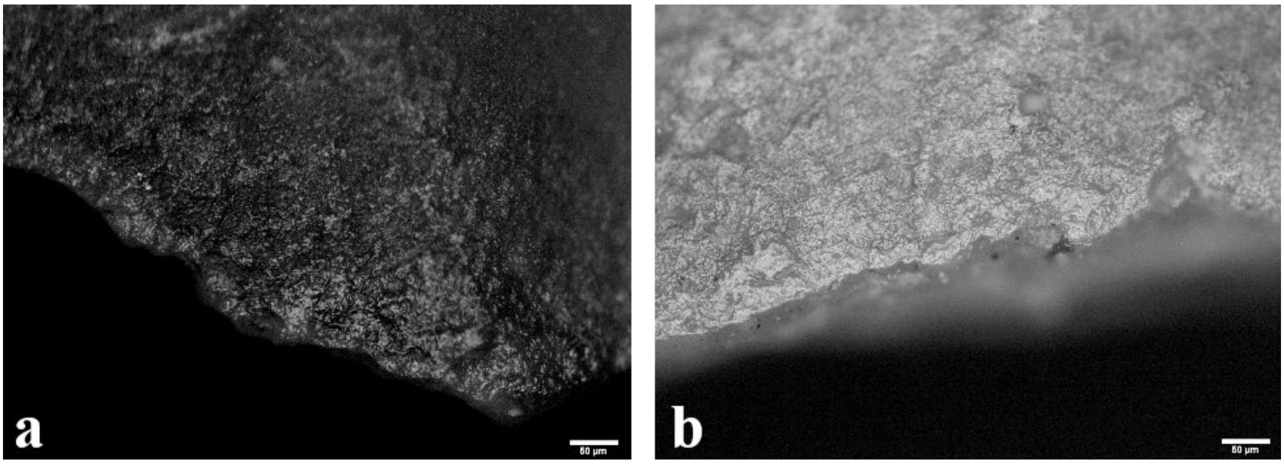
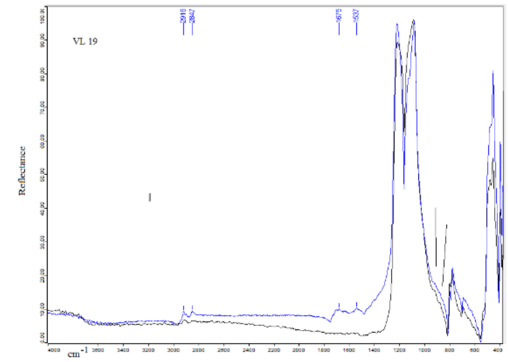
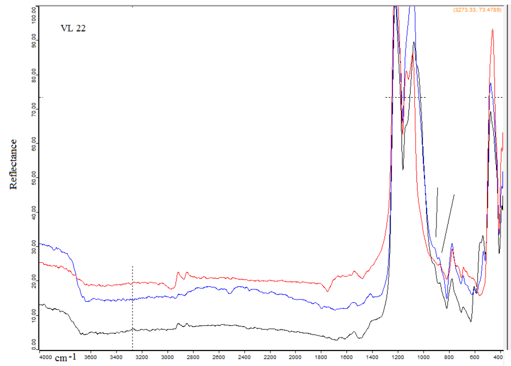
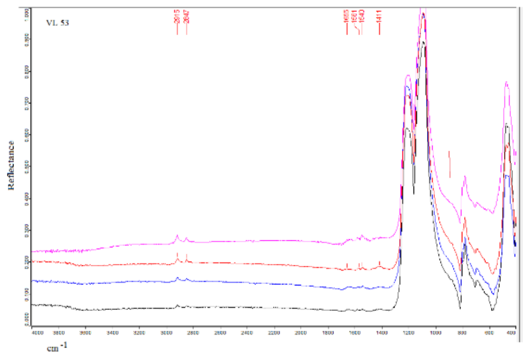
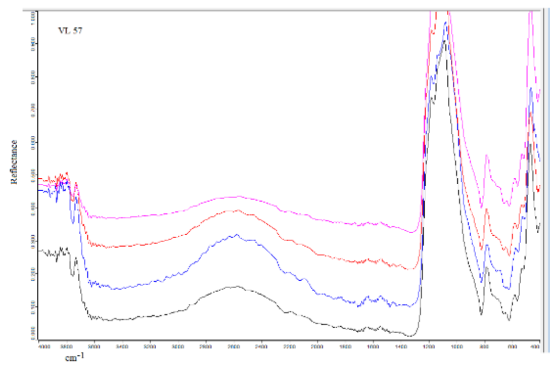


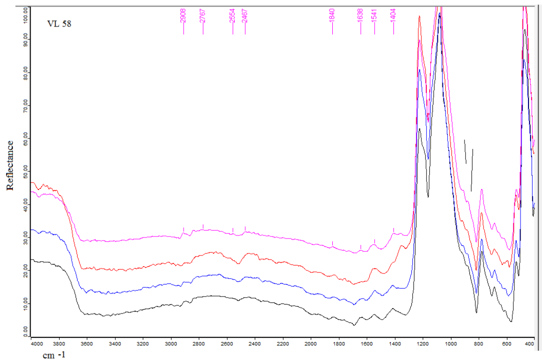
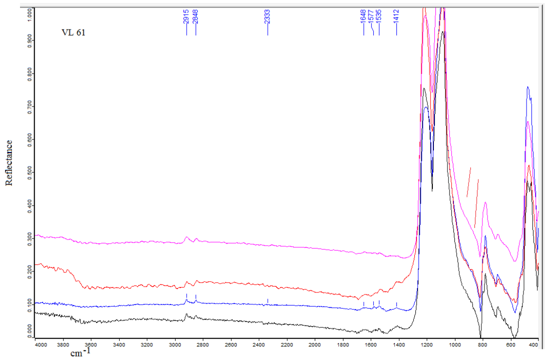
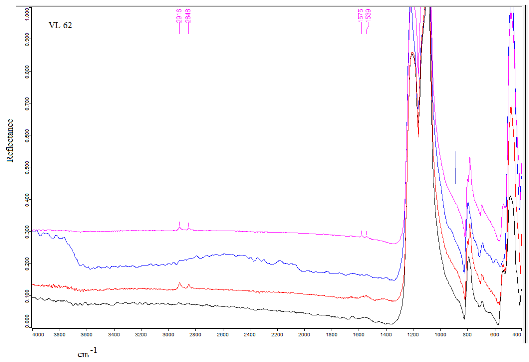
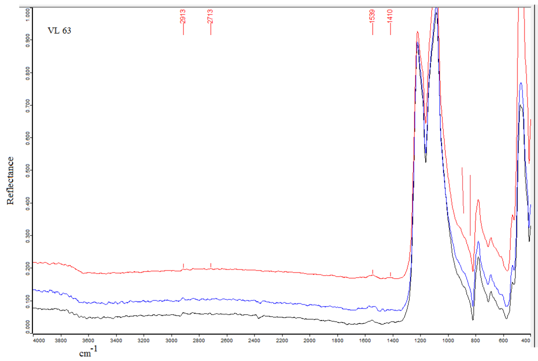
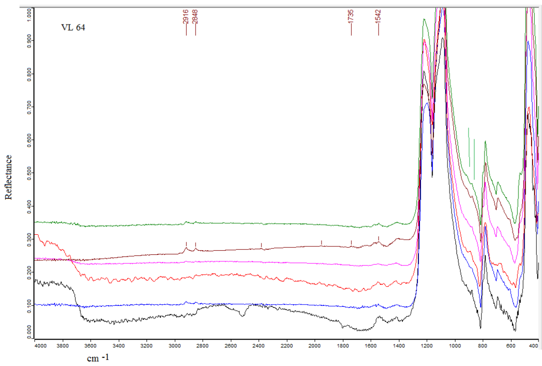
Figure 167: a) Superposition of animal and vegetal based materials, VL 75,
b) Superposition of wood and another unidentified material, VL 99 (photo A. Petrović)

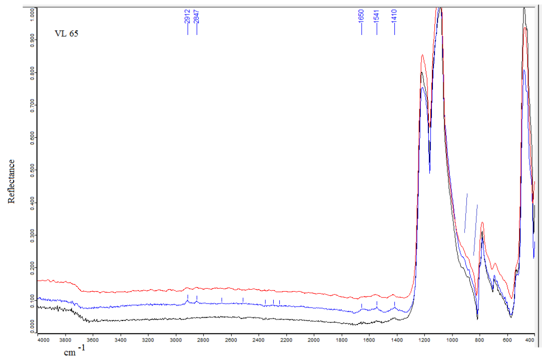
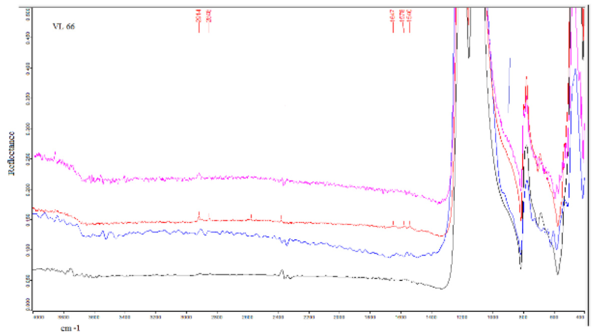
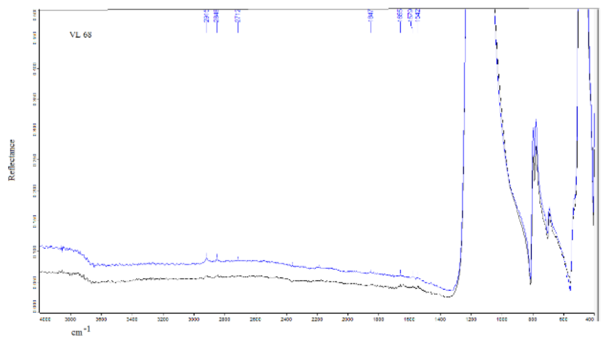
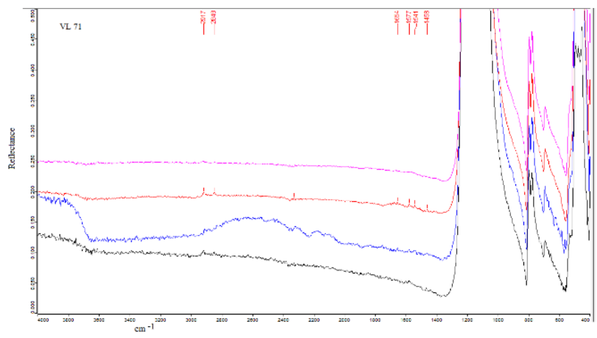
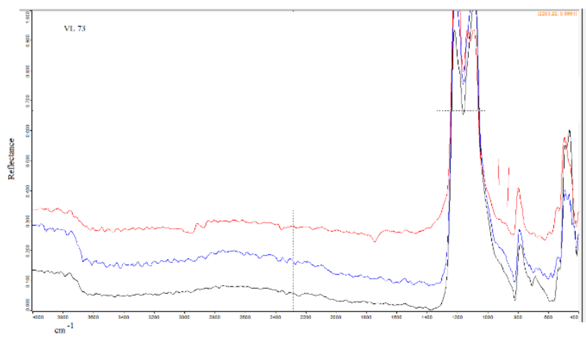
FTIR analysis results

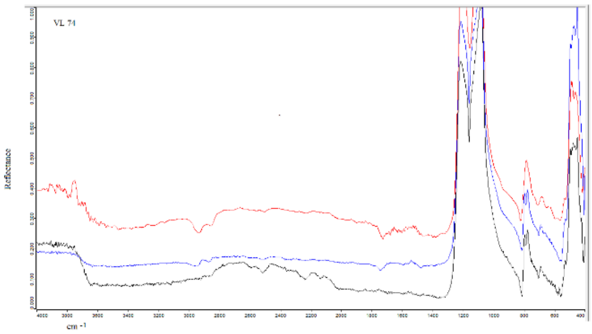
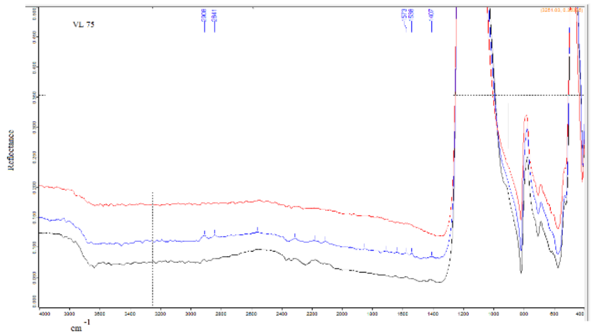
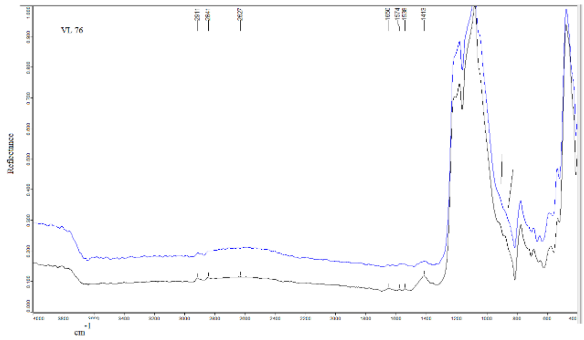
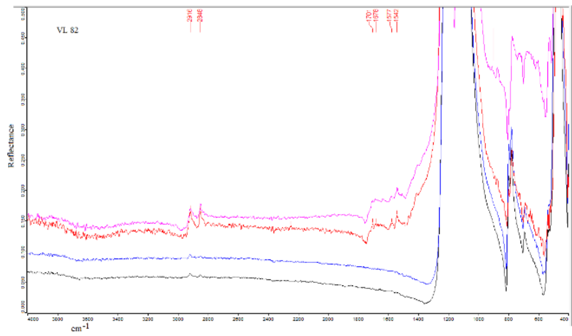
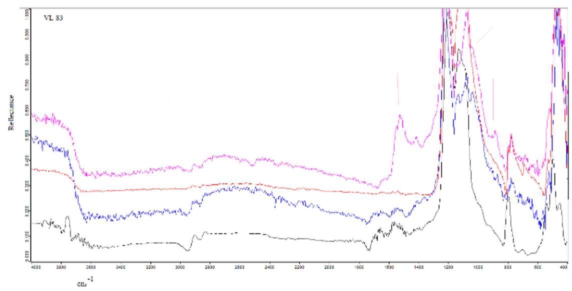
Twenty-five (25) tools, from and above the house floors, were analysed with FTIR spectroscopy, and 28% of the assemblage did not bear any (in)organic remains (Table 39). The rest of the tools had traces of residues, either isolated or in combination. The most frequent observed bands are ~1650 cm^{-1} interpreted as collagen, ~1420 cm^{-1} as calcium carbonate, adipocere at 1576, 1540 cm^{-1} and bone at ~913 cm^{-1}. Bone, adipocere, collagen and combinations of these residues were found among the other tools used for the processing of animal resources, as well on the six (6) tools (VL 93, VL 19, VL 22, VL 66, VL 62, VL 82) that have been used for worked the vegetal-based matters, according to the use-wear analysis. These discordances could be caused by numerous taphonomical factors. Nevertheless, bands attributed to the wood (at 1735 cm^{-1}) were observed in the spectra of samples VL 64 and VL 65, a scraper and flake used for processing a woody material, which contributed to the evaluation of the use-wear analysis results and confirmed them.

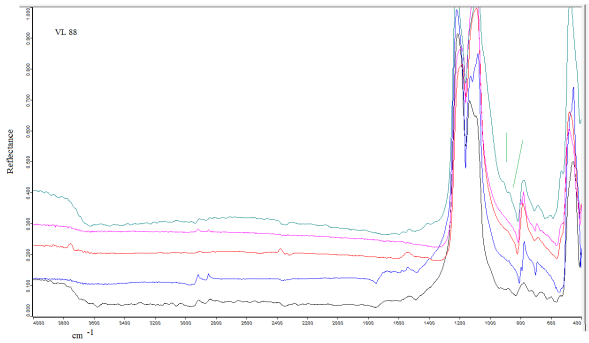
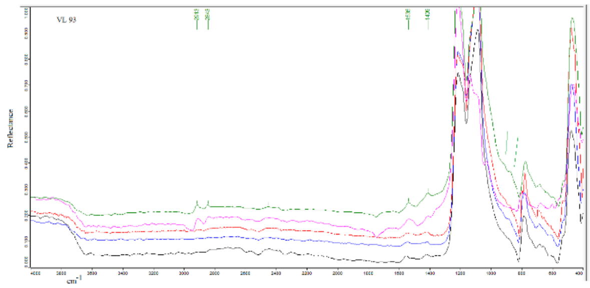
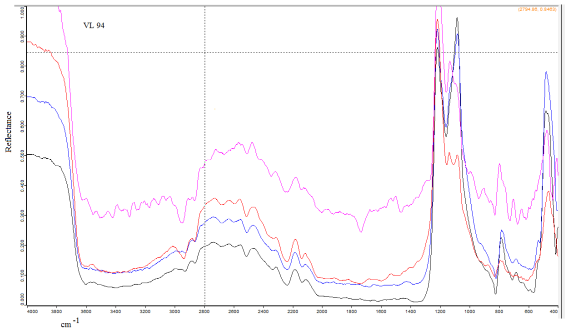
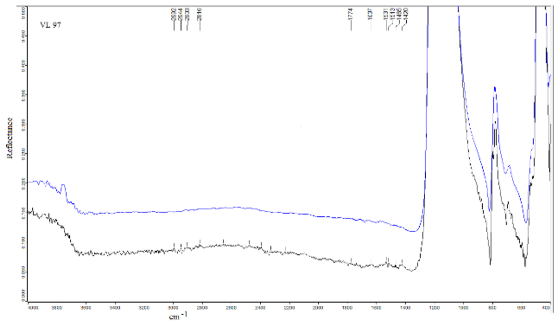
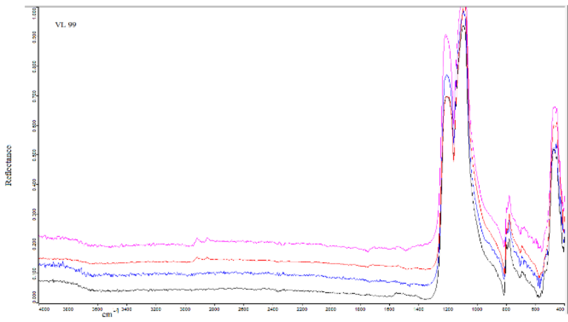
Table 39: Samples from houses, and above the house floors, Vlasac, FTIR analysis results
(spectra by S. Nunziante Cesaro)

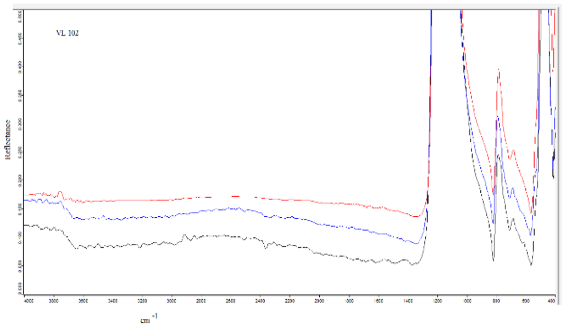
SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
VL 19	~1530, ~913 ~1650, ~1530	Collagen, bone	
VL 22	~1650, ~1530, ~1420, ~913, 877	Collagen, Bone, CaCO3	
VL 53	1576,1540, ~1420, 877	Adipocere, CaCO3	
VL 57	~1650, ~1540~1420	Collagen, CaCO3	

VL 58	~1650, ~1530, ~1420, ~913, 877	Collagen, Bone, CaCO3	
VL 61	1576, 1540, ~1650, ~913, 877	Adipocere, Collagen, Bone	
VL 62	1576, 1540, ~913, 877	Adipocere, Bone	
VL 63	/	/	
VL 64	1576, 1540, ~913, 877 , 1735	Adipocere, Bone, Wood	

VL 65	1576, 1540, ~913, 877 , 1735	Adipocere, Bone, Wood	
VL 66	1576,1540,	Adipocere	
VL 68	1576,1540,	Adipocere	
VL 71	/	/	
VL 73	/	/	

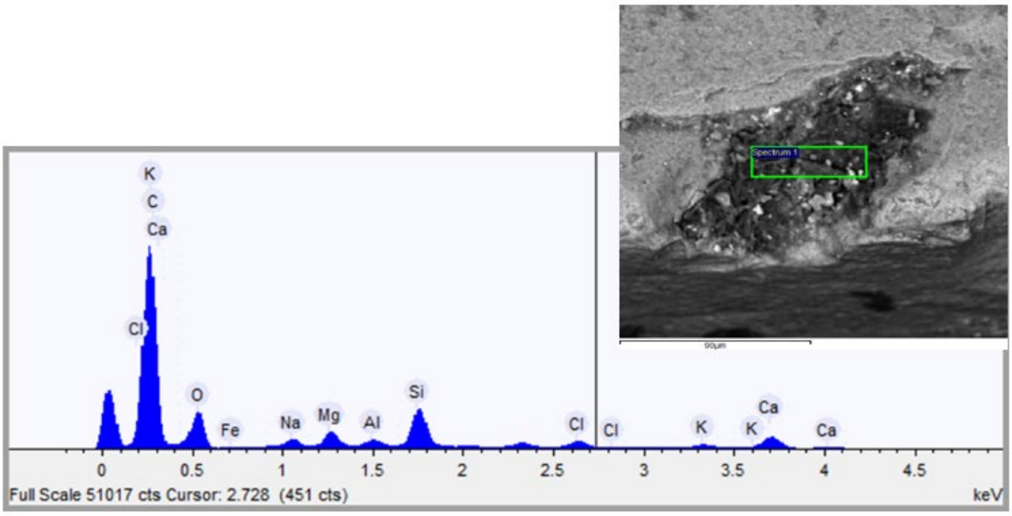
VL 74	/	/	
VL 75	/	/	
VL 76	1576,1540,~1420, ~913, 877	Adipocere, CaCO3, Bone	
VL 82	1576,1540, 913	Adipocere, Bone	
VL 83	~1650, ~1530, ~1420, ~913, 877 1576,1540	CaCO3, Bone, Adipocere	

VL 88	1576,1540 ~1530, ~1420, ~913, 877	Adipocere, CaCO3, Bone	
VL 93	~1530, ~1420, ~913, 877	CaCO3, Bone	
VL 94	~1420, ~913, 877	CaCO3, Bone	
VL 97	/	/	
VL 99	~1530, ~1420	CaCO3	

VL 102	/	/	

SEM-EDX analysis

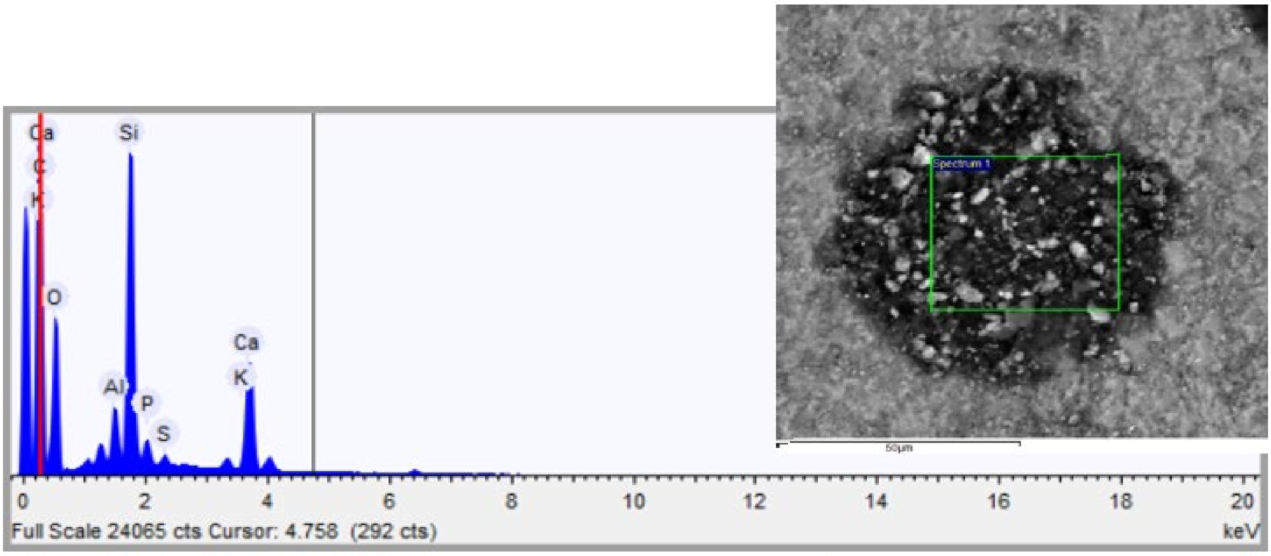
Splinter VL 19, used for processing wood, displayed a number of residue conglomerations along the working edge (Fig. 168). These residues were tested with SEM-EDX which resulted in the presence of sodium, aluminium, chlorine and potassium, which can be indicative for vegetal based matters together with the residues of the terrain.



Element	Weight %	Weight % σ	Atomic %
Carbon	18.105	4.002	26.758
Oxygen	47.871	2.354	53.114
Sodium	2.871	0.164	2.217
Magnesium	4.704	0.243	3.435
Aluminum	1.801	0.106	1.185
Silicon	12.102	0.600	7.649
Chlorine	3.006	0.162	1.505
Potassium	1.789	0.106	0.812
Calcium	6.890	0.348	3.052
Iron	0.860	0.109	0.273

Figure 168: VL 19, SEM-EDX analysis

Regarding the flake VL 22, used for processing the siliceous plant, SEM-EDX observations showed various combinations, and as it was showed on the point 2 aluminium, phosphorus, potassium, calcium (Fig. 169) Other points showed similar element combinations, which most probably indicated the external part of the plant.



Element	Weight %	Weight % σ	Atomic %
Carbon	10.469	2.184	16.772
Oxygen	48.514	1.199	58.348
Aluminum	3.253	0.090	2.320
Silicon	19.439	0.484	13.318
Phosphorus	2.255	0.075	1.401
Sulfur	0.943	0.045	0.566
Potassium	1.176	0.049	0.579
Calcium	13.950	0.351	6.697

Figure 169: VL 22, SEM-EDX results

5.3.3. Burials

Use-wear analysis

Chipped stone tools recovered from the funerary contexts are belonging to diverse occupational phases of Vlasac (Table 40). Burials from the building horizon I (Vlasac Ia and Ib) are classified in both group A and B. The burials 30, 33-34, 38, 49, 51, 72 are belonging to group A, and these tombs are characterised as used in the phase of forming the horizons Vlasac Ia and Ib. The burial 72 was dated to the range of 9756 to 8804 cal BC and this is considered to be the oldest human burial at Vlasac, while the burial 51 is dated to an earlier phase of the Late Mesolithic – the second half of the 8th millennium BC.

Regarding the burials from group B, from Vlasac III, the burial 24 is dated to the range 6640 to 6220 cal BC (Borić et al. 2008). The burials 5, 11, 79 are belonging to group C, which is found in the mesolithic layer, but the small thickness of the layer and the absence of the objects in these burials cannot be connected to any phase of Vlasac specifically. Grave 11, after the calibration, resulted in the range 5762 to 5480 cal BC, placing the burial in Middle Neolithic.

Table 40: Samples from burials, Vlasac, use-wear result

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
VL 24	Burial 64	Blade	Cutting	Vegetal material		
VL 34	Burial 64	Scraper	/	Not used		
VL 35	Burial 64	Flake	Indeterminable	Non-diagnostic		Glossy Appearance
VL 29	Burial 64	Flake	Indeterminable	Hide		
VL 25	Burial 24	Point	Cutting, Scraping	Animal Tissues, Meat		Glossy Appearance
VL 26	Burial 40	Flake	Indeterminable	Hide + another material		
VL 27	Burial 14	Flake	Indeterminable	Woody		Glossy Appearance
VL 31	Burial 14	Flake	Indeterminable	Vegetal material		
VL 28	Burial 72	Flake	Scraping	Bone + wood		
VL 30	Burial 33-34	Flake	Cutting	Vegetal material		

VL 32	Burial 11	Point	Indeterminable	Non-diagnostic		
VL 33	Burial 51	Scraper	Indeterminable	Non-diagnostic		
VL 36	Burial 78	Point	Cutting	Vegetal material		Glossy Appearance
VL 37	Burial 78	Blade	Indeterminable	Dry Hide		
VL 38	Burial 5	Flake	Cutting, Scraping	Mineral material	Hafting	Bright Spots
VL 39	Burial 5	Bladelet	Indeterminable	Soft material		
VL 40	Burial 5	Flake	Indeterminable	Soft stone		
VL 41	Burial 49	Flake	Cutting	Medium material		
VL 42	Burial 49	Blade	Cutting	Bone + Animal tissues	Prehension	
VL 43	Burial 49	Scraper	Cutting	Medium material		
VL 44	Burial 49	Blade	Cutting, Scraping	Soft material		
VL 45	Burial 30	Flake	Indeterminable	Vegetal + mineral material		
VL 46	Burial 30	Core	/	Not used		
VL 47	Burial 30	Core	/	Not used		
VL 48	Burial 30	Point	Cutting, Scraping	Woody		Any
VL 49	Burial 30	Geometric	Cutting	Vegetal material		

VL 50	Burial 38	Blade	Scraping	Vegetal material		
VL 51	Burial 38	Flake	Indeterminable	Hide		
VL 105	Burial 14	Flake	Drilling	Hide	Prehension	
VL 106	Burial 14	Flake	Indeterminable	Woody		
VL 107	Burial 14	Flake	Cutting	Mineral material		
VL 108	Burial 14	Flake	Cutting	Soft-medium material		
VL 109	Burial 14	Flake	Cutting	Animal material	Handheld	
VL 110	Burial 14	Flake	/	Not used		
VL 111	Burial 14	Flake	Cutting	Dry hide + hard material		
VL 112	Burial 14	Raw material fragment	/	Not used		
VL 113	Burial 14	Flake	Scraping	Butchering (meat)		Glossy Appearance
VL 114	Burial 14	Flake	Indeterminable	Woody		
VL 115	Burial 14	Scraper	Indeterminable	Medium material		
VL 116	Burial 14	Flake	Cutting	Vegetal material		

The tools found in the burial contexts at the Vlasac site have not been altered in greater quantity and the modifications are present on seven (7) tools – a light glossy appearance and bright spots. Five (5) tools, one from burial 64, two cores from burial 30, and two finds from burial 14, did not have any trace of use.

Artefacts utilized for animal-based matters confirmed the processing of bone and butchering. Bone working as isolated activity was not found, but its traces were found in the combination with other materials: bone and wood (VL 28), and bone and animal tissues (VL 42). The polish of two animal-based matters resulted in the snap and step scars and high edge rounding (Fig. 170a), and micro-wear was granted by flat topography, smooth texture and tight linkage (Fig. 170b). The hide is noted based on the granular topography (Fig. 170c), and dry hide was singled out due to the rough texture. Traces of butchering are found on only one flake recovered from burial 14. Macro traces are described as a small step and feather scar terminations and light edge-rounding (Fig. 170d).

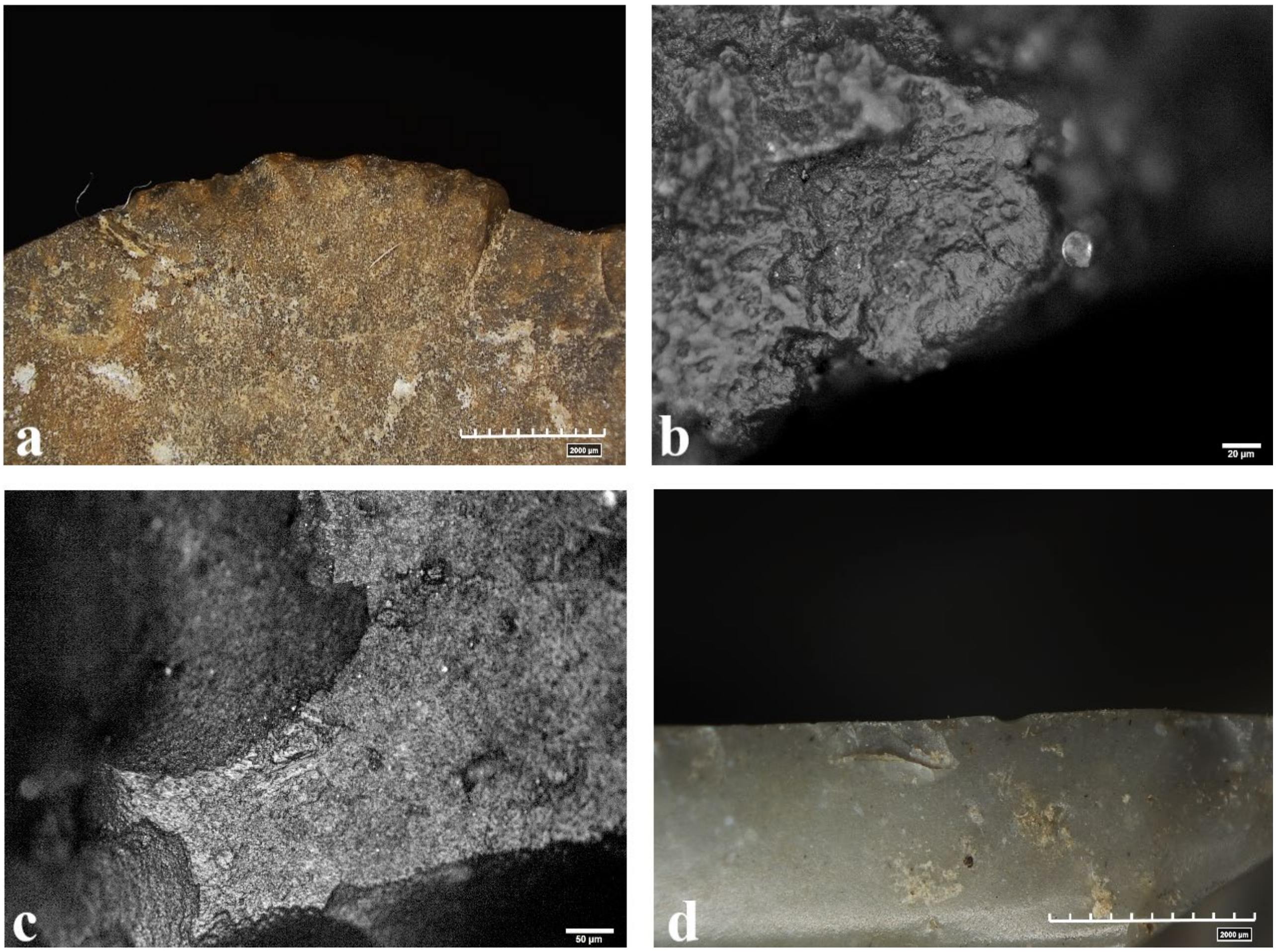


Figure 170: Vlasac, burials a) Macro traces, bone and animal tissues, VL 42, b) Micro traces, flat topography, tight linkage, bone and animal tissues, VL 42, c) Micro traces, granular topography, hide, VL 51, d) Macro traces, small step and feather scars, butchering, VL 113 (photo A. Petrović)

Traces of vegetal based matters are represented on the tools found in the burial contexts in higher quantity compared to the traces of animal materials. The noted ratio of utilized material types is not very common and not frequently seen among the observed chipped stone assemblages. Wood polish is characterised by domed topography and rough texture, while micro-traces attributed to the generic vegetal materials have a diverse type of linkage, which is not diagnostic and sufficient for a detailed classification (Fig. 171a-c).

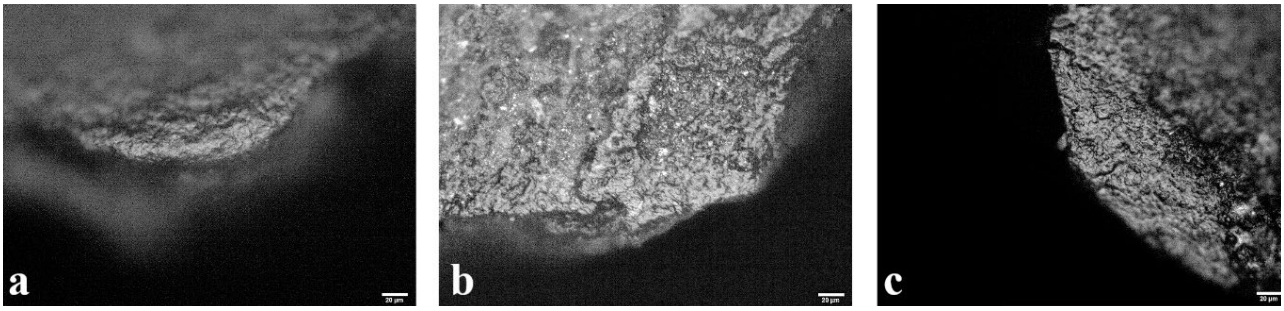


Figure 171: Vlasac, burials a) Micro traces, woody material VL 27, b) Micro traces, domed topography, vegetal material, VL 30, c) Micro traces, domed topography, vegetal material, VL 50 (photo A. Petrović)

As already mentioned, the superposition of the traces is noted, and, besides the overlapping of the same contact matters, the utilization of the chipped stone tools for diverse animal and vegetal materials was recorded. The interpretation is established on the flat topography on the outer edge (Fig. 172a) and flat and domed topography on the inner edge (Fig. 173b).

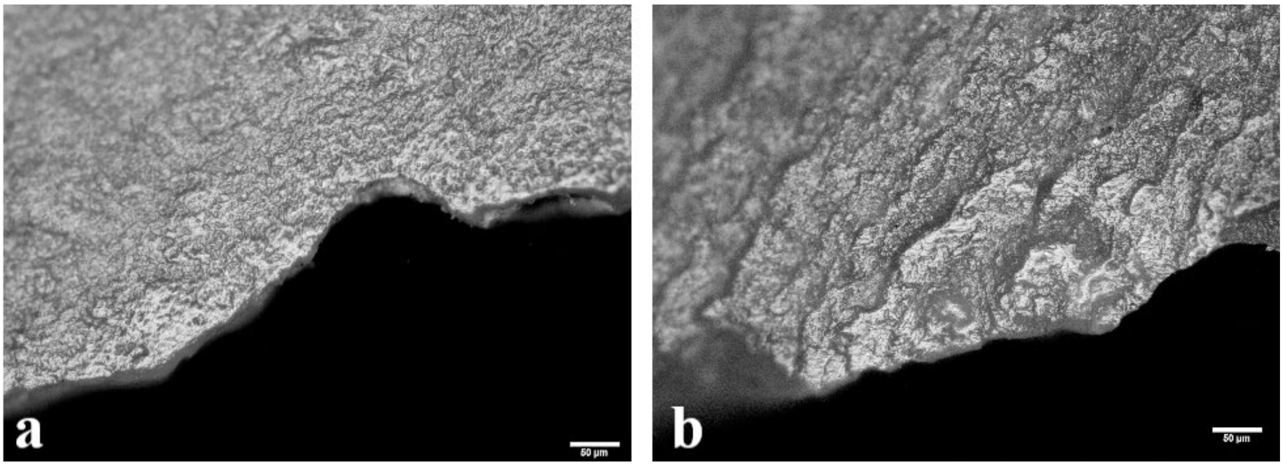
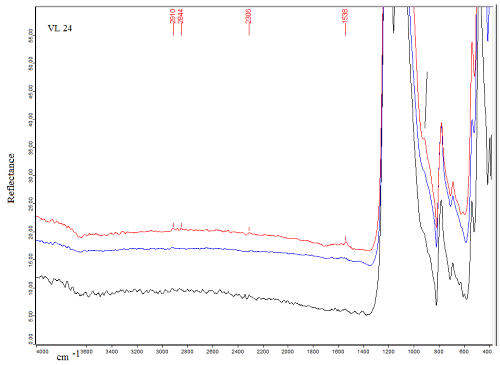
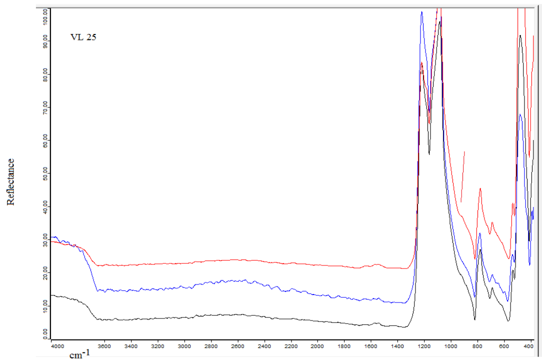
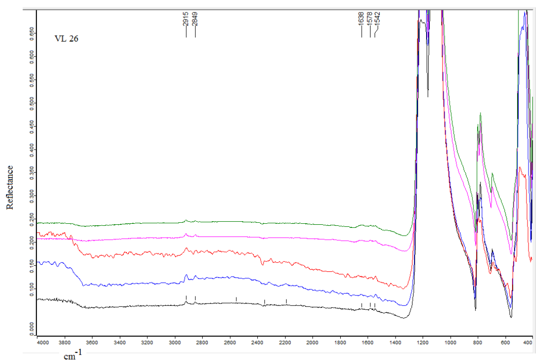
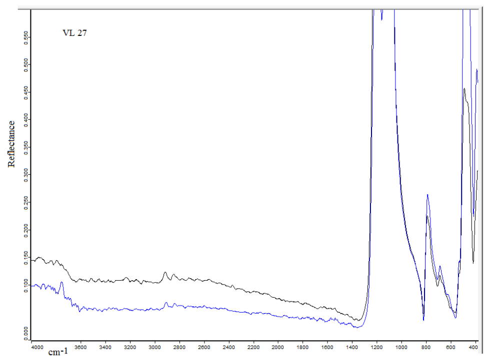


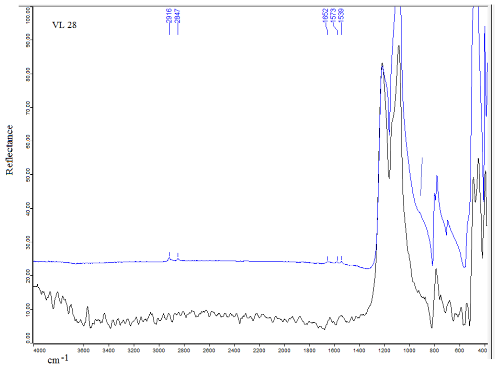
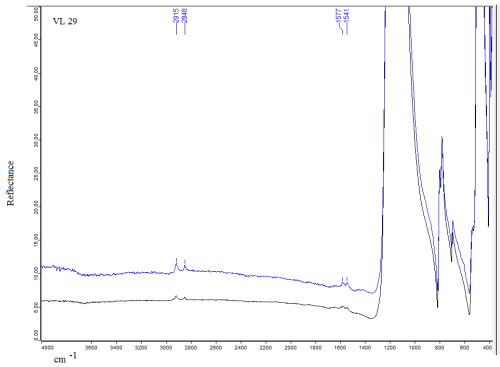
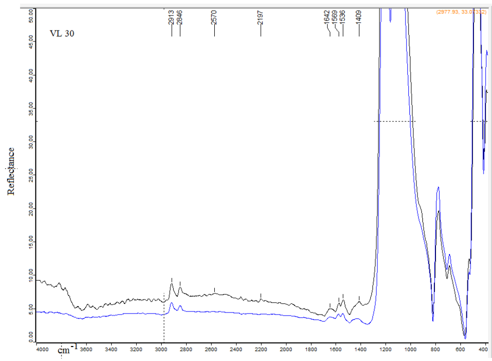
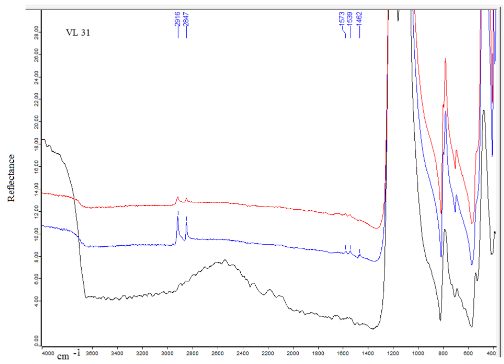
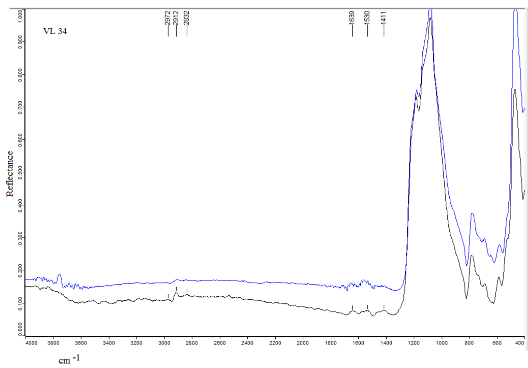
Figure 172: superposition of bone and wood, VL 28 a) flat topography, outer edge, b) flat and domed topography (A. Petrović)

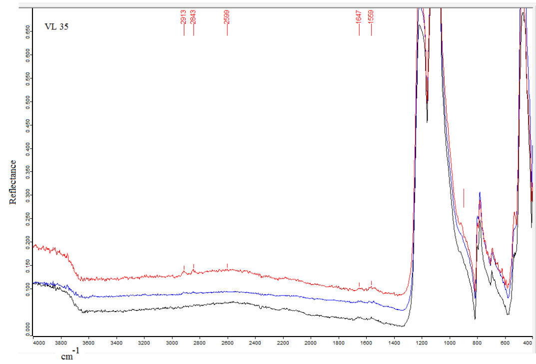
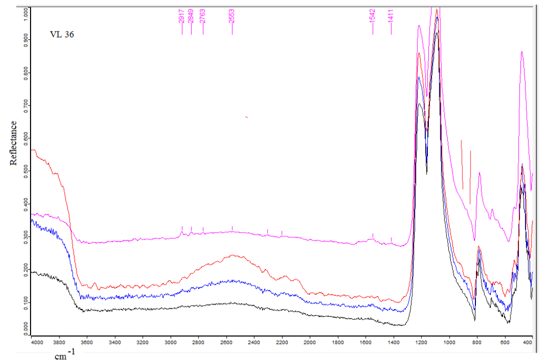
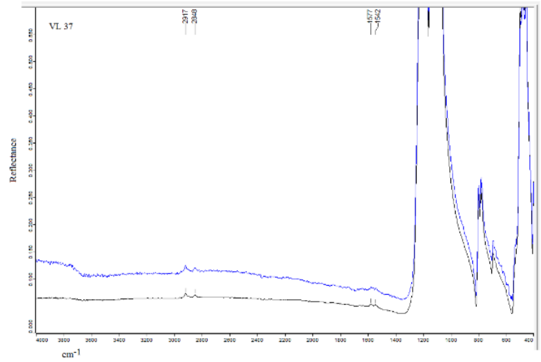
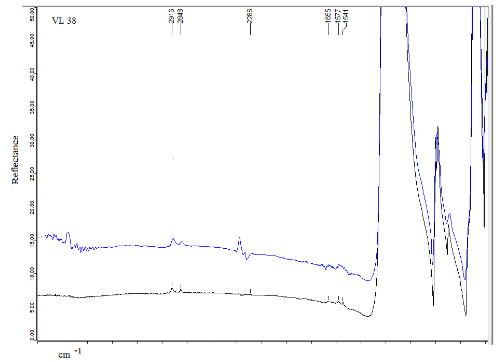
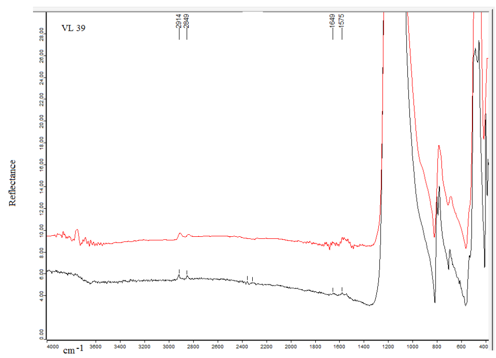
FTIR analysis results

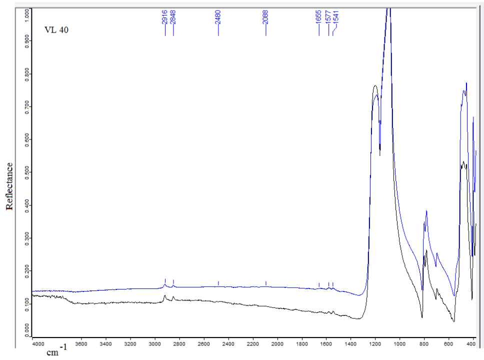
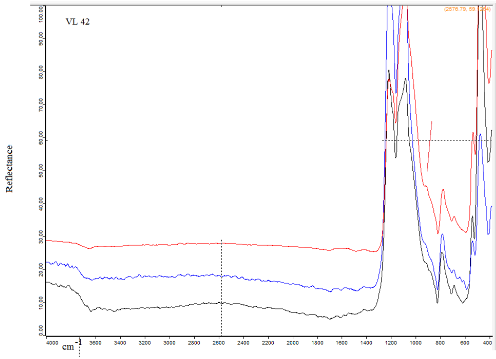
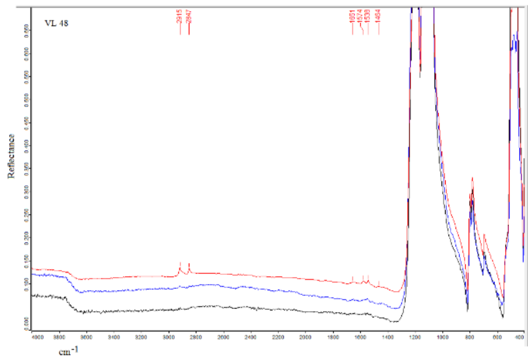
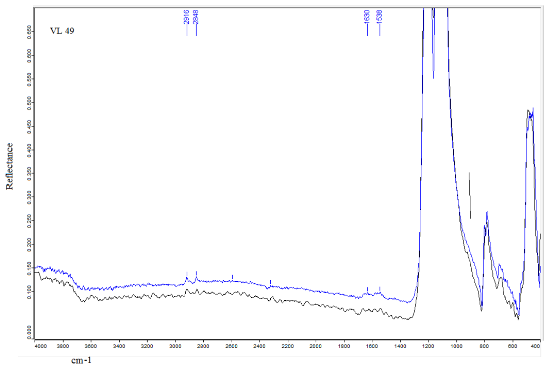
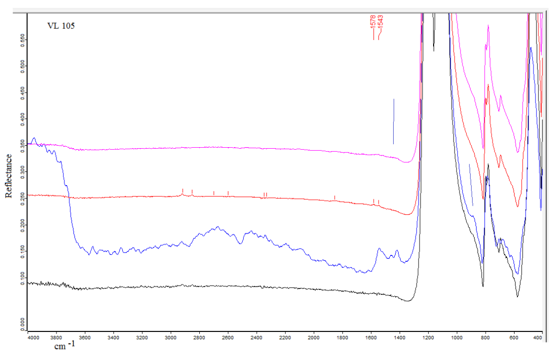
Twenty-three (23) tools, from the burial context, were analysed with FTIR spectroscopy (Table 41). Four types of residues were found on the analysed tools: band at ~1650 cm^{-1} interpreted as collagen, band at ~1420 cm^{-1} as calcium carbonate, adipocere at 1576, 1540 cm^{-1} and bone residues at ~913 cm^{-1}. The 30% of the analysed assemblage does not coincide with the results of the use-wear analysis. Tools used for processing the vegetal-based materials and artefacts without traces of use have residues of collagen and bone. However, the presence of these residues can be a result of taphonomic issues, as the tools were found in the burial contexts together with human remains.

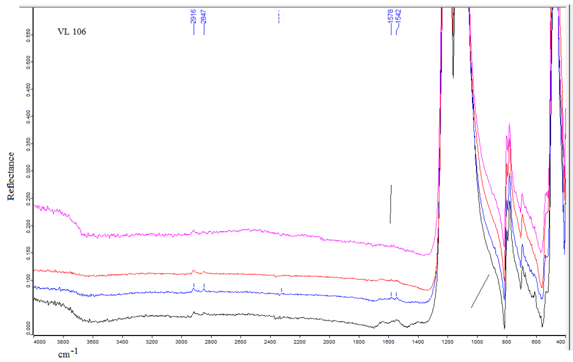
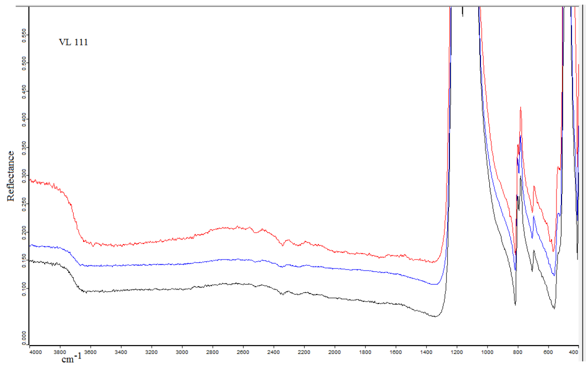
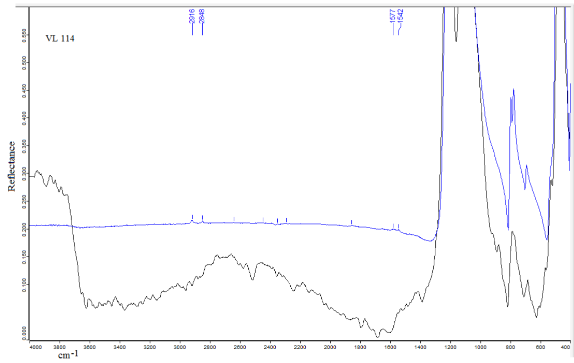
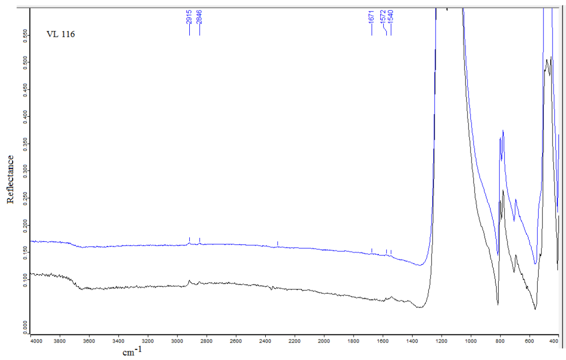
Table 41: Samples from burials, Vlasac, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
VL 24	~1530, ~913	Collagen? Bone	
VL 25	~1650, ~1530, ~913	Collagen, Bone	
VL 26	1576,1540	Adipocere	
VL 27	/	/	

VL 28	~1650, ~1530,	Collagen, H_2O	
VL 29	/	/	
VL 30	~1650, ~1530, ~913 ~1650, 1530	Collagen, Bone Collagen, H_2O	
VL 31	/	/	
VL 34	~1650, ~1530,	Collagen, H_2O	

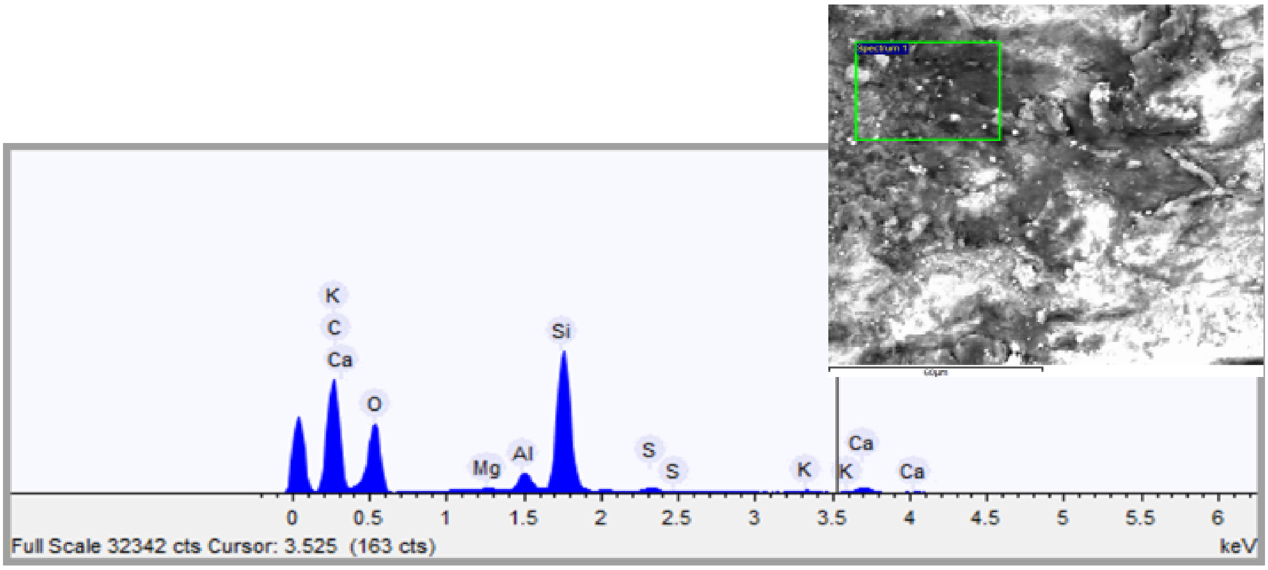
VL 35	~913	Bone	
VL 36	/	/	
VL 37	1576,1540	Adipocere	
VL 38	/	/	
VL 39	~1650, ~1530,	Collagen, H_2O	

VL 40	1576,1540	Adipocere	
Vl 42	~1650, ~1530, ~1420, ~913, 877	Collagen, bone, CaCO3	
VL 48	1576,1540	Adipocere	
VL 49	~913	Bone	
VL 105	~1530, ~1420 1576,1540	CaCO3. Adipocere	

VL 106	~1530, ~1420 1576,1540	CaCO3. Adipocere	
VL 111	/	/	
VL 114	~1420, ~913, 877	CaCO3, bone	
VL 116	~1530, ~1420, ~913, 877	CaCO3, bone	

SEM-EDX analysis

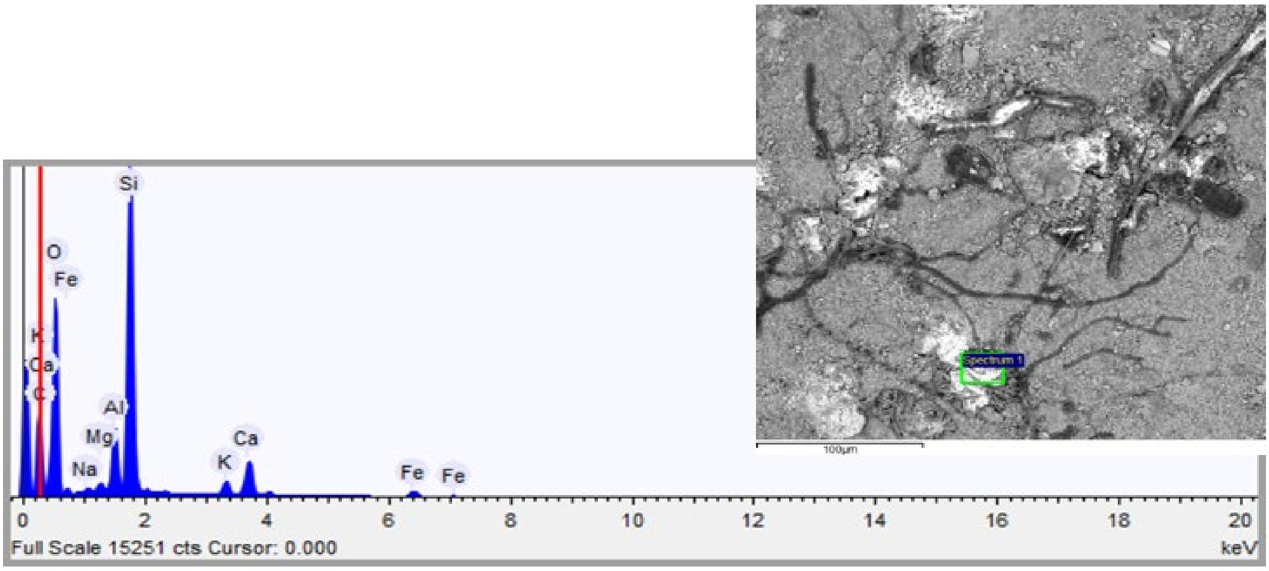
Blade (VL 24) that cut the vegetal matters under the SEM-EDX observations showed traces of potassium, sulfur, aluminium and calcium which correspond to the vegetal structure (Fig. 173), (Monnier et al. 2017, Hayes and Rots 2019).



Element	Weight %	Weight % σ	Atomic %
Carbon	11.134	4.347	16.973
Oxygen	52.099	2.561	59.623
Magnesium	0.627	0.059	0.473
Aluminum	3.002	0.160	2.037
Silicon	28.682	1.414	18.698
Sulfur	1.330	0.088	0.759
Potassium	0.776	0.064	0.363
Calcium	2.350	0.133	1.073

Figure 173: VL 24, SEM-EDX results

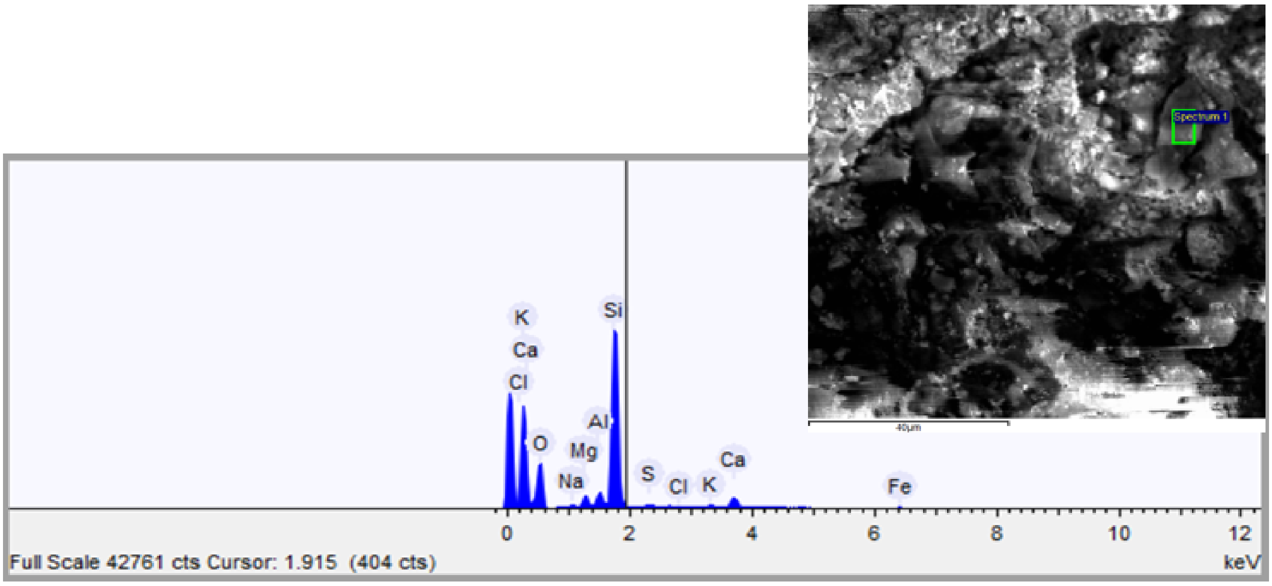
Point (VL 25) used for cutting and scraping of animal tissues and meat, which was additionally confirmed with the traces of collagen and bone detected by the FTIR, while the SEM-EDX analysis displayed high values of aluminium, calcium, potassium and iron (Fig. 174). The first two elements can be indicators for skin processing.



Element	Weight %	Weight % σ	Atomic %
Carbon	4.041	2.260	6.607
Oxygen	54.015	1.291	66.304
Sodium	0.451	0.050	0.385
Magnesium	0.596	0.044	0.482
Aluminum	4.581	0.125	3.334
Silicon	26.159	0.633	18.292
Potassium	1.861	0.067	0.935
Calcium	5.375	0.147	2.634
Iron	2.920	0.126	1.027

Figure 174: VL 25, SEM-EDX results

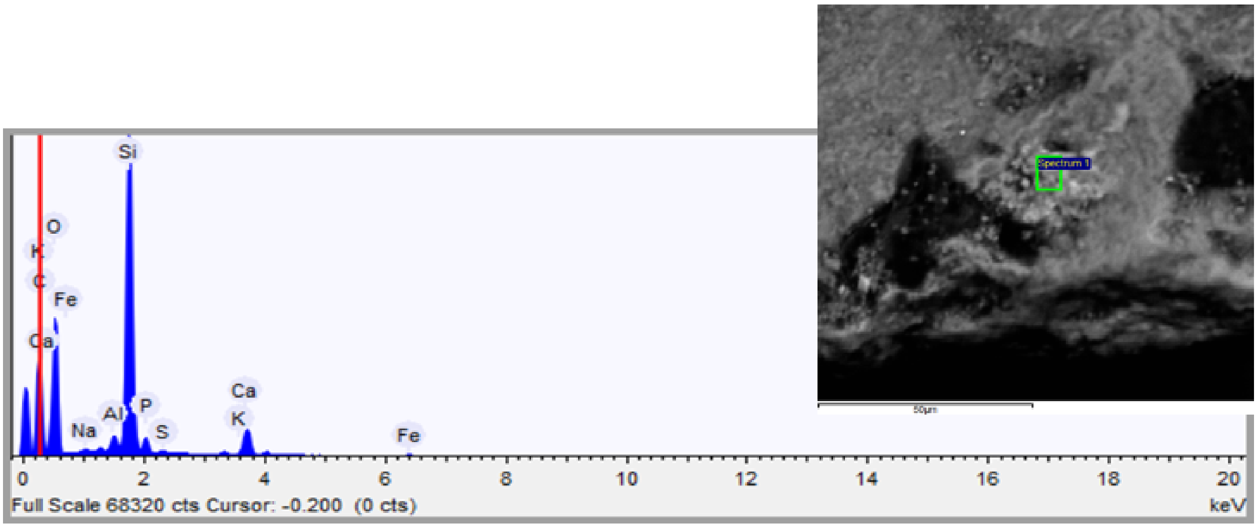
Another point (VL 36) used for cutting vegetals showed higher peaks of aluminium, sulfur, calcium, potassium and magnesium (Fig. 175). There are no clear indications, based on the SEM-EDX, for this tool.



Element	Weight %	Weight % σ	Atomic %
Oxygen	43.505	0.272	58.305
Sodium	0.573	0.052	0.534
Magnesium	2.573	0.058	2.270
Aluminum	2.736	0.060	2.174
Silicon	41.995	0.224	32.061
Sulfur	1.200	0.060	0.802
Chlorine	0.490	0.056	0.296
Potassium	0.928	0.061	0.509
Calcium	4.934	0.089	2.639
Iron	1.066	0.134	0.409

Figure 175: VL 36, SEM-EDX results

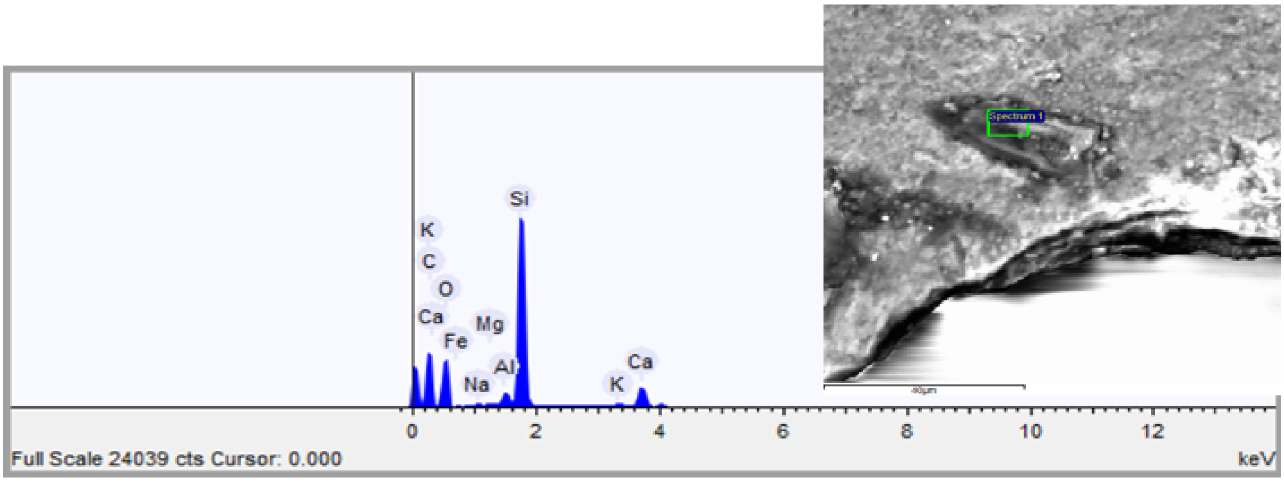
Blade (VL 42) was used for cutting bone and animal tissues. The FTIR analysis confirmed the use-wear analysis, and traces of bone and collagen were found. The results were additionally reviewed with SEM-EDX analysis, where the ratio 3:1 of calcium and phosphorus confirmed the bone/antler residues (Fig. 176).



Element	Weight %	Weight % σ	Atomic %
Carbon	9.239	1.305	14.518
Oxygen	51.051	0.743	60.224
Sodium	0.371	0.024	0.305
Aluminum	1.151	0.027	0.805
Silicon	29.376	0.430	19.741
Phosphorus	2.180	0.045	1.328
Sulfur	0.391	0.020	0.230
Potassium	0.420	0.020	0.203
Calcium	5.111	0.082	2.407
Iron	0.711	0.041	0.240

Figure 176: VL 42, SEM-EDX results

Traces of potassium, aluminium and calcium which could correspond to the vegetal structure in general were found on the point (VL 48), used for both scraping and cutting of the woody matter. The residues were noted based on the fibril structure near the working edge (Fig. 177).



Element	Weight %	Weight % σ	Atomic %
Carbon	7.777	3.805	13.013
Oxygen	42.813	1.797	53.782
Sodium	0.491	0.064	0.429
Magnesium	0.376	0.051	0.311
Aluminum	1.885	0.099	1.404
Silicon	36.477	1.524	26.103
Potassium	1.131	0.079	0.581
Calcium	7.915	0.346	3.969
Iron	1.135	0.128	0.408

Figure 177: VL 48, SEM-EDX results

5.3.4. Hearths

Use-wear analysis

The analysed chipped stone tools are coming from diverse layers of hearth 3 (Table 42). The hearth 3 was found in the block B/V and it was partially discovered. The hearth was built from the limestone slabs, and only three were recovered, which does not provide enough information about the exact shape of the hearth.

Table 42: Samples from hearths, Vlasac, use-wear results

SAMPLE	CONTEXT	TYPOLOGY	ACTIVITY	WORKED MATERIAL	TOOL HANDLING MODE	PDSM
VL 117	under the hearth 3 V, VI	Splinter	Indeterminable	Meat	Prehension	Thermal stress
VL 118	under the hearth 3 V, VI	Splinter	/	Not used		Thermal stress
VL 119	under the hearth 3 V, VI	Splinter	Indeterminable	Soft-medium material	Prehension	
VL 120	under the hearth 3 V, VI	Splinter	/	Not used		Thermal stress
VL 121	under the hearth 8	Point	Cutting	Woody	Prehension	Thermal stress
VL 122	under the hearth 3 V, VI	Splinter	/	Not used		Thermal stress
VL 123	under the hearth 3 V, VI	Splinter	Indeterminable	Hide	Prehension	
VL 124	under the hearth 3 V, VI	Splinter	Indeterminable	Animal material in general		
VL 125	under the hearth 3 V, VI	Splinter	Indeterminable	Dry Hide		
VL 126	under the hearth 3 V, VI	Splinter	Indeterminable	Non-diagnostic		
VL 127	under the hearth 3 V, VI	Splinter	/	Not used		
VL 128	under the hearth 3 V, VI	Splinter	/	Not used		Thermal stress

VL 129	under the hearth 3 V, VI	Splinter	/	Not used		
VL 130	Vlasac IX, X, under the hearth 3	Flake	Indeterminable	Woody		Thermal stress
VL 131	Vlasac IX, X, under the hearth 3	Flake	Cutting	Hide		
VL 132	Vlasac IX, X, under the hearth 3	Flake	Indeterminable	Hard-medium material		Glossy Appearance Thermal stress
VL 133	Vlasac IX, X, under the hearth 3	Flake	Indeterminable	Woody	Prehension	
VL 134	Vlasac IX, X, under the hearth 3	Flake	Cutting	Medium material		Thermal stress
VL 135	Vlasac IX, X, under the hearth 3	Flake	Cutting	Hard-medium material		Thermal stress
VL 136	Vlasac IX, X, under the hearth 3	Flake	Indeterminable	Non-diagnostic		
VL 137	Vlasac IX, X, under the hearth 3	Flake	Indeterminable	Non-diagnostic		Any
VL 138	Vlasac IX, X, under the hearth 3	Flake	Indeterminable	Hide + bone		
VL 139	Vlasac IX, X, under the hearth 3	Point	Indeterminable	Medium material		
VL 140	Vlasac IX, X, under the hearth 3	Flake	Indeterminable	Non-diagnostic		
VL 141	Vlasac IX, X, under the hearth 3	Flake	Cutting	Non-diagnostic		Glossy Appearance
VL 142	Vlasac IX, X, under the hearth 3	Flake	Indeterminable	Non-diagnostic		Any
VL 143	Vlasac IX, X, under the hearth 3	Flake	Indeterminable	Hide		Thermal stress
VL 144	Vlasac IX, X, under the hearth 3	Flake	/	Not used		
VL 145	Vlasac IX, X, under the hearth 3	Flake	Indeterminable	Non-diagnostic		

VL 146	Vlasac IX, X, under the hearth 3	Flake	/	Not used		
VL 147	Vlasac IX, X, under the hearth 3	Flake	Indeterminable	Non-diagnostic		
VL 148	Sonda A, VII and VIII, under the hearth 3	Flake	Indeterminable	Meat		Thermal stress
VL 149	Sonda A, VII and VIII, under the hearth 3	Flake	Indeterminable	Vegetable		
VL 150	Sonda A, VII and VIII, under the hearth 3	Flake	Indeterminable	Vegetable, Medium, worked on the ground		
VL 151	Sonda A, VII and VIII, under the hearth 3	Flake	Indeterminable	Vegetable		

Having in mind the exact context where the tools were found, 34% of the observed artefacts have proofs of thermal stress. These alterations affected only three flakes, where the interpretation was limited on macro traces for this reason.

The variety of animal-based resources is restricted to the bone, hide and meat. Traces of processing of bone and hide were found on the flake VL 138. Bone element is characterised by a flat polish surface near the outer edge, while the hide is defined by granular topography on the inner parts of a tool (Fig. 178a). The hide is defined by granular topography, while the linkage and texture indicate the phase and time of use (Fig 178b-d).

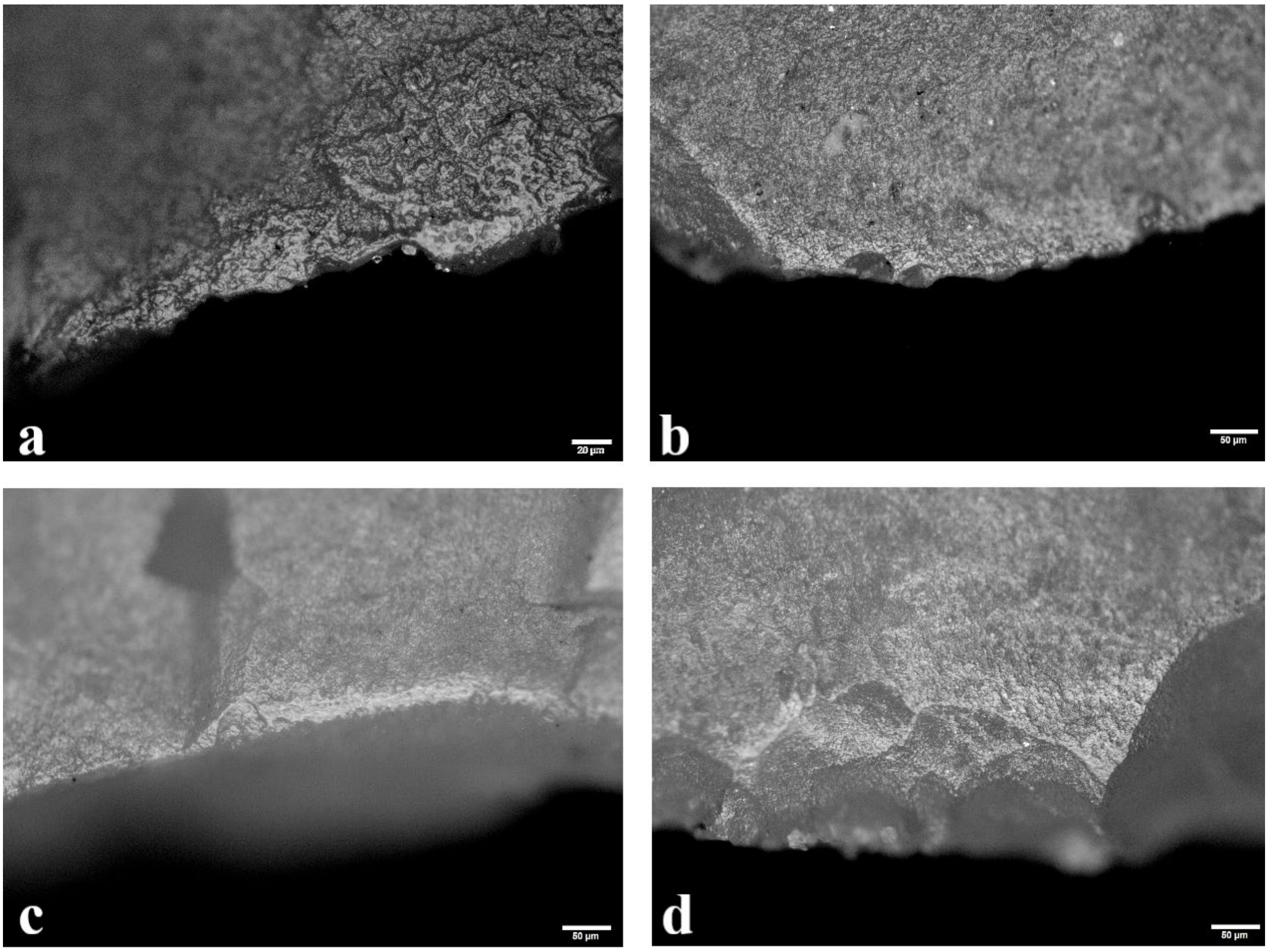


Figure 178: Animal materials a) Hide and bone, VL 138, b) Dry hide, VL 125, c) Hide, VL 123, d) Hide, VL 131 (photo A. Petrović)

Vegetal materials are represented by domed topography (Fig. 179a), and woody matters with domed to flat topography on higher parts and medium brightness (Fig. 179b).

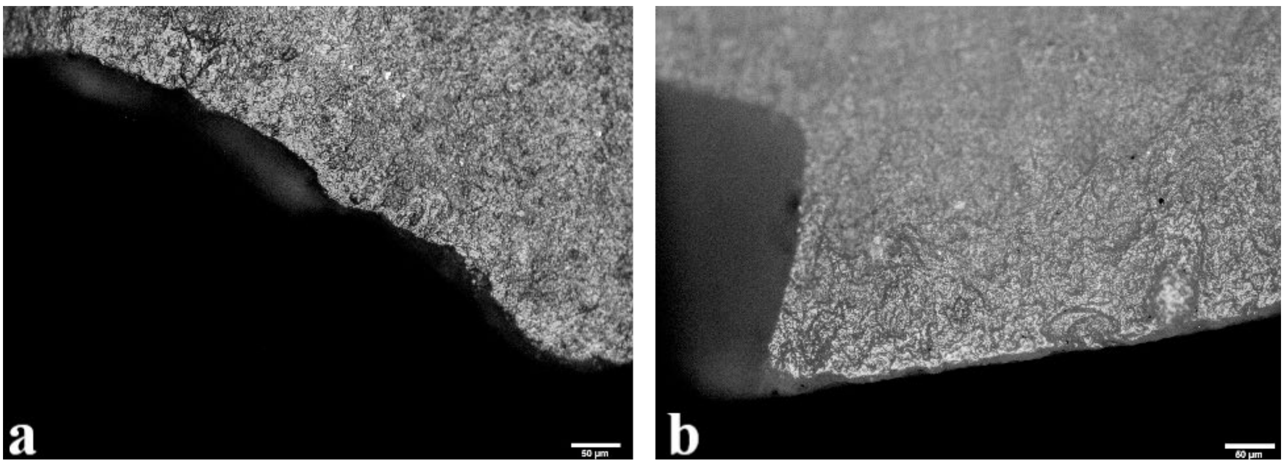
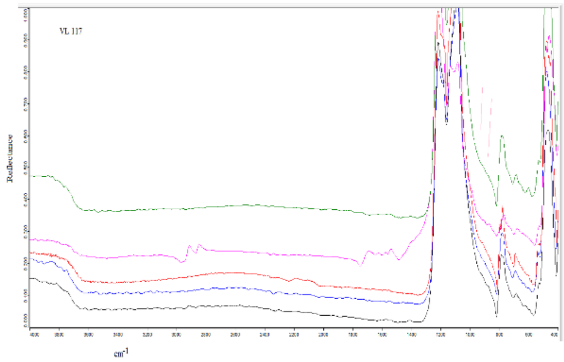
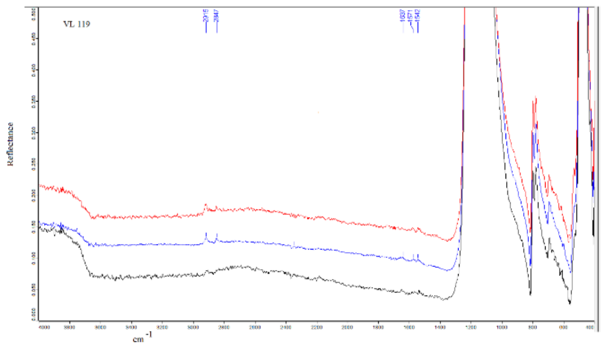
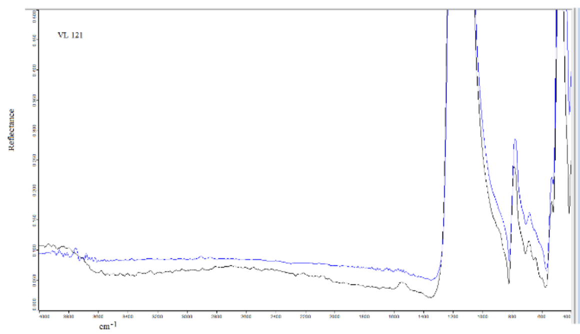


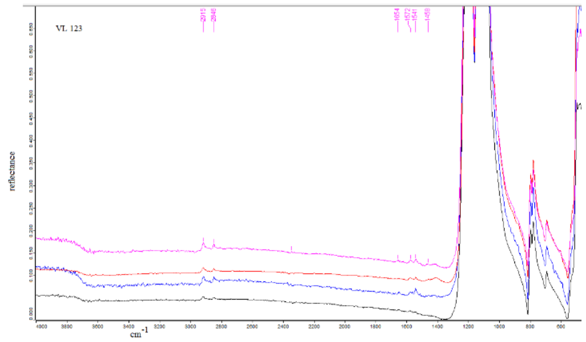
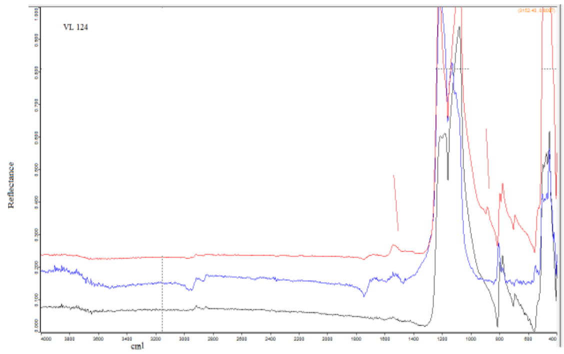
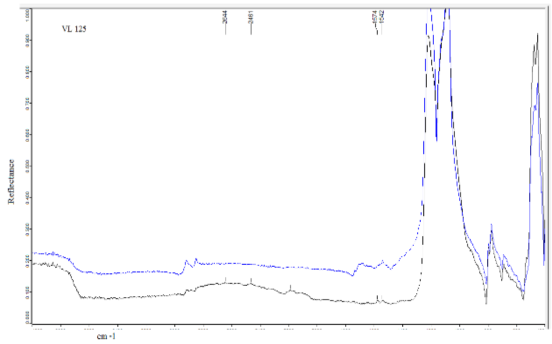
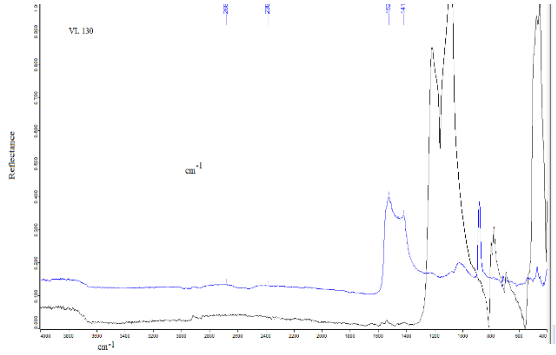
Figure 179: Vegetal based contact materials a) Vegetal material in general, domed topography, VL 150, b) Woody material, domed topography on higher parts, medium brightness, VL 133 (photo A. Petrović)

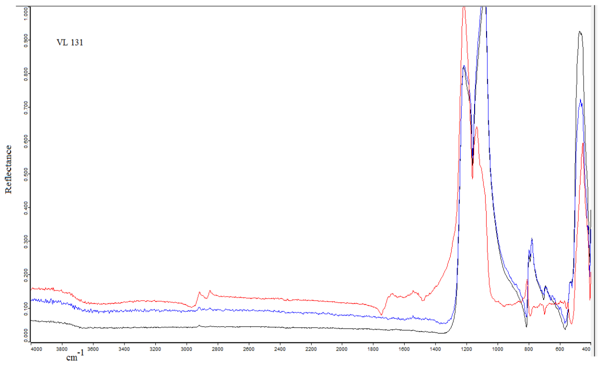
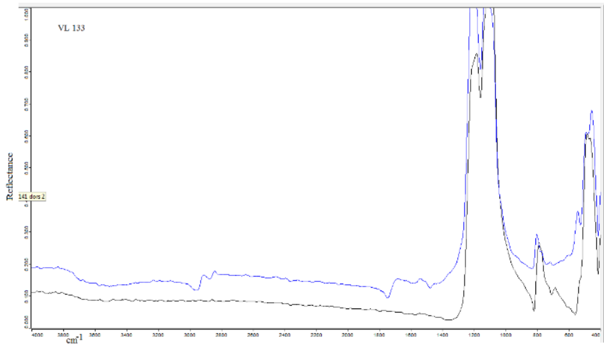
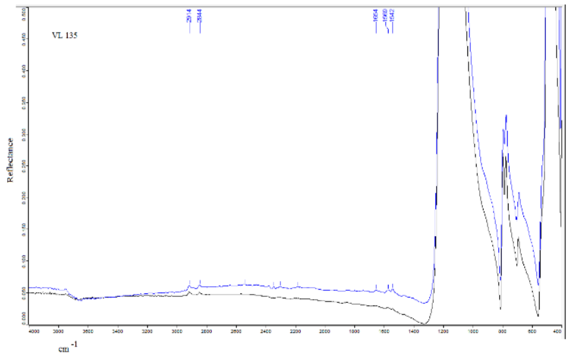
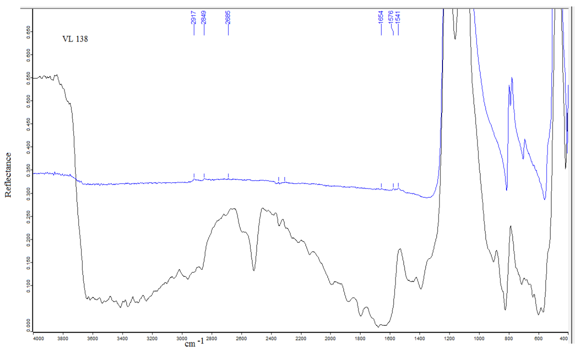
FTIR analysis results

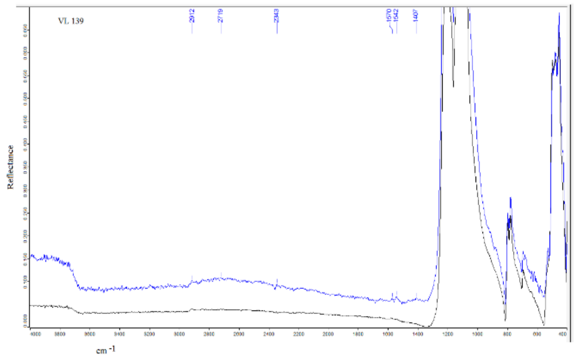
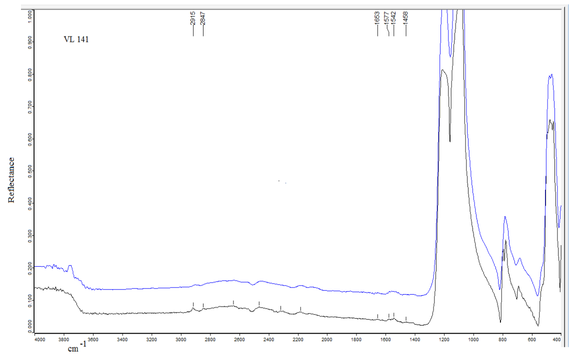
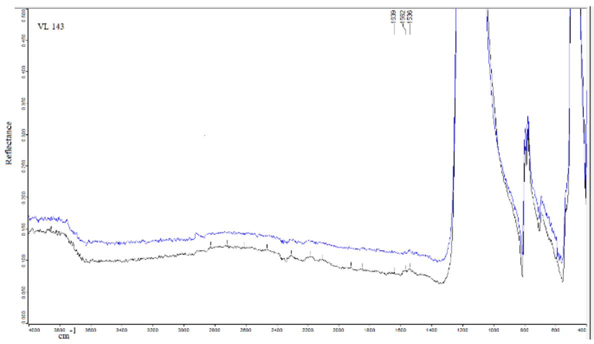
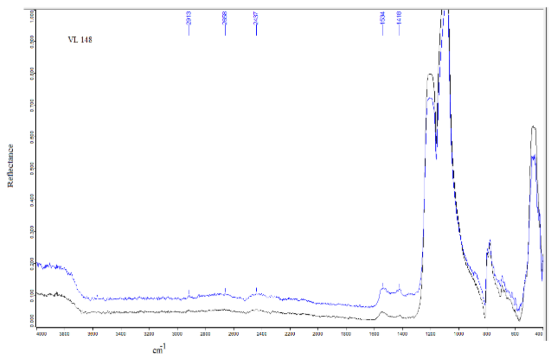
Eighteen (18) tools were analysed with FTIR spectroscopy (Table 43). Bands observed at 1576, 1540 cm^{-1} indicate the presence of adipocere, fatty acid salts, usually present in animal-based materials. The tools where the adipocere bans were observed are corresponding 100% to the results of the use-wear analysis. In the case of the residues of collagen (~1650 cm^{-1}), three out of four tools have been used for the processing of animal-based matters.

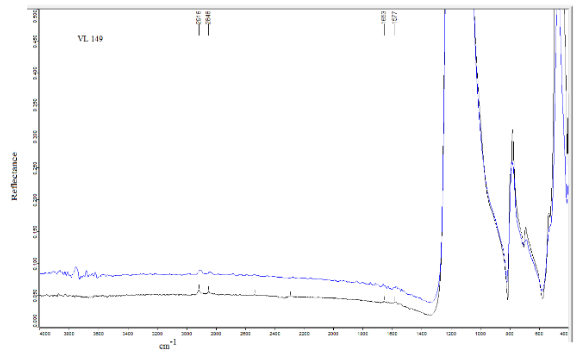
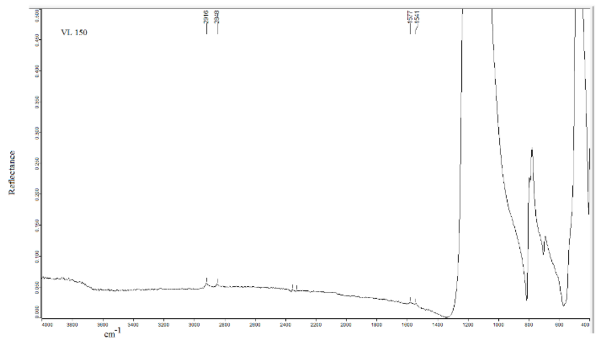
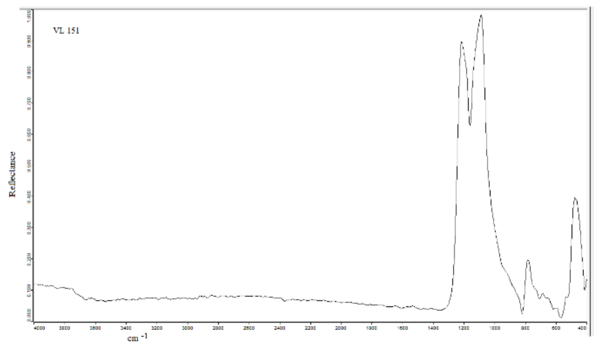
Table 43: Samples from hearths, Vlasac, FTIR analysis results (spectra by S. Nunziante Cesaro)

SAMPLE	OBSERVED BANDS	INTERPRETATION	FTIR spectra
VL 117	~1680, 1576,1540	Adipocere	
VL 119	1576,1540	Adipocere	
VL 121	/	/	

VL 123	1576,1540	Adipocere	
VL 124	~1650, ~1530, ~1420, 877	Collagen, CaCO3	
VL 125	1576,1540 ~1650, ~1530,	Adipocere, collagen	
VL 130	~1530, ~1420, 877	CaCO3	

VL 131	~1650, ~1530	Collagen	
VL 133	~1650, ~1530	Collagen	
VL 135	/	/	
VL 138	~1530, ~1420, 877	CaCO3	

VL 139	1576,1540	Adipocere	
VL 141	1576,1540	Adipocere	
VL 143	/	/	
VL 148	~1530, ~1420, 877	CaCO3	

VL 149	/	/	
VL 150	/	/	
VL 151	/	/	

5.3.5. Summary of the results of the chipped stone tools from Vlasac site

In total, 150 chipped stone artefacts were analysed both with low and high-power approach, and 10% did not bear any traces of use. Additionally, FTIR analysis was done on 75 artefacts. Most of the artefacts have indeterminable activity. Statistically considering, cutting is the most represented activity. Scraping and combined activity of scraping and cutting were almost equally displayed (Fig. 180).

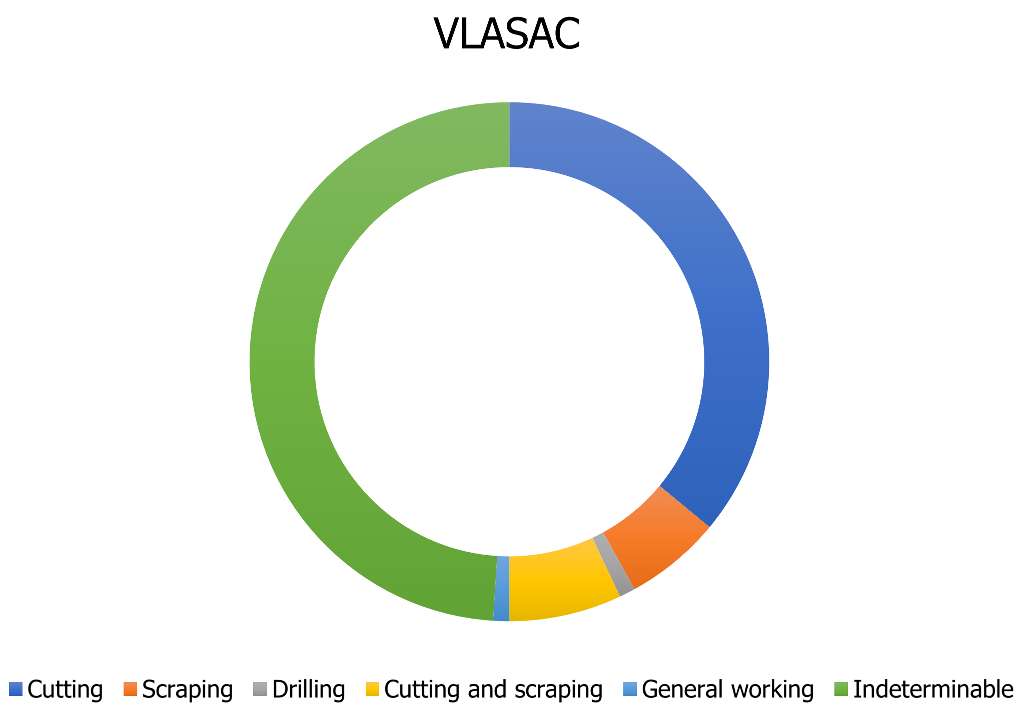


Figure 180: Worked materials, Vlasac

What should be noted is the slight dominance of the vegetal-based matters over the other types of worked materials (Fig. 181). Even though, statistically speaking, this advantage is quite low, this is the only site from the Iron Gates region where the tools used for processing the vegetal-based matters are present in a higher quantity. Superposition of both animal and vegetal traces on the same tools is present in the assemblage, which is depicting the experience of the community.

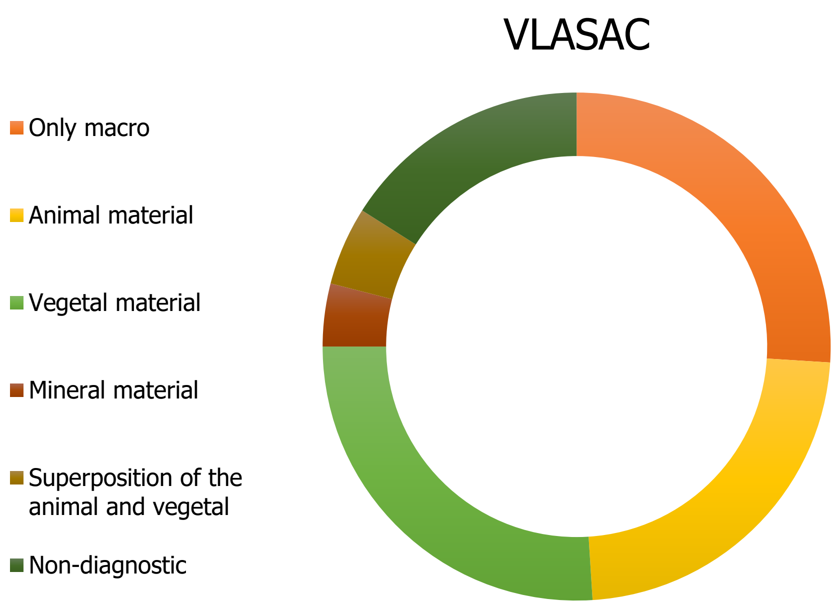


Figure 181: Activities, Vlasac

6. DISCUSSION

The following discussion is focused on the most important results of the study. The division of the subjects that should be analysed in detail is based on the type of information or data that was gained through the research process. In the first part, the most important elaborations regarding the used methodology are being debated since this is the first study where this kind of integrated approach was applied to the chipped stone assemblage from SE Europe. The use-wear results of the archaeological sample were partially discussed in Chapter 5, but only in the cases of one, specific work activity, having in mind the nature of the analysis. Here, the use-wear results are being discussed based on the period, and a cohesive summary addressing specific settlement contexts will be made since the statistical results noted in Chapter 5 were focused on the general observations and presence of materials and activities overall. In the third part of the discussion, some of the important patterns and models noted in the specific phases and contexts will be observed from the point of the primary hypothesis and research questions posed as a foundation of this study.

6.1. METHODOLOGY REMARKS

Experimental approach and residue analysis as important allies

As it was mentioned earlier experimental approach is very important and it helps during the identification of the edge removals or micro-wear, but it also offers numerous information about the time and strength needed to process different matters. The experiment can indicate various problem(s) during specific activities, for example, as the difficulty to process antler or shell, and it can offer means to overcome these obstacles. The way these problems are becoming visible during the reproduction of the prehistoric activities indicates the variety of the possible struggles that prehistoric groups in the Iron Gates had experienced.

The initial purpose of the experimental approach and creating a reference collection was to observe the formation of the macro and micro traces of various contact materials. The idea was to recognize the scar patterns formed by the simple activities and *ordinary* materials, as scraping bone or wood, and by more complex activities, as processing softened antler, hide tanning, or fish processing. In the group of ordinary experiments, all the possible materials that were available to the prehistoric communities in Iron Gates in the Late Glacial and Early Holocene were tested. The repertoire of the contact matters in the prehistory that should be incorporated was already proposed by L. Keeley (1980) which was accepted, improved and modified in certain aspects of the study.

Regarding the activity and variety of movements, the oblique unidirectional or bidirectional trend of the scars is connected to the cutting and the transversal motion to the scraping. In the case of the drilling bidirectional oblique traces are recognized while the micro polish penetrated the edge surface in the contrast to the other activities (cf. Chapter 4.3.4 and 4.4.1). Some of the main observations for each of the tested contact materials are gathered:

- Soaked wood: (macro) snap, step and feather termination with medium edge-rounding; (micro) smooth texture (Fig. 37 and 39),
- Tubers (*Asphodelus ramosus*): (macro) snap and half-moon terminations with medium-high edge rounding; (micro) domed topography, inner surface distribution, tight to the covered linkage (Fig. 41),
- Grass: (macro) a mixture of step, snap and feather trace terminations, high edge rounding; (micro) bright, smooth texture and tight to the covered linkage (Fig. 44 and 45),
- Bone with ash: (macro) overlapping, step terminations, high edge rounding; (micro) smooth texture and flat topography (Fig. 46b-c, and 47b),
- Shell: (macro) overlapping, snap, step termination; (micro) flat topography, tight linkage, smooth texture (Fig. 52 and 53),
- Hide with ochre: (macro) snap terminations; (micro) rough to smooth texture (Fig. 55b-c),
- Butchering (meat + ligaments + bone): (macro) snap, step and overlapping termination; (micro) flat topograph, tight linkage (Fig. 57, 58, 59 and 60),
- Butchering (hide + meat + tendions + bone): (macro) halfmoon, step termination, discontinous distribution; (micro) linear polish on edge, rough texture, half-tight to tight linkage (Fig. 62),
- Liver: (macro) snap, step termination; (micro) tight linkage, granular and flat topography (Fig. 71 and 72),
- Spleen: (macro) snap termination (Fig. 76),
- Ceramics: (macro) overlapping scars with feather and step termination; (micro) smooth texture (Fig. 91b-c),
- Soapstone (steatite): (macro) step, feather terminations; (micro) smooth polish texture (Fig. 93).

Concerning the more specific and controlled trials, the need and the idea together with the plan and execution of the operation chain of subsequent processes was registered after preliminary use-wear analysis of the archaeological sample. The thermal stress was observed in around 10% of the total archaeological sample. These tools, in the case of the Lepenski Vir settlement, were observed in houses 32, 36, 35 and 26 and the hearth 70, and in the hearth 3 in the case of the Vlasac site. The impressions were made mostly based on the macro analysis where most of the initial modifications as a change of colour, and surface crazing (cf. Rick 1878, Patterson 1995) were noted. However, the need for more detailed experimental trials was observed based on the tools from building 32, from Lepenski Vir where the interpretation of the micro traces was endangered by the glossy appearance. The trials showed that the distinction of the animal and vegetal matters, at least in the general micro categories was possible even after the thermal alteration up to 800˚C in the experimental oven. The glossy appearance did emerge, but it did not affect the traces. Regarding the experiment performed in the underground oven with a temperature up to 750℃, at the Early Neolithic site of Portonovo-Fosso Fontanaccia, the results of the micro-observations showed that it was not possible to distinguish did the polish arose from the use or the alteration. It is very important to note that in the case of the tools exposed to the fire alteration in the replica of the Neolithic oven, in less controlled conditions, the use-wear traces are barely visible. On the contrary, the damage is low on the artefacts that were heated in the experimental oven in the laboratory in completely controlled conditions. Here, we can only assume that alteration as thermal gloss is comparable with the archaeological cases, but that the glossy appearance visible on both archaeological and experimental tools is not directly and only connected to the thermal stress. Nevertheless, it should be stated that the archaeological tools went through the heath treatment near/or above 750℃ since it affected the micro trace identification of the tools found in building 32 of Lepenski Vir in the same amount as in the case of the experimentally produced tools heated at the Portonovo underground oven.

Another suggestive trail was the processing of the softened antler, which was done after the topography similar to the bone was noted in the case of the archaeological tools from the Padina assemblage. Since it is not easy to distinguish between the bone and antler traces it was necessary to conduct this type of trials. Additionally, this test was of utmost importance given the variety and quantity of the osseous material from Lepenski Vir, Vlasac and other Iron Gates sites in the region (Vitezović 2011, Mărgărit and Boroneanţ 2017, Vitezović 2017, Cristiani and Borić 2021). As it was mentioned, many ways of softening the antler or bone as shown in ethnographic parallels and archaeological experiments are known and the results of previous studies supported differentiation between the tools that were employed in the activities with softened and unsoftened materials in the Late Palaeolithic, Mesolithic, and Neolithic communities in Poland (Osipowicz 2007). Our testing confirmed that the soaking of the antler was an important stage in the processing (cf. Langley and Wisher 2019) since it is very challenging to process this material without losing the durability or elasticity, which are important aspects for tool production.

Recognition of the fish traces on the archaeological samples was facilitated by the experimental trial, where the tools used for the scaling and all the other operations involved in the fish processing as head cutting, gutting, skinning and filleting were tested separately. The importance of the observed use-wear and residue results of the experimental tools will be discussed in the context of the fish processing at Lepenski Vir and its (in)visibility in the archaeological record.

Tanning and skin depilation trials are a result of the large amount of animal-based activities observed in archaeological sample from all three sites (Chapter 5.1.16, Chapter 5.2.4, and Chapter 5.3.5), demonstrating the need for the distinction of the fresh, semi-dry to dry skin or working of the hide with additives.

All these, structured activities could be traced and described with the following characteristics:

- Antler, softened with water: (macro) overlapping; (micro) flat, domed and melting topography, soft texture (Fig. 49b, 50b-c),
- Fish, scaling: (macro) snap, halfmoon scar termination; (micro) rough texture, domed and flat topography (Fig. 81),
- Fish, decapitation, gutting and filleting: (macro) snap, step termination, regular distribution; (micro) granular topography, smooth texture (Fig. 84),
- Tanning: (micro) rough texture on lower parts, smooth texture on higher parts, domed topography, edge distribution (Fig. 64b, 66b-c),
- Skin depilation: (macro) snap, step, feather; (micro) granular topography, striae (Fig. 69).

The importance of the implementation and development of the residue analysis has been proven in many studies (e.g. Jahren et al. 1997, Cristiani et al. 2009, Nunziante Cesaro and Lemorini 2009, Lemorini and Nunziante Cesaro 2014, Monnier et al. 2018), therefore, the application of the residue analysis on both the experimental and archaeological tools was of the utmost value for the final interpretation of the traces in the case of the Iron Gates artefacts as well.

Comparison of the FTIR spectra of the experimental and archaeological tools was in most cases a beneficial supplement. Mainly in the occasions where the exact worked material was not known. Bands attributable to the adipocere, collagen, calcium carbonate, lignin and bone were found. All of them, except the lignin, are attributable to the animal-based matters, while the adipocere can be found in the greasier plants (cf. Chapter 4: Fig. 42, Chapter 5; Table 8, 24, 27, and 33).

Calcium carbonate can be connected to the worked material, but also the environment where the tools were used, as ground. It could be associated with any of the given factors and it does not give any clear indication regarding the processed matter. Having in mind the presence of the calcium carbonate and some other ambiguous FTIR results, as the presence of the adipocere in tools that were used for processing the vegetals, the additional SEM-EDX analyses were done. The double-checking effect was very successful when using SEM-EDX, but it should be also highlighted that this technique offers a broader interpretation, and it targets the exact residue.

To be more illustrative, in the cases where the use-wear analysis did not bear specific interpretation, the combination of all three types of analysis was helpful. Among many, an excellent example is VL 1 where the overlapping of the traces was found (animal material – underneath, and hard material – above). The SEM-EDX analysis indicated the ratio 3:1 of the calcium and phosphorus in the observed points which is a direct indicator of the bone, the same result was gained with the FTIR analysis, where a band of collagen was observed as well.

In the cases where we did not have the exact match of all three techniques, some additional information was essential, such as the context of the sample. A model of possible contamination of the tools was noted in the cases of the chipped stone tools found in the burials at the Vlasac site, where the presence of adipocere could be explained by the vicinity of the chipped stone tools and human remains (see Table 41).

6.2. QUOTIDIAN LIVES OF IRON GATES INHABITANTS

Human activities in Iron Gates before, after and during the transitional period

The results displayed in Chapter 5 manifest the general, preliminary statistics and overall impressions that are gained based on the use-wear and residue analysis of chipped stone tools from three sites: Lepenski Vir, Padina and Vlasac. However, the aim of the study together with the proposed hypothesis demands a more comprehensive analysis of the gained results. The raw data will be furtherly evaluated by site, context and chronological period (Fig. 182).

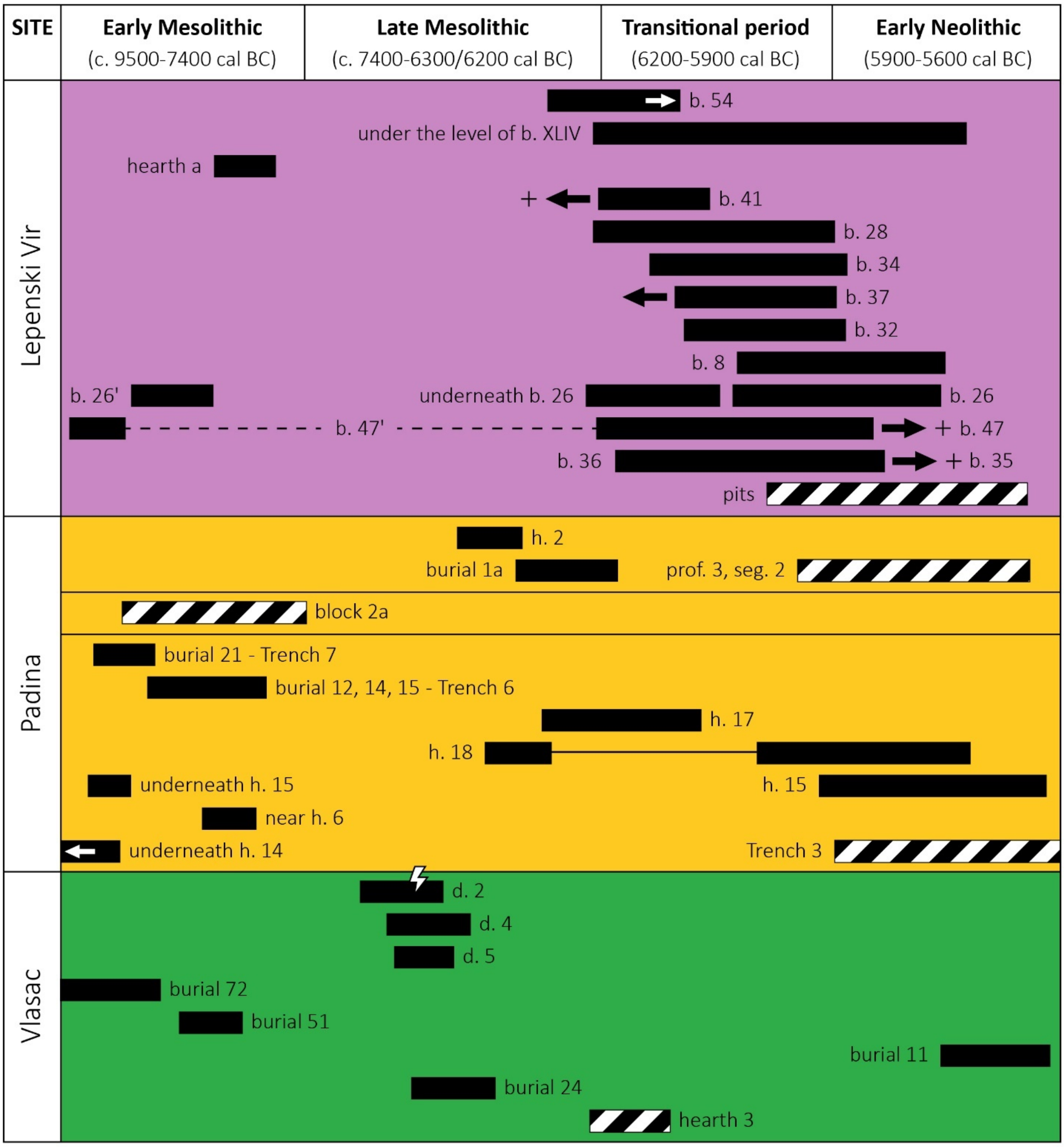


Figure 182: Simplified presentation of the dated contexts that were taken into consideration for the study, (Legend: b=building, h=house, d=dwelling)

Lepenski Vir is the site where most of the sampled tools are attributed to the Transitional period, based on the absolute dates. The importance of the assemblage lies in the idea that the same feature could be observed through different chronological periods and phases. These data can create a space for the discussion about the change of the preferences during the time, but also it can indicate if there were particular areas designated for certain activities. The gained results testified that the overlapping buildings (as 26, 26' 47, 47', 35 ad 36) did not bear any shifts in the variety and quantity of the contact materials and activities that took place. The only difference is the amount of the tools, ergo, more tools were found in the younger phase. It should be highlighted that the archaeological sample is *sealed* in a way, having in mind the fate of the site, so the new excavations on the larger area are not possible.

Analysis of Lepenski Vir assemblage showed that the tools were, often utilized to their maximum, regardless of the period (Fig. 183). The usage was found on several or all working edges. The PDSMs affected the sample but in most of the cases, both macro and micro identification were achievable. The identification based on the macro traces was furtherly represented in the Early Mesolithic contexts since these pieces were affected to a greater extent by alterations. A general result is that processing of animal-based matters are the most present types of activities in all of the observed periods. It should be noted, that in the case of the Transitional period, the prevalence of the unused tools is solely based on the fact that building 35 is quantitatively the largest assemblage (245 artefacts, out of which 104 were not used). The reason for such a high number of unused tools is that building 35 was a knapping spot (cf. Mitrović 2018). Buildings 54, 32, 41, 26, 36 and 35 are singled out as the places where the tools were mainly used for processing animal matters. Building 36 is recognized as the place where most of the specialized activities on the hide took place, based on the utilization of the small tools used for refining the tiny skin portions (Fig. 4).

The vegetal materials are less present, and non-existent in the case of the tools found in the Early Neolithic contexts. Houses 35 and 36, connected to the Transitional period, were the only contexts where the vegetal activities are in the increase. If closely observed, house 36 could be separated by the presence of both specific activities related to the hide treatment and a variety of the processed vegetal resources. Mineral matters, as soft stone, are only present in the Transitional period.

All the samples that originated from the pits, both the ones found outside the buildings and the ones found inside building 37 (Fig. 4), have been used for processing animal matters, as bone/antler, fresh hide, animal tissues and for butchering. These data indicate the possibility that the pits were used for discard, since besides the chipped stone tools other remains were found, like bone and pottery fragments. Obtained results question the idea that these chipped stone tools were deposited for a reason after their implementation in particular activities as butchering. Furthermore, the tools that were found were still efficient and no signs or need for discard were found, which raises a question were the tools intentionally deposited in the pits after utilization, or they were intended to be saved for some future tasks.

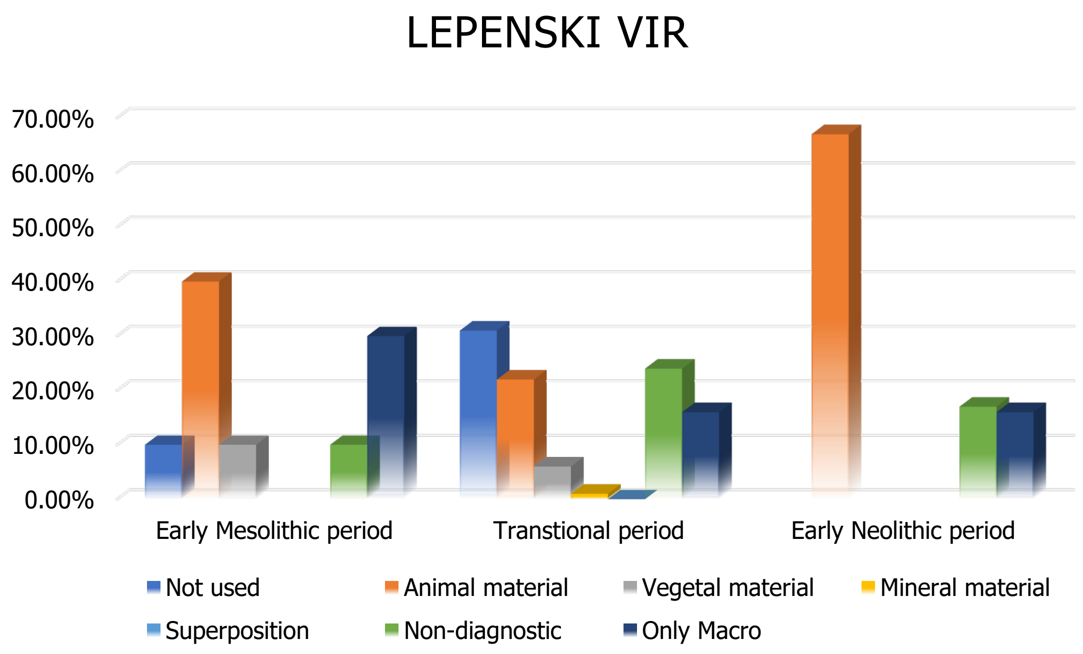


Figure 183: Results of use-wear analysis of the Lepenski Vir assemblage

In the contrast to the Lepenski Vir, Padina has a record of the Late Mesolithic inhabitation where most of the tools were characterised solely based on the macro traces. There were no unused tools among the analysed assemblages from the Transitional and Early Neolithic period. As it could be observed, the processing of the animal-based matters is represented in the highest quantity in all the other periods (Fig. 184), suggesting the significant place of these activities in the everyday life of the Padina inhabitants.

The Early Mesolithic period is marked with the predominance of working of animal materials, which is at its peak in the Transitional and Early Neolithic. These concentrations are noted in the blocks which are connected to the areas near the houses dated to the Early Mesolithic, Transitional, and Early Neolithic period (Sector I – house 2, Fig. 13 and Sector III – houses 15, 16m 17 and 18, Fig. 16). The number of diverse materials as hard animal materials – bone and antler, hide in diverse phases of processing and butchering should be highlighted. On the other side, the presence of vegetal traces is very important since this is one of not so many contexts in Iron Gates that have shown a high percentage of wood and tuber processing. Besides the rise of vegetal activities in the Early Mesolithic, the same trend is noted in the Early Neolithic. Processing of the mineral matter is notable in the Early Mesolithic contexts and the Transitional period.

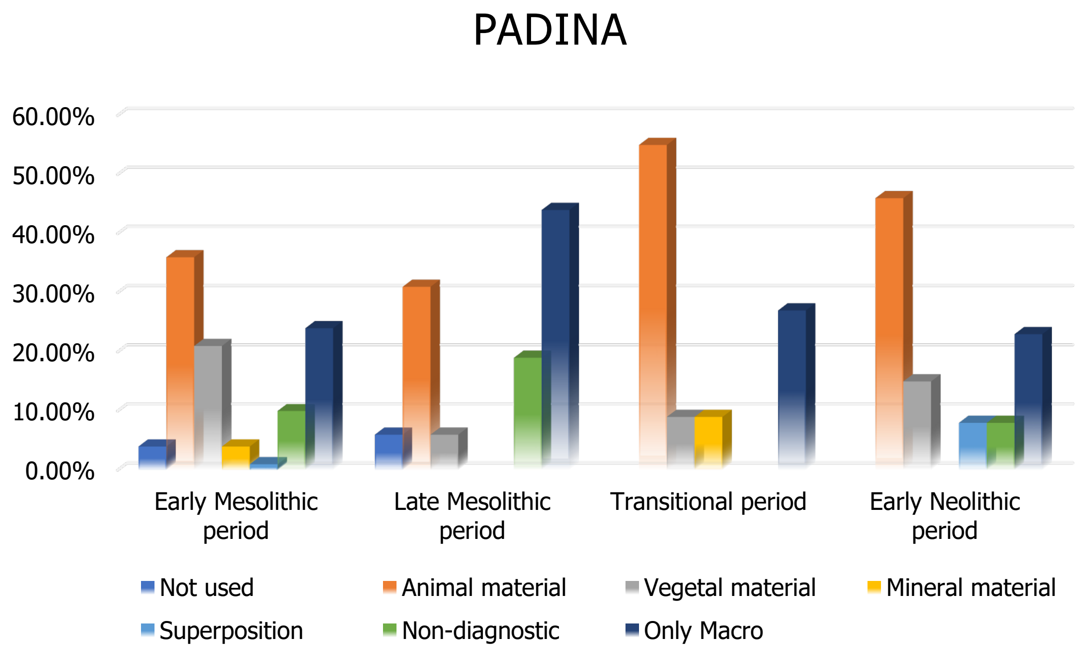


Figure 184: Results of use-wear analysis of the Padina assemblage

Vlasac is the settlement with one of the most evident shifts in the variety of activities in the diverse phases of site utilization, compared to the Lepenski Vir and Padina (Fig. 185). This was noted based on the domination of the tools used for the processing of the vegetal-based matters in the Early and Late Mesolithic period. This increase is important for the observation of the dynamics of the human groups in the region. The vegetal-based activities, in higher number, were recovered in the dwellings and burials.

In the Late Mesolithic period, out of the observed buildings, only dwelling 2 (Fig. 23) had all the indications for a place that was frequented by larger groups and where most of the activities in this phase took place. This is established by the presence of various processed matters but also the amount of the found tools (Table 38). More tools are originating from the layer above the floor, and 43% are defined only based on the macro traces and utilized with mostly medium to medium-hard matters, while 20% of the tools were used for processing vegetal-based resources, like wood and tubers.

Regarding the Transitional period, the quantity of the vegetal activities is in second place but the percentual difference between the vegetals and animal-based matters is low. The artefacts connected to the Transitional period are coming from hearth 3.

The results of artefacts found in the burial contexts, where only four tools out of eighteen were not used, indicate that they were placing the already utilized tools in the tombs. However, the direct connection between these chipped artefacts, accomplished activities and individuals could not be drawn, having in mind that these tools could have been placed randomly in the graves. Otherwise, they could have been deliberately chosen, as an offering, because they were used by that exact person during life. The idea for the latter hypothesis is based on the fact that people and craftsmen are bonded with the tools they use daily since they help them produce objects or harvest food. It should be mentioned that there are burials, as 14, 30 and 64, where the quantity of the recovered chipped artefacts is higher, and it is not the case of one or two lithic tools, rather than small assemblages used for both animal and vegetal processing. One point, from burial 11, attributed to the Early Neolithic period, has no diagnostic traces and no further interpretation could be made. Overall this is the only find that is connected to this period, which is the reason for the statistical depiction in Fig. 185.

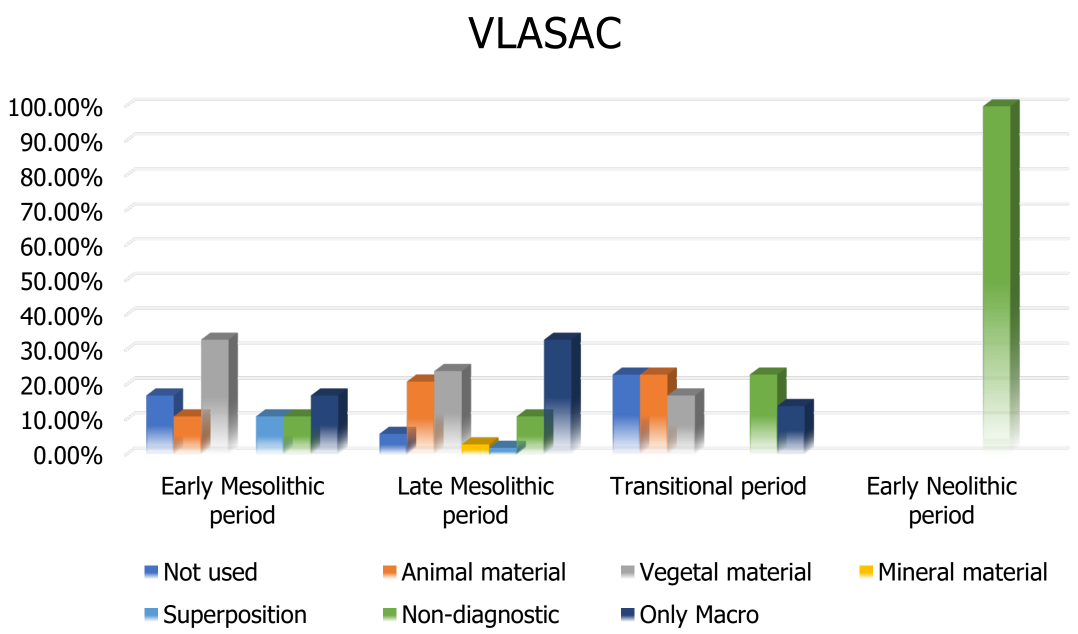


Figure 185: Results of use-wear analysis of the Vlasac assemblage

Some of the most important conclusions could be made based on the utilization of the chipped stone tools through the periods in all the studies settlements. Regarding the division by the material type, the animal based-matters and connected activities are predominant in all the observed phases of all the sites, overall (Fig. 186). Processing of the vegetal resources, if observed per phase, is high in the Early Mesolithic and Late Mesolithic period, but it is in the decline in the Transitional period. This can be a result, based on the chronological frame, of an encounter or even a marker for certain tensions between the two populations making the first interactions. An instability of period could be reflected in some degree to the processing of the vegetal resources, either wild or in the context of domestication attempts. Processing of the mineral matter, which is in the case of the analysed Iron Gates assemblages in 99% equal to a soft stone, possibly limestone, is mostly present in the Early and Late Mesolithic. Superposition of diverse contact materials is common for the tools found in the Early Mesolithic and Early Neolithic layers.

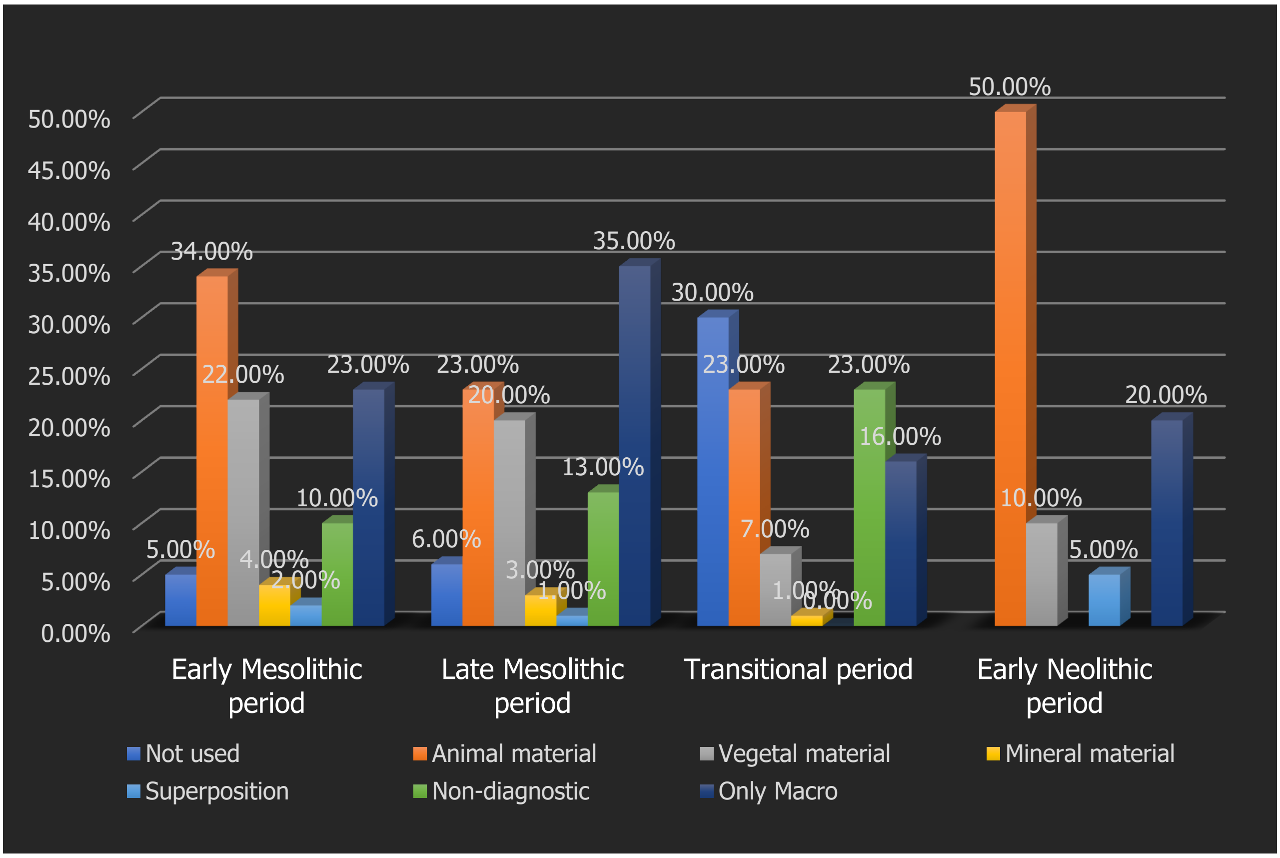


Figure 186: Results of use-wear analysis through different inhabitation phases at Iron Gates region

6.3. COGNITIVE POSSIBILITIES

Behavioural patterns: specialization or overcoming the everyday small-scale crisis

A variety of complex activities that were conducted on an everyday basis in the Iron Gates settlements during the Transitional period are observed in 6% of the total tools. These actions were singled out based on the specific evidence extracted from the micro-wear found on the chipped stone tools. These specific tasks, that involve the ulterior elaboration of the contact materials as preparing the hard animal materials before their modification, and use of the additives testify about human behaviour, everyday challenges and/or a possibility of low-level expertise inside the communities.

The three most important tasks should be emphasized. The first one is the preparation and adjustment of hard animal materials for easier processing. The need for possessing this kind of knowledge is justified by the quantity of the osseous material found in the region and at the studied sites as well (Cristiani and Borić 2021). Soaking of the antler as a part of the *chaîne opératoire* is still to be explored in detail, but previous studies (e.g. Newcomer, 1976; Osipowicz, 2007; Langley and Wisher 2019) together with the results presented in this study have shown both the need, but also the proof that prehistoric people were familiar with softening techniques.

The use of additives in the processing of hide and bone is the second type of occurrence that is being closely observed. Many benefits and aspects of ash were confirmed through human history, including its utilization for roasting, preservation of vegetal foods for delayed consumption, and for treating and conservation of fresh hide by the Late Lower Palaeolithic population at the Qesem cave (Lemorini et al. 2020). Oche, similar to the ash, has both antibacterial properties and preservative effects (e.g. Mandl, 1961; Rifkin, 2011). In the observed assemblages from Iron Gates, there is an apparent use of ash and ochre for the preservation and processing of hide and bone. The observed traces indicated that the population that inhabited Lepenski Vir, Padina and Vlasac was aware of the specific advantages of the additives, and they were able to utilize them for overcoming the problems of storage since the quantitatively large amount of hide processing indicates expedient refinement of the larger amounts of this matter. Hence, the considerable volume of this type of material requires means of postponement or redeposition.

The scraper found in the ash place of house 32, from Lepenski Vir with traces indicating both bone and ash created a peculiar situation: are the traces of ash a result of the contact with the bone that was previously mixed with ash, or are we dealing with the contamination from the environment? Supplementary data show that other tools from the same context do not have traces of ash (Petrović et al. 2021b), which should be the case if all the tools from the area were contaminated. Thus, the traces of ash found on the scraper are strictly connected to the activity, which was additionally confirmed by a targeted experimental trial (Chapter 4.3.1. and 4.3.2.) This case shows the intentional use of ash for the preservation of bone, and the same procedure is used nowadays for storing the animal bones for archaeological experiments at the LTFAPA Laboratory.

In an archaeological context, it has been noted that two types of hide processing could be easily recognized: *fresh hide scrapers* that were used to clean the skin without absorbents, and *dry hide scrapers* involved in the latter phases of skin processing which displayed a larger amount of rounding and matt polish (Van Gijn 2010:81). These observations were found in the case of Iron Gates assemblages, and activity as working dry hide is singled out. The dry hide traces are correlated to the final phase after the tanning is applied. This activity improves the hide structure and creates elasticity, which makes it suitable for the manufacture of clothes, recipients, and other leather objects. The high percentage of tools, used for dry hide processing at Padina site indicates the awareness of the Iron Gates inhabitants of the tanning procedures. These results are complementary to the number of tools used for the refinement of the small leather goods found at the Lepenski Vir, as in the case of the activities that took place in building 36. The gathered data is demonstrating that the patterns of confronting both the daily struggles, as modification and shaping of hard animal matter (bone/antler), and tendencies for hide/bone preservation by using additives were spread in the whole region, and it provokes the question of specialization inside the area.

As it has been demonstrated the application of the use-wear analysis in prehistoric studies can be used as a tool for gradual progress in the better introduction of the possibilities and limits of human cognition in the past. Based on the use-wear analysis the elementary process as scraping hide is reconstructed by phases, the tool is being placed in the perspective, and we are certain about its role in the household. Supplementary, some small, auxiliary information as scraping *dry* hide is completely changing the perspective. To be able to note the exact phase of the worked material is affecting the amount of information we have about the ancient communities. The knowledge of prehistoric groups to utilize additives in hide tanning procedures or softening methods for antler shaping is testifying that the population of Iron Gates was acquainted with the techniques that helped them overcome the small-scale crises in everyday life. Additionally, these results are showing the ability of the communities to exploit to the maximum the animal resources and to produce secondary products. The skin by-products are not (usually) preserved in the archaeological record, yet the represented results directly provide an insight into their manufacture and existence in the region.

6.4. BEYOND THE MICROWEAR

Fish: reality or fiction

Since the importance of fish in the communities of Iron Gates has been highlighted in several spheres it became clear that the fish had both symbolic values but was also consumed through all the studied periods. It was important to test the capacity and the potential of chipped stone tools in the preparation and diverse fish processing activities as scaling, head-cutting, filleting. Only two artefacts have traces that could be interpreted and exclusively related to fish processing, and they were recovered in the building 32 and 35 of Lepenski Vir settlement. The value of these results is emphasized since it is recognized that traces of fish processing are known to be very difficult to uncover. Additionally, the cut marks corresponding to the traces of the lithic tools were found on fish bones from transitional and Early Neolithic contexts from Lepenski Vir and Padina, while the ichthyological material from Vlasac was poorly preserved and fragmented (Živaljević 2017). These results further support the use of chipped stone tools in the activities of the fish preparation.

Another important suggestion is *hidden* in the general results. As it was mentioned many times, the majority of the tools used in the studied settlements exhibit traces connected to animal processing, among them meat and animal tissues. It should be underlined that the meat traces, in the terms of polish characterization are principally detectable in most of the cases. However, the identification is limited to the meat in general, or it can be found mixed with other materials such as tendons, bone, or skin. Despite the fact that the traces of meat are standardized, it is not possible to distinguish between types of meat and exact animal species. In our case, it was not possible to determine between the traces of processing fish and meat of other animal species. This represents an obstacle for a better understanding of fish processing in the case of the Iron Gates sites, leaving the vast number of meat processing traces in a general characterisation, which implies that some of these traces could have resulted from contact with fish meat as well. For example, traces of meat and fresh hide processing were detected on tools found on the floor of building 26, under its floor, in building 26', and under building 26' where fishbones with cut marks were also found. This supports the hypothesis that some of these traces could be a result of fish meat processing as well. Even though these finds reveal possible activities in the mentioned houses, they do not exclude the possibility that the fish were processed elsewhere and brought to these areas to be consumed or they simply discarded the remains in the mentioned areas. Fishbones were found all over the site, in all buildings and outside of them, and no specific areas associated with fish processing could be isolated.

Regarding the observed traces and their interpretation, we should revise the idea of using one tool for processing fish at specific times (cf. Van Gijn, 1984/85/86). Archaeological traces which could confirm this hypothesis were found on the blades from La Esparragosa (Clemente-Conte et al. 2007). This idea should not be excluded as one of the scenarios in the case of the Iron Gates communities in general. Since the quantity of artefacts with combined traces is low, the usage of a single tool in all activities can only be suggested as a possibility. However, we should mention the fact that there are chipped stone tools from the Iron Gates which were used in more than one activity, and it is quite apparent that some of the secondary traces and the activities could have covered or cancelled previous uses, and that fish processing is among those.

Even though the fish processing is less detectable on the lithic tools, but also in general, the specific situation in the case of the Iron Gates leaves a couple of possible scenarios. One of them is the use of some other kind of tools for fish cleaning. Although the osseous tools were mostly related to the fishing, supported by findings of bone hooks, harpoons, and projectile points, it is possible that some of them were used in the cleaning processes, as awls or boar tusk tools, having in mind their abundance at Lepenski Vir and other sites in the region (Srejović and Letica 1978, Bačkalov 1979, Petrović et al. 2021c) However, based on the experimentations, it should be noted that lithic tools would have been among the most efficient ones in the cleaning process. Even in a situation where the person involved had little or no experience, for example, as in the case of the experimental trial

(Chapter 4.3.12.) chipped stone tools would have an advantage. This is important since during the peaks of the fishing season, the Iron Gates communities would have a larger amount of prey to process and not all people would have the same knowledge or practice, yet a precise and sharp flake or a blade could easily compensate for incapacity.

Regarding the residue analysis, a small test was applied, but both FTIR and SEM-EDX analysis did not bear any results between the differentiation of the composition of the animal and fish bones. Calcium and phosphorus are the most abundant minerals in fish, human and other organisms, and they are mostly present in the bones. While calcium is needed to form bones and regulate functions, phosphorus is a major component of bone and teeth and is a regulator of energy metabolism. Given that the similar amount of these elements is present in fish bones, scales, and carnivore bones, the results were not very indicative to separate these two types of residues.

However, apart from the chemical elements correlated to the bone structure, there are a couple of those whose values are higher than usual and which could be indicative of fish residues. For example, potassium promotes cellular growth and helps maintain normal blood pressure, while chlorine allows the maintenance of the electrolyte balance. Fresh seafood is low in sodium, but the content of this mineral increases during processing by the addition of salt or sodium-containing compounds. There is a wide variation in the sodium content of fishes. The sodium content is 60 mg/100 g in freshwater and marine fish and 120–140 mg/100 g in shellfish, while the potassium concentration is reported to be higher than the sodium, ranging from 198 to 440 mg/100 g in seafood (Gokoğlu, 2002). These small differences in sodium values could be a foundation for some future studies regarding the fish residues where a larger amount of different fish species could be tested and compared.

Vegetal-based resources and cereal processing

If the quantity of the tools used for processing the vegetal matters is observed, the number is quite low. But, the variety of worked species is broad. The communities of Iron Gates were processing wood (in diverse phases, both dry and soaked), tubers, silicious and herbaceous plants. The situation at the Vlasac site is different and it's lead in the utilization of the chipped stone tools for vegetal matters is revealing that they were exploiting these resources to a greater extent in the older periods in this particular settlement. A similar rise in the vegetal exploitation is noted in the Early Mesolithic period of the Padina site, while on the Lepenski Vir the activities connected to the plant-based resources were placed in the background. Even though fewer tools were used for processing the vegetal matters the variety of the species is remaining similar to the ones found in the Padina and Vlasac. New dental calculus analysis is revealing frequent either modification or consummation of a variety of plants including grasses, woody plants and tree taxa at the Lepenski Vir (Jovanović et al. 2021), which completely corresponds to the micro-traces found on the chipped stone tools.

The processing of the cereals is present, only in two cases, in the Sector II of Padina and under the floor of house 47 at Lepenski Vir. Span for the sample LV 1807, found underneath the house floor of building 47 is determined to the Early/Middle Neolithic if the stratigraphical sequence is being followed. However, even if this tool has some of the elements of the tribulum (Fig. 131c) we cannot be sure and categorize it as one, since the context where it was found represent a very early framework, having in mind some of the first, archaeological records in the other regions (e.g. Diamond 1975, Skakun 1993). Additionally, the separation of the wild from domestic types of cereals should be kept in mind, and that the traces of the tribulum may be associated with cutting both species at this stage of identification. The issue and perception of the tribulum may be premature at this point based on the obtained results. However, the first sign of the harvest was noticed, although it is far from any wider interpretation. The nearest indications where one may expect the evidence of agriculture is most probably the site of Aria Babi (Early to Middle Neolithic), presumably established by clearing the patches of forested areas in hinterlands of Iron Gates during its occupation (Borić 2011). The indirect evidence of agricultural practices at Aria Babi is assumed by the macroscopically visible shine on the working edge of the retouched blades made on dark grey raw material, expected to be used for harvesting (Borić 2011:183). However, these indications were not confirmed since the results of the use-wear analysis were never published.

It has been reported that domesticated species of wheat and barley were consumed at Vlasac, at the end of the Mesolithic (~6600 cal. BC), which coincide with the result of the Neolithic individuals from Lepenski Vir (~5900–5700 cal BC), (Cristiani et al. 2016). Additionally, cereal consumption was confirmed in the teeth of the Early/Middle Neolithic individuals from Lepenski Vir and Ajmana site (Jovanović et al. 2021). Even though the possibility that the cereals and plants were harvested by the other types of tools, or that they were collected by hand exists, the efficiency of the chipped stone tools for processing cereals implies that any kind of substitution could not be practical enough (e.g. Clemente and Gibaja 1998). Some of the authors argued that the rough terrain of the Gorges was not a suitable environment for the development of cereal agriculture (Borić 2011), which could explain the low number of tools employed in this task. The low number also addresses two different inquiries. Did they own narrow areas for cultivation so that the limited amount of the tools was enough to cover the basic activities, or they did not cultivate themselves the grains which questions the origin of these tools. They could have been brought by immigrants since it is considered that the region was a meeting point of interaction between groups of different origin, customs and tradition (cf. Borić and Mirackle 2004, Borić and Price 2013, Mathieson et al. 2018). From the methodological point of the view, cereal processing traces in the use-wear analysis are unique and could not be easily covered by another type of use and micro polish. This is being appointed since some other types of activities, as processing hide or meat, which are less pronounced could be concealed by succeeding uses.

Economical utilization and invisible components of the tools

It has been noted that the majority of the tools were used to their maximum. This type of behaviour has been specifically recorded in the Lepenski Vir assemblage, where the morphological shape of the edge profile and angles were utilized to its limits. There are some indications for the recycling of the tools through different chronological periods (blade from building 54, Chapter 5.1.1.), but this could not be easily confirmed having in mind the preservation of the collection in general. Furtherly, the tools recovered from the Padina site were used to a regular extent, in other words, they did not show the extensive utilization as it was noted on the Lepenski Vir. Does this mean that the population at the Padina had enough raw materials needed for the season, so they were able to have certain comfort, or they simply had the better organization of the work processes? Lepenski Vir assemblage is the smallest of all the studies collections so the utilization of the tools to their maximum, and possible recycling could be a result of limited availability of the raw materials or maybe an indication of the potential danger that could reduce the exploitation of the raw materials. Or are we simply dealing with an economical concept that the inhabitants of Lepenski Vir had towards the chipped stone tools?

Some of the artefacts displayed superposition of the use traces and ones created from the prehension. These cases are present in all three studied collections. A smaller quantity displayed an almost incomprehensive characteristic of micro traces which was a result of frequent shift between the use and handling edge from task to task. This observation is adding up to the frequent choice to exploit the tools to their upper limits.

Around 3% of the total sample shows elements of hafting, while wooden haft was confirmed as the main handling mode of the following artefacts LV 1764, PA 27, PA 73, PA 80. This is very important since the hafts are rarely recovered in the archaeological context because of their organic structure. Additionally, this unearths the important process of preparation of the tools which was, previously, only speculated about. At this point, it is important to introduce the analysis of hafting as part of the standard procedure in the use-wear analysis of the unstudied collections. Insertion into the wooden handles, probably also into a bone frame, are assumptions that are transformed into concrete information, as is the case of tools from Lepenski Vir and Padina. Wooden handles are a logical choice of Iron Gates communities considering the accessibility of raw materials, the production of polished adzes, and bearing in mind the fact that there is an increase of wood processing in the Neolithic (Antonović 2003a and Antonović 2003b: 29-31).

Based on the presented results from three Iron Gates settlements it is possible to single out the basic practices of communities during the transition from the Mesolithic lifestyle to the Neolithic framework of behaviour. Although these are interpretations of general activities such as processing of bones, hide, meat or plants, and work operations such as cutting or scraping, a far more nuanced picture is obtained in relation to the data of typological-statistical analyses. Using both types of data, it is possible to be better prepared to enter the study of the daily program of activities of the inhabitants of the Iron Gates region during the Mesolithic and the transition to the Neolithic. It is important to point out that these activities are based on the accumulated knowledge, which has been constantly improved. This knowledge is part of the general strategy of the Lepenski Vir, Padina and Vlasac communities. The steps were evident, enabling a more comfortable life and increasing the degree of adaptation to the environment and the circumstances that took place.

7. CONCLUSIONS

Even though the excavations of the Iron Gates region finished around half a century ago, the intriguing hypothesis and new testimonies about the prehistoric communities in this closed eco-niche remained an endless resource of information for the life in the Late Glacial and Early Holocene. Many diverse analyses applied to the human and animal remains, studies of flora and fauna, burial practices or the architecture of the Iron Gates settlements revealed very precise information about the Mesolithic and Neolithic groups inside the region and their interactions with incomers. The evidence gained by the application of the use-wear and residues analysis had a simple goal: to take part in this colossal mosaic that recreates habits, customs, and everyday activities.

The first outcome represents an initial investment for the use-wear studies of the chipped stone artefacts in the Balkans since no similar and extensive experimental programme was done in the region. Except for the variety of the macro and micro traces noted on the tools, broad documentation is testifying about other elements of the process, as knapping technique, time, strength, efficiency, encountered problems, and all the auxiliary procedures depending on the trial. Despite the fact that the experiments were conducted precisely for the study of the processes that took part in the Late Mesolithic and Early Neolithic period, the observed trace patterns of the diverse contact materials could serve for the future use-wear studies of the chipped stone tools, considering the variety of the worked matters and motions.

The second result of the study is the comprehensive data, derived from the use-wear analysis of the chipped stone artefacts originating from Lepenski Vir, Padina and Vlasac, which fully contributed to the perception of the human activities in the Iron Gates region. The key importance lies in the fact that these types of information were not available in the previous decades and could not be extracted by any other method. The applied methodology is not destructive, still, it offers irreplaceable data about the prehistoric communities, including the possibility to *whiteness* the production and use of numerous matters that are invisible in the archaeological record, as leather goods or wooden hafts. The record of the worked materials and motions, the modest shifts between the communities through periods are carefully viewed from several angles, but, moreover, the presented study reveals the complete processes behind the activities. The insight we can gain based on the traces, and then test it experimentally, is comparable to reviewing the whole chain of produced motions, for example, needed for bone shaping. However, it allows us to note all the possible problems the groups could have confronted, as a need for the preservation of the excessive animal-based resources, like bone or hide.

The possibility to preserve materials, use additives or soften the antler are some of the behavioural concepts that could be traced based on the micro polish of the lithic tools. The predominance of animal-based matters is contributing to the possibility of the specialized production of leather products inside the region. On the other hand, to achieve absolute certainty we would need more paleodemographical studies, but based on the use-wear analysis we can say that the inhabitants of all three sites were quite familiar with hide tanning procedures of both larger sized skins, but, also, with the refinement of the smaller hides (details), needed for accessories, as belts can be. The other component of the animal results is focused on the butchering and working of the animal tissues, tendons, ligaments and meat in general. The presence of the carnivore diet in both the local and incomer groups is supporting the amount of the tools employed in the skinning, filleting and bone cleaning processes. Lepenski Vir is singled out as the settlement with the most specific utilization of the tools in animal-related processes, including the only two artefacts that were used in fish preparation.

The observed results noted the smaller quantity of the chipped stone tools used for working the vegetal resources which are consequently confirmed in the similar analysis of the ground stone artefacts. However, the quantity of vegetal activities is higher in the Early and Late Mesolithic period. Vlasac is recognized as the only settlement with the predominance of vegetal resources in the mentioned periods. The variety of the processed vegetal materials coincide with the species detected by the dental calculus analysis in the same chronological span. This indication is important because it shows no discrepancies between the prepared vegetals and consumed ones. Another similarity between the data acquired from the dental calculus analysis is the low presence of cereals. As there are many possibilities and hypothesis for the domestication of the cereals in the region, the quantity of the individuals where consumption of both domesticated and wild species was discovered and the number of the tools employed in the cereal processing is quite moderate in general. To conclude, they existed, the Iron Gates inhabitants consumed them in unknown amounts, but did they harvest them with only chipped stone tools is still unknown.

Traces of the mineral matters were found on all three sites, and in most of the cases are connected to the working of the soft stone, for instance, limestone. Only a couple of the tools have been used in the contact with the ceramics, sporadically. The low percentage can indicate that the tools were not frequently utilized for the shaping of stone and ceramics and that this was not a common practice.

The observed collections left diverse fingerprints that testify about the similar range of worked materials, but about the diverse level of commitment to the production of the matters inside the settlements. The assemblages are distinguished by the different level of trace preservation. Some of them are more and others less manipulated during previous decades. For example, the Lepenski Vir sample is poorly preserved compared to the other assemblages, but it was possible to observe the traces, and results indicated the most complex activities, while in the case of Padina the classification of used matters is wide, the traces are clear, but not many tools were employed in the compound tasks. Vlasac is singled out for its use of the lithic tools for vegetal resources, but it should be taken into consideration that the assemblage consists of a large quantity of quartz and quartzite, hence the complete list of the activities and worked matters should be supplemented with the additional studies that would target the alternative raw materials in future.

The gained results enriched the dataset and general impressions that were previously formed, based on divergent types of analysis and artefacts, about the groups that lived at Lepenski Vir, Padina and Vlasac in the period from c. 9500-5600 cal BC. The chipped stone tools are transformed, impersonated and they have become key indicators of the preferences of the Iron Gates communities towards the production, preparation, and consumption inside the region. The tools are being placed in the specific context revealing a complete chain of the tasks, from the simple woodcutting to the utilization of the ochre during the hide processing, disclosing the behavioural concept of the prehistoric groups and their ability to confront daily tasks.

Additionally, the study represents a fertile ground for the observation of the contact inside and outside the Iron Gates region, both in the Transition and Early Neolithic in a broader inter-regional framework, with an accent on the sites of the hinterland of Montenegro, Istria, and Croatian coast, Slovenia and northern Italy.

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BIOGRAPHY

Anđa Petrović was born in 1992, in Kraljevo (Serbia), where she finished elementary school. In 2011, she finished high school in Belgrade, and initiated her BA studies at the Department of Archaeology, at the University of Belgrade (Serbia). During her BA studies, Anđa spent her third academic year at the University of Ljubljana (Slovenia). She graduated in 2015, and in 2016 obtained her MA degree (thesis entitled *Transitional period at Lepenski Vir: use-wear analysis on chipped stone artefacts*) at the University of Belgrade, for which she received the Award of the National Museum in Belgrade. In 2016 Anđa enrolled in the Co-Tutela Doctoral studies at Sapienza University of Rome and University of Belgrade with a thesis entitled *Mesolithic-Neolithic transition in Iron Gates (Serbia): Human activities from use-wear perspective*, under the supervision of professors Dušan Mihailović and Cristina Lemorini.

Anđa focuses her research on the use-wear and technological analysis of chipped stone artefacts. Her main interests are human activities during the Late Glacial and Early Holocene period in SE Europe. During the last couple of years, she attended over fifteen international congresses and conferences, and published five scientific papers. In 2020 she co-organized a session at the European Association of Archaeologists (EAA) Conference – session #225 *Looking beyond the microscope: interdisciplinary approaches to use-wear and residue analysis*.

Since 2012, Anđa has been involved in various archaeological projects in the Near East, Eastern Turkey, Cyclades, and central Balkans. Among others, they include the *Çatalhöyük Research Project*, *ERC Prehistoric Anatolia*, *Stélida Naxos Archaeological Project*, *Cultural changes and population movement in early prehistory of the Central Balkans*, and *Lojanik – chert mine of prehistoric communities in Central Serbia*. In 2019, together with colleagues from Sapienza University of Rome she started the project *ATOS - Archaeological Traces Organization Software* in a collaboration with University of Paris 1 Panthéon-Sorbonne. In 2020, she became a member of the project *Scelte economiche delle comunità umane del Mediterraneo centrale e relazione con le fluttuazioni climatiche dell'Olocene medio* directed by Professor Cecilia Barbaro Conati. Since 2021, Anđa is involved in the project *Primate Archaeology e Primate Etology: studio archeometrico degli strumenti litici utilizzati da Primati non umani* led by Professor Lemorini.

Anđa recieved various grants from MAECI - Ministry of Foreign Affairs and International Cooperation (Il Ministero degli Affari Esteri e della Cooperazione Internazionale), MIUR (Ministero dell'istruzione, dell'università e della ricerca) and Sapienza Univeristy of Rome funding (Bando per progetti di mobilità di studenti di dottoratodi ricerca), Ministry of Education, Science and

Technological Development of the Republic of Serbia, and the Andrew Sherratt grant for postgraduate students for research projects in Old World Prehistory, University of Sheffield.

She is a member of AWRANA – Archaeological Wear and Residue Analysts, ICOM – International Council of Museums, EAA – European Association of Archaeologists, CIG – The Canadian Institute in Greece (KIE – Το Καναδικό Ινστιτούτο στην Ελλάδα), and SAS – Serbian Archaeological Society. Anđa speaks fluently English, Italian and German, while she posses an elementary knowledge of Spanish and Slovenian and a satisfactory performance on an intermediate level of Latin and Ancient Greek proficiency.

Образац 5.

Изјава о ауторству

Име и презиме аутора Анђа Петровић

Број индекса 7А16-1

Изјављујем

да је докторска дисертација под насловом

Mesolithic-Neolithic transition in Iron Gates (Serbia): Human activities from use-wear perspective

- резултат сопственог истраживачког рада;
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Образац 6.

Изјава о истоветности штампане и електронске верзије докторског рада

Име и презиме аутора Анђа Петровић

Број индекса 7A16-1

Студијски програм археологија

Наслов рада **Mesolithic-Neolithic transition in Iron Gates (Serbia): Human activities from use-wear perspective**

Ментор проф. др Душан Михаиловић и проф. др Кристина Леморини

Изјављујем да је штампана верзија мог докторског рада истоветна електронској верзији коју сам предао/ла ради похрањена у **Дигиталном репозиторијуму Универзитета у Београду.**

Дозвољавам да се објаве моји лични подаци везани за добијање академског назива доктора наука, као што су име и презиме, година и место рођења и датум одбране рада.

Ови лични подаци могу се објавити на мрежним страницама дигиталне библиотеке, у електронском каталогу и у публикацијама Универзитета у Београду.

Потпис аутора

У Београду, _________________

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Образац 7.

Изјава о коришћењу

Овлашћујем Универзитетску библиотеку „Светозар Марковић“ да у Дигитални репозиторијум Универзитета у Београду унесе моју докторску дисертацију под насловом:

Mesolithic-Neolithic transition in Iron Gates (Serbia): Human activities from use-wear perspective

која је моје ауторско дело.

Дисертацију са свим прилозима предао/ла сам у електронском формату погодном за трајно архивирање.

Моју докторску дисертацију похрањену у Дигиталном репозиторијуму Универзитета у Београду и доступну у отвореном приступу могу да користе сви који поштују одредбе садржане у одабраном типу лиценце Креативне заједнице (Creative Commons) за коју сам се одлучио/ла.

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