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Content

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Preface

Ina Miloglav

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Methodology and Archaeometry (*MetArh*) is an annual scientific conference organized since 2013 by the Department of Archaeology of the Faculty of Humanities and Social Sciences of the University of Zagreb, and the Croatian Archaeological Society. The goal of the conference is to entice interdisciplinarity, critical thinking, new insights and approaches as well as new theoretical frameworks in contemporary archaeological science. This edition of the conference Proceedings contains four papers from 10th *MetArh* conference which was held in a hybrid format at the Faculty of Humanities and Social Sciences of the University of Zagreb from 1st – 2nd of December 2022 (https://metarh.ffzg.unizg.hr/).

Considering the rapid and dynamic progress in the field of methodology and archaeometry, the goal of the Proceedings is to publish papers within the current year. Although this edition has a relatively small number of articles, we have decided to continue with the same dynamic of publication, so that the results of research and new methodological tools are made available to all interested researchers. We will continue to work in the same way in the coming years.

I would like to thank all the reviewers for their contributions and the time dedicated to improving the quality of the research, thereby helping to maintain the credibility and integrity of the research output.

Filling in the blanks: the application of palaeoproteomics in faunal analysis

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Faunal assemblages from archaeological contexts often consist of highly fragmented osseous remains which can be a limiting factor for the purposes of standard archaeozoological analysis. Therefore, efforts to further improve our knowledge of human—animal relationships in the past have been intensified in the last few decades. Apart from the already well-established ancient DNA analyses, in the past ten years, we have seen a rise in the use of palaeoproteomics in archaeology. Proteomic studies range from exploring whole proteomes of tissue or substrate (e.g., bone, enamel, shell) to detecting peptides to identify the taxon from the bone specimen. The latter can be achieved through Zooarchaeology by Mass Spectrometry (ZooMS), a technique of peptide mass fingerprinting (PMF), that aims at discriminating tissue rich in collagen type I from a taxonomic point of view. Collagen is a protein less prone to decay owing to its high abundance in osseous tissues and its arrangement into a highly stable triple helix making it suitable for ancient samples. ZooMS is fast, cost-effective, and is being explored and improved rapidly making it an accessory tool for improving and complementing morphological faunal analysis. Its effectiveness varies based on the taphonomic processes and the age of the sample itself but, generally, it has a significantly higher success rate than the DNA analysis. Here, we present the basic principles, history, possibilities, and limitations of proteomic studies in archaeology as well as preliminary results of the analysis conducted on the Late Pleistocene sites in Istria, Croatia, the first of its kind in the region.

Keywords: *palaeoproteomics, ZooMS, faunal analysis, Late Pleistocene, Istria*

Introduction

In the attempt to accurately reconstruct life in the past, archaeology has become an inherently interdisciplinary science. Therefore, the field of biomolecular analyses, such as stable isotope, ancient DNA, lipids, and proteomic studies, is becoming crucial in archaeological research projects (van Doorn 2012; Cappellini et al. 2018). These analyses can give us insight into nutritional habits, trophic niches changes, migrations, and other forms of human adaptations in all periods of the past (van Doorn 2012). In the last ten to fifteen years, the study of ancient proteins has shown great potential as a rich source of information. Proteins are building blocks of all life and their robust morphology and abundance in various tissues are making their decomposition much slower in relation to, for example, the DNA molecule (Warinner et al. 2022). The rise and advancements in palaeoproteomics have been swift and today this type of research is being used in the fields of biology, palaeontology, palaeoecology, and archaeology, to name a few (Hendy 2021; Warinner et al. 2022).

In archaeology, its appeal is mostly recognized in the studies of prehistory. Archaeological contexts are notoriously rich in biomineralized tissues, such as bones and teeth, but sometimes also egg shells, skin, and keratinous tissues (van Doorn 2012; Buckley 2018a). The most abundant and common protein in vertebrates is collagen with most of its mass being stored in bones (Buckley 2018b; Shoulders & Raines 2009). Therefore, collagen is the most commonly targeted protein in proteomic studies which are cost-effective, relatively simple, and have a high success rate (Buckley 2018a). These are mostly being used to complement standard analysis, as those assemblages are often highly fragmented and therefore the success of “classical” archaeozoological methods can be limited. It is a fast-evolving field that will certainly result in more analyses and, consequently, in more precise results in the near future (Hendy et al. 2018).

A brief history of palaeoproteomics

The beginnings of what became the field of ancient proteomics is in the 1950s when the first amino acids have been found in the fossils of Devonian fishes, Jurassic and Cretaceous dinosaurs and Oligocene and Pliocene horses (Abelson 1954, 1956; Warinner et al. 2022). The first few decades of research were focused on amino acids, immunological approaches and the efforts to sequence ancient proteins (Buckley 2018a). Nevertheless, the real, rapid evolution of palaeoproteomics begins at the start of this millennium, with the first successful sequencing of the non-collagenous protein osteocalcin from the 53-thousand-year old bison (*Bison priscus*) bone (Ostrom et al. 2000). Later on, a few collagen peptides have been (debatably) identified in a dinosaur fossil dating to 68 million years ago (Asara et al. 2007). Still, the first significant use of ancient proteins in the field of archaeology was the taxonomic identification of faunal remains based on collagen peptide mass fingerprinting (Buckley et al. 2009). Since then, techniques and protocols for the successful extraction and differentiation of collagen peptides have started to develop. It was hoped these would broaden our understanding of human-animal relationships, ecological conditions of the past, and phylogenetic connections (Cappellini et al. 2018). In the last 13 years, proteomic analyses have successfully been applied for distinguishing sheep (*Ovis aries*) and goat (*Capra hircus*) bones (Buckley et al. 2010), a non-destructive protocol for collagen extraction has been developed (van Doorn et al. 2011), glutamine deamidation in collagen peptides was correlated with the thermal age of the samples (van Doorn et al. 2012), hominin fossils were identified in Pleistocene faunal assemblages (Brown et al. 2016; Welker et al. 2016; Douka et al. 2019), a bone ring from a Denmark Neolithic site was determined as red deer (*Cervus elaphus*) (Jensen et al. 2020), and many faunal assemblages have been broadened in at least their NISP, if not with new species using peptide mass fingerprinting (Welker et al. 2015; Sinet-Mathiot et al. 2019; Pothier-Bouchard et al. 2020; Silvestrini et al. 2022a, 2022b; Paladugu et al. 2023; Ruebens et al. 2023). Also, methods exploring other, non-collagenous proteins, such as amelogenin from the tooth enamel for sexing of human remains, have been developed (Stewart et al. 2017; Lugli et al. 2019, 2020).

Basic principles and application in archaeology

Proteome is the entire set of proteins in a single organism and *palaeoproteomics* is a discipline studying ancient proteins and proteomes, mostly in archaeological and fossil samples (van Doorn 2012; Warinner et al. 2022). Due to its abundance and stability, proteins can survive in biomineralized tissues for long periods of time and are a source of genetic information that are valuable for reconstructing phylogenetic relationships (Buckley 2018a). The advances in palaeoproteomics were made possible by the development of mass spectrometry and especially by advances in soft ionization methods and protein sequencing (van Doorn 2012; Buckley 2018a). Today, the MALDI-TOF MS (*Matrix Assisted Laser Desorp-*

tion/Ionization- Time of Flight Mass Spectrometer) and the LC-MS/MS (*Liquid Chromatography-Tandem Mass Spectrometry*) are most commonly used to detect single amino acid polymorphisms (SAPs) that cause protein sequence variation (Welker 2018). This variation allows taxonomic and phylogenetic analysis of ancient proteins (Welker 2018).

Generally, there are two main approaches to studying proteomes. On one hand, top-down proteomics analyses proteins in their unchanged form to gain information on post-translational modifications, isoforms, and other valuable information (Cappellini et al. 2018). This is a computationally complicated and, for now, high-end resource approach and is, therefore, not used for ancient samples that often (Cappellini et al. 2018). In archaeology, the second approach, known as bottom-up, is most commonly used as it identifies the protein sequence (Cappellini et al. 2018). Proteomes and proteins are more easily studied as smaller fractions, so most protocols use proteinases to digest the proteins into peptides that are up to 20 amino acids long (van Doorn et al. 2011).

Even though there are many different types of protein in vertebrates, the ones that can be found in bones and teeth are of special interest for archaeological purposes. The most abundant protein is collagen type 1 (COL1), a structural, fibrous molecule making 1/3 of all proteins in human organism (Shoulders & Raines 2009). Its water resistance and mineralized bone environment make its decay slower and is therefore a suitable candidate for palaeoproteomic investigations (van Doorn 2012; Buckley 2018a). In addition, due to its triple-helix structure, it is a highly stable molecule (Shoulders & Raines 2009). Apart from collagen, other proteins of significance for archaeological analysis include e.g. osteocalcin, albumin, and amelogenin (van Doorn 2012; Stewart et al. 2017; Cappellini et al. 2018).

Zooarchaeology by mass spectrometry (ZooMS)

As discussed previously, faunal assemblages are very often composed of a high percentage of bone fragments, drastically limiting their taxonomic identifications through the morphological approach. To overcome this, the so-called zooarchaeology by mass spectrometry, or ZooMS, was developed. It aims at discriminating tissues rich in COL1 from a taxonomic point, based on peptide mass fingerprinting (PMF) approach (Welker 2018). Namely, it measures the mass of taxon-specific peptides (markers) in the extract and is most often successful up to a genus level of determination (van Doorn 2012; Wang et al. 2021). It depends heavily on the available reference databases as the resulting MS spectra need to be inspected and compared to identify the sample. Today, it is mostly used for determinations of mammal bones, but the databases for birds, fish, reptiles and amphibians are being developed (Buckley 2018b; Richter et al. 2021). This is a fast and cost-effective method that is developing rapidly, suitable for complementing faunal analysis (e.g. Silvestrini et al. 2022a, b) but could also be a large-scale screening tool for identifying hominin fossils in large, fragmented osteological assemblages (Warinner et al. 2022). Also, it is a minimally destructive approach, given the fact that 10-30 mg bone chip usually yields enough collagen for successful analysis (Wang et al. 2021). It was shown that protocols including demineralization phase, usually using hydrochloric acid, have the highest success rate (Wang et al. 2021), but there are non-destructive protocols that can also yield accurate results (van Doorn 2012).

Preliminary results of palaeoproteomic analyses of faunal assemblages from Istria, Croatia

Apart from analyses carried out on the assemblages from layer G from the Vindija cave (Devièse et al. 2017), whose primary goal was the identification of new hominin remains, so far there has been no attempt to implement palaeoproteomics to osteological assemblages from Croatian sites. As a part of the PREHISTRIA project (HRZZ IP-2019-04-7821), there are ongoing excavations of two Late Pleistocene sites in Istria: Abri Kontija 002 and Ljubićeva pećina. ZooMS analyses for both, but also for the samples from the Romualdova pećina in the same region (Fig. 1), are underway and therefore represent the first attempt at systematically identifying fragmentary faunal assemblages, to help reconstruct the palaeoenvironment and subsistence strategies of hunter-gatherer groups that inhabited this region during different periods in the Late Pleistocene.

Ljubićeva pećina

Ljubićeva pećina is a vast cave located in southern Istria, with a wide entrance at the bottom of a karstic sinkhole, composed of two big chambers on two levels (Percan et al. 2020) (Fig. 2). Excavation of this site began in 2008 and the layers assigned to the Epigravettian period of the Upper Palaeolithic have been found in the side chamber of the upper level (Percan et al. 2009). Even though the sedimentation was slow, and layers with the evidence of

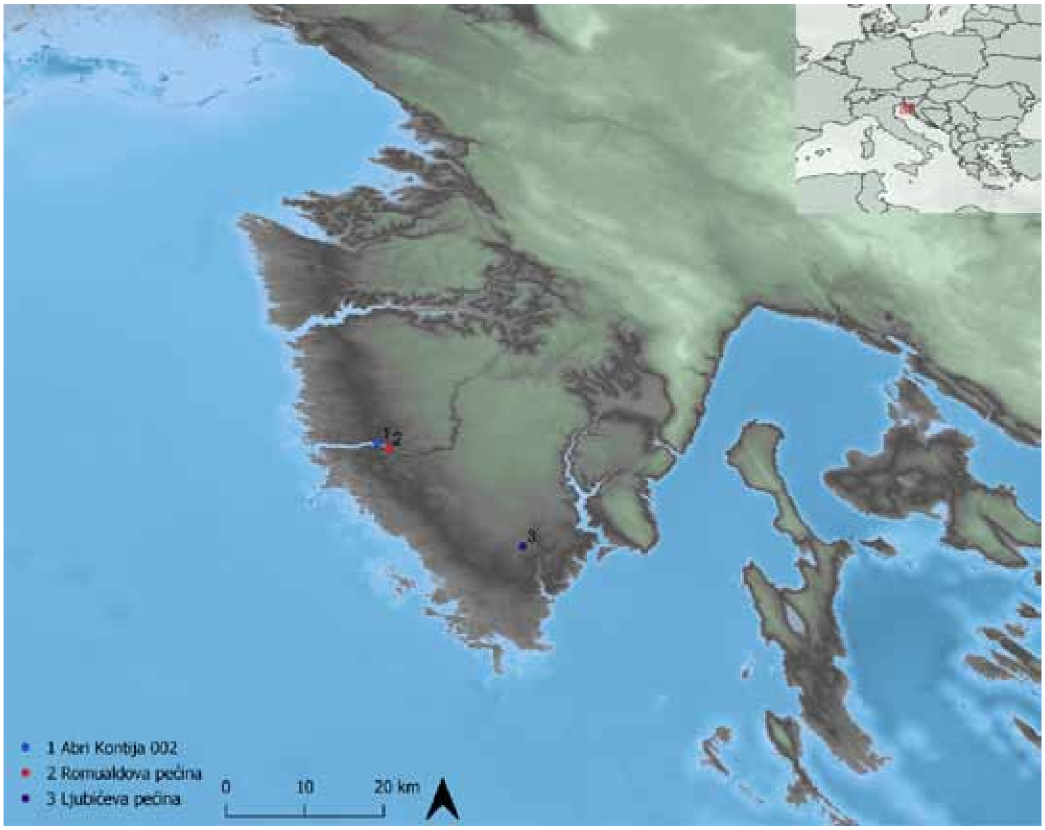


Figure1. Geographic position of the sites mentioned in the text. (Created by the authors).

Figure 2. The inside of Ljubićeva pećina. (Photo by the authors).

Pleistocene human activities are not too thick, they are rich in bone and lithic material, attesting to intense human occupation at different times.

Preservation of the osseous material is exceptionally good and traces of human activities, such as cutmarks, fractures and thermal alterations, are common. Due to the abundance of bone material, archaeozoological analyses are still ongoing, but we were able to identify medium and large herbivores, such as aurochs or bisons (*Bos/Bison*), horses (*Equus ferus*) and red deer (*Cervus elaphus*). On the other hand, remains of small carnivores, such as foxes (*Vulpes vulpes*), badgers (*Meles meles*) and pine martens (*Martes martes*) were also present (Percan et al. 2020). Still, the fragmentation of this assemblage is high which makes it a good candidate for the use of palaeoproteomic approach, and around 100 bones were sampled for ZooMS analysis. The available results are in accordance with the morphological analysis, showing a big prevalence of large bovids (Fig. 3). It also confirmed remarkably good preservation of bone samples, as none of them failed to provide identification on a scale lower than subfamily or genus. Future work using ZooMS on this assemblage will help us to better understand human occupation and exploitation of animal sources in the region during the Late Upper Palaeolithic.

Abri Kontija 002

Abri Kontija 002 is a rockshelter on the northern slopes of the Lim channel on the western coast of the Istrian peninsula (Janković et al. 2022) (Fig. 4). The trench, positioned close to the rock wall, in front of the cave entrance now filled with sediment, yielded an almost 2-meter-deep cultural sequence dating to Early/Middle Upper Palaeolithic period.

The layers are extraordinarily rich with archaeological material (lithics, bones, shells, ochre) suggesting the intense use of this area overlooking a river gorge during the Late Pleistocene. Faunal assemblage at this site is heavily fragmented and morphological analysis is therefore very limited. Nevertheless, remains of horses, red deer, hares (*Lepus europaeus* or *Lepus timidus*) and cave bears (*Ursus spelaeus vel ingressus*) have been identified so far. ZooMS analysis has been performed on around 100 unidentified bone fragments from the whole archaeological sequence of the site. For now, it seems that the uppermost layers do not have enough collagen preserved for successful determinations. On the other hand, samples from the rest of the sequence, from approximately layer 4 to layer 9, have produced enough collagen, and taxa like horses, red deer and large bovids have been identified (Fig. 5).

Figure 3. An example of the sample from Ljubićeva pećina, defined as Bos/Bison. Created by the authors

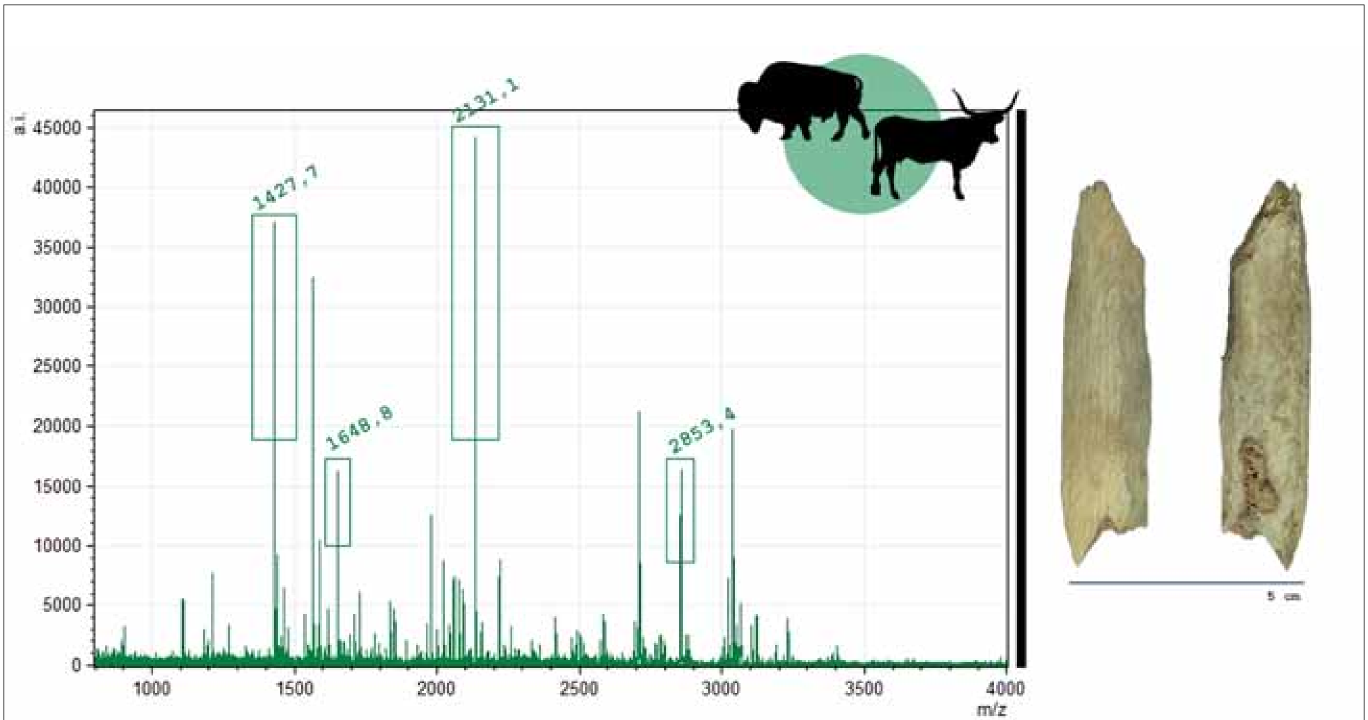
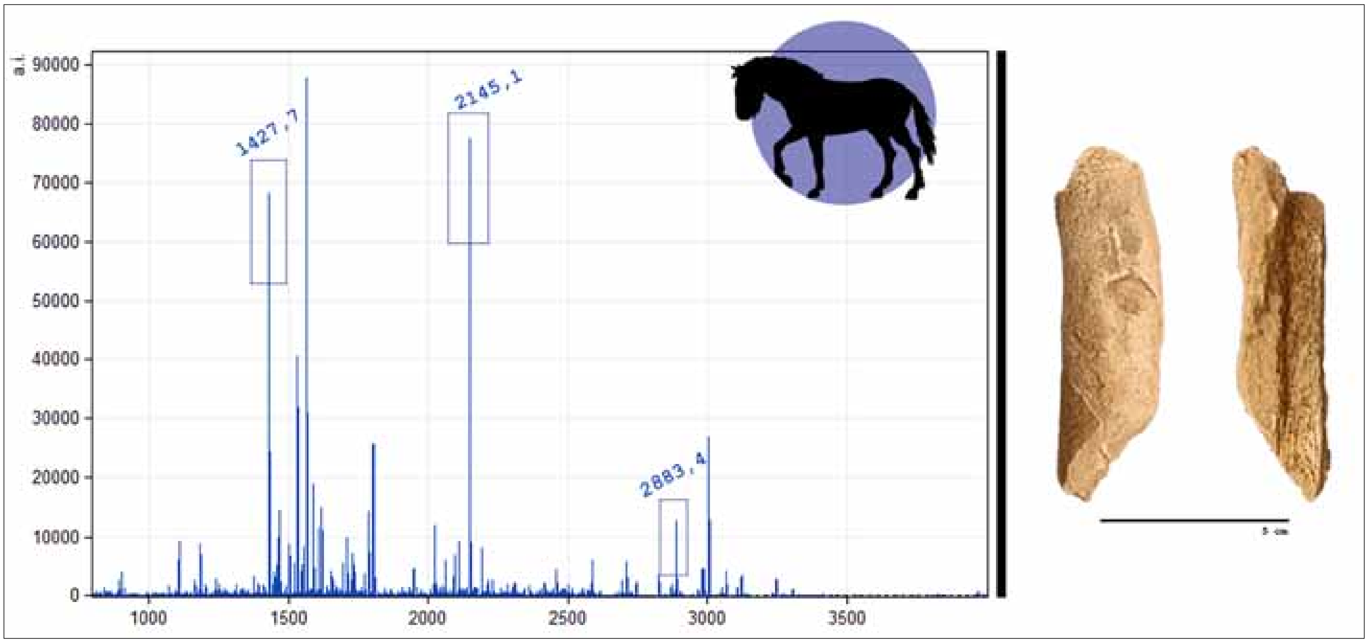


Figure 4. The site of Abri Kontija 002. (Photo by the authors).

Figure 5. An example of the sample from Abri Kontija 002, defined as Equus sp. (Created by the authors).

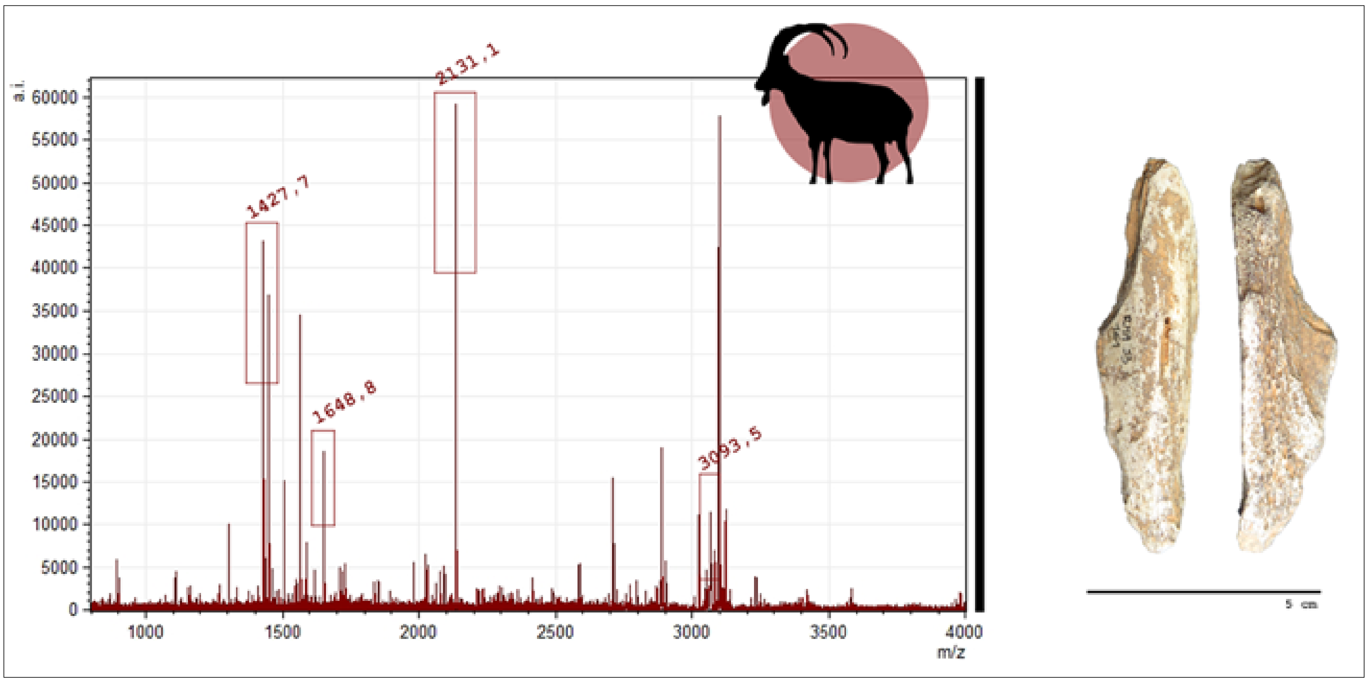


Romualdova pećina

Romualdova pećina is located in close vicinity of the Abri Kontija site, on the opposite (southern) slope of the Lim Channel. It is a cave of simple morphology, with a long hall that branches out into several smaller chambers (Janković et al. 2016) (Fig. 6). The stratigraphic sequence, testifies to episodes of sporadic human occupation during both Middle and Upper Palaeolithic, as well as later prehistoric periods (Bronze and Iron Age, see Janković et al. 2015).

Figure 6. The inside of Romualdova pećina. (Photo by the authors).

Figure 7. An example of the sample from Romualdova pećina, defined as Capra ibex. (Created by the authors).



Still, the primary visitors to the site were animals, mostly bears, that used the cave as a hibernation den. Nevertheless, lithic material is present at the site, as well as the faunal assemblage rich in bears, ibex (*Capra ibex*) and red deer. For the purposes of ZooMS identification, 35 bone fragments were sampled from the Middle Palaeolithic layers. Even though the state of preservation seemed to be poorer at this site, with common manganese coating, 33 samples were successfully identified to a subfamily or genus level, with bears and ibexes being the most common ones (Fig.7). Yet, further analyses are needed, but the current results are optimistic even for this site with different, more complicated post-depositional conditions. Also, analysis of sediment DNA from the site is in progress and already yielded results, confirming the presence of several different Pleistocene taxa.

Discussion and conclusion

In general, ancient biomolecules are an invaluable source of information about the past. In particular, much work that used the biomolecular approach has been done on issues on modern human origins and various archaic human groups, demography, species extinction, exploitation and domestication of plants and animals, phylogenetic relationships of extinct species, palaeoclimate and palaeoenvironmental reconstruction, and so on (Cappellini et al. 2018). While being the most valuable in terms of information gaining, the DNA molecule is also very prone to decay and analyses are often complicated and expensive. On the other hand, analyses of ancient proteins have been proven to be cost-effective and often more successful. In addition, ancient proteins could contribute to our understanding of phylogenetic relationships in geographic regions where the DNA survival is poor (Cappellini et al. 2018). Furthermore, palaeoproteomic analyses can be combined with other collagen-based approaches, such as radiocarbon dating and stable isotope analysis, which minimizes the destruction of the sample (Hendy 2021). These approaches can thus have an impact on some of the long-lasting questions relating to archaeological science, such as the timing and nature of water-resource exploitation or raw-material choices in regard to the worked-bone industry (Buckley 2018b). Future proteomic analyses on different types of materials and from different contexts will allow a better understanding of the agents preventing or speeding up the degradation of proteins (Hendy 2021). Current evidence suggests that stable, cold and anaerobic environments are more likely to preserve collagen, than hot, highly-seasonal and humid conditions (Warinner et al. 2022).

Particularly useful for taxonomic identification of large assemblages of fragmented collagen-rich archaeological materials is the so-called zooarchaeology by mass spectrometry (ZooMS). Having the ability to discern taxa based on peptide mass fingerprints is being used more and more among researchers of all periods, but especially prehistory. In less than 15 years since its implementation, ZooMS has found its niche in the research of faunal assemblages from mid-tempered Late Pleistocene European sites, such as Les Cottès (Welker et al. 2015), Grotte du Renne (Welker et al. 2016), Grotta di Fumane (Sinet-Mathiot et al. 2019), Uluzzo C, Riparo del Broion (Silvestrini et al. 2022a, 2022b), Salzgitter-Lebenstedt (Ruebens et al. 2023) and so on. Also, the efforts to further improve, standardize and optimize analytical protocols and interpretation of the results are continuous. For example, a non-destructive protocol for collagen extraction has been developed only two years after the first successful application of PMFs for taxonomic identification (van Doorn et al. 2011). Still, there is a need for more in-depth sequencing of collagen type 1 in the hope of identifying new variations among more closely related species, as well as improving data for classes of birds (Aves) and fish (Pisces) (Richter et al. 2022). The lack of centralized, accessible, and complete databases of all known peptide markers is a somewhat limiting factor, making the work slower and more prone to mistakes (Brown et al. 2021). Because of the fact that the rate of changes in protein sequence is slower and less frequent compared to that in genes, proteins have a smaller resolution potential (Warinner et al. 2022). Therefore, species that diverged from one another less than five million years ago, at the moment cannot be differentiated using peptide fingerprinting (Buckley 2018b). Nevertheless, the dating of the observed sequence, site formation processes, and information on palaeoenvironment can oftentimes help eliminate some of the taxa (e.g. comparing the Pleistocene and Holocene samples). Still, methods like ZooMS stand out as a valuable approach and its fast development will most likely result in better precision of the results in the upcoming years. In order to maximize efficiency of these, and other methods, field and laboratory work needs to be optimized and the communication among researchers prompt and clear. Reporting on the protocols and materials used in specific analysis is still uneven and should be made obligatory when publishing the results (Hendy 2021). In the end, it is crucial to combine the results of ZooMS with the results of morphological analyses of faunal remains in order to better understand the context of the site. It should be mentioned that ZooMS cannot increase categories like the MNI (Minimal Number of Individuals) and the MNE (Minimal Number of Elements), but it can increase the NISP (Number of Identified Specimens).

Even though still relatively new, and not without limitations, palaeoproteomic approaches are successfully being implemented as an archaeological accessory tool (Buckley 2018a). The chemical and biological characteristics of proteins make them one of the more robust biomolecules with high survival rates for hundreds of thousands of years. Therefore, their use in the realm of prehistory does not come as a surprise. For the Palaeolithic, they could have a big impact on reconstructing environmental conditions, subsistence strategies, mobility patterns, and so on. Their high compatibility with morphological archaeozoological, but also palaeogenomic analyses, makes them one of the most promising fields of interdisciplinary research. At the moment, no systematic efforts were performed to implement methods like ZooMS in southeastern Europe. Therefore, we hope that the preliminary results presented in this paper will contribute to the understanding of major issues of the Pleistocene research in the region, and that they soon will become a standard in the archaeological analysis of faunal material. The examples listed here prove that faunal assemblages from Croatian sites, at least those in the region of Istria, have a substantial amount of collagen preserved which enables the taxonomic identification up to the genus level for most samples.

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References

Abelson, P. H. 1954. Amino acids in fossils, *Science* 119, 576.

Abelson, P. H. 1956. Paleobiochemistry, *Scientific American* 195 (1), 83-96.

Asara, J. M., Schweitzer, M. H., Freimark, L. M., Phillips, M. and Cantley, L. C. 2007. Protein Sequences from Mastodon and Tyrannosaurus Rex Revealed by Mass Spectrometry, *Science* 316, 280-283. https://doi.org/10.1126/science.1137614

Brown, S., Higham, T., Slon, V., Pääbo, S., Meyer, M., Douka, K., Brock, F., Comeskey, D., Procopio, N., Shunkov, M., Derevianko, A. and Buckley, M. 2016. Identification of a new hominin bone from Denisova Cave, Siberia using collagen fingerprinting and mitochondrial DNA analysis, *Scientific Reports* 6 (1), 23559. https://doi.org/10.1038/srep23559

Brown, S., Douka, K., Collins, M. J. and Richter, K. K. 2021. On the standardization of ZooMS nomenclature, *Journal of Proteomics* 235, 104041. https://doi.org/10.1016/j.jprot.2020.104041

Buckley, M. 2018a. Paleoproteomics: An Introduction to the Analysis of Ancient Proteins by Soft Ionisation Mass Spectrometry, In: Lindqvist, C. and Rajora, O. P. (eds.), *Paleogenomics,* Springer, Cham, 31-52.

Buckley, M. 2018b. Zooarchaeology by Mass Spectrometry (ZooMS) Collagen Fingerprinting for the Species Identification of Archaeological Bone Fragments, In: C. M. Giovas and M. J. LeFebvre (eds.), *Zooarchaeology in Practice: Case Studies in Methodology and Interpretation in Archaeofaunal Analysis,* Springer, Cham, 227-247. http://dx.doi.org/10.1007/978-3-319-64763-0_12

Buckley, M., Collins, M. J., Thomas-Oates, J. and Wilson, J. C. 2009. Species identification by analysis of bone collagen using matrix-assisted laser desorption/ionisation time-of-flight mass spectrometry, *Rapid Communications in Mass Spectrometry: An International Journal Devoted to the Rapid Dissemination of Up-to-the-Minute Research in Mass Spectrometry* 23 (23), 3843-3854. https://doi.org/10.1002/rcm.4316

Buckley, M., Whitcher Kansa, S., Howard, S., Campbell, S., Thomas-Oates, J. and Collins M. 2010. Distinguishing between archaeological sheep and goat bones using a single collagen peptide, *Journal of Archaeological Science* 37 (1), 13-20. https://doi.org/10.1016/j.jas.2009.08.020

Cappellini, E., Prohaska, A., Racimo, F., Welker, F., Winther Pedersen, M., Allentoft, M. E., de Barros Damargaad, P., Gutenbrunner, P., Dunne, J., Hammann, S., Roffet-Salque, M., Ilardo, M., Moreno-Mayar, J.V., Wang, Y., Sikora, M., Vinner L., Cox, J., Evershed, R. P. and Willerslev, E. 2018. Ancient Biomolecules and Evolutionary Inference, *Annual Review of Biochemistry* 87, 1029-1060. https://doi.org/10.1146/annurev-biochem-062917-012002

Douka, K., Brown, S., Higham, T., Pääbo, S., Derevianko, A. and Shunkov, M. 2019. FINDER project: collagen fingerprinting (ZooMS) for the identification of new human fossils, *Antiquity* 93 (367). 1-6. https://doi.org/10.15184/aqy.2019.3

Devièse, T., Karavanić, I., Comeskey, D., Kubiak, C., Korlević, P., Hajdinjak, M., Radović, S., Procopio, N., Buckley, M. Pääbo, S. and Higham, T. 2017. Direct dating of Neanderthal remains from the site of Vindija Cave and implications for the Middle to Upper Paleolithic transition, *Proceedings of the National Academy of Sciences* 114 (40), 10606-10611. https://doi.org/10.1073/pnas.1709235114

Hendy, J. 2021. Ancient protein analysis in archaeology, *Science Advances* 7 (3): eabb9314, 1-11. https://doi.org/10.1126/sciadv.abb9314

Hendy, J., Welker, F., Demarchi, B., Speller, C., Warinner, C. and Collins, M. J. 2018. A guide to ancient protein studies, *Nature ecology & evolution* 2 (5), 791-799. https://doi.org/10.1038/s41559-018-0510-x

Janković, I., Ahern, J. C. M., Mihelić, S. and Premužić, Z. 2015. Bronze and Iron Age finds from Romuald's Cave, Istria: 2014. Excavation season, *Collegium Anthropologicum* 39 (4), 943-946.

Janković, I., Komšo D., Ahern, J.C.M., Becker, R., Gerometta, K., Mihelić, S. and Zubčić, K. 2016. Arheološka istraživanja u Limskom kanalu 2014. i 2015. Lokaliteti Romualdova pećina i Abri Kontija 002, Pećina kod Rovinjskog sela, Lim 001 i podvodni pregled Limskog kanala. *Histria Archaeologica* 46, 5-23.

Janković, I., Ahern, J., Becker, R., Komšo, D., Radović, S., Čuka, M., Vukosavljević, N., Vidas, L., Gerometta, K., Novak, M. 2022. Terenska istraživanja na nalazištima Ljubićeva pećina i Abri Kontija 002 u okviru projekta PREHISTRIA tijekom 2021, *Vjesnik Arheološkog muzeja u Zagrebu* 55 (2), 155-173. https://doi.org/10.52064/vamz.55.2.1

Jensen, T. Z. T., Mackie, M., Taurozzi, A. J., Lanigan, L. T., Gundelach, C., Olsen, J., Sørensen, S. A., Collins, M. J., Sørensen, M. and Schroeder, H. 2020. The biomolecular characterization of a finger ring contextually dated to the emergence of the Early Neolithic from Syltholm, Denmark, *Royal Society Open Science* 7 (1), 191172. https://doi.org/10.1098/rsos.191172

Lugli, F., Di Rocco, G., Vazzana, A., Genovese, F., Pinetti, D., Cilli, E., Carile, M. C., Silvestrini, S., Gabanini, G., Arrighi, S., Buti, L., Bartolini, E., Cipriani, A., Figus, C., Marciani, G., Oxilia, G., Romandini, M., Sorrentino, R., Sola, M. and Benazzi, S. 2019. Enamel peptides reveal the sex of the Late Antique 'Lovers of Modena', *Scientific Reports* 9 (1), 1-8. https://doi.org/10.1038/s41598-019-49562-7

Lugli, F., Figus, C., Silvestrini, S., Costa, V., Bortolini, E., Conti, S., Peripoli, B., Nava, A., Sperduti, A., Lamanna, L., Bondioli, L. and Benazzi, S. 2020. Sex-related morbidity and mortality in non-adult individuals from the Early Medieval site of Valdaro (Italy): The contribution of dental enamel peptide analysis, *Journal of Archaeological Science: Reports* 34, 102625. https://doi.org/10.1016/j.jasrep.2020.102625

Ostrom, P. H., Schall, M., Gandhi, H., Shen, T. L., Hauschka, P. V., Strahler, J. R. and Gage, D. A. 2000. New strategies for characterizing ancient proteins using matrix-assisted laser desorption ionization mass spectrometry, *Geochimica et Cosmochimica Acta* 64 (6), 1043-1050. https://doi.org/10.1016/S0016-7037(99)00381-6

Paladugu, R., Richter, K. K., Valente, M. J., Gabriel, S., Detry, C., Warinner, C. and Dias, C. B. 2023. Your horse is a donkey! Identifying domesticated equids from Western Iberia using collagen fingerprinting, *Journal of Archaeological Science* 149, 105696. https://doi.org/10.1016/j.jas.2022.105696

Percan, T., Komšo, D. and Bekić, L. 2009. Ljubićeva pećina. *Hrvatski arheološki godišnjak* 5 (2008), 344-347.

Percan, T., Ahern, J., Komšo, D., Radović, S., Novak, M., Gerometta, K., Vidas, L. and Janković, I. 2020. Istraživanja u Ljubićevoj pećini kraj Marčane u sezoni 2020, *Annales Instituti Archaeologici* 16 (1), 219-228.

Pothier-Bouchard, G., Riel-Salvatore, J., Negrino, F. and Buckley, M. 2020. Archaeozoological, taphonomic and ZooMS insights into the Protoaurignacian faunal record from Riparo Bombrini, *Quaternary International* 551, 243-263. https://doi.org/10.1016/j.quaint.2020.01.007

Richter, K. K., Wilson, J., Jones, A. K. G., Buckley, M., van Doorn, N. and Collins, M. J. 2021. Fish 'n chips: ZooMS peptide mass fingerprinting in a 96 well plate format to identify fish bone fragments, *Journal of Archaeological Science* 38, 1502-1510. https://doi.org/10.1016/j.jas.2011.02.014

Richter, K. K., Codlin, M. C., Seabrook, M. and Warinner, C. 2022. A primer for ZooMS applications in archaeology, *Proceedings of the National Academy of Sciences* 119 (20), e2109323119. https://doi.org/10.1073/pnas.2109323119

Ruebens, K., Smith, G. M., Fewlass, H., Sinet-Mathiot, V., Hublin, J. J. and Welker, F. 2023. Neanderthal subsistence, taphonomy and chronology at Salzgitter-Lebenstedt (Germany): a multifaceted analysis of morphologically unidentifiable bone, *Journal of Quaternary Science* 38 (4), 471-487. https://doi.org/10.1002/jqs.3499

Shoulders, M. D. and Raines, R. T. 2009. Collagen structure and stability, *Annual review of biochemistry* 78, 929-951. https://doi.org/10.1146/annurev.biochem.77.032207.120833

Silvestrini, S., Romandini, M., Marciani, G., Arrighi, S., Carrera, L., Fiorini, A., López-García, J. M., Lugli, F., Ranaldo, F., Slon, V., Tassoni, L., Higgins, O. A., Bartolini, E., Curci, A., Meyer, M., Meyer, M. C., Oxilia, G., Zebroni, A., Benazzi, S. and Spinapolice, E. E. 2022a. Integrated multidisciplinary ecological analysis from the Uluzzian settlement at the Uluzzo C Rock Shelter, south-eastern Italy, *Journal of Quaternary Science* 37 (2), 235-256. https://doi.org/10.1002/jqs.3341

Silvestrini, S., Lugli, F., Romandini, M., Real, C., Sommella, E., Salviati, E., Arrighi, S., Bortolini, E., Figus, C., Higgins, O. A., Marciani, G., Oxilia, G., Delpiano, D., Vazzana, A., Piperno, M., Crescenzi, C., Campiglia, P., Collina, C., Spinapolice, E. E. and Benazzi, S. 2022b. Integrating ZooMS and zooarchaeology: New data from the Uluzzian levels of Uluzzo C Rock Shelter, Roccia San Sebastiano cave and Riparo del Broion. *PLOS ONE* 17 (10): e0275614. https://doi.org/10.1371/journal.pone.0275614

Sinet-Mathiot, V., Smith, G. M., Romandini, M., Wilcke, A., Peresani, M., Hublin, J. J. and Welker, F. 2019. Combining ZooMS and zooarchaeology to study Late Pleistocene hominin behaviour at Fumane (Italy), *Scientific Reports* 9 (1), 1-13. https://doi.org/10.1038/s41598-019-48706-z

Stewart, N. A., Gerlach, R. F., Gowland, R. L., Gron, K. J. and Montgomery, J. 2017. Sex determination of human remains from peptides in tooth enamel, *Proceedings of the National Academy of Sciences* 114 (52), 13649-13654. https://doi.org/10.1073/pnas.1714926115

van Doorn, N. L. 2012. *The applications and limitations of a minimally destructive approach to archaeological proteomics,* Department of Archaeology, University of York, PhD thesis.

van Doorn, N. L., Hollund, H. and Collins, M. J. 2011. A novel and non-destructive approach for ZooMS analysis: ammonium bicarbonate buffer extraction, *Archaeological and Anthropological Sciences* 3, 281-289. https://doi.org/10.1007/s12520-011-0067-y

van Doorn, N. L., Wilson, J., Hollund, H., Soressi, M., and Collins, M. J. 2012. Site-specific deamidation of glutamine: a new marker of bone collagen deterioration, *Rapid communications in mass spectrometry* 26 (19), 2319-2327. https://doi.org/10.1002/rcm.6351

Wang, N., Brown, S., Ditchfield, P., Hebestreit, S., Kozilikin, M., Luu, S., Oshan, W., Grimaldi, S., Michael, C., Horwitz, K. L., Spriggs, M., Summerhayes, G., Shunkov, M., Richter, K. K. and Douka K. 2021. Testing the efficacy and comparability of ZooMS protocols on archaeological bone, *Journal of proteomics* 233, 104078. https://doi.org/10.1016/j.jprot.2020.104078

Warinner, C., Richter, K. K. and Collins, M. J. 2022. Paleoproteomics, *Chemical Reviews* 122, 13401-13446. https://doi.org/10.1021%2Facs.chemrev.1c00703

Welker, F. 2018. Palaeoproteomics for human evolution studies, *Quaternary Science Reviews* 190, 137-147. https://doi.org/10.1016/j.quascirev.2018.04.033

Welker, F., Soressi, M., Rendu, W., Hublin, J. J. and Collins, M. 2015. Using ZooMS to identify fragmentary bone from the late Middle/Early Upper Palaeolithic sequence of Les Cottés, France, *Journal of Archaeological Science* 54, 279-286. https://doi.org/10.1016/j.jas.2014.12.010

Welker, F., Hajdinjak, M., Talamo, S., Jaouen, K., Dannemann, M., David, F., Julien, M., Meyer, M., Kelso, J., Barnes, I., Brace, S., Kamminga, P., Fischer, R., Kessler, B. M., Stewart, J. R.,

Pääbo, S, Collins, M. J. and Hublin, J. J. 2016. Palaeoproteomic evidence identifies archaic hominins associated with the Châtelperronian at the Grotte du Renne, *Proceedings of the National Academy of Sciences* 113 (40), 11162-11167. https://doi.org/10.1073/pnas.1605834113

The construction history of the Ledenice castle: application of the archaeology of standing structures

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The remains of the Ledenice castle are situated on the top and the south slope of a hill named Gradina, in the hinterland of Novi Vinodolski, on the southeast rim of the Vinodol valley. The castle is known from written sources at least from the mid-13th century. The castle and the settlement continued to flourish from the 13th till the 16th century, stagnating during the 17th century, to be abandoned through the 18th and 19th centuries. Since 2019, the Department of Art History of the Faculty of Arts in Rijeka, in collaboration with the Croatian Conservation Institute, has been documenting the standing structures. The aim of the project is to document the remaining structures, analyze them, and establish the construction history of this site.

During the 2021 campaign, the remains of the central castle have been surveyed and documented. Using the archeological methodology of the stratigraphy of standing structures, the remains of the castle have been analyzed. Six distinct construction phases have been identified among the standing structures. The earliest one is represented by the remains of a possible church dated to the 12th/13th centuries. That structure was supplemented by the construction of the castle that was enlarged during the next three construction phases, dated from the 13th to the end of the 15th century. The change of the owner, from the noble Frankopan family to the Habsburg Military Frontier, caused new construction changes during the 16th century. The last phase is represented by the physical remains of trenches and pill boxes of the Italian army during World War II. The aim of this paper is to present the results of the structural and field survey of the Ledenice castle and to show the possibilities of the analysis of standing structures in archaeology as one of the noninvasive field methods.

Keywords: *Ledenice castle, archaeological documentation, stratigraphic analysis of standing buildings, medieval castles, Vinodol valley*

Figure 1. Medieval castles in Vinodol valley (from Janeš 2021: 221)

Introduction

The remains of the old town Ledenice are located on the summit and the southern slope of a hill named Gradina, in the hinterland of Novi Vinodolski, on the southeast rim of the Vinodol valley. The architectural remains of the castle and the Ledenice settlement are positioned on a conical elevation situated on the south-eastern rim of the Vinodol Valley (Fig. 1). The site is named Gradina, and the remains of a medieval settlement are spread across an elevation that extends from northwest to southeast. On the very top of the hill, a fortress was built in the Middle Ages, next to which a settlement developed, known from written sources as early as the middle of the 13th century. (Laszowski 1923: 269; Kraljić 1995a: 58).[1]

Methodology

With the aim of documenting the remaining architecture of the old Ledenice, we began the project of recording and documenting the current state of the Ledenice castle. At the outset, its architectural remains were recorded (photographed) in a georeferenced system by an unmanned aerial vehicle. These photographs were used to create a 3D model from which the floor plan of the fortress, cross-sections and views of the remains of all its walls preserved in elevation were obtained. The generated models and photographs formed the basis for making precise drawings of the walls in their current, existing condition and were used for processing using the archaeological structural survey method. It is a non-invasive procedure used to define specific architectural structures of a building (walls, openings, staircases, vaults, etc.) – commonly referred to as stratigraphic units, their archaeological content (building materials, spolia, state of preservation, etc.) and their relationship with other structures (Harris 1989:109-113; 2003: 11). The method involves arranging the observed stratigraphic units into a chronological sequence according to the Harris matrix, which provides insight into construction phases and architectural changes throughout different stages (Harris 2003: 11). In order to contextualize the obtained data, it is necessary to interconnect it with data from other sources, primarily written legal docu-

[1] Stephan from Ledenice was mentioned in a charter from 1248

ments, graphic historical representations and, in areas where this is possible, with the results of archaeological research and archaeometric analyses. This approach is necessary as there are no formal and stylistic elements on the architectural remains which could usually indicate more clearly the construction period (Janeš 2022: 28). However, since this research is based exclusively on the archaeological remains preserved above the ground, it should be kept in mind that the results of the analysis are subject to change, especially if subsequent archaeological excavations take place. Such excavations would then allow for the interpretation of certain structures not only based on the formal characteristics of architecture but on the artifacts of material culture.

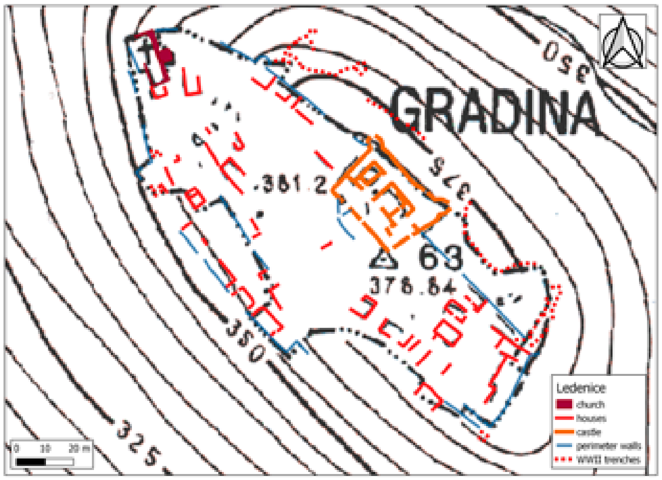

Figure 2. Layout of the Ledenice settlement. (Map by: A. Janeš).

Analysis of architectural remains of the Ledenice castle based on an archaeological structural survey and analysis of historical sources

The core of the Ledenica settlement is the castle located on the highest elevation of the Gradina hill. The north-western part of the top of the hill is made up of prominent, bare rocks that turn into a plain towards the south and southeast (Fig. 2). The architecture of the castle adapts to the rocks and the plain, which is why, we presume, the walking surface was based on at least two levels (Fig. 3). To the east of the castle lies the core of the settlement itself.

The preserved architectural remains of the castle show a significant number of additions and remodeling, indicating construction activity over an extended period. Through stratigraphic analysis, we have identified six construction phases.

Figure 3. Aerial photo of the Ledenice castle. (Photo by: Ruina Ltd).

Figure 4. Ledenice castle: construction phases. (Plans by: Valdir, edited by: A. Janeš).

First phase

Identified as the earliest phase at the castle site are two walls that enclose a rectangular area measuring around 8.5 x 6.5 meters, oriented in the northeast-southwest direction (SU 1001, SU 1005) (Fig. 4: Construction phase (CP) 1). Remains of a vaulted construction in the form of a calotte can be observed on the northern wall. Only the aforementioned south-eastern and northern walls, along with a fragment of a vaulted construction that may have been a part of a smaller semi-circular apse, are currently visible at the site. Judging by the simple floor plan, construction technique, and the presence of an apse, the most likely scenario suggests its identification with a smaller structure that predates the construction of the castle. In the Vinodol area, there are multiple instances of isolated ecclesiastical structures situated on elevations. For instance, the early medieval church located on the site of the present-day chapel of Sts. Cosmas and Damian, at the Sopalj site between Dramalj and Tribalj. There are also those positioned on elevations, near settlements, such as the Romanesque church of St. George atop the highest peak of Kotor hill, overlooking the settlement of Kotor. This construction phase can be tentatively attributed to either the 12th century or the first half of the 13th century. Even though there are no surviving written records for this period, the stratigraphy of the walls suggests that the structure is older than the castle.

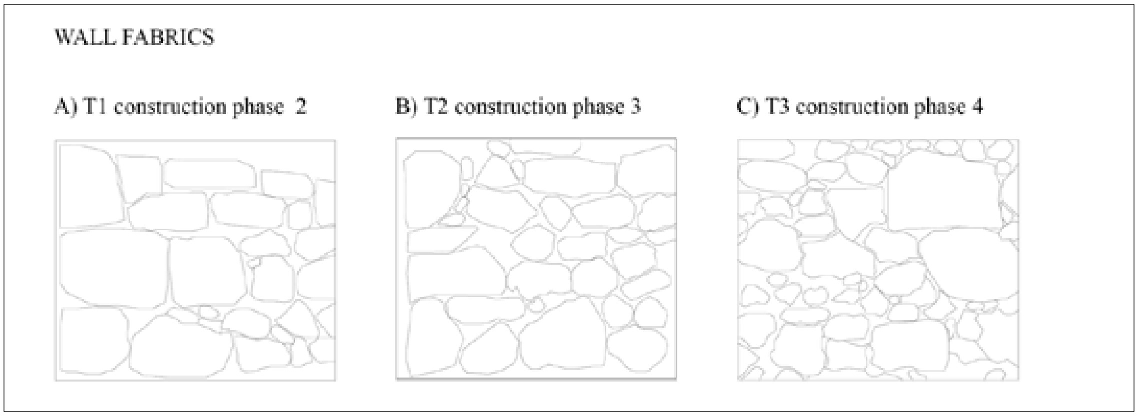

Figure 5. Typology of masonry fabrics of Ledenice castle. (Made by: A. Janeš).

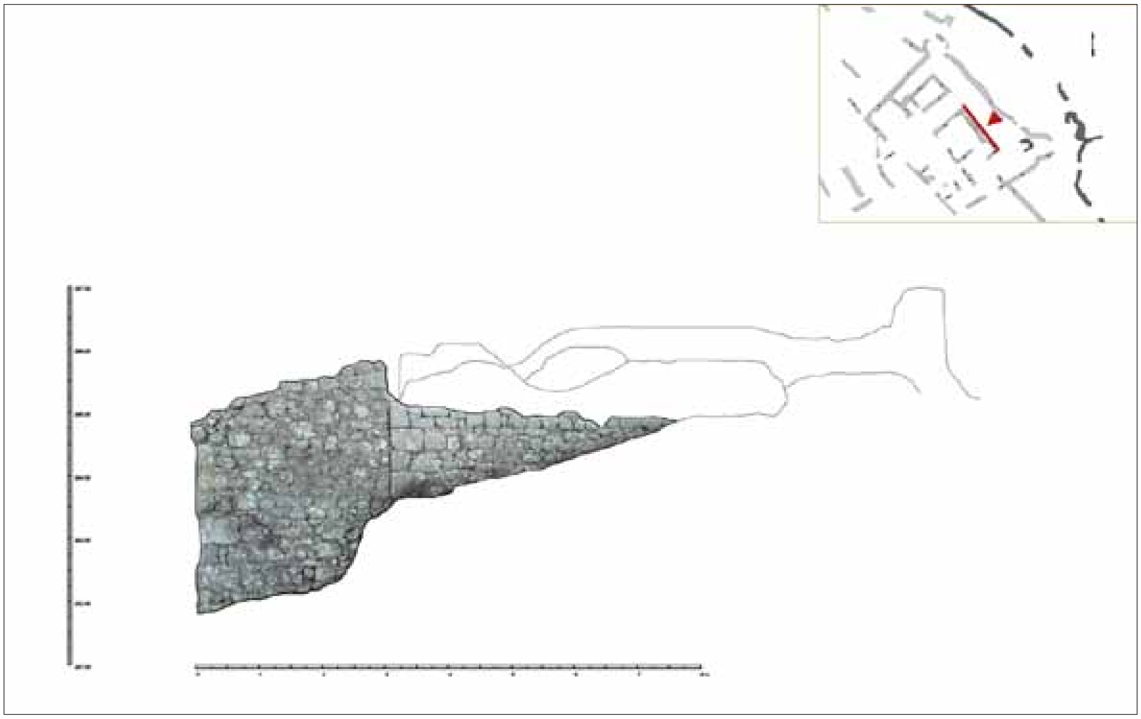

Figure 6. Masonry fabric of walls SU 1002 (CP2) and SU 1003 (CP3). (Plan by: Valdir).

Second phase: first half/mid-13th cent. to the 1320s; construction of the initial defensive tower castle

The following construction phase of the Ledenice castle includes at least three walls that, along with the walls of the „apse-like" structure, enclose a square-shaped area measuring approximately 8.5 x 8.5 meters (SU 1002, SU 1006, SU 1007) (Fig. 4: CP 2). The walls of this phase differ from those of the previous phase as they are thicker, made of regular cut stones and are arranged in orderly rows with prominent cut cornerstones alternating between the short and long sides (Fig. 5A: T1; Fig. 6). We find analogies in construction techniques in the walls of the first phase of the Gradec castle and Fortičina (Omišalj) on the island of Krk, which date to the early 13th century (Starac and Višnjić 2018a: 92-96; 2018b: 102-104).[2]

According to R. Matejčić, the initial set of medieval fortifications in the Vinodol municipalities were built in the first half of the 13th century, during or shortly after the Mongol invasion (Matejčić 1988: 255-256).[3]

[2] In the Primorje region this type of construction is connected to the fact that the masons were familiar with Roman building techniques (Horvat 2010: 46).

[3] For other Vinodol examples see: Horvat 2010: 48.

As examples, she mentions the castles in Trsat, Grobnik, and Bribir, which preserve the remains of a prismatic tower, known as a ”turanj”, characteristic of the Romanesque defensive architecture of the Kvarner region.

The mentioned remains of the walls from the second 2nd phase could therefore, due to their square plan and construction technique, be parts of such a tower. In the first phase of Petrapilosa in Istria, which predates the 13th century, the castle consisted of a single rectangular defensive tower, constructed using a technique similar to that of the Ledenice castle. The courtyard, enclosed by ramparts on three sides due to steep cliffs, contained several smaller buildings.

Besides the castle, there are other significant construction activities in Ledenice which can be dated back to the 13th century, for example, the construction of the parish church of St. Stephen the Protomartyr and the cemetery church of St. George, both of which exhibit formal architectural traits typical of the 13th century (Matejčić 1988: 250-251; Starac 2000: 60-63).

Third phase: 1320s – mid-15th century; restoration and expansion of the original castle, which likely suffered partial damage in the earthquake of 1321

Based on the archaeological structural survey, we have determined that the architectural remains of the next phase – the 3rd phase of the Ledenice castle, consists of a series of walls that connect to the square tower in the north, northwest, and south directions (Fig. 4: CP 3). In addition to the spatial expansion, there is also an observable shift in the construction technique – smaller stones with rougher finishes are used, but they are also arranged in orderly rows with chiselled corners alternating on the shorter and longer sides (Fig. 5B: T2). Through these interventions, the original defensive tower is expanded, and adjacent to it, an elongated rectangular space is built on its northwest side, with at least one floor and wall openings (SU 1003, SU 1004, SU 1008-1010, SU 1012, SU 1013, SU 1015-1017, SU 1021, SU 1023-1025). Thanks to the photographs of the western facade of the structure and the results of their processing, we have determined that a square corner space, with at least one floor and multiple wall openings, was constructed on the western side of the castle. The opening on the ground floor still offers a view on the entire settlement, the coast, and the Vinodol hinterland from Senj to Kraljevica. Based on its shape and position relative to the other structures, we presume that this is another defensive tower (Fig. 7).

From the tower in the direction of northwest to southeast, a wall has been preserved, which, based on its position and its comparison with cartographic representations, can be defined as the perimeter wall of the castle, which encloses a rectangular courtyard in its central part. That is the wall of the entrance to the castle, as seen marked on the above mentioned historical maps. Despite an *in situ* inspection, its remains could not be observed today. On the 1844 map, on the outer left side of the entrance, there was a structure resembling a barbican whose function was protecting the entrance to the castle. It is highly likely that the barbican was used as a foundation of a bunker during the Second World War, the remains of which are still visible today. There is a significant difference in the levels between the courtyard’s walking surface and the foundation of the perimeter wall, which is why we presume that there was a ramp or a similar structure leading to the entrance of the castle.

Within the courtyard area, a well is marked on the maps, where it remains to this day. Its circular opening is surrounded by finely crafted chiselled stones. The placement of these stones also indicates the difference in the elevation of the courtyard’s walking area, which is higher than that of the exterior level, yet lower than the foundation of the initial defensive tower and the northern part of the fortress – which is also indicated in Stier’s map. The representation includes a marked pathway that starts from the entrance of the fortress and goes through the courtyard, where it traverses in a „roundabout manner“ leading to the original defensive tower on its eastern side. Nevertheless, we presume that the tower was directly connected to the courtyard, possibly via a staircase or a comparable structure. A clear line of the lintel of the opening, which can still be observed today, is oriented southwards towards the courtyard.

The castle’s south-eastern tracts of its perimeter wall are also preserved from the 3rd phase. In one place, from the inside, there is a sequence of five irregular holes all at the same height, and below them, another sequence of small holes forming a rectangular shape, possibly indicating the remains of openings for wooden consoles – supporting elements of the floor structure. Just above, there are traces of a window that extended almost to the floor, most likely serving as a source of light.[4] Based on its position and construction technique, we assume that here, as well as on the opposite side, there was an

[4] The window was walled-up in the 5th phase and is preserved till today.

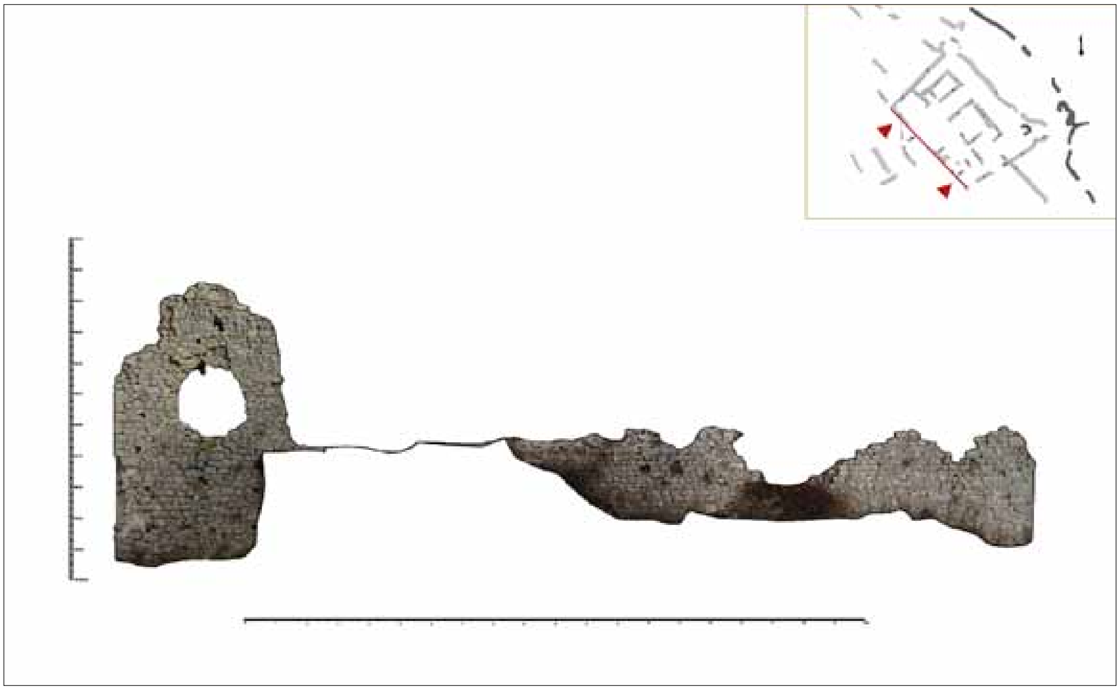

Figure 7. Walls SU 1016 and 1017. (Plan by: Valdir).

elongated rectangular space with at least one floor. In the continuation of the wall, above the ground, there are preserved remains of two more walls which form a right angle. A single arrow slit is preserved in the wall that stretches from northwest to southeast, which means that the wall served as the northern perimeter wall of the fortress during the 3rd phase.

It is, therefore, a castle of an irregular quadrilateral plan, with a courtyard on its west side, two square towers, and several accompanying structures that, given the presence of windows, could have served for residential purposes. There is no structure here that could be identified as a ”typical“ palas – a self-contained, multi-floor structure of residential and representative character, akin to those in Gradec, Grobnik, or Trsat. However, it is more likely that multiple areas of the fortress, especially those situated on the first floor, could have taken that function.

When and under what circumstances could the construction interventions of the 3rd phase have taken place? According to Matejčić, a section of the initial Vinodol fortifications (built in the first half of the 13th century) must have suffered damage in the 1321 earthquake (Matejčić 1988: 256-257). A part of these existing structures, such as Ledenice, was most likely restored through the mediation of the Krk counts, while some, like Badanj, were abandoned. It is our opinion that the refurbishment and the extension of the Ledenice castle during that period can be linked to the presence of the Krk count’s representatives – Friks, the Ledenice viscount, as attested by two documents from 1354. and 1359 (Laszowski 1923: 270).[5] Evidence supporting the assumption of the existence of a single, larger architectural complex can be found in the interpretation of the term used to refer to Ledenice in the marriage contract between its subsequent owners, Count Ivan V and Ana Gorička from 1364, in which Ivan pledges to her the *Schloss Ledenice* and *Dorff Grižane* (Janeš 2021: 226).

The construction of the 3rd phase of the Ledenice castle should be, therefore, attributed to the period following the earthquake of 1321.

The assumption is that the restoration-expansion of the castle was funded by the Krk counts, and the presence of their representative – a viscount, has been confirmed in Ledenice (Laszowski 1923: 270). The castle was expanded with another defensive tower, a residential area, and a courtyard, elements typical of the fortification architecture of the High Middle Ages.

[5] *Frixonus vicecomes Ledinicçe*; Laszowski, 1923, 270.

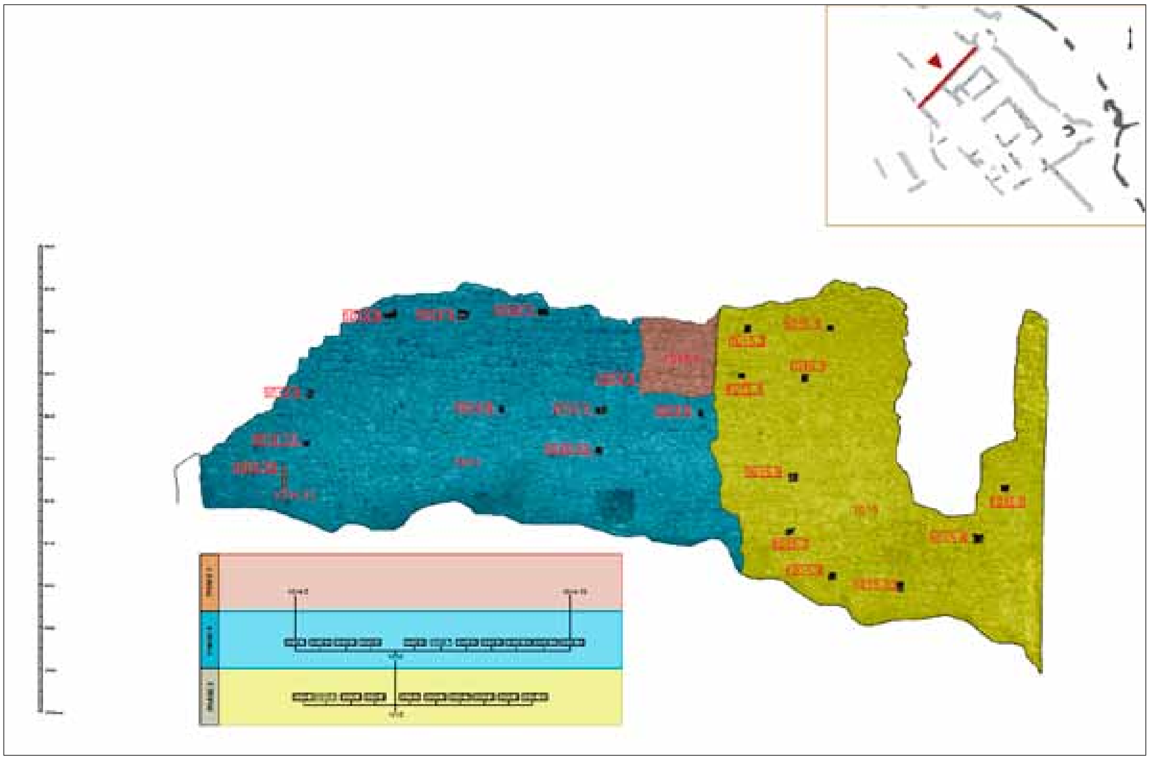

Figure 8. Stratigraphy of the western façade of walls SU 1014 and 1015. (Plan by: Valdir, edited by: A. Janeš).

Fourth phase

The fourth phase encompasses the extension of walls on the north, northeast and east side in relation to the 3rd phase of the castle (Fig. 4: CP 4). It is a narrow, elongated space that now connects the western defensive tower and the central part of the castle, as well as the northern and north-eastern perimeter ramparts with two corner semi-circular towers (SU 1014, SU 1026-1029; Fig. 5: T3). The configuration is to a large extent adapted to the topography of that particular area of the hill. They were built using roughly shaped stones arranged in relatively regular lines. Today, in the narrow space there are remains of a stub of a vaulted construction with a pointed cross-section, above which there are slots for the wooden beams of the floor structure. Below the stub of the north-eastern wall's vault, there are remains of openings. There was a passage between the vaulted room, the guard tower, and the central part of the castle, as suggested by the remains of former openings. On the ”new“ perimeter walls, there are three preserved elongated rectangular loopholes in shallow rectangular niches.

We observe that even in this phase, a separate palas building was not constructed, but that the rooms located on the first floor of the northern, north-eastern, and south-eastern parts, with the presence of windows, could had still have been used as living quarters.

In relation to the dating of this phase, the introduction of the structural element of the pointed arch indicates the period of the 15th century, along with the presence of simple rectangular loopholes.[6] In a similar fashion, the fortification of the Grobnik castle included the construction of two additional perimeter walls and semi-circular towers during the period between the 15th and 17th centuries (Miculinić 1988: 158-159).

This phase of the Ledenice castle is associated with Dujam IV of Slunj (1416-1487), who resided in Ledenice, which could explain the expansion of the residential part of the castle in the north-west (Laszowski 1923: 270; Kraljić 1995b: 28-29).

It is also a period of an increasing Ottoman threat and the formation of the 1463 Banates of Jajce and Srebrenik, as well as the establishment of the Captaincy of Senj in 1469 (Moačanin & Holjevac 2007: 12), which could explain the need for additional fortifications, the construction of the two semicircular towers and ramparts.

During the first half of the 16th century, the Ottomans penetrated the regions of Lika and Primorje (Kruhek 1995: 89). At that time in Ledenice, there were already four

6 For 15th century types of loopholes. Horvat 2014: 382.

recorded members of the imperial-frontier army. Later, that number rose to 10. Laszowski believes that even then, Ledenice castle, where the frontier garrison was situated, was already expropriated from the Frankopan family as a castle and territory of the Captaincy of Senj (Laszowski 1923: 273). The following period was once again marked by sieges of Ledenice, first by the Ottoman troops (1577), and subsequently by the Venetian siege (1600). From the correspondence of Ledenice captains with King Ferdinand and the Military Frontier administration, it is known that there are 10 soldiers residing in the town at the moment, that the settlement infrastructure is in poor condition, and that financial assistance is necessary for its defence (Laszowski 1923: 273-274, 278-280). The provided information can be connected to the 5th phase of the Ledenice castle. There are no recorded additions or renovations, only the walling up of its big openings – we assume for better safeguarding (Fig. 8). The focus, we presume, after the two sieges in the late 16th and the early 17th century, had to be on the defence of the town in its entirety, leading to the construction of ramparts encircling the entire settlement. As a *terminus ante quem* of the ramparts construction, we can take the Ledenice plan from M. Stier's 1664 manuscript which depicts the entire town surrounded by ramparts (Karković Takalić and Janeš 2022).

The final construction phase of the castle consists of defensive objects and structures built by the Italian army during the World War II: a bunker created at the site of the medieval barbican, right next to the entrance to the fortress; another square bunker located at the southern corner of the ramparts, etc.

Concluding remarks

By conducting research on the preserved architecture of the Ledenice castle, we have identified, based on the analysis of formal structural characteristics (construction techniques, architectural elements) and their relations (stratigraphy), that there were six construction phases, connected to historical events of the broader Vinodol area: the transfer of the Vinodol property into the possession of the Krk counts, the Vinodol earthquake, the transfer of the Vinodol property under the administration of the Slunj branch of the Frankopan family, its subsequent administration by the Captaincy of Senj, sieges of Ledenice by the Ottoman and Venetian forces, and the presence of historical figures such as Viscount Friksa and Dujam IV of Slunj, whose presence in Ledenice is documented in written sources. The implementation of the archaeology of architecture has made it possible to dissect specific stratigraphic and constructional phases, which are chronologically defined based on written sources. This non-invasive method, if circumstances permit, should be supplemented with archaeological excavations and movable archaeological materials, which would either determine, complement, or rectify prior findings.

Translation: Marija Marić

References

Harris, E. C. 1989, *Načela arheološke stratigrafije*, Ljubljana.

Harris, E. C. 2003. The Stratigraphy of Standing Structures, *Archeologia dell' Architettura* VIII, 9-14.

Horvat, Z. 2010. Stilska stratigrafija burgova 13.-15. stoljeća u kontinentalnoj Hrvatskoj, *Prostor* 18, 42-61.

Horvat, Z. 2014. Pseudokašteli kraja 15. i prve polovine 16. stoljeća u obrani od Turaka, In: M. Karbić, H. Kekez, A. Novak and Z. Horvat (eds), *Ascendere historiam. Zbornik u čast Milana Kruheka*, 371-398.

Janeš, A. 2021. The Castle Estate: A Self-sufficient or Dependent Economy - the Case Study of Grižane Castle in the Vinodol Valley, *Castrum bene* 16, 219-234.

Janeš, A. 2022. The use of archaeological structural survey and the analysis of standing structures on medieval castles, In: I. Miloglav (ed.), *Proceedings of the 8th and 9th scientific conference Methodology and Archaeometry*, 25-35. https://doi.org/10.17234/METARH.2022.03

Karković Takalić, P. and Janeš, A. 2022. Promjene u arhitekturi ledeničke utvrde "na granici" srednjeg i novog vijeka, In: N. Belošević (ed.), *Migracije, granice i kontekst u razvoju kasnoantičke i srednjovjekovne umjetnosti*, Sveučilište u Rijeci, Rijeka, 143-175.

Kraljić, J. P. 1995a. Povijest Ledenice* do godine 1871. (1. dio), *Dometi* 1-6, 55-59.

Kraljić, J. P. 1995b. Povijest Ledenice* do godine 1871. (2. dio), *Dometi* 7-12, 26-49.

Kruhek, M. 1995. *Krajiške utvrde i obrana hrvatskog kraljevstva tijekom 16. stoljeća*, Institut za suvremenu povijest, Monografije i studije, Knjiga 1, Zagreb.

Laszowski, E. 1923. *Gorski kotar i Vinodol: dio državine knezova Frankopana i Zrinskih: mjestopisne i povijesne crtice*, Matica hrvatska, Zagreb.

Matejčić, R. 1988. Sakralna i profana arhitektura na području stare župe Vinodol, *Vinodolski zbornik* 5, 249-281.

Miculinić, S. 1988. Grad Grobnik, *Grobnički zbornik* 1, 119-161.

Moačanin, N. and Holjevac, Ž. 2007. *Hrvatsko-slavonska Vojna krajina i Hrvati pod vlašću Osmanskoga Carstva u ranome novom vijeku*, Leykam International d.o.o.

Starac, R. 2000. Sakralna kultura srednjovjekovnog Vinodola, *Senjski zbornik* 27, 45-95.

Starac, R. and Višnjić, J. 2018a. Gradec-Rovoznik, In: I. Srdoč-Konestra and S. Potočnjak (eds.), *Putovima Frankopana*, Primorsko-goranska županija, Sveučilište u Rijeci, Filozofski fakultet, 94-99.

Starac, R., Višnjić, J. 2018b, Omišalj-Fortičina, in: Srdoč-Konestra, I, Potočnjak, S. (eds.), *Putovima Frankopana*, Primorsko-goranska županija, Sveučilište u Rijeci, Filozofski fakultet, 102-104.

Sickle Gloss on Artefacts recovered at the Galovo Site in Slavonski Brod and the Dužine Site in Zadubravlje

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This paper discusses finds of knapped chert from the Galovo site in Slavonski Brod and the Dužine site in Zadubravlje on which functional analysis identified sickle gloss. The two sites are 15 km apart, both located in the proximity of Slavonski Brod in the Brodska Posavina region [the Sava River basin in the Slavonski Brod area]. The Starčevo horizon of the Galovo site has been dated to 6100 to 5000 cal BC, while finds recovered from the ploughed layer and immediately beneath it are attributed to a later Late Bronze Age horizon of the Barice-Gređani group. The Zadubravlje site corresponds to the Starčevo Culture and is dated from 6000 to 5000 cal BC. Various phases of the formation of sickle gloss were identified on 19 blades, blade fragments or blade tools from the Galovo site, and a truncated bladelet and a flake from the Zadubravlje site. The distribution of gloss on individual specimens at these sites exhibits the characteristic appearance of harvesting tools.

Keywords: *Neolithic, agriculture, use-wear analysis, sickle gloss, Starčevo Culture*

Introduction

The early neolithic Starčevo Culture is a part of the Starčevo-Körös-Criş cultural group, which encompasses the Proto-Sesklo Culture, the Anzabegovo-Vršnik Culture, and the Čavdar-Kremikovci-Karanovo Culture (Minichreiter 2007: 14). Its distribution over a vast area as well as an insufficient number of explored settlements institutes problems in chronology (Šošić Klindžić and Hršak 2014). The settlements are mostly single-layered, and chronologies are usually based on decorated pottery and painting on pottery as well as on smaller geological areas (Šošić Klindžić and Hršak 2014). The beginning of the neolithic in the Brodska Posavina region is represented by Starčevo Culture. For Starčevo Culture in Croatia the chronology of S. Dimitrijević, later modified by K. Minichreiter, is used (Minichreiter 2007: 14).

Functional analysis of finds exhibiting sickle gloss is important for the interpretation of neolithic archaeological material. Sickle gloss appears on artefacts used to cut silica-rich plants, such as domesticated cereals and other grasses, bulrush, and marsh-elder (Vaughan 1985: 35-37). Highly developed gloss is visible to the naked eye while observing less pronounced gloss requires the use of a microscope. The presence of macroscopically inferred gloss must be confirmed by microscopic analysis, because gloss visible to the naked eye may be the result of contamination with present-day materials, such as adhesive applied when assigning call numbers, natural processes that acted on a tool, or the result of the use of a tool on other materials as well as post-depositional surface modification (PDSM). Microscopic analysis can rule out other factors that may have led to its formation.

This paper discusses the examination of knapped lithic material and the performance of microscopic analysis of use-wear traces of finds recovered from the Galovo site in Slavonski Brod and the Dužine site in Zadubravlje to determine the activities that were performed at these sites. In prehistoric and later periods, the selected sites - situated in the Brodska Posavina region (the Sava River basin in the Slavonski Brod area) - were one of the more vital hubs of transport routes. The eastern settlement in Slavonski Brod was situated at Osječka street, within the grounds of the brickworks, on the Galovo land plot, and was discovered in 1995 (Minichreiter 2007). The archaeological site at Dužine in Zadubravlje has been known since 1989 and lies 15 km from Galovo. Alongside Galovo and Dužine there are other Starčevo sites in Slavonski Brod (Minichreiter 2007). The vicinity of multiple contemporaneous settlements is characteristic of the Starčevo Culture (Minichreiter 1992a: 37; Šošić Klindžić 2010: 197). Both sites discussed in this paper are from the Linear A phase of the Starčevo Culture[1], while at Galovo there is also a more recent layer that corresponds to the Barice-Gređani cultural group. The absolute date of the site at Zadubravlje puts the settlement in the period between approximately 6000[2] and 5000 cal BC (Krajcar Bronić 2011: 183). At Galovo there are visible three Starčevo Culture settlement phases, with absolute dates between 6100 to 5000 cal BC (Krajcar Bronić 2011: 182). The Starčevo Culture settlements at Galovo and Zadubravlje were founded at a small geographic distance from one another and are mutually almost contemporaneous, which points to the interaction and coexistence of their inhabitants.

Structures were found at both sites related to production and daily life, including pit houses (both dwellings and those used for work activities), and structures on posts of unknown purpose. We do not see grave pits at the Dužine site in Zadubravlje, but we do see pits of small dimensions and specific inventories, such as the three-lobed Pit 22. The sites present an abundance of knapped lithic material in almost all phases of production. Functional analysis of knapped lithics was performed to compare activities performed in Starčevo Culture settlements that coexisted in the same area over a period of about 1 000 years[3].

Lithic analysis of finds from the grave pit SU 15/16 (Šošić 2007: 176-188), the working pit SU 291/292 (Bunčić 2009: 291-308) and the grave pit SJ 9/10 (Šošić Klindžić 2010) has been from Slavonski Brod – Galovo has been conducted. SU 14, 17, 19, 20, 23, 25, 27, 30 and 31 have as well been analysed but it is not certain if these finds can be related to the Starčevo Culture (Šošić Klindžić 2010: 148-151). The lithic analysis of the finds from Dužine in Zadubravlje was performed in 2009. and it included typological analysis, the analysis of raw materials as well as spatial analysis (Karavanić et al. 2009).

No traceological analysis[4] was performed on the lithic assemblage on these sites. This preliminary analysis of use-wear traces on lithic artefacts from Slavonski Brod opens the gate to further exploration of lithic industries as well as other everyday activities performed there.

Sickle gloss analysis of artefacts from these sites provides insight into the appearance of sickles and agricultural activity. Sickle gloss was confirmed on 19 artefacts recovered from Galovo and on two artefacts recovered from Zadubravlje in different contexts within the settlements.

The finds recovered from the Starčevo Culture strata in the settlements at Zadubravlje and Galovo (Minichreiter 2007) exhibit features of all aspects of the Neolithic package (see Childe 1958, but also Zvelebil 2002; Çilingiroğlu

[1] After Dimitrijević.
[2] Where the earliest date of 6600 cal BC was not considered (Krajcar Bronić 2011).
[3] The analysis was performed for unfinished PhD thesis *Rekonstrukcija svakodnevnih djelatnosti u naseljima starčevačke kulture analizom tragova uporabe lomljenoga kamenoga oruđa*.
[4] Excluding the commentary on 9 blades from SU 15/16 (Šoršić Klindžić 2010) and 2 blades from SU 291/292 (Bunčić 2009) that was given based on macroscopic observation.

2005; McCarter 2007; Shennan 2018; Nowak 2022), the biggest issue, however, is proving the presence of organised agriculture. In archaeological terms demonstrating the presence of early agriculture is relatively difficult. A small number of fossilized seeds were found at Zadubravlje[5] (Đukić 2014: 158), while no plant remains were found at Galovo. Neolithic cereals were found in Starčevo Culture contexts at the Sopot and Tomašanci-Palača sites (Reed 2014; 2015; 2020.). The sickle, i.e., sickle gloss on knapped stone tools, constitutes indirect evidence. Sickle gloss develops as the result of cutting plants like those from the *Gramineae* (domesticated cereals and other grasses, e.g., barley), *Typhaceae* (e.g., bulrush) and *Compositae* (e.g., marsh-elder) families (Vaughan 1985: 35-37). The objective of this paper is to establish the presence of sickle gloss on knapped stone artefacts at the Zadubravlje and Galovo sites. Although sickle gloss has at times been posited as present on finds recovered from other Neolithic period sites in Croatia on the basis of macroscopic examination (e.g., Forenbaher 2008; Šošić Klindžić 2010), functional analysis of use-wear traces on knapped lithic tools is scarce. Some of the exceptions are the use-wear analysis of the Dalmatian site Crno Vrilo (Kačar and Philibert 2022), and the analysis of artefacts with sickle gloss found on Dalmatian sites (Forenbaher 2008; Mazzucco et al. 2018), as well as analysis of the Palaeolithic period material recovered from the Mujina pećina (cave) site (Petru 2020). Continued work on functional analysis and the interpretation of use-wear traces is an essential source of new insight into knapped lithics from what Croatia is now.

Materials and Methods

This article includes the lithic assembly from the Galovo site excavated between 1997 and 2015. A total of 17606 finds were examined. Not all of the finds can be associated with certainty to Starčevo Culture, but all were examined for traces of wear. The lithic assembly of 17117 chert fragments originates from the Starčevo cultural horizons. A relatively small count of 19 artefacts used to cut cereals can be due to the presence of all the phases of chaîne opératoire that were present on site.

[5] The seeds were not further analysed.

In the assemblage of 5274 chert finds from Zadubravlje (Minichreiter 1992a: 35) use-wear from cutting cereals was observed on only two artefacts. It is essential to note that 80,33% of the finds can be characterised as “workshop assemblage” (Karavanić et al. 2009).

Nineteen blades, blade fragments, and tools on a blade from Galovo[6], and a truncated bladelet[7] ad a flake[8] from Zadubravlje, were isolated in the course of the functional analysis of the knapped lithic material as exhibiting sickle gloss[9] in its various phases of formation (Tab. 1).

All the finds exhibiting sickle gloss on the site of Galovo are blades and blade fragments. The entirety of the assemblage of finds exhibiting sickle gloss from this site consists of blades and tools created on blades; not retouched blades appear in eight cases (42.1%), there are two not retouched fragments of blades (10.5%), and seven truncated blades (36.8%), while one retouched blade and one trapeze each account for 5.3% of the total number of finds exhibiting sickle gloss. The observed damage is manifested as sickle gloss, edge rounding, and comet-shaped striations, visible both dorsally and ventrally, with an emphasis on the flat dorsal side. Functional analysis implies macroscopic and microscopic analysis of a tool’s surface and is aimed at determining its purpose. It includes macroscopic examination with

[6] The artefacts are relatively small with an average length of 3.02 cm, width of 1.26 cm, thickness of 0.83 cm, and weight of 1.76 g.

[7] 1.98 cm long, 1 cm wide, 0.33 cm tick and 0.7 g in weight

[8] 2.82 cm long, 1.5 cm wide, 0.45 cm tick and 2.1 g in weight

[9] Sickle gloss is a characteristic wear trace present on tools used to cut silica-rich plants of the *Gramineae* (domesticated cereals and other grasses), *Typhaceae* (e.g., bulrush) and *Compositae* (e.g., marsh-elder) families. To the naked eye, it is recognisable as a high “wet” sheen that extends from the working edge and runs across much of a tool’s surface. Sickle gloss is formed over an extended period, developing from small gloss-covered areas to coating the entire working edge, at times even the whole tool. Viewed microscopically, sickle gloss - in its most developed form - exhibits comet-shaped striations, pronounced rounding of the edge, and a dense, uniform, bright and “wet” surface sheen.
The formation of sickle gloss can be observed with a microscope. Sickle gloss is developed when silica compounds from the processed material meet the surface of the tool and, with the evaporation of water, adhere to it (Anderson 1980: 183-185). The speed at which the gloss develops is very slow and depends on the number of silica compounds and water in the plants being processed. Thus, grasses such as barley will develop lustre the fastest, and fresh plants will develop lustre faster than dry ones (Anderson 1980: 183; Vaughan 1985: 35). The gloss formed by the cutting of plants is very bright, shining from the surface of a tool and extending deep into its surface (Semenov 1964; Vaughan 1985: 36). Striations and comet-shaped pits often appear. These consist of a pit and a striation extending out from it and occur due to the non-uniformity of a tool’s surface (Semenov 1964; Vaughan 1985: 36).

SF	Description	SU	Location of use-wear traces	Activity / sickle gloss phase	Worked material
G97 1293	Blade, grainy yellow chert	?	Right lateral edge towards the distal edge	Cutting / sickle gloss Ph.3	silicious plant - cereal
G99 391-10	Truncated blade, brown chert	3	Left lateral edge towards the distal edge	Cutting / sickle gloss Ph.4	silicious plant - cereal
G99 414-18	Fragment of a truncated blade, brown chert	3	Left lateral edge towards the proximal edge	Cutting / sickle gloss Ph.2	silicious plant - cereal
G01 663-5	Blade, light brown/ reddish chert	108	Left lateral edge distally and distal edge	Cutting / sickle gloss Ph.5	silicious plant - cereal
G02 1254-22	Blade, translucent white chert	154	Right lateral edge distally and distal edge	Cutting / sickle gloss Ph.2	silicious plant - cereal
G02 1302-25	Blade, grey/brown chert	156	Left lateral edge distally and distal edge	Cutting / sickle gloss Ph.5	silicious plant - cereal
G02 1305-12	Fragment of a blade, white chert	156	Right lateral edge distally and distal edge	Cutting / sickle gloss Ph.3	silicious plant - cereal
G02 1411-25	Truncated blade, light brown/reddish chert	206	Left lateral edge distally and distal edge	Cutting / sickle gloss Ph.5	silicious plant - cereal
G03 1713-39	Truncated blade, light yellow chert	154	Left lateral edge and distal edge	Cutting / sickle gloss Ph.4	silicious plant - cereal
G07 441-6	Blade, white chert with burn traces	980	Left lateral edge and distal edge	Cutting / sickle gloss Ph.4	silicious plant - cereal
G08 479-3	Blade, light brown/ reddish chert	4	Left lateral, proximal, and distal edges	Cutting / sickle gloss Ph.5	silicious plant - cereal
G08 483-4	Blade, light brown/ reddish chert	4	Right lateral edge and distal edge	Cutting / sickle gloss Ph.2	silicious plant - cereal
G09 556-3	Fragment of a blade, brown chert	3	Right lateral edge and distal edge	Cutting / sickle gloss Ph.5	silicious plant - cereal
G09 564-32	Blade, brown chert	3	Left lateral edge and distal edge	Cutting / sickle gloss Ph.5	silicious plant - cereal
G10 578	Blade, white chert	4	Left lateral edge and distal edge	Cutting / sickle gloss Ph.3	silicious plant - cereal

SF	Description	SU	Location of use-wear traces	Activity / sickle gloss phase	Worked material
G10 610	Truncated blade, yellow chert	2013	Left lateral edge and distal edge	Cutting / sickle gloss Ph.3	silicious plant - cereal
G11 703	Fragment of a blade with alternating retouch and truncation, dark brown chert	2243	Left lateral edge and proximal edge	Cutting/ sickle gloss Ph.4	silicious plant - cereal
G11 721	Truncated blade, brown chert	2243	Distal edge	Cutting / sickle gloss Ph.2	silicious plant - cereal
G12 763	Trapeze, white chert	2621	Right lateral edge and proximal edge	Cutting / sickle gloss Ph.3	silicious plant - cereal
ZA DU 179a	Truncated bladelet, light brown/reddish chert	Pit 8J	Left lateral edge distally and distal edge to the left	Cutting / sickle gloss Ph.3	silicious plant - cereal
ZA DU 333	Flake, light brown/ reddish chert	Pit 22	Left and right lateral edges and distal edge	Cutting / sickle gloss Ph.5	silicious plant - cereal

Table 1. Finds exhibiting sickle gloss from the Galovo site in Slavonski Brod and Dužine site in Zadubravlje

the naked eye and low-magnification loupes, microscopic examination, with a metallurgical microscope, usually at magnifications of from 100× to 400× and using SEM at various factors of magnification.[10] The work described here involved the use of an AmScope ME300TZB-2L-9M 40× to 2000× metallurgical trinocular microscope with 10× magnification at the objective and 20× at the eyepiece. Photographs were taken with an Olympus E-500 camera with a trinocular microscope photo eyepiece mount without additional magnification, as well as, in three cases,[11] with the original 9MP digital camera and were processed with the CombineZP software package to achieve depth of field. SEM imaging was performed at the INA laboratories[12] at 1200× magnification.

The archaeological material was compared against four experimental fragments of brown Slavonian chert, which correspond to the raw material of a part of the analysed finds. The experimental fragments were inserted into a wooden handle and were used to cut wild grasses and cereals in the spring, and ripe wheat in the summer. The more pronounced results were produced by the cutting of ripe wheat. Two experimental specimens were inserted, without adhesive, into a curved piece of wood. After two and a half hours of use an intensive sickle gloss formed at the working edge, while fine chipping appeared at the opposite edge. The process of the formation of the gloss was monitored under a microscope and was consistent with the phases of formation as described on the archaeological material later on. The specimen was imaged with a metallurgical microscope at 200× magnification, and under an SEM at 1200× magnification (Fig. 1).

The experimentally obtained gloss corresponds to the gloss identified on archaeological material and the published reference collections (Keeley 1980; Vaughan 1985; Van Gjin 2010; Bogosavljević Petrović 2016; Bogosavljević Petrović et al. 2017). Vaughan (1985: 36) described three phases in the formation of sickle gloss: generic weak polish, smooth pitted polish, and well-developed polish. In

[10] SEM provided high quality photographs in larger magnifications (up to 2400x)
[11] Fig. 4b, Fig. 7b and Fig. 15b
[12] Imaged by Mario Matošević

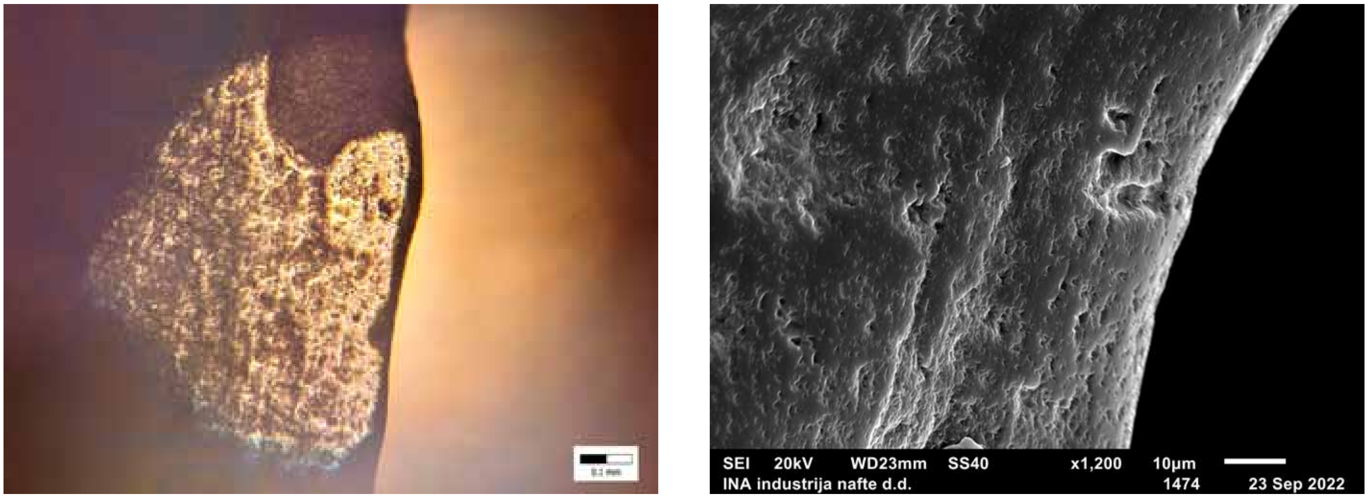


Figure 1. Sickle gloss on tools from the reference collection at 200× magnification under a metallurgical microscope(a) and at 1200× under an SEM (b).

the production of this paper, there were five discernible phases in the formation of sickle gloss visible at 200× magnification. Differences, namely, in the appearance of damage that corresponds to Vaughan's second phase were shown to be very prominent, prompting a finer discrimination. The first phase of sickle gloss corresponds to Vaughan's generic weak polish and cannot be differentiated from glosses formed in the initial phases of use on other materials. Consequently, this paper does not cover finds exhibiting damage from the first phase of sickle gloss formation. In the second phase the gloss develops at the highest points on the tool surface, there is no linkage between the highly glossy elevated spots, and the lower parts show more topography while being soft and rounded. In the experiment the second phase of use-wear traces developed after about 45 minutes of working. In the third phase high spots merge, forming a network. The characteristics of traces stayed the same as in phase two, but elevated spots developed further "covering" the lower parts of the tool surface. It developed after about 1 hour and a half of cutting cereals. The fourth phase in the development of sickle gloss is characterised by pitting that appears in the developed gloss. The surface is mostly elevated, smooth and pitted with smaller areas of lower softly rounded, with more pronounced topography. It developed in the next 45 minutes of work. These three phases correspond with Vaughan's smooth pitted polish. They can be recognised as the early phases of the formation of sickle gloss. The fifth phase is a well-developed, dense, transparent gloss that covers the working edge and deep into the surface of the tool. It corresponds to Vaughan's final phase. It developed in the final stages of the experiment. In this phase, grooves along the rounded edge started appearing. These grooves are due to the same motion of cutting individual strains of cereals (Bogosavljević Petrović et al. 2017: 38). Along with the gloss, from the second phase on we also see the appearance of comet-shaped striations, where the "tail" indicates the orientation of use. We also see pronounced edge rounding. There is fine chipping present on some specimens, less frequent on the working edge and more frequent on the edge opposite to it. Gloss on experimental flakes largely corresponds with phase four gloss, although we do see phase five gloss appearing closer to the working edge.

Cutting of wild grasses and cereals in spring was performed with a similar "small sickle" consisting of two inserts inserted in a curved wooden handle without adhesive. After three hours of cutting wild grass a small amount of traces, mostly visible as underdeveloped sickle gloss, were achieved.

Archaeological finds were first cleaned with a soft plastic brush and water. When necessary, recent polish or glue applied due to inventory was removed with acetone. Prior to microscopic examination alcohol was used to remove any residue due to recent handling. Experimental tools were cleaned with a soft plastic brush and soapy water, alcohol, and acetone to remove any residue.

Results

Sickle gloss on finds from Slavonski Brod – Galovo and Dužine near Zadubravlje was divided into 5 stages of formation depicting the degree of tool use. The first phase corresponds to generic weak polish, the second, third, and fourth phases correspond to smooth pitted polish, while the fifth phase corresponds to well-developed polish. The phases of polish formation were observed on experimental tools as well as archaeological finds. Only the tools that show phases two, three, four, and five were considered since the generic weak polish is not exclusively characteristic of certain traces of wear. All the finds exhibit a highly reflective, glossy surface in different ratios. Protruding parts show high gloss with comet-shaped striations. Sunken parts are more topographic while still quite rounded. The amount of linkage is described through phases: phase two demonstrates the least amount of linkage, glossy spots are contained in small areas with a lot of sunken space, phase five shows no sunken space, the texture of the surface is smooth, almost reflective, comet-shaped striations are clearly visible. The rounding of the working edge is noticeable in all the described tools. In two cases[13] residue on the surface of the find was spotted, but further analysis is necessary to confirm its origin.

Damage caused by cutting silica-rich plants that runs along the left lateral and distal edges of blades was observed on truncated blade G99 391-10 (Fig. 2) of brown chert from layer SU 03, blade G01 663-5[14] (Fig. 3) of light brown/reddish chert from work activity pit house SU 107/108, blade G02 1302-25[15] (Fig. 4) of grey/brown chert from work activity pit house SU 155/156, truncated blade G02 1411-25 (Fig. 5) light brown/reddish chert from work activity pit house SU 205/206, truncated blade G03 1713-39 (Fig. 6) light yellow chert from work activity pit house SU 153/154, a blade of white chert with burn traces G07 441-6[16] (Fig. 7) from the uninvestigated pit house SU 979/980, a blade of brown chert G09 564-32 likely from grave pit SU 2012/2013[17] (Fig. 8), and a blade of white chert G10 578 (Fig. 9) from layer SU 04, and G10 610 (Fig. 10) yellow chart from grave pit SU 2012/2013.

On the distal fragment of a truncated blade of brown chert G99 414-18 (Fig. 11) from layer SU 03 the characteristic damage runs from the left lateral edge to the broken proximal edge.

Sickle gloss running from the right lateral edge to the distal edge was observed on blade G97 1293[18] (Fig. 12) of grainy yellow chert, blade G02 1254-22 (Fig. 13) of translucent white chert from pit house dwelling SU 153/154, a fragment of a blade without a bulb of white chert G02 1305-12 (Fig.14) from work activity pit house SU 155/156, G08 483-4[19] (Fig. 15) of light brown/reddish chert from layer SU 04, and the medial fragment of a blade of brown chert G09 556-3 (Fig. 16) which likely comes from grave pit SU 2012/2013.[20]

A blade with alternating retouch and truncation G11 703 (Fig. 17) of dark brown chert from grave pit SU 2242/2243 exhibits sickle gloss on the left lateral and proximal part, while a trapeze of white chert G12 763 (Fig. 18) from north excavation SU 2620/2621 of semi-circular fence SU 2194/2195 exhibits sickle gloss on the right lateral edge, from which it runs to the tool's proximal edge.

Sickle gloss on a blade of light brown/reddish chert G08 479-3 (Fig. 19) from layer SU 04 is present on the left lateral, distal, and proximal edges, while on a truncated blade of brown chert G11 721 (Fig. 20) we see it only on the distal edge.

Blades and tools on a blade from the Galovo site in Slavonski Brod exhibit a preferential distribution of sickle gloss over one lateral to a distal or, less often, a proximal edge, with gloss covering the blade surface diagonally in a triangular form.

Fine chipping is not a common phenomenon on tools exhibiting sickle gloss, although it does sporadically appear in the form of a retouch or damage to the working edge

[13] On G08 483 – 4 and G03 1713 – 39.

[14] The sickle gloss on the find was imaged using an electron microscope at 1 200× magnification.

[15] G02 1302-25 exhibits a certain degree of PDSM, but it does not cover the entirety of the observed surface and the original phase two of use-wear is still recognizable.

[16] The topography of use-wear on silica-rich plants is still visible, and the gloss is observed only in the triangular shape consistent with other traces of use on the working edge, the rest of the tool is smoothened and crackled due to exposure to fire.

[17] Given the positions of finds within layer SU 03, which Botić (oral communication) posits also contains the tops of Starčevo Culture pits/bottoms of Barice-Gređani cultural group pits.

[18] Unknown find position within the Galovo site in Slavonski Brod, 1997.

[19] Some PDSM striations are visible, but the topography of the tool surface shows traces of use-wear, there is a significant amount of rounding and formation of polished surfaces in contrast to the pitted surfaces.

[20] Given the positions of finds within layer SU 03, which Botić (oral communication) posits also contains the tops of Starčevo Culture pits/bottoms of Barice-Gređani cultural group pits.

as seen on finds G97 1293, G01 663-5, G02 1254-22, G10 610, G12 763 and on G02 1411-25 and G08 483-4, on which we also see fine chipping of the lateral edge opposite the working edge. Damage on the lateral edge is visible on finds G99 414-18, G02 1302-25, G02 1305-12 and G09 564-32. Possible traces of resin, i.e., an adhesive, were observed on the medial part of blade G08 483-4.

Of the 19 blades and fragments of blades exhibiting sickle gloss from Galovo, seven are from the group of truncated blades (G99 391-10, G99 414-18, G02 1411-25, G03 1713-39, G10 610, G11 721) of which one has an alternating retouch on the right lateral edge (G11 703), and one trapeze has been observed (G12 763). Truncations and trapezes exhibit abrupt retouch, which is typical of these types of tools.

Blades exhibiting sickle gloss come from various contexts within the sites, whereas for those from layers SU 03 and 04 the cultural affiliation has not been confidently attributed. A part of the finds recorded in these layers may be attributable to the bottoms of pits of the Barice-Gređani cultural group, or the tops of pits of the Starčevo Culture (Botić oral communication). None of the fragments exhibiting traces of wear can relate to another in the same group, i.e., to the same sickle. The tools found were not always used to the point of full gloss development. The first phase has not been considered here. From the second phase, there are truncated blades G99 414-18 and G11 721 and blades G02 1254-22 and G08 483-4. Blades G97 1293, G02 1305-12, and G10 578, truncated blade G10 610, and trapeze G12 763 exhibit phase three wear. We see fourth phase wear on truncated blades G99 391-10, G03 1713-39, G11 703, and blade G07 441-6. Fifth phase wear is found on blades G01 663-5, G02 1302-25, G08 479-3 and G09 564-32, blade fragment G09 556-3, and truncated blade G02 1411-25.

At the Dužine site in Zadubravlje sickle gloss was observed on two finds, which exhibit third and phase five sickle gloss. Truncated bladelet PNL 179A (1989) (Fig. 21) from Pit 8 of light brown/reddish chert exhibits phase three gloss. The gloss is manifested on the left lateral edge distally, and on the distal edge to the left, with fine chipping present on the working edge and the lateral edge opposite the working edge. On flake PNL 333 (1990) (Fig. 22) of light brown/reddish chert from Pit 22 fifth phase sickle gloss is present on the left and right lateral and distal edges, with retouch present on the right edge. Comet-shaped striations and edge rounding are present on both specimens. No indicators of wedging into a composite tool were observed, apart from fine chipping on the right lateral edge of PNL 179A (1989).

In all second and fourth phases, sickle gloss formation is present on four finds (19.05%). Five finds from Galovo and one from Zadubravlje exhibit phase three sickle gloss formation, accounting for 28.57% of the total number of finds exhibiting sickle gloss. The fifth phase is most represented, with a total of seven finds, one of which is from Zadubravlje, i.e., 33.33% in all.

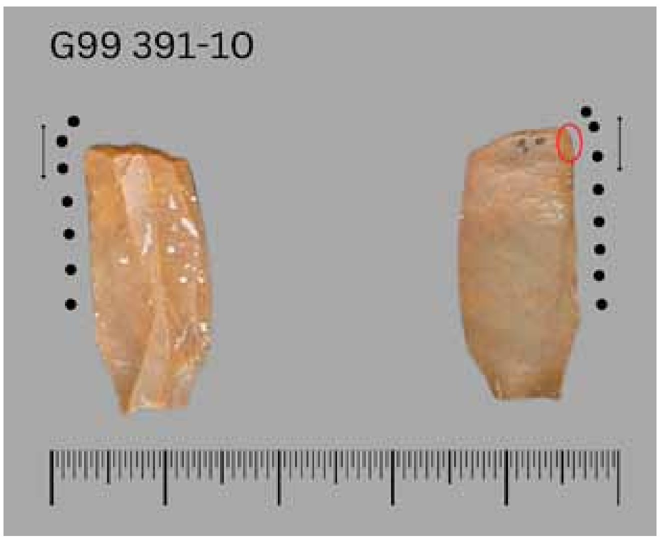
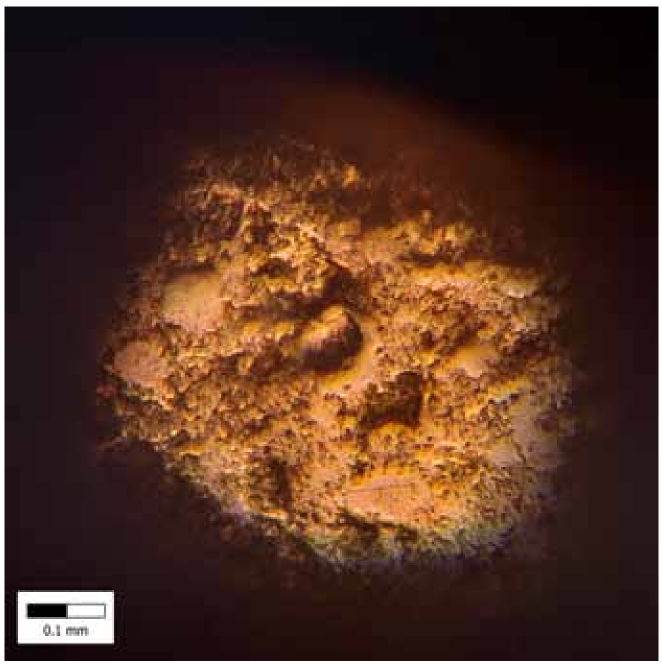
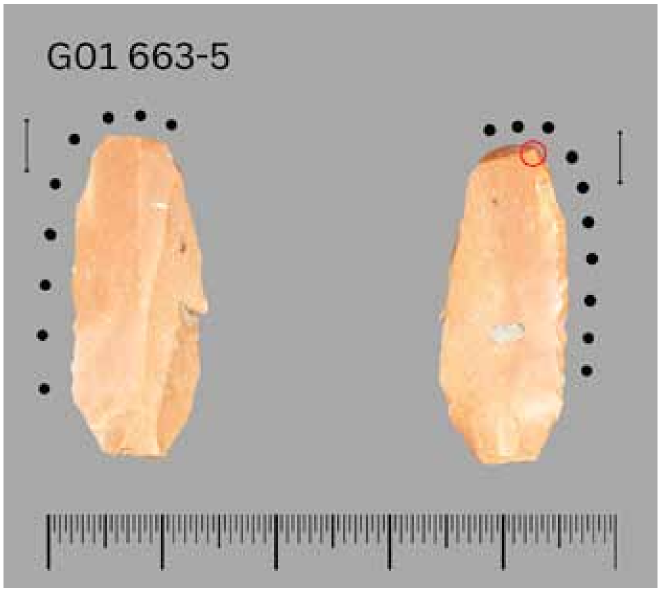
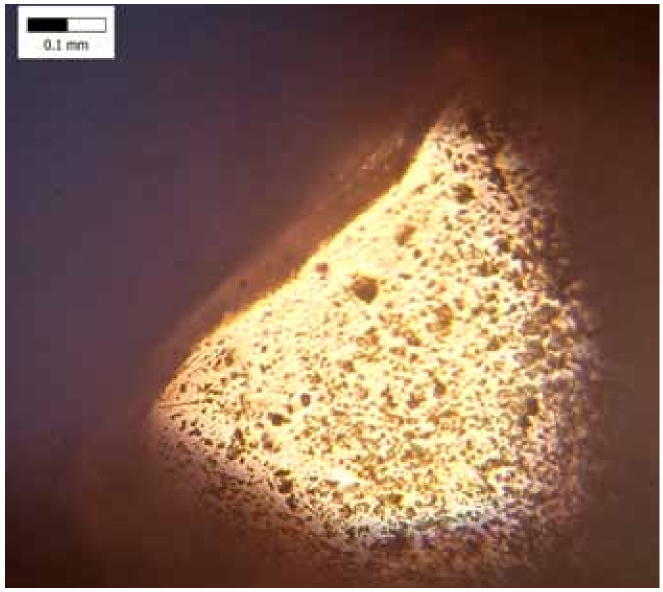


Figure 2. PNL G99 391-10 (a) at 200× magnification under a metallurgical microscope (b)







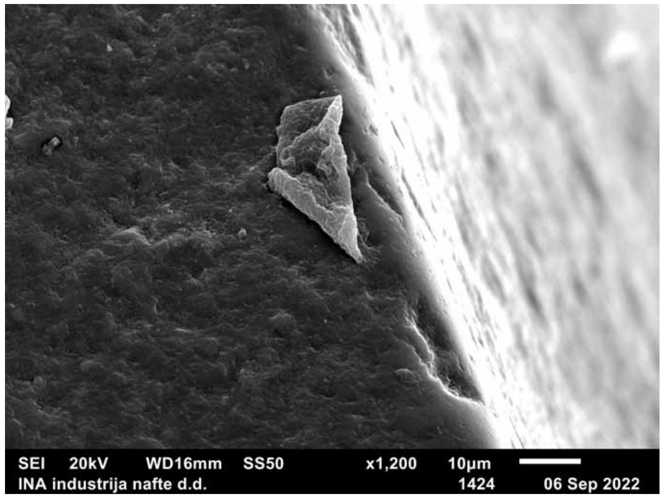
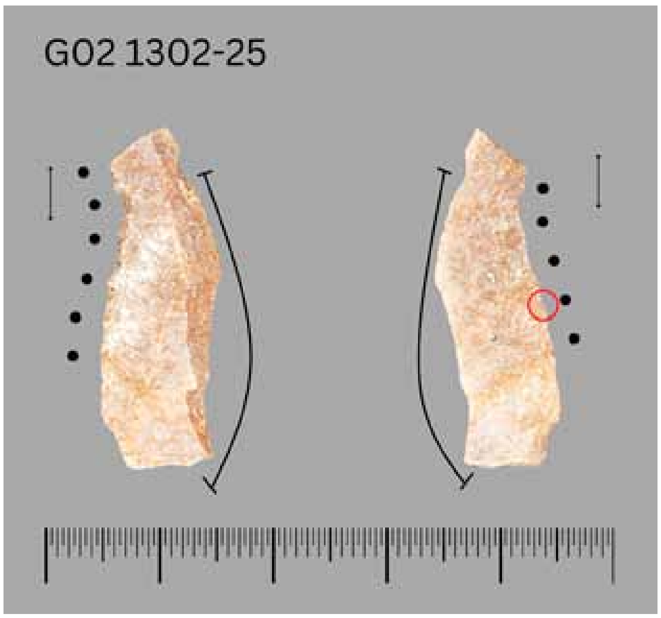


Figure 3. PNL G01 663-5 (a) at 200× magnification under a metallurgical microscope (b) and at 1200× under an SEM (c)



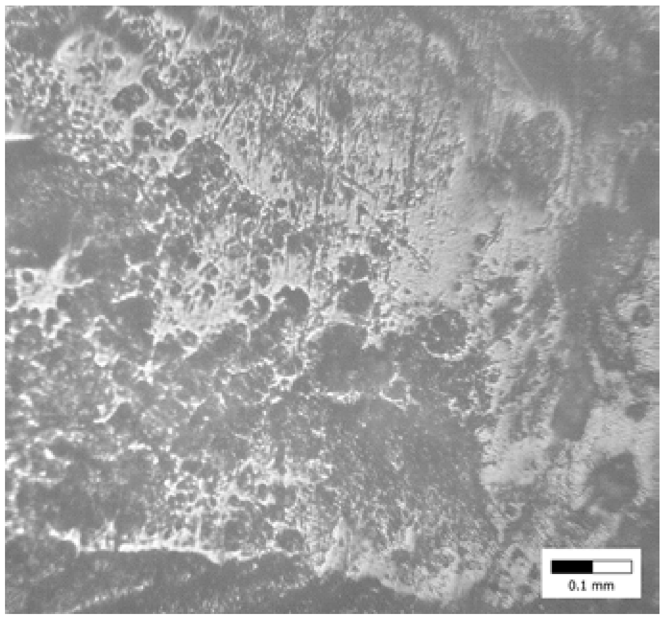


Figure 4. PNL G02 1302-25 (a) at 200× magnification under a metallurgical microscope (b)

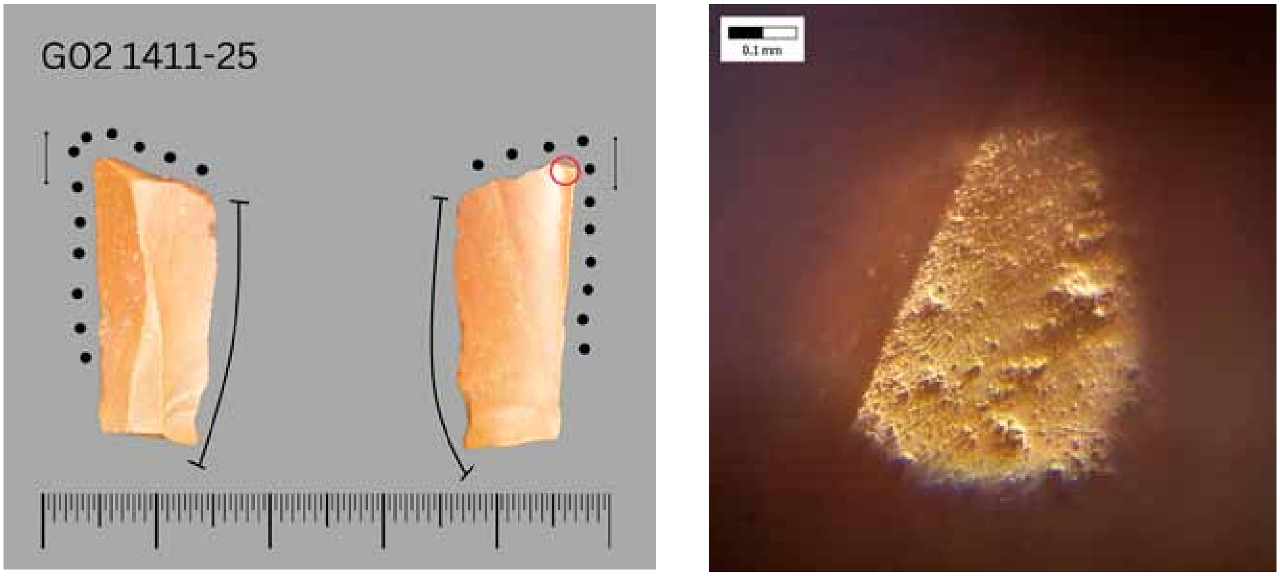


Figure 5. PNL G02 1411-25 (a) at 200× magnification under a metallurgical microscope (b)

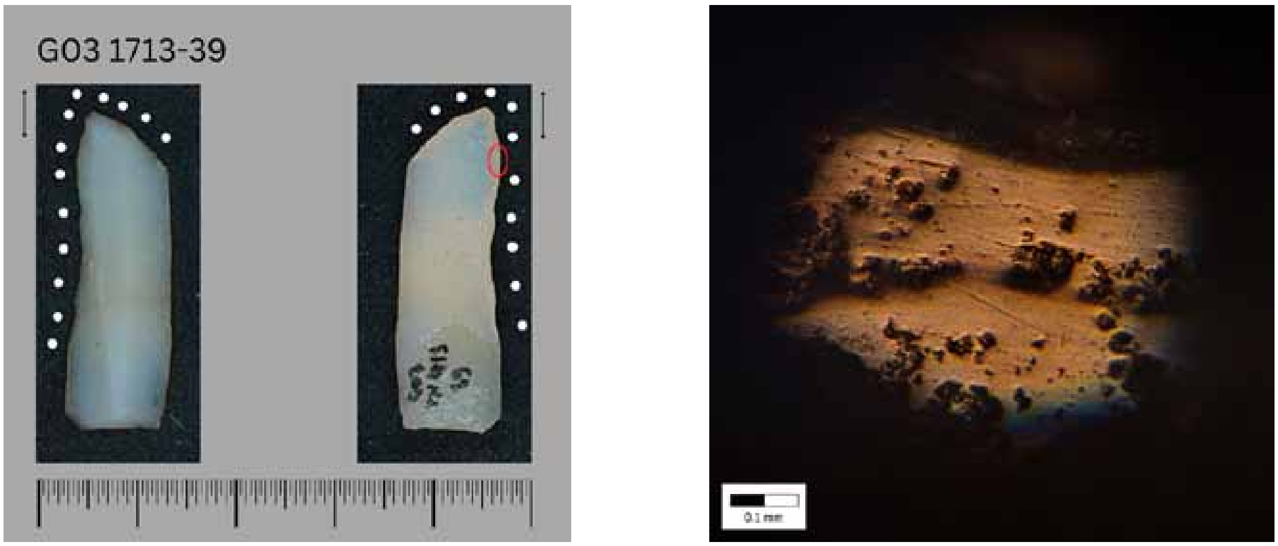


Figure 6. PNL G03 1713-39 (a) at 200× magnification under a metallurgical microscope (b)

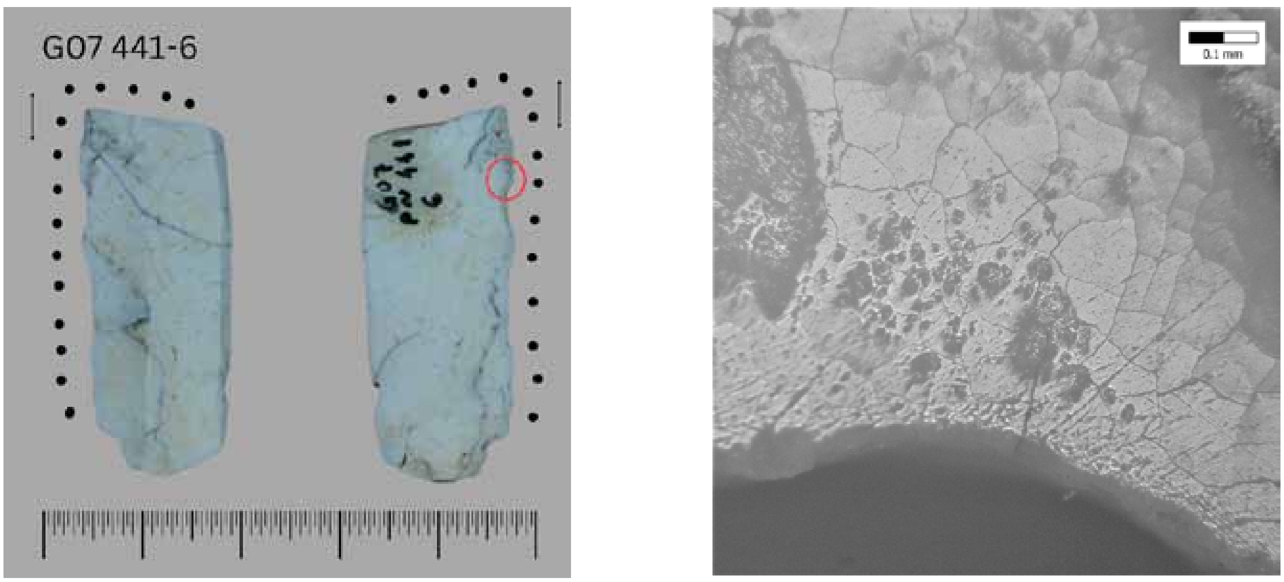
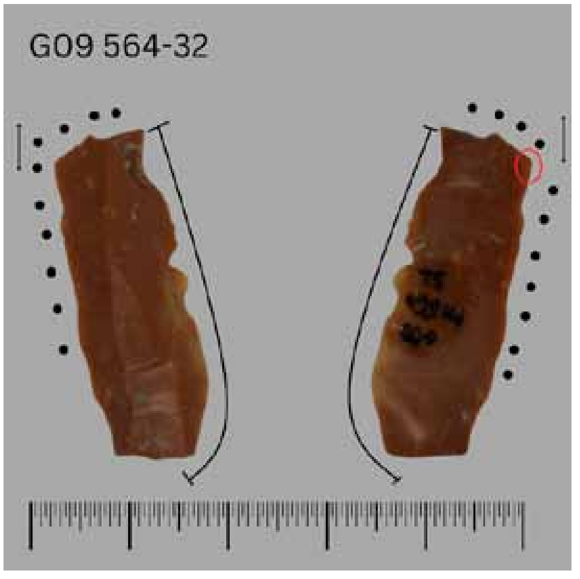


Figure 7. PNL G07 441-6 (a) at 200× magnification under a metallurgical microscope (b)



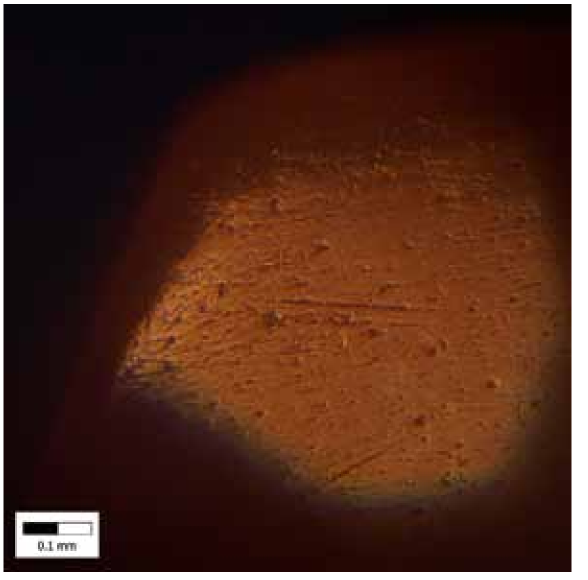


Figure 8. PNL G09 564-32 (a) at 200× magnification under a metallurgical microscope (b)

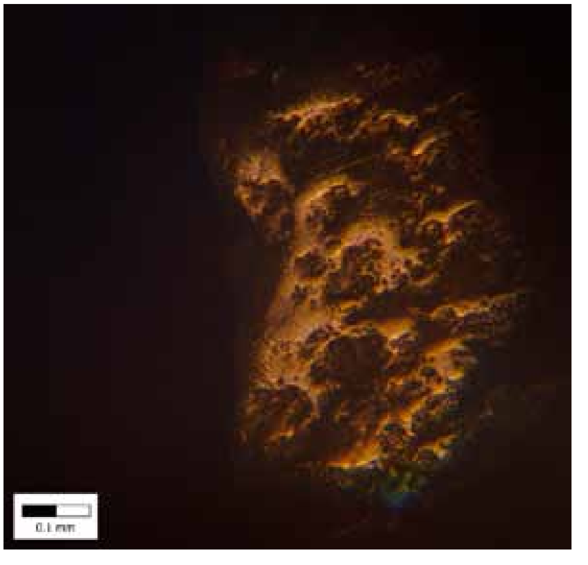


Figure 9. PNL G10 978 (a) at 200× magnification under a metallurgical microscope (b)

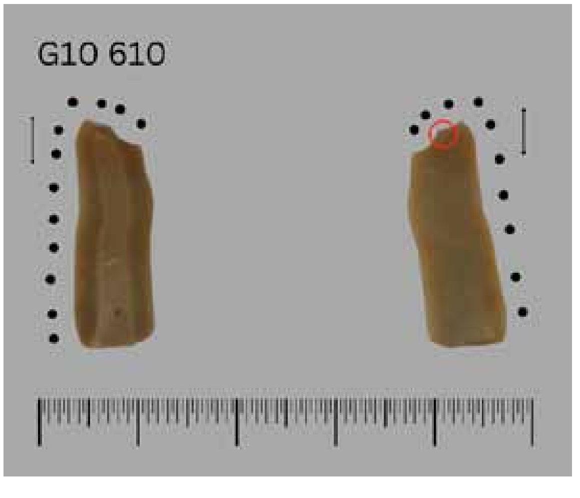
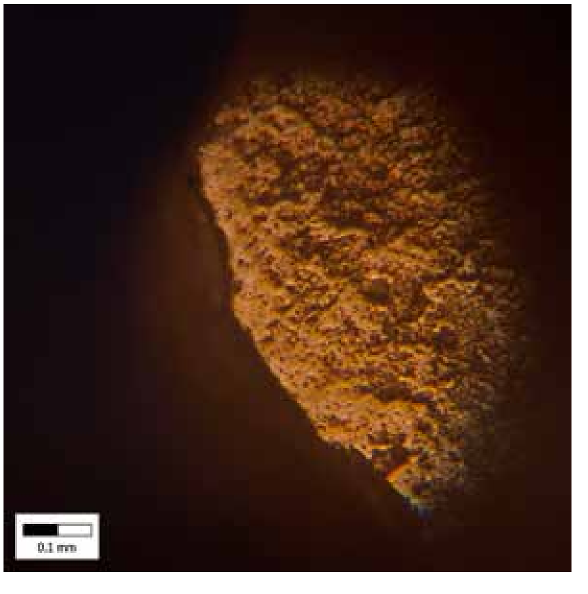


Figure 10. PNL G10 610 (a) at 200× magnification under a metallurgical microscope (b)



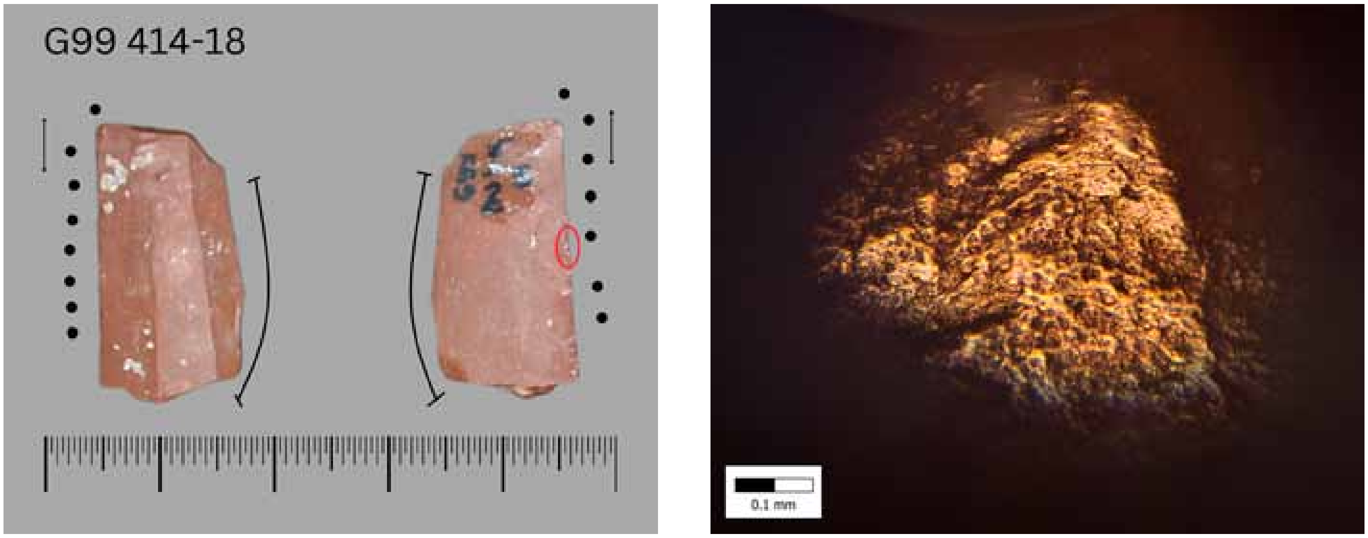


Figure 11. PNL G99 414-18 (a) at 200× magnification under a metallurgical microscope (b)

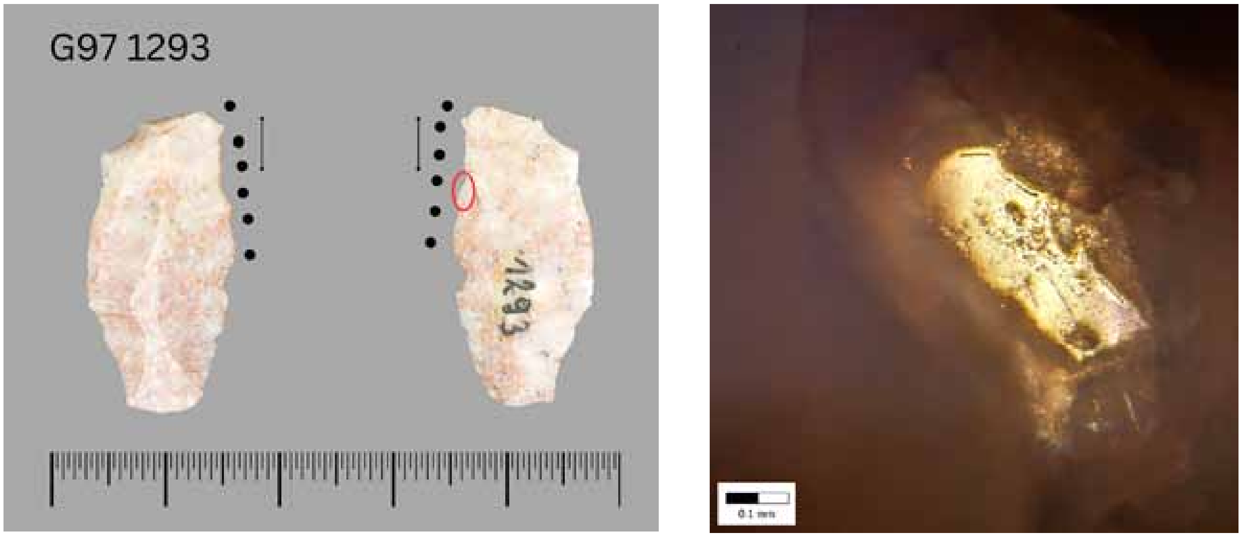


Figure 12. PNL G97 1293 (a) at 200× magnification under a metallurgical microscope (b)

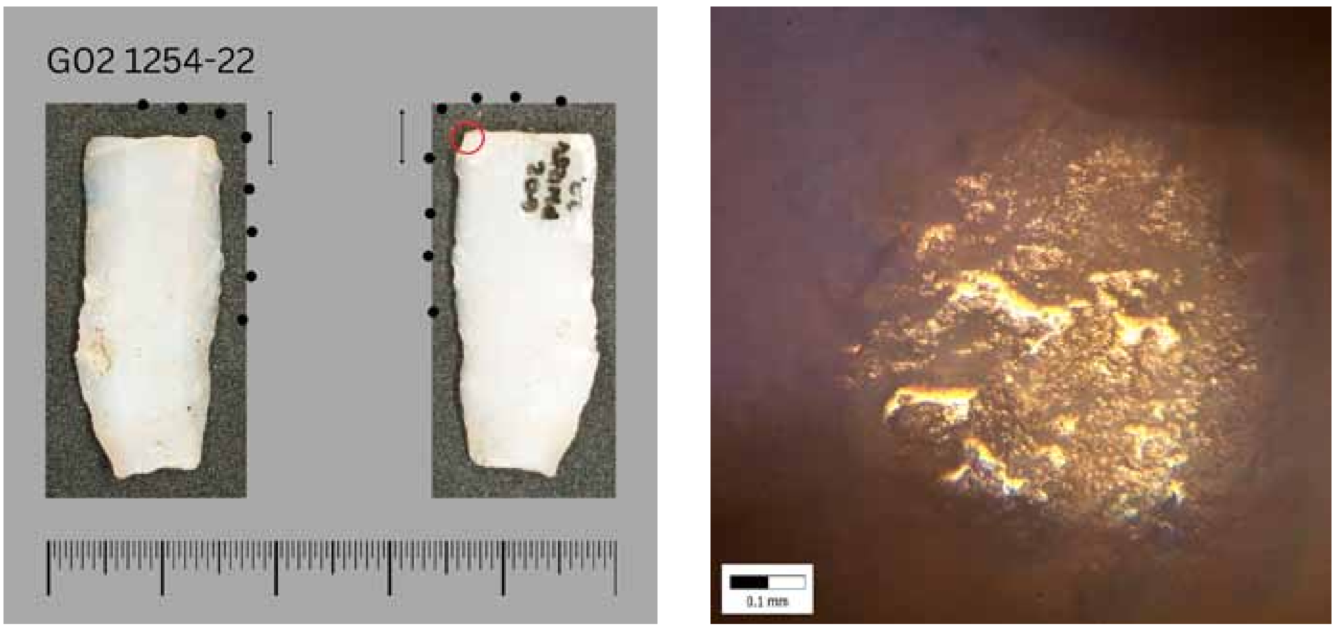


Figure 13. PNL G02 1254-22 (a) at 200× magnification under a metallurgical microscope (b)

Figure 14. PNL G02 1305-12 (a) at 200× magnification under a metallurgical microscope (b)

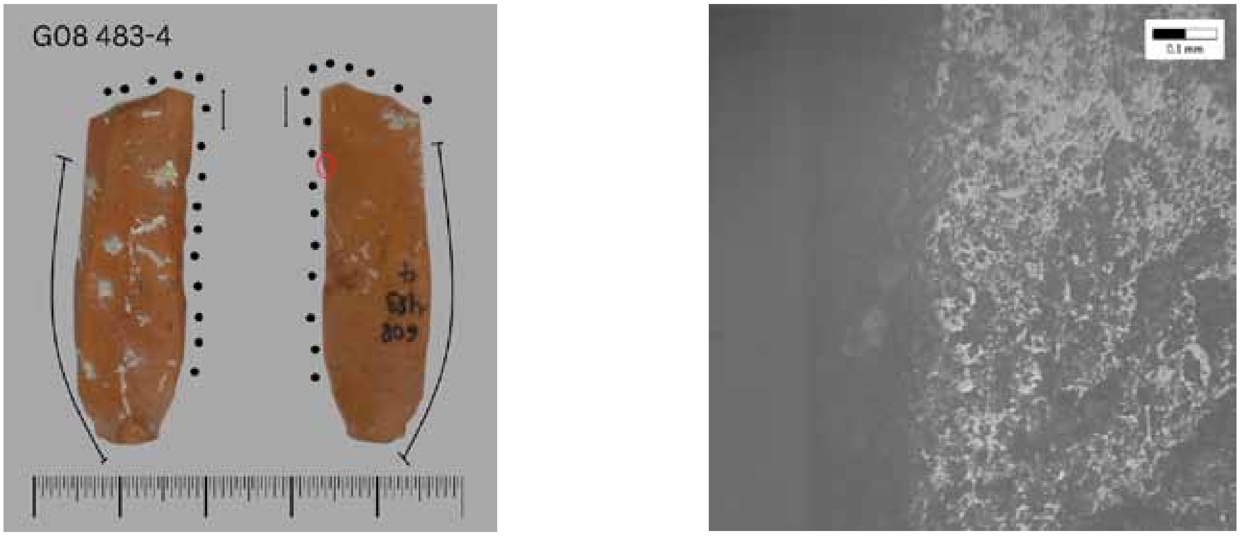


Figure 15. PNL G08 483-4 (a) at 200× magnification under a metallurgical microscope (b)

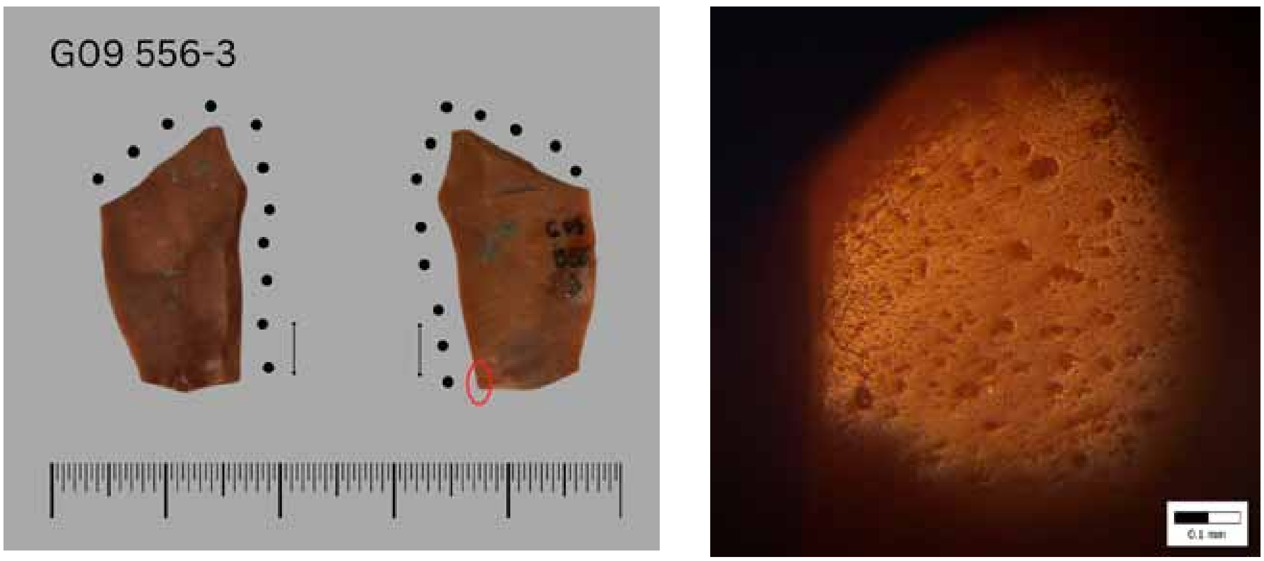


Figure 16. PNL G09 556-3 (a) at 200× magnification under a metallurgical microscope (b)

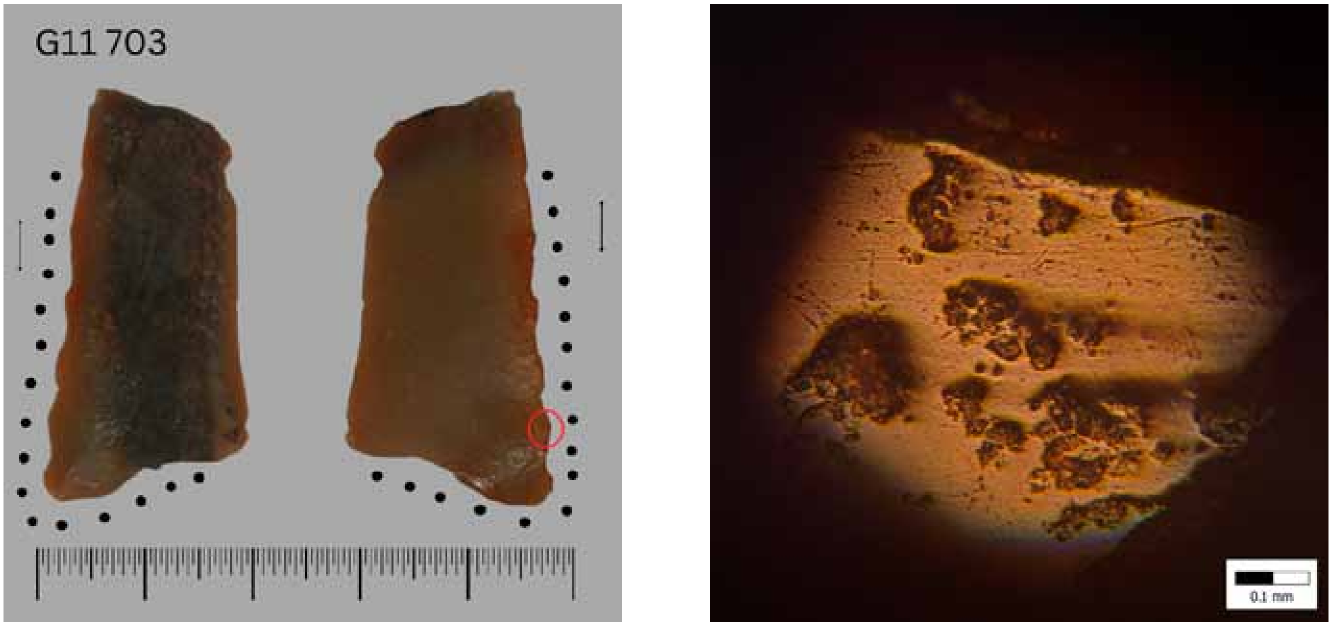


Figure 17. PNL G11 703 (a) at 200× magnification under a metallurgical microscope (b)

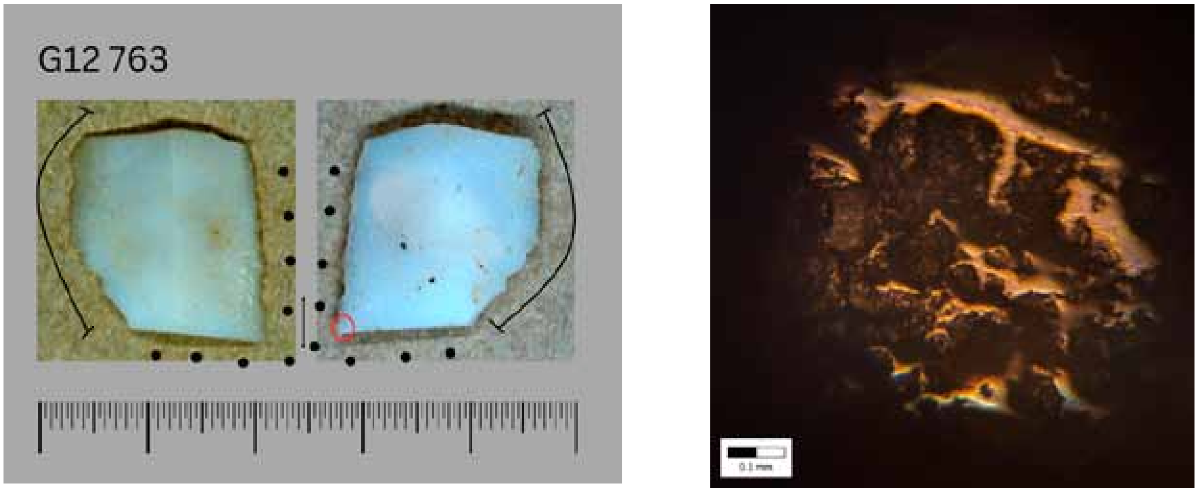


Figure 18. PNL G12 763 (a) at 200× magnification under a metallurgical microscope (b)

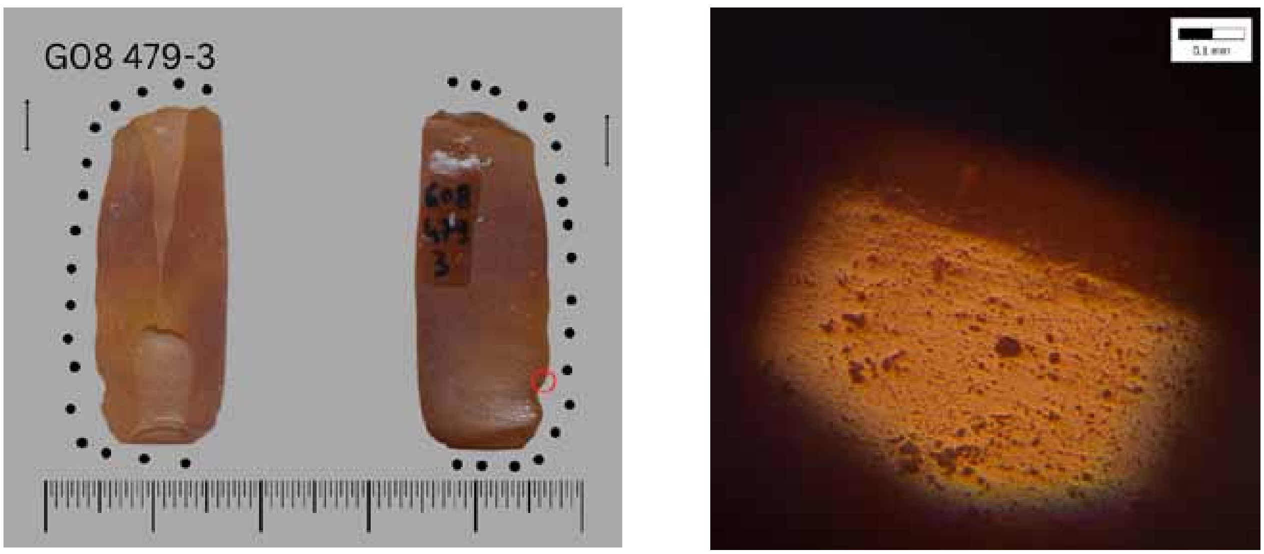


Figure 19. PNL G08 479-3 (a) at 200× magnification under a metallurgical microscope (b)

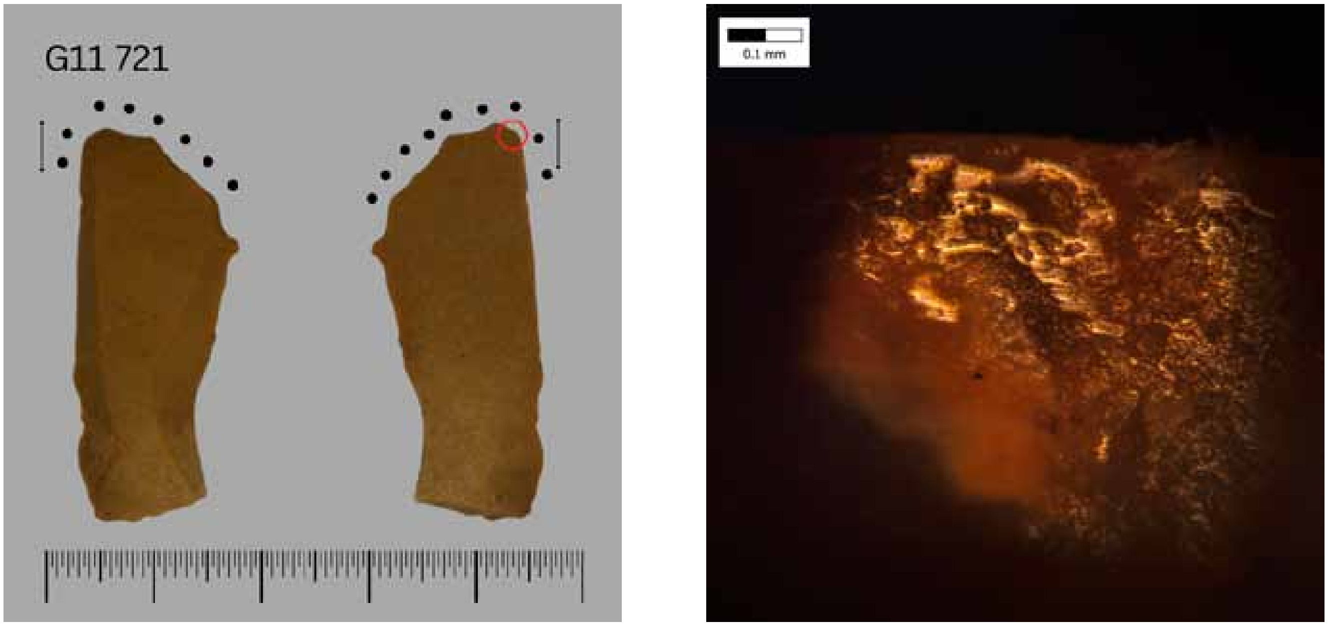


Figure 20. PNL G11 721 (a) at 200× magnification under a metallurgical microscope (b)

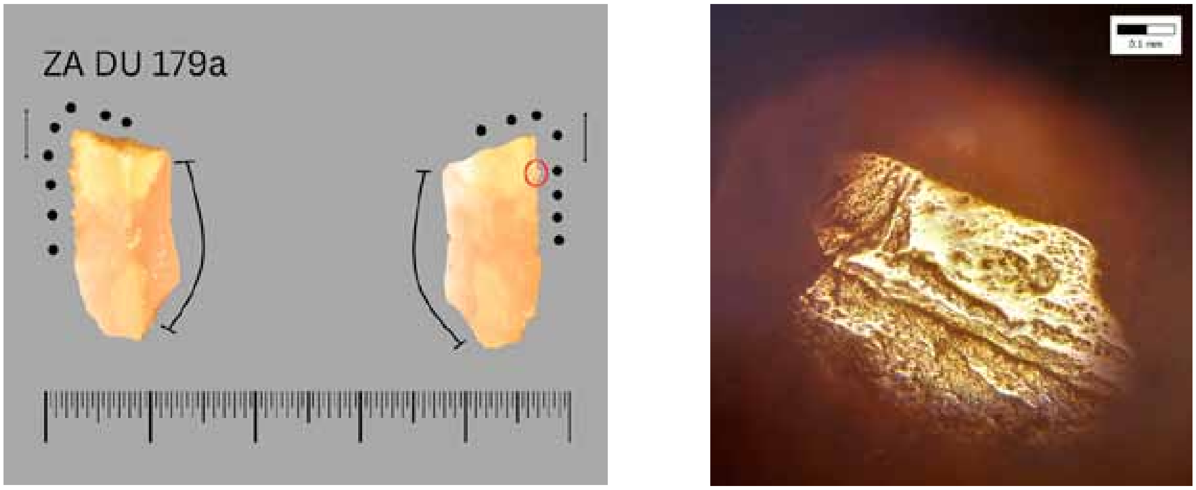


Figure 21. PNL ZA DU 179A at (a) 200× magnification under a metallurgical microscope and (b) at 1200× under an SEM

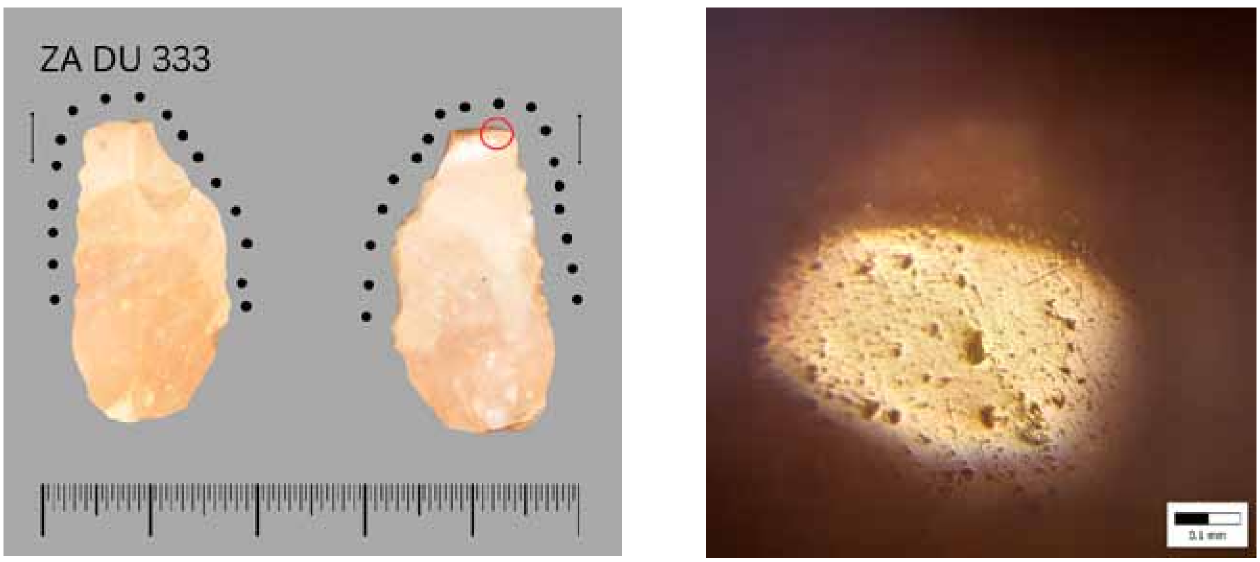


Figure 22. PNL ZA DU 333 at (a) 200× magnification under a metallurgical microscope and (b) at 1200× under an SEM

Discussion

The Starčevo Culture settlements at Galovo and Zadubravlje coincide chronologically across almost their entire duration. The attribution of these settlements to the early Starčevo Culture, based on the components of the Neolithic package, presumes the production of cereal crops. Organic remains, however, are not easily proven *in an archaeological context*, and the lack of use-wear evidence of harvesting cereals does not immediately imply the lack of agricultural effort (Petrović et al. 2021: 29). Fossilised cereal grains have been found in the archaeological strata, as is the case at Zadubravlje,[21] but the methodology of the excavation of Neolithic settlements (Reed 2014: 158) often provides an incomplete picture. Domesticated cereals came to what is now Croatia from the Middle East around 6000 cal BC (Reed 2014: 157), which coincides with the formation of settlements at Galovo and Zadubravlje. The first cultivated species were einkorn wheat (*Triticum monococcum*), emmer wheat (*Triticum dicoccum*), barley (*Hordeum vulgare*), peas (*Pisum sativum*), lentils (*Lens culinaris*), chickpeas (*Cicer arietinum*), bitter vetch (*Vicia ervilia*) and flax (*Linum usitatissimum*) (Zohary 1996). Over 70 samples of plant remains were collected at the Tomašanci-Palača Starčevo Culture settlement site (Reed 2020), constituting the first direct evidence of agriculture in the region. Remains of einkorn and emmer wheat, barley, lentils, flax and dwarf elder (*Sambucus ebulus*) were found (Reed 2014: 158; 2020: 252). Finds of bread wheat (*Triticum aestivum*) and spelt (*Triticum spelta*) were made in the Starčevo Culture strata at the Sopot site (Reed 2015: 606).

Tools for the cultivation and processing of plants are secondary indicators of the exploitation of cereals. Sickle gloss is one of the most relevant indirect indicators of agriculture, along with chemical analyses (Torrence and Barton 2006) such as lipid analysis (Charters et al. 1993; Evershed et al. 1995; Hammann et al. 2022) and dental plaque (Christiani et al. 2016; Jovanović et al. 2021). Although sickle gloss is often visible to the naked eye, the functional analysis must be performed microscopically. The small number of samples of domesticated plants may be the result of the investigative methodology (Reed 2014: 158), but also of the limited import or theft of domesticated plants from nearby agricultural settlements. Food processing tools such as grindstones and knapped lithics found both at Galovo and Zadubravlje (Minichreiter 1992a; 1992b; 2007) point to the intensive use of domesticated plants. The species has not been determined in the case of the find of cereals at Zadubravlje, while at Galovo there were no similar finds. At the same time, only two finds exhibiting sickle gloss originate from Zadubravlje. The greater number of finds exhibiting sickle gloss from Galovo is an indicator of agricultural production at this site.

When analysing the distribution of finds at Galovo one ought to bear in mind that for a part of the finds from layers SU 03 and SU 04, no confident determination of cultural affiliation has been made, as described above. Seven of the finds from these strata should be considered with reservation, even though they do correspond to blades and fragments of truncated blades on which sickle gloss extends diagonally, as has also been observed on finds from Starčevo Culture structures. One find is from an unknown context. The remaining 11 finds originate from structures. Four of the finds are from work activity pit houses SU 107/108 (1), SU 155/156 (2) and SU 205/206 (1), three are from grave pit contexts SU 2012/2013 (1) and SU 2242/2243 (2), two from pit house dwelling SU 153/154, one from uninvestigated pit SU 979/980, and one from SU 2620/2621, which is the north excavation of semi-circular fence 2194/2195. The bulk of finds exhibiting sickle gloss at Galovo are from the contexts of work activity pit houses and grave pits. Work activity pit houses correspond to a broad range of activities, evident among which are food preparation, pottery manufacture, and lithic technology. This distribution of finds indicates that the sickle was a relatively specialised tool that had its place in the workshop environment. Associating a sickle to a particular individual is likely not feasible, although blades have also been found in grave contexts. Given that the burial ritual in the Starčevo Culture is typical of Croatian Neolithic, where the deceased is interred in an oval grave pit in a crouched position with little or no personal accessories (Težak-Gregl 1998: 65-68), these blades probably did not constitute the deliberate inventory of a grave.[22] Further investigation is needed because the sample is too small, and we lack a complete set of blades from a single sickle.

Pits 8 and 22 at Zadubravlje are smaller in size (Minichreiter 1992b). Pit 22 has a specific shape, and an unusual inventory (including the find of a turtle shell) and layout.

[21] The species of the remains could not be determined (Minichreiter 1992a, 31, 51)

[22] In a wider area, Early Neolithic graves occasionally show a larger number of grave goods (e.g. Vlasac) (Borić et al. 2014).

Minichreiter describes it as a cult pit (Minichreiter 2005: 9). Notably, the inventory of this pit includes the sole flake, of elongated form, confirmed as exhibiting sickle gloss at these two sites.

Blades, retouched and unretouched are, next to flakes, predominant at Starčevo Culture sites in the broader area of distribution (Šošić Klindžić 2010; Šarić 2014: 160-161), as evidenced by the finds from Galovo and Zadubravlje. The 19 finds from Galovo constitute a group comprising blades, blade fragments of which six are truncations, and one is a trapeze. These finds exhibit sickle gloss in various phases of development. Vaughan (1985) describes three phases in the development of gloss, of which two can be attributed to use on silica-rich plants, and where the first phase should be considered separately because the generic weak polish is generally characteristic of initial use-wear trace development. The analysis of finds from Galovo required discriminating between five phases of gloss development indicating the degree of tool use. The first phase again corresponds to generic weak polish. The second, third, and fourth phases correspond to smooth pitted polish, while the fifth phase corresponds to Vaughan's well-developed polish (1985). The necessity of introducing a broader division was prompted by the significant differences observed in the development of the degree of damage on individual finds, which was also evident in experimental tools. The presence of finds exhibiting different phases of sickle gloss development indicates that not all the tools were used to the final stage of wear prior to being discarded, deliberately or unintentionally. This can be compared to the observation that Mazzucco et al. (2018.) noticed on sickle blades from nine sites in Dalmatia dated between 6000 - 5300 cal BC (Forenbaher et al. 2013). Sickle blades attributed to the Early Neolithic Impressed Ware phase were mostly replaced rather than reshaped, such was the practice in the later Danilo layers (Mazzucco et al. 2018: 94-95). We see the same division among the finds from Galovo.

Thirteen of the finds from Galovo exhibit a clearly visible distribution of the gloss on one lateral and one transversal edge. At times the gloss extends to the other transversal edge. On two additional finds from Galovo, the gloss is distributed on one lateral edge and a part of one transversal edge. The distribution of sickle gloss and attendant use-wear traces, especially in combination with fine chipping at the edge opposite to the working edge may indicate – based on comparisons with the experimental material – the wedging of blades into a composite tool. The diagonal distribution of gloss we see on fifteen of the Galovo finds and one find from Zadubravlje identify the angle at which the blades were inserted into the handle. When used, the edges of the debitage inserted into a wooden handle opposite the working edges are pressed against the surface of the handle, which produces fine chipping. Chemical analysis of what may be traces of resin, i.e., an adhesive, observed on one specimen from Galovo may further corroborate the appearance of a composite tool as thus envisaged. Given the lack of flakes and tools on a flake exhibiting sickle gloss among the finds from the Galovo site in Slavonski Brod we can posit that composite sickles at this site were crafted by the diagonal insertion of blades, truncated blades and, less often, trapezes into a handle of organic material, which has not survived.[23] Use-wear traces observed on the finds from Galovo and Zadubravlje show sickle gloss distributed diagonally across the segments, indicative of a more or less curved composite sickle with diagonally set teeth, which is consistent with Group 1 composite sickles of the Riedschachen type according to Pétrequin et al. (2006) (Fig. 23). Sickles of the same shape have been identified at sites in Bulgaria, for example, the Tell Karanovo site (Gurova and Bonsall 2014), that is attributed to the Čavdar-Kremikovci-Karanovo Culture group of the Starčevo cultural complex (Težak-Gregl 1998: 63) and the Impressed Ware Culture in Dalmatia (Mazzucco et

Figure 23. Conceptual reconstruction of the kind of sickle that may have been used in the Starčevo Culture settlement at the Galovo site in Slavonski Brod.

[23] The handle at Galovo and Zadubravlje were most probably wooden and not made of antler as Bogosavljević Petrović (2016; 2017) suggested in experiments connected to agriculture of Late Neolithic of Srbija.

al. 2018), as well as in the Early Neolithic of Greece, Albania, Monte Negro, Italy (Mazzucco et al. 2020), Spain, and south France (Ibáñez-Estévez et al. 2008: 185-186). The two finds exhibiting sickle gloss from Zadubravlje only partially correspond with the sickle type observed at Galovo. The bladelet from Zadubravlje exhibits the diagonal distribution of sickle gloss. There are not enough finds from Zadubravlje for any confident determination of the appearance of sickles at this site. Group 1 composite sickles were likely used, with the sickle cutting diagonally at the middle of the stalk, to harvest densely planted fields (Pétrequin et al. 2006). Sickle gloss on finds from Galovo indirectly point to the presence of agricultural activity, and we can thus confidently posit that this site presents all of the features of the Neolithic package. Further investigation is required to confirm the entirety of the Neolithic package at Zadubravlje. At Galovo we see the entire Neolithic package, which is to be expected given the chronological position of the Starčevo Culture in the broader sense.

Conclusion

Nineteen finds from Galovo and two from Zadubravlje exhibit sickle gloss. At Galovo most are blades, fragments of blades with or without truncation, and - as an exception - one trapeze, while at Zadubravlje the finds are a bladelet, which does not correspond with most of the Galovo finds only in terms of their size, and a flake from Pit 22. On sixteen of the finds, sickle gloss is distributed diagonally along the body of the tool, occupying for the most part one lateral edge and one transversal edge. Less often the gloss runs to a part of the other lateral edge. In some cases, the lateral edge opposite the working edge exhibits fine chipping, and on one specimen a residue was observed that may be a resin that secured the tool in a handle. The distribution of wear points to the conclusion that sickles at the Galovo site were composite sickles of the Group 1 Riedschachen type as described by Pétrequin et al. (2006: 109-112), in which blades or truncated blades and, less often, trapezes were inserted. The same distribution of wear was noticed by Mazzucco et al. (2018) on examples from the Early Neolithic Impressed Ware Culture in Dalmatia. A handle of organic material, most likely wood, diagonally intersected a chert microlith. No set was found that could be characterised as a single sickle, which, in combination with the different degrees of gloss development, may point to the replacement of sickle segments that had worn out or had been lost. Finally, the lack of a complete set means that we do not know the form of sickle handles from Galovo and Zadubravlje, although blades exhibiting gloss on three edges may indicate that the sickles were of the more or less curved type (Pétrequin et al. 2006), as this achieves the functional alignment of the edges. This sickle configuration would correspond with Neolithic sickles found in Bulgaria, Greece, Albania, Monte Negro, Dalmatia, Italy, France and Spain (Ibáñez-Estévez et al. 2008: 185-186; Gurova & Bonsall 2014; Mazzucco et al. 2018; 2020). The appearance of the sickles of individual Cultures may point to the process of Neolithisation and the introduction of agriculture into an area (Ibáñez-Estévez et al. 2008: 183-196). If these processes are also to be followed in eastern Europe we will require further investigation of use-wear traces and the development of a typology of Neolithic sickles in this area.

Given the number of finds and the various contexts in which they were found, and their morphology, we can confidently posit that the inhabitants of the Galovo site, and likely of the site at Zadubravlje, used the described composite sickles to cut silica-rich plants, which is also indicated by the find of cereals at Zadubravlje. Given that the Starčevo Culture in all other segments corresponds to Childe's Neolithic package, that it marks the first Neolithic phenomenon in the Brodsko Posavlje region (Težak-Gregl 1998), and that it chronologically corresponds to the Middle Neolithic in the broader sense, that the sickle gloss on tools from these sites is the result of the cutting of domesticated cereals.

In conclusion, it is necessary to continue with the functional analysis of the lithic assembly of the Starčevo-Körös-Criş cultural group as well as of its both temporal and spatial neighbouring cultures to procure data on everyday activities of their inhabitants. Results obtained in this study indicate similarities between the Early Neolithic sickle inserts from the Brodska Posavina region with Early Neolithic sickles from the entire northern Mediterranean region.

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References

Anderson, P. C. 1980. A testimony of prehistoric asks: Diagnostic residues on stone tool working edges, *World Archaeology* 12 (2), 181-194. https://doi.org/10.1080/00438243.1980.9979791

Bogosavljević Petrović, V. 2016. An archaeological experiment and new knowledge about the chipped stone industry from the Vinča Culture, *Journal of Lithic Studies* 3 (2), 54-71. https://doi.org/10.2218/jls.v3i2.1437

Bogosavljević Petrović, V., Borojević, K., Dimić, V. and Marković, J. 2017. Proces sečenja kultivisinaih žitarica u poznom neolitu Srbije – eksperimentalna istraživanja, *Arhaika* 5, 1-64.

Borić, D., French, Ch., Stefanović, S. and Dimitrijević, V. 2014. The Mesolithic life and death at Vlasac (Serbia). *Journal of Field Archaeology* 39, 1-28. https://doi.org/10.1179/0093469013Z.00000000070

Bunčić, M. 2009. Kameni nalazi starčevačke kulture s nalazišta Galovo u Slavonskom Brodu, *Prilozi Instituta za arheologiju u Zagrebu* 26, 291-308.

Charters, S., Evershed, R. P., Goad, LJ., Leyden, A., Blinkhorn, P. W. and Denham, V. 1993. Quantification and distribution of lipid in archaeological ceramics: implications for sampling potsherds for organic residue analysis and the classification of vessel use. *Archaeometry* 35 (2), 211-223. https://doi.org/10.1111/j.1475-4754.1993.tb01036.x

Childe, V. G. 1958. *Prehistory of European Society*, Institute of Archaeology, University College London.

Christiani, E., Radini, A., Edinborough, M. and Borić, D. 2016. Dental calculus reveals Mesolithic foragers in the Balkans consumed domesticated plant foods, *Proceedings of the National Academy of Sciences* 113 (37), 10298-10303. https://doi.org/10.1073/pnas.1603477113

Çilingiroğlu, Ç. 2005. The concept of "Neolithic package": considering its meaning and applicability, *Documenta Prahistorica* 32, 1-13. https://doi.org/10.4312/dp.32.1

Đukić, A. 2014. Biljni ostaci s četiri novoistražena lokaliteta Đakovštine, *Vjesnik Arheološkog Muzeja u Zagrebu* 3.s, XLVII, 7-38.

Evershed, R. P., Turner-Walker, G., Hedges, R. E. M., Tuross, N. and Leyden, A. 1995. Preliminary results for the analysis of lipids in ancient bone, *Journal of archaeological science* 22, 277-290.

Forenbaher, S. 2008. *Special Place, Interesting Times. The Island of Palagruža and Transitional periods in Adriatic Prehistory*, Archaeopress, Oxford.

Forenbaher, S., Kaiser, T. and Miracle, P.T. 2013. Dating the East Adriatic Neolithic, *European Journal of Archaeology* 16 (4), 589-609. https://doi.org/10.1179/1461957113Y.0000000038

Gurova, M. and Bonsall, C. 2014. 'Pre-Neolithic' in Southeast Europe: a Bulgarian perspective, *Documenta Praehistorica* XLI, 95-109. https://doi.org/10.4312/dp.41.5

Hammann, S., Bishop, R. R., Copper, M., Garrow, D., Greenwood, C., Hewson, L., Sheridan, A., Sturt, F., Whelton H. L. and Cramp, L. J. E. 2022. Neolithic culinary traditions revealed by cereal, milk and meat lipids in pottery from Scottish crannogs, *Nature Communications* 13, 5045. http://dx.doi.org/10.1038/s41467-022-32286-0

Ibáñez-Estévez, J. J., Clemente-Conte, I., Gassin, B., Gibaja, J. F., González Urquijo, J. E., Márquez, B., Philibert, S. and Rodríguez, A. 2008. Harvesting Technology During The Neolithic in SW Europe, In: J. Marreiros, J. Gibaja Bao and N. Bicho (eds.), *"Prehistoric Technology" 40 years later: Functional Studies and the Russian Legacy*, Cambridge Scholars Publishing, Cambridge, 183-196.

Jovanović, J., Power, R. C., De Becdelièvre, C., Goude, G. and Stefanović, S. 2021. Microbotanical evidence for the spread of cereal use during the Mesolithic-Neolithic transition in the Southeastern Europe (Danube Gorges): Data from dental calculus analysis, *Journal of Archaeological Sciences* 125, 105-288. https://doi.org/10.1016/j.jas.2020.105288

Kačar, S. and Philibert, S. 2022. Early Neolithic Large Blades from Crno Vrilo (Dalmatia, Croatia): Preliminary Techno-Functional Analysis, *Open Archaeology* 8, 256-272. https://doi.org/10.1515/opar-2022-0232

Karavanić, I., Šošić Klindžić, R., Bunčić, M. and Kurtanjek, D. 2009. Cijepani litički materijal s ranoneolitičkog nalazišta Zadubravlje, *Prilozi Instituta za arheologiju u Zagrebu* 26, 5-20.

Keeley, L. H. 1980. *Experimental Determination of Stone Tool Uses: A Microwear Analysis*, The University of Chicago Press, Chicago & London.

Krajcar Bronić, I. 2011. Određivanje starosti metodom 14C i primjer datiranja dvaju neolitičkih naselja u Hrvatskoj, In: M. Dizdar (ed.) *Panonski prapovijesni osviti. Zbornik radova posvećenih Korneliji Minichreiter uz 65. Obljetnicu života*, Institut za arheologiju, Zagreb, 175-188.

Mazzucco, N., Guilbeau, D., Kačar, S., Podrug, E., Forenbaher, S., Radić, D. and Moore, A. M. T. 2018. The time is ripe for a change. The evolution of harvesting technologies in Central Dalmatia during the Neolithic period (6th millennium cal BC), *Journal of anthropological archaeology* 51, 88-103. https://doi.org/10.1016/j.jaa.2018.06.003

Mazzucco, N., Ibáñez, J. J., Capuzzo, G., Gassin, B., Mineo, M. and Gibaja, J. F. 2020. Migration, adaptation, innovation: The spread of Neolithic harvesting technologies in the Mediterranean, *PLoS ONE* 15 (4), 1-27. https://doi.org/10.1371/journal.pone.0232455

McCarter, S. F. 2007. *Neolithic*, Routledge, New York, London.

Minichreiter, K. 1992a. *Starčevačka kultura u sjevernoj Hrvatskoj*, Arheološki zavod Filozofskog fakulteta Sveučilišta u Zagrebu, Disertacije i monografije 1, Zagreb.

Minichreiter, K., 1992b. Kultni predmeti starčevačke kulture u sjevernoj Hrvatskoj, *Prilozi Instituta za arheologiju u Zagrebu* 9, 7-22.

Minichreiter, K. 2005. Zadubravlje – kultni predmeti u naselju starčevačke culture, *Prilozi Instituta za arheologiju u Zagrebu,* 22, 5-24.

Minichreiter, K. 2007. *Slavonski Brod, Galovo, deset godina arheoloških istraživanja*, Monografije Instituta za arheologiju 74, 1, Institut za arheologiju. Zagreb.

Nowak, M. 2022. Do We Finally Know What the Neolithic Is? *Open Archaeology* 8 (1), 332-342. https://doi.org/10.1515/opar-2020-0204

Pétrequin, P., Lobert, G., Maitre, A. and Monnier, J. 2006. Les outils à moissonner et la question de l'introduction de l'araire, *in* : P. Pétrequin, R.M. Arbogast, A.M. Pétrequin, S. van Willigen and M. Bailly (eds.), *Premiers chariots, Premiers araires. La diffusion de la traction animale en Europe pendant les IV^e^ et III^e^ millénaires avant notre ère*, Monographies du CRA, 29, Paris, CNRS Editions,107-132.

Petrović, A. 2021. Daily struggles of prehistoric communities in the Iron Gates during the Late Mesolithic and Early Neolithic*,* In: S. Babić (ed.), *Archeology of Crisis*, Faculty of Philosophy, University of Belgrade, Belgrade, 43-61.

Petru, S. 2020. Preliminarna analiza istrošenosti kamenih oruđa iz Mujine pećine, In: I. Karavanić and I. Kamenjarin (eds.), *Mujina pećina: geoarheologija i litička analiza*, FF Press, Muzej grada Kaštela, Zagreb-Kaštela, 111-118.

Reed, K. 2014. Prehrana i poljoprivreda u neolitičkoj Hrvatskoj: arheobotanički ostaci, In: J. Balen, T. Hršak and R. Šošić Klindžić (eds.), *Darovi zemlje. Neolitik između Save, Drave i Dunava*, Arheološki muzej u Zagrebu, Muzej Slavonije Osijek, Filozofski fakultet Sveučilišta u Zagrebu, Zagreb-Osijek, 156-165.

Reed, K. 2015. From the field to the hearth: plant remains from Neolithic Croatia (ca. 6000–4000 cal BC). *Vegetation History and Archaeobotany*, 24, 601-619. https://doi.org/10.1007/s00334-015-0513-3

Reed, K. 2020. Tomašanci-Palača – Arheobotanički rezultati, In: J. Balen (ed.), *Tomašanci-Palača – naselja iz mlađeg kamenog, bakrenog i brončanog doba*, Arheološki muzej u Zagrebu, Zagreb, 245-256.

Semenov, S. A. 1964. *Prehistoric Technology: An Experimental Study of the Oldest Tools and Artefacts from Traces of Manufacture and Wear*, Adams & Dart, Bath.

Shennan, S. 2018. *The first farmers of Europe. An evolutionary perspective*, Cambridge University Press, Cambridge. https://doi.org/10.1017/9781108386029

Šarić, J., 2014. *Artefakti od okresanog kamena u ranom neolitu na tlu Srbije*, Archaeological Institute, Belgrade.

Šošić, R. 2007. Značajke cijepanog litičkog materijala iz male grobne jame 15 s lokaliteta Slavonski Brod - Galovo u Slavonskom Brodu, In: K. Minichreiter, *Slavonski Brod - Galovo. 10 godina arheoloških istraživanja*, Monografije Instituta za arheologiju 1, Institut za arheologiju, Zagreb. 176-187.

Šošić Klindžić, R. 2010. *Proizvodnja cijepanih kamenih artefakata ranih poljodjelskih zajednica na prostoru istočne Hrvatske,* Unpublished doctoral dissertation, Filozofski fakultet Sveučilišta u Zargebu, Zagreb.

Šošić Klindžić, R. and Hršak, T. 2014. Starčevačka kultura, In: J. Balen, T. Hršak and R. Šošić Klindžić (eds.), *Darovi zemlje. Neolitik između Save, Drave i Dunava*. Arheološki muzej u Zagrebu, Muzej Slavonije Osijek, Filozofski fakultet Sveučilišta u Zagrebu, Zagreb-Osijek, 14-28.

Težak-Gregl, T. 1998. Neolitik i eneolitik. In: S. Dimitrijević, T. Težak-Gregl and N. Majnarić-Pandžić, *Prapovijest*, Naprijed, Zagreb. 57-158.

Torrence, R. and Barton, H. 2006. *Ancient Starch Research*, Routledge, New York. https://doi.org/10.4324/9781315434896

Van Gjin, A. 2010. *Flint in Focus*. *Lithic Biographies in the Neolithic and Bronze Age,* Sidestone Press, Leiden.

Vaughan, P. C. 1985. *Use-wear analysis of flaked stone tools*, University of Arizona Press, Tucson.

Zohary, D. 1996. The mode of domestication of the founder crops of Southwest Asian agriculture, In: D. R. Harris (ed.), *The Origins and Spread of Agriculture and Pastoralism in Eurasia*, University College London Press, London, 142-158.

Zvelebil, M. 2002. Demography and dispersal of early farming populations at the Mesolithic-Neolithic transition: Linguistic and genetic implications, In: P. Bellwood and C. Renfrew (eds.), *Examining the farming/language dispersal hypothesis*, McDonald Institute of Archaeological Research, Cambridge, 379-394.

All soul is immortal (Plato)[1]

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In this paper, the authors dealt with the idea of souls of the deceased taking a journey from and back into our known world. In order to achieve this, a soul would need light to reach the Afterlife, but also some light to return safely. The idea of a souls' return journey was debated by several ancient philosophers, among others Plato and Cicero. One possible material manifestation of this idea is the fact that many times, oil-lamps were placed into graves that had never been used before, as well as those that were placed into graves upside-down. The motifs depicted on the deposited oil-lamps were possibly meant to encourage the deceased to take the journey back, while some were meant to make them remember this life easier and become eager to come back. Also, oil containers (jugs) that were deposited as grave-goods contain large amounts of oil, which might also be explained with the idea that a soul was expected to go to the Afterlife, but also come back and use all of the oil.

Keywords: *oil-lamp experiment, Afterlife, soul, journey, Plato, Cicero*

Introduction:

After lamps were invented, human life reached a new dimension. Lamps offered light that was always helpful in moving around and doing work during nighttime. Roman lamps were made in different sizes, from the extremely big ones, that could hold a large amount of fuel, thus ensuring a long-lasting and uninterrupted flame, to the really small ones that are considered toys. They were lit on different occasions – family feasts, birth, wedding, and they were lit above doorsteps or windows (Vučić 2009: 12). They were also lit during funerals and as part of funerary rituals, but they also played a symbolic role. In all of the ancient cemeteries, oil-lamps belong to the most frequently encountered grave-goods. Within graves, they are usually found in a regular position and such positioning could be connected to symbolic lighting of deceased's way into the Afterlife. However, in some cases, oil-lamps are discovered turned upside-down and such a position could be understood as a symbolic disappearance of light and of the forthcoming death (Škarica 2022: 3).

[1] Plato, *The Republic*, book X, 611a-b; Plato, *Epistulae* 7, 335a.

Materials and methods

Most of the oil-lamps discovered on ancient cemeteries possess burning traces on their nozzles. Still, it remains unclear whether they were used during the funerary procession and deposited into the grave pit while the flame was still flickering. One thing is certain and that is that after the grave pit was closed and the oxygen was cut, the lamp would stop lighting.[2] Sometimes, lamps were deposited into graves that showed no traces of burning, indicating that they were never used in their primary purpose. Such lamps are proofs of the symbolic of lighting a way to the soul that departs into the other "darker world".

Regarding other grave-goods, pottery and glass vessels, cosmetic and medical tools, jewelry, bone and metal needles for sawing, spinning tools, fishermen's hooks were also deposited. Their purpose in everyday life is clear. If one accepts that the ancient man believed in the continuation of life in another world, then the purpose of putting different everyday items in graves is clear (Giunio and Alihodžić 2019: 114). The same could be said about the oil-lamps, but the authors consider that they played a double role in the Afterlife: not just the basic one of lighting one's way, but also the guiding role from here to Beyond and possibly also back. A lamp, deposited together with a jug filled with oil, certainly represents a set or a toolkit necessary for a wondering soul. If one looks further into the matter, it becomes clear that at a certain point, a lamp had to be re-filled and the wick needed to be pulled out, so that the light would last until the end of the journey.

Within experimental archaeology, there are not many experiments that deal with using and kindling of oil-lamps, possibly because finds of this kind are rather frequent and one usually considers that all about them is already said and written. However, one usually does not think about all of the actions that need to be taken to get the lamp ready for usage: to fill it with fuel, set and light the wick, put the lamp in a place with enough oxygen but wind-free and then continuously pull out the wick and re-fill the fuel container. Further questions are related to the connection between the length of the wick, the material it is made of, and its burning time, and also, what is the relationship between oil capacity and burning time (Vaiman 2020)?

The experiments described below offer answers to some of these questions raised above. The authors find it precious for their further research on journeys of the soul.

Experiments

The first experiment, the one executed by Vaiman,[3] included replicas of oil-lamps from the Mediterranean area and dated from the 1st to the 7th century AD. For kindling material, Vaiman used non-distilled olive oil, castor oil and linseed oil, although the first one was the most widely used in the Mediterranean region. As material for wicks, he used cotton, flax, and hemp, all of them widely spread in Roman times, too (Vaiman 2020).

Regarding the length of the burning time, the average was one hour with wicks that were 7.5 cm long. Cotton wicks proved to be the best ones, i.e. their burning time was the longest (Vaiman 2020). What affected the burning time was temperature: when it was colder, the burning time was longer and vice versa (Vaiman 2020). The same goes for fuel type: if it is cold, burning time lengthens and the flame is lower, and vice versa. Olive oil showed to be the best fuel. It does not give off smell and smoke during burning. The flame is strong, high, and bright. However, olive oil was expensive and was used mostly in the south of the Roman Empire (Vaiman 2020). A fact must be added here that says that an average Roman lamp consumes 8 gr of olive oil per hour (Crnobrnja 2008: 411). It seems that the lamp type has no significant effect on oil burning.

Result or the general conclusions reached with this experiment were the following (Vaiman 2020):

1) Ceramic lamps that were used during the experiment became heated.

2) It was impossible to use them outside, especially during windy weather. They had to be closed with a special cover and used as lanterns.

3) The combustion time is different for each kind of ceramic lamp and is related to the length of the wick.

4) A wick needs to be pulled every 40–45 minutes with pincers.

5) The nozzle form was not only aesthetic, since it replaced the wick holders.

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[2] A grave inscription from Ostia can be named here, saying „*Hic situs finita luce*" (When you lie here, the light has gone out). CIL XIV, 1865.

[3] Vaiman Aleksei, The Hebrew University of Jerusalem, Department of Archaeology, Israel.

The second experiment was executed by Alihodžić and Bilić (Bilić 2019: 4). The following items were used for it: replica of a firma-lamp of the FORTIS type, 10.5 cm long, 7.2 cm wide, 3.2cm high, with a bottom diameter of 4.1 cm It possessed a cotton wick. Olive oil was used as a fuel and its volume was 0.030 l. The covering of the lamp was performed with a cylinder shaped laboratory vessel that was 22 cm high and 17 cm in diameter. The air volume in the vessel was 4.990 cm^3.

Result or the general conclusions reached with this experiment were the following:

After the flame from the lamp was covered with the vessel, it burned at the minimum length of 38.44 sec and the maximum length of 56.58 sec. A total of six experiments were performed. During all of them, it was noticed that after the twentieth second, the flame would stop flickering and became reduced, in order to get extinguished in the end. The maximum of 56.58 sec was achieved only after the lamp was lit for at least ten minutes, in standard conditions and with the presence of air (oxygen). This simple experiment confirms the well-known fact that it is not possible to keep the flame burning without the presence of air.

Discussion

Oil-lamps certainly belonged to the inevitable grave-goods of Roman times.[4] Their function was to light the way of the departing soul into the Underworld. Since the burning time of each lamp is limited, it needs to be refilled. This is why in many cases there are also jugs filled with fuel and also deposited as grave-goods. The soul would therefore have a safe and secure journey that was lit all the way.

However, this might have not been the only journey one's soul was intended to make. There is a quote frequently appearing with many search engines, apparently overtaken from Plato and indicating that a soul would also undergo a return journey. It goes as follows: *„The souls of people, on their way to Earth-life, pass through a room full of lights; each takes a taper - often only a spark - to guide it in the dim country of this world. But some souls, by rare fortune, are detained longer - have time to grasp a handful of tapers, which they weave into a torch. These are the torch-bearers of humanity - its poets, seers and saints, who lead and lift the race out of darkness, toward the light. They are the law-givers and saviors, the light-bringers, way-showers and truth-tellers, and without them, humanity would lose its way in the dark*."[5]

Plato dedicated several of his works to the idea of immortality of the soul (Alt 2005: 43). In "Apology", he considers the Hades as a place in which souls dwell forever, meaning at the same time that the souls resting there remain immortal (Plato, Apology: 41c). On the other hand, the central idea in "Gorgias" (Plato, Gorgias: 523e – 525c) is righteousness of souls: they are being judged by judges and are either sent to Tartarus or to the Island of the Blessed, depending on their righteousness. In none of these works does Plato mention reincarnation. In "Meno" (Plato, Meno) it is introduced as support about the idea of remembering previous knowledge: from birth onwards, as well as in Hades, the soul has seen and learned a lot and this is why it can achieve a lot in its present life (Plato, Meno: 81b-e). In "Phaedo" however, Plato states that before souls reach human bodies, they dwell in Hades, which is a noble, pure, and invisible world. In Hades, or in the realm of ideas, souls reach ultimate knowledge. Further on, after having returned into human bodies, they find it difficult to remember what they had learned there. This is why human knowledge about many things (like beauty, for example) does not represent permanent possession, but it requires knowledge about ideas to be understood over and over again (Plato, Phaedo: 68b and 80d).

Only in the dialogue "Phaedo" (Plato, Phaedo) does immortality become an issue (Alt 2005: 44). Presence and re-birth of a soul are described in two different ways. Rebirth can either take place immediately (Plato, Phaedo: 81d – 82 b), or it can occur after a certain period of time during which the soul has been in one of the different regions of Beyond (Plato, Phaedo: 107d – 114c). In both cases, the soul is considered as a purely spiritual entity. Further on, only in "Phaedo" it is mentioned that a limited number of souls get the possibility to comprehend eternal light of the Afterlife, while all of the others inevitably return to this mortal coil.

In the dialogue „Phaedo", Plato also speaks about different ideas, including the idea of beauty. He understands the ideas though his soul and through the soul having

[4] It is interesting to mention that almost 87% of all oil-lamp finds from Moesia Superior come from funerary contexts (Crnobrnja 2008: 411).

[5] The quote does not appear as such in any of Plato's works. However, he wrote a lot about the soul and the body in such a way that it becomes clear that he believed in souls' return (see quotes from „Apology", „Gorgias", „Meno" or „Phaedo" listed in the main text).

insight into itself. He tends to understand the ultimate truth about the nature of the divine and human soul. Herewith, Plato understands death as separation of soul from the body. Only when it is separated from the body and the outer world, the soul can reach ultimate knowledge and ideas. The outer world is something that is changeable and tends to decay and this is why it tricks the soul, by showing it deceitful reality (Plato, Phaedo: 66 b-e and 67d).

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The time span between the life and work of Plato on one hand and the Roman imperial period on the other includes about four centuries. Even longer, if one considers the Balkans and the Roman provinces established there. However, in this period in between, there was a philosopher who studied the same questions and discussed them in his writings.

Cicero's philosophical works played a significant part in the evolution of a new understanding of the nature of philosophy, as primarily a matter of the meanings of texts and the intellectual evaluation of the claims and arguments presented in them (Blyth 2010: 93). By writing philosophical texts in Latin that achieved such wide circulation, Cicero had a decisive influence on the growth in the western Roman world of a conception of philosophy he had not intended to promote, but which subsequently became dominant (Blyth 2010: 71). In the period from approximately 55 BC to his death in 43 BC, he wrote at least fourteen works of philosophy, eleven of which remained substantially intact.

Cicero's works functioned as the primary model of Latin philosophical prose and of philosophy as prose. He initiated the process of forging a Latin philosophical vocabulary, both producing terms himself and discussing how to do so (Blyth 2010: 94). In this way, philosophy was no longer a life but a leisurely, literary adjunct to life (Blyth 2010: 91). The later reception of his philosophical texts played a significant role, since their formal characteristics, in conjunction with their foundational influence in the Latin tradition, modelled and insinuated the idea that philosophy is primarily related to texts (Blyth 2010: 93).

Cicero was well acquainted to Platonic works (e.g., Plato's Republic and Laws), but also to the fact that aspects of it were present in many other works throughout antiquity. Though there are substantial differences in the way these two key thinkers (and their successors and near-contemporaries) articulate their thoughts on a community, they agree that its care is presented as the promotion of the life of virtue through the appropriate use of laws, education, and ritual (Márquez 2012: 198-199).

What is of great importance for this paper is that both Plato and Cicero agreed on many aspects regarding the soul. Cicero's most detailed and systematic philosophical treatment of the emotions and the soul appears in the *Tusculan Disputations*, a work composed in the second half of the year 45 BC, at a time of grief following the death of his daughter Tullia (McConnell 2021: 150). The *Tusculans* consist of five books in which Cicero attempted to popularize Greek philosophy in ancient Rome. The soul was being discussed in the first, third, and fourth one.

The nature of the soul is immediately addressed in the first book through a discussion about the philosophical question whether death is or is not evil. This dispute further leads to two questions: what does death actually involve and what is the nature of the soul (McConnell 2021: 151)? As an extension to the second question, a third, maybe crucial one, could be added: is the soul mortal or immortal? One of Cicero's positions on the matter is that the soul is a thing that is separate from the body, it lasts forever and it is immortal (McConnell 2021, 152). This position is associated most of all with Plato, and in particular with the arguments put forward by Socrates in the Phaedo (*Tusculans* I. 24, 39-40, 53-77). In other words, it matches Plato's views on the fundamentally separate natures and capacities of soul and body, with the crucial differences concerning the questions of immortality and immateriality.

Cicero offers a series of arguments for the soul's immortality that appeal instead to the authority of popular cultural traditions. Cicero first observes that the ancient Romans held that people remained sensate after death, hence the sacred burial rites, the pontifical law, and the established beliefs about the afterlife – the esteemed go to the heavenly realm, the rest to a place under the ground (*Tusculans* I. 27). He also noted that the Greeks had similar pre-philosophical traditions (*Tusculans* I. 28-29) (McConnell 2021: 153). Nature itself gives further grounds for believing in the immortality of the soul since people universally have all kinds of concerns about the future after their own death (*Tusculans* I. 31-36) and these natural impulses only make sense if there really is a self after death, which implies the immortality of the soul. Although it offers a clear indication that the soul is immortal, Cicero stresses that the nature of the soul's survival after death is not accounted for properly in popular tradition – the bodily afterlife is emphasized erroneously, because the ancients were unable to grasp the life of the soul separate from the body (*Tusculans* I. 36-38). This is where the philosophers come into their element and the Pythagoreans are identified as the first to distinguish the soul from the body, with Plato in particular (*Tusculans* I. 38-39).

Cicero further recounts the argument from Plato's Phaedo, in which the soul is identified as a self-moving thing without origin or birth (*Tusculans* I. 53-55; Plato, *Phaedo*: 245 c-e), and also the recollection argument in Plato's Meno and Phaedo, in which learning is explained by the soul having acquired knowledge of the forms in a prenatal mode of existence, before being entombed in a body here on earth (*Tusculans* I. 55-59; Plato, *Phaedo*, 72e–78b; *Meno*, 81a–86c). Plato distinguished the immortal soul from the mortal body by virtue of its immaterial and divine nature (McConnell 2021: 155).

On the other hand, Cicero left the question of the soul's material nature open, but he surely considered that the soul had a divine nature on any account (McConnell 2021: 155). He argued that the soul is divine because it is pure and unblended with any of the base earthly elements, but it is the Platonic line that the soul is divine because it has the capacity for memory and for thought and contemplation about divine things (*Tusculans* I. 60-65).

More arguments are drawn from *Phaedo*, saying that the soul is subject to reward and punishment after death (*Tusculans* I. 72) and death welcomes the good person (*Tusculans* I. 73-75). This is why one should not fear death if he/she had lived a good, honest, and decent life and it is also regarded the so-called final argument by Plato and Cicero that the soul by its very nature must be deathless and indestructible (*Tusculans* I. 71).

It is also noteworthy to take a brief look at the Roman law on the matter of souls' immortality. The Romans assumed that the soul was the immaterial part of a person which left the body when that person breathed his last. The soul remained under the ground, generally in the grave. On the other hand, after the soul had left the body, its immortality depended on the way in which the dead body had been handled. By writing their will or codicil, a person could take steps during his lifetime to ensure that his soul would find rest after death, requesting their heirs or legatees to carry out their wishes regarding their funeral (Tellegen 2012: 181). In other words, when someone died, their relatives were expected to perform a number of rituals with care and precision. For example, in order to mark a household struck by death, they needed to set up cypress branches and light lamps (Giunio and Alihodžić 2019: 108). If they failed to perform the rituals or had not performed them well, the soul went to join the *Lemures*. Such souls could not find peace and roamed around at unseasonable hours. If the relatives had performed the rituals well they hoped that the soul would go to join the *Dii Manes*. Despite the will or a codicil that had been written, it was sometimes very difficult to enforce them and in cases of heirs' conflict, the immortality of the soul became a legal problem (Tellegen 2012: 182).

Regarding the argument by Plato and Cicero mentioned earlier in this paper, through which learning is explained by the soul having acquired knowledge of the forms in a prenatal mode of existence, before being entombed in a body here on earth, one needs to think of the souls' return to this world over and over again. This hypothesis sheds new light on the matter. Clearly, since it was believed that the soul is immortal, it needs to come back and for this, it again needs lamps and light (and fuel). This again brings us back to the disposition of lamps deposited in graves, since their position might again represent a way leading to re-birth. This might also explain the presence of oil-lamps that were deposited as grave-goods but never used before. Finally, the fact is that the volume of jugs containing lamp fuel many times exceeds the volume of oil-lamps and this could indicate that lamps were needed for a return journey.

When motifs on oil-lamps are considered within this debate, it becomes rather clear that many of them indicate resurrection and re-birth. In many cases, there are images of Dionysus and his associates and attributes depicted on oil-lamps, like Amor or Cupid (Anđelković Grašar and Tapavički-Ilić 2016: 119). They are usually depicted with vines, grapes or wine and through the Dionysian cult, they are linked to apotheosis and the afterlife. On oil-lamps, but also sarcophagi, they are represented either independently or within a scene, always indicating epiphany, salvation, triumph, and love (Elsner 1998: 150-152; Ramage and Ramage 2005: 292-293). In addition, because of his rebirth, Bacchus-Dionysus was considered the god of abundance and therefore, immortality and resurrection could have been accomplished through him. The appearance of mask motifs on oil-lamps can be explained in this context, too (Крунић 2009: 246). Other related motifs, like grapevine or ivy, are typical ornaments in the Dionysus' cult and they represent longevity, continuity and eternity (Anđelković Grašar and Tapavički-Ilić 2016: 120, 121). In addition, the wine's greatest importance in Roman art was gained in

Figure 1. Oil-lamp with the image of a gladiator (AmZD, A31105). (Photo by N. Škarica).

the Dionysian cult due to the connection with the idea of metamorphosis (Црнобрња 2006: 57). On some oil-lamps, images of dogs chasing rabbits are depicted. Rabbit is a lunar animal, a follower of lunar and chthonic goddess Hecate, but also an attribute of Aphrodite, Eros and Dionysus. It is a symbol of life renewal, dying and rebirth (Кузмановић Нововић 2013: 71).

Rosettes also come as motifs on oil-lamps. They resemble a solar character and the cycle of birth and death and thus, they are important in the cult of death. In the territory of Upper Moesia, it represents one of the most commonly used motifs decorating oil-lamp discs (Anđelković Grašar and Tapavički-Ilić 2016: 119).

Very often, on discs, there are images taken from Roman everyday life. Besides the already mentioned masks, there are also scenes of gladiator fights, dogs chasing deer, chariot races or erotic scenes, all made in such a manner to gain buyers' affection (Cambi 2002: 197; Vučić 2009: 12). Here, one might ask whether these motifs were also souls' reminders of their previous lives, aiming for them to remember it easier?

At the territory of Zadar, a total of around 2400 graves has been discovered. According to the grave-goods found within them, they were dated from the 1st to the beginning of the 5th century, actually in the period when one lived and was buried according to the Roman laws. During archaeological research, both cremated and supine burials were found (Giunio and Alihodžić 2019: 88). In numbers, there were 1237 cremated graves, 1147 graves with supine burials, and 84 graves with an unknown burial ritual (Gluščević 2005: 191, 217; Plohl 2018: 65-97). Regardless of the ritual, the graves always contained oil-lamps as grave-goods (Fig. 1 and 2).

Although over two thousand oil-lamps are kept in the Archaeological Museum of Zadar, for the purposes of this paper, only 863 of them were considered. The reason for this is that many lamps come from old excavations and do not possess the necessary finding context and related data. The lamps that were taken into consideration come from the excavation years 1989 and 1998, as a shopping mall was built in Zadar (Gluščević 2005). The majority originates from cremated burials (143 lamps from 396 graves), while much less originates from skeletal ones (63 lamps from 467 graves). Several graves contained more than just a single oil-lamp.

If one observes oil-lamps in the context of grave-goods represented on the ancient cemetery of Zadar, it is possible to conclude that their disposition within graves does not follow any specific pattern. In cremated graves, oil-

Figure 2. Selection of oil-lamps from cremation graves discovered at the ancient Roman cemetery of Zadar. (Photo by I. Čondić).

lamps are usually encountered next to vessels in which the remains of the deceased were deposited. In most of cases, they are placed regularly, but there are also cases of them being placed upside-down or leaning vertically against the urn (Fig. 3). Oil-lamps deposited in skeletal graves were also deposited in different positions, close to the head, feet, or anywhere near the body (Fig. 4). Regardless of the fact whether they were cremations or skeletal graves, oil-lamps that were positioned upside down or vertically could not burn at all, since these positions would make all of the fuel run out. On the other hand, for those lamps positioned regularly, the question remains how long would they remain lit after the grave pit was closed and the oxygen flow was cut?

It needs to be mentioned that around all of the well-preserved grave-goods from the Zadar graves, deposited either around cremated remains or a deceased body, a large amount of iron nails was discovered, too. They might imply the existence of a wooden grave cover. Its shape and dimensions remain unknown since the wood had rotten away, but one can suspect that it fitted the shape and size of the grave pit. In time, the wood would decay and the eath gradually filled in the grave pit. Such gradual descending of the earth into the pit might be a reason for the good and full preservance of glass and ceramic grave-goods. Further on, graves covered with tegulae were noted, them being placed as covers and disposed in the shape of a lid or as gable roofs. Such architectural constructions were noted with both burial rituals. With either wooden covers or grave constructions, it is clear that there was enough room within the grave pit that was filled with air. In cases of depositing a lit oil-lamp into the grave pit and next to the deceased, there was a possibility to keep the flame burning as long as there was enough air. The question arises whether that was enough to light the way of the departing soul?

There is no answer to the question about what was deposited within glass or pottery vessels discovered at the Zadar cemetery. In several stone urns that were hermetically closed, there were glass urns with bones and some kind of liquid, but no samples were taken for a chemical analysis (Fig. 5). At the end of the 19th century, during the excavation at Pompeii and within the monumental tomb of Nevoleia Tiche, Munazio Fausto and their relatives, urns had been discovered containing a mixture of water, wine and oil (Taborelli 1999: 472). Regarding re-filling of the oil-lamps, one certainly should expect oil in at least some of the deposited vessels.

Figure 3. Cremation grave from the ancient Roman cemetery of Zadar. (Photo by T. Alihodžić).

Figure 4. Skeletal grave from the ancient Roman cemetery of Zadar. (Photo by I. Fadić).

Finally, wick needles also need to be mentioned in this context. Although there are no finds of this kind from Zadar, there is an interesting one from Crikvenica. In 2012, during the excavation of the south-western part of Crikvenica's *figlina*, two inhumation burials were unearthed (Šiljeg et al. 2013). Both graves were infant burials in simple pits, with the first grave being rather damaged and the second one (G2) discovered intact (Konestra and Ožanić-Roguljić 2016: 128).

The grave-goods deposited within G2 included a jug, a pearl, a nail and an oil-lamp with a pointy needle inserted into its filling hole, its head exiting from the hole (Konestra and Ožanić-Roguljić 2016: 130). This position indicates a secondary usage of the needle, which can probably be interpreted as a tool used for adjusting the wick (Konestra and Ožanić-Roguljić 2016: 133). Oil-lamp toolkits are known from many sites and museum collections, usually made of bronze and associated with metal lamps (Konestra and Ožanić-Roguljić 2016: 133). They were used for adjusting the wick's length and trimming its burnt-out section, allowing optimal illumination at all times (Chrzanovski 2013: 48-49). Apart from these specific tools, various objects were used to regulate wicks, from simple sticks to iron nails (Chrzanovski 2003-2006: 119). The position of the broken sewing needle in the lamp from G2 could point to such an interpretation, supported also with the blackened wick-hole indicating that the lamp had been used at some point. In accordance with this, all of the lamp's features and the placement of the needle could suggest that the lamp was lit when placed in the grave or, at least, that it was burning while the funerary ceremony was being performed (Konestra and Ožanić-Roguljić 2016: 133).

Many oil-lamps were excavated at the Roman town and legionary fort of Viminacium, actually its cemeteries, where almost 14.000 graves were unearthed. The oil-lamps from this site represent the most numerous collection of oil-lamps from the territory of the Roman Empire and those coming from archaeological excavations. At the Viminacium cemeteries, the total of over 8.000 oil-lamps were discovered, with almost three quarters coming from closed contexts, actually graves (Korać 2018: 11-12).

Figure 5. Liquid in a stone urn from the ancient Roman cemetery of Zadar. (Photo by I. Fadić).

Conclusion

Although throughout the Roman Empire, the numbers of oil-lamps as grave-goods are measured by thousands, some aspects of their presence in graves still remain uncertain. They were surely deposited in order to fulfill their primary purpose, i.e. light someone's way, but was that only a one-way or a return journey? Was a soul expected to re-fill the lamp and pull the wick out in order to keep the flame lit for a longer time? Would such an action represent knowledge gained during one's previous life and not forgotten during the Afterlife? Was the duration of the journeys just right and in accordance with the amount of fuel deposited within pottery jugs? Is this time measurable by the average life-span of a human being, is it measurable at all or does it stand close to infinity?

One thing is certain and that is the unbroken tradition of symbolic light reflected in the fact that the ancient oil-lamp was replaced with a wax candle. This is especially clear with the Christian religion, since during the last moments of one's life, a lit candle is placed in their hands in order to light the way of the departing soul.

Even today, light is brought to the deceased in the shape of different lanterns. While praying for the deceased, among others there is the phrase "let perpetual light shine upon him/her", indicating that this belief is not forgotten (Lukač and Artuković Župan 2015: 64).

Here, the authors played with the idea of souls taking a return journey from and back into our known world. For that, a soul would need light to reach the Afterlife, but also some light to have a safe return. This might be a possible explanation of the fact that many times, oil-lamps were placed into graves that had never been used before, as well as those that were placed into graves upside-down. The motifs depicted on the deposited oil-lamps were meant to encourage the deceased to take the journey back. Some were possibly meant to make them remember this life easier and to become eager to come back. Also, oil containers (jugs) that were deposited as grave-goods contain large amounts of oil, which might also be explained with the idea that a soul was expected to go to the Afterlife, but also come back and use all of the oil.

The idea of never seeing the beloved ones again is difficult to accept. After their death, for a long period of time, friends and relatives in many ways act as if that person is still around. Logically, the idea of the deceased's return is therefore close to every human being that lost someone who was close to them. Although it might be considered wishful thinking, it might also be considered as an optimistic perspective. And the ones that were left behind would do anything to make another encounter possible, so why not leave a light on? At least as long as someone else lights the light for us?

References

Alt, K. 2005. Zur Auffassung von Seele und Geist bei Platon, Mittelplatonikern, Plotin, *Hyperboreus* 11 (1), Bibliotheca Classica Petropolitana, St. Petersburg, 30-59.

Anđelković Grašar, J. and Tapavički-Ilić, M. 2016. Life after death, light after death, *Tibiscvm Serie nouă*, Istorie - Arheologie 6/2016, Caransebeş 6/2016, Editura Mega, Cluj-Napoca, 115-128.

Bilić, N. 2019. *Pokusi sa svijećom i mjerenja u nastavi kemije*, bachelor thesis, Sveučilište u Zagrebu, Prirodoslovni-matematički fakultet, Zagreb.

Blyth, D. 2010. Cicero and the Philosophy as Texta, *The Classical Journal* 106 (1), The Classical Association of the Middle West and South, 71-98. https://doi.org/10.5184/classicalj.106.1.0071

Cambi, N. 2002. *Antika.* Povijest umjetnosti u Hrvatskoj, Knjiga 2, Ljevak d.o.o., Zagreb.

Chrzanovski, L. 2003-2006. Conscia lucerna. Seules les lampes savent l'usage que l'on fit d'elles, *Bulletin de l'Ecole Antique de Nîmes*, 26, 114-121.

Chrzanovski, L. 2013. *De Prométhée à la Fée Electricité. Pour une sociologie de l'éclairage à travers les âges, les croyances et les continents*, Académie Roumaine, Centre d'Études Transylvaines, Cluj-Napoca.

Црнобрња, А. Н. 2006. *Култна намена римских жижака у Горњој Мезији*, Београд.

Crnobrnja, A. 2008. Economic aspects of the use of Roman oil-lamps in Moesia Superior, *Phosphorion, Studia in honorem Mariae Čičikova*, Bulgarian Academy of Sciences, National Institute of Archaeology with Museum, Sofia, 408-412.

Giunio, K. and Alihodžić, T. 2019. *Pogrebni obredi i običaji staroga Rima*, Katalozi i monografije 36, Arheološki muzej Zadar, Zadar.

Gluščević, S. 2005. *Zadarske nekropole od 1. do 4. stoljeća, Organizacija groblja, pogrebni obredi, podrijetlo, kultura, status i standard pokojnika*, doctoral thesis, Sveučilište u Zadru, Zadar.

Elsner, J. 1998. *Imperial Rome and Christian Triumph: The Art of the Roman Empire A.D. 100-450*, Oxford University Press, Oxford, New York.

Konestra, A. and Ožanić Roguljić, I. 2016. Illuminating the way: Later Roman factory lamp from a grave context in Crikvenica, In: G. Lipovac Vrkljan, M. Ugarković and I. Ožanić Roguljić (eds.), *Rimske i kasnoantičke svjetiljke: Proizvodnja i distribucija, kontakti na Mediteranu*, Zagreb, 128-136.

Korać, M. 2018. *Oil-lamps from Viminacium (Moesia Superior)*, Institute of Archaeology, Monographs 67, Belgrade.

Круниħ, С. 2009. Мотиви маске на светиљкама из Сингидунума, *Зборник Народног музеја* 19 (1), 233-253.

Кузмановиħ Нововиħ, И. 2013. Иконографске сличности неких представа на глиптици и лампама римског периода, In: С. Круниħ (ed.) *Акта са стручног скупа Античке светиљке, хронологија, типологија и орнаментика*, Музеј града Београда, Београд, 67-78.

Lukač, K. and Artuković Župan, I. 2015. *Put u vječni dom - Predodžbe naših starih o smrti i zagrobnom životu*, Muzej Brodskog Posavlja, Slavonski Brod.

Márquez, X. 2012. Between Urbs and Orbis, Cicero's Conception of the Political Community. In: W. Nicgorski (ed.), *Cicero's Practical Philosophy*, Notre Dame Press, Notre Dame, 191-221. https://doi.org/10.2307/j.ctvpj74jm.14

McConnell, S. 2021. Cicero on the Emotions and the Soul, In: J. Atkins and T. Bénatouïl (eds.), *The Cambridge Companion to Cicero's Philosophy*, Cambridge University Press, Cambridge, 150-165.

Plohl, M. 2018. Tipologija ukopa na nekropoli Vrt Relja u Zadru, *Miscellanea Hadriatica et Mediterranea* 5, 65-97. https://doi.org/10.15291/misc.2746

Ramage, N. H. and Ramage, A. 2005. *Roman Art*, Pearson, New Jersey.

Šiljeg, B., Lipovac Vrkljan, G., Ožanić Roguljić, I. and Konestra, A. 2013. Crikvenica – Ad Turres, rezultati sustavnih arheoloških istraživanja rimske keramičarske radionice na lokalitetu Igralište 2012. godine, *Annales Instituti Arcaheologici*, IX, 121-130.

Škarica, N. 2022. *Tipologija keramičkih svjetiljaka sa antičke nekropole „Hypo banka 2006"*, written essay for obtaining the title of a custodian, defended May 21st 2022, unpublished.

Taborelli, L. 1999. L´instrumentum vitreo nell´edizione del Real Museo Borbonico, *Archeologia Classica* 51, 469-478.

Tellegen, J. W. 2012. The Immortality of the Soul and Roman Law. In: O. Tellegen-Couperus (ed.), *Law and Religion in the Roman Republic*, Leiden and Boston, 181-202.

Vučić, J. 2009. *Lux in tenebris - Svjetlo u tami*, Katalozi i monografije 7, Arheološki muzej Zadar, Zadar.

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Corpus Inscriptionum Latinarum

Internet sources

Cicero, English translation by Younge C. D. https://www.gutenberg.org/files/14988/14988-h/14988-h.htm (Accessed: 31. 07. 2023.)

Plato Apology (The Death of Socrates)
English translation by Jowett B., Project Gutenberg, release #1656, https://onlinebooks.library.upenn.edu/webbin/gutbook/lookup?num=1656 (Accessed: 13. 03. 2023.)

Plato Epistulae
English translation by Morrow G. R.
https://archive.org/details/platosepistles
(Accessed: 13. 03. 2023.)

Plato Meno
English translation by Jowett B., Project Gutenberg, release #1643, https://onlinebooks.library.upenn.edu/webbin/gutbook/lookup?num=1643 (Accessed: 13. 03. 2023.)

Plato Phaedo
English translation by Fowler H. N.
http://www.perseus.tufts.edu/hopper/text?doc=plat.+phaedo+57a (Accessed: 13. 03. 2023.)

Plato The Republic
English translation by Shorey P.
http://www.perseus.tufts.edu/hopper/text?doc=Plat.+Rep.+1.327a (Accessed: 13. 03. 2023.)

Vaiman, A. 2020. Experiment with kindling Oil-lamps, *EXARC Journal* 2020/3 https://exarc.net/ark:/88735/10527 (Accessed: 16. 11. 2022)