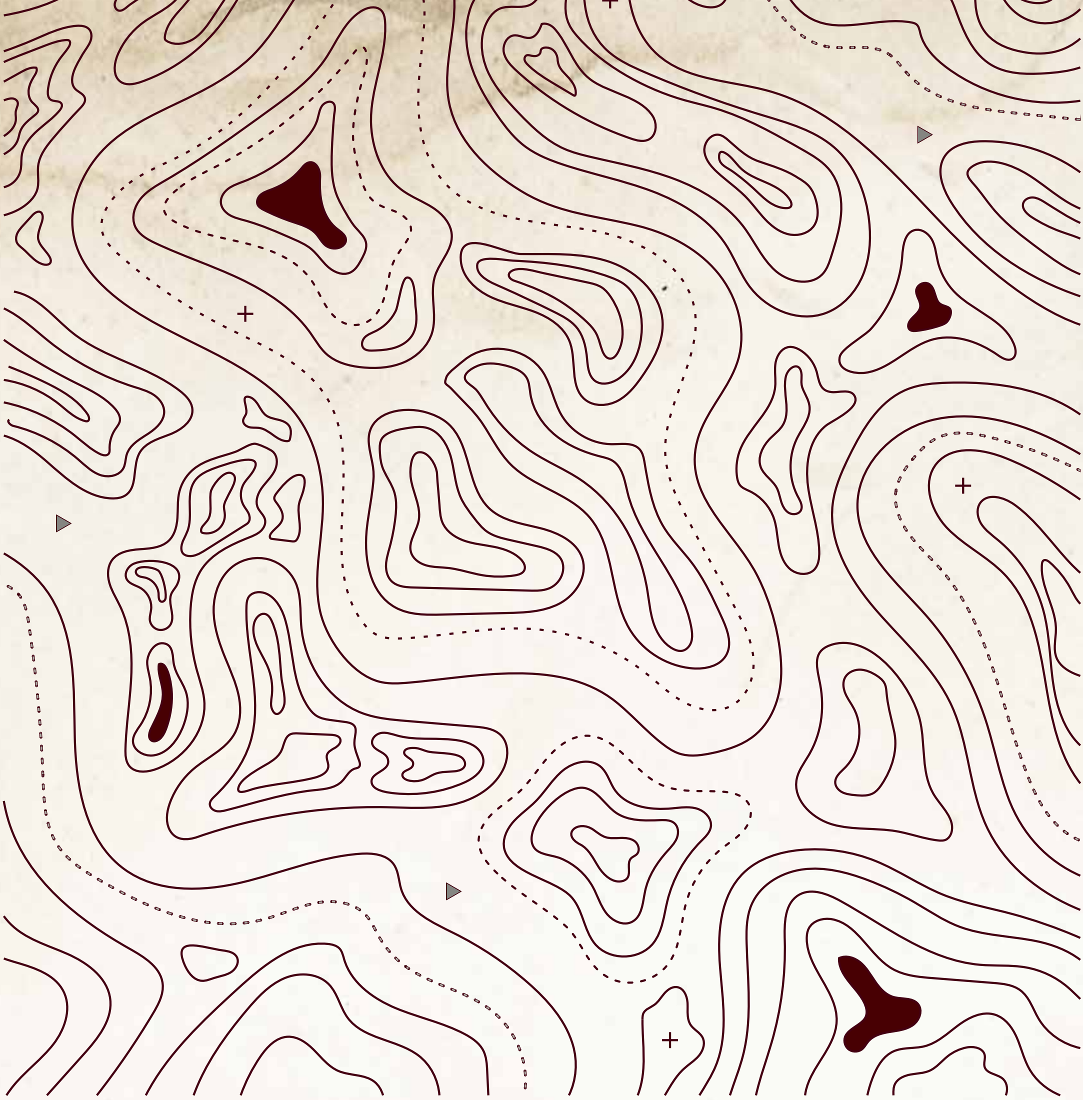

STEM in Heritage: Procedures, Methods, and Teaching

Edited by

Jasna Vuković

UNIVERSITY OF BELGRADE
FACULTY OF PHILOSOPHY
1838

HERISTEM

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CONTENTS

PREFACE

The edited volume *STEM in Heritage: Procedures, Methods, and Teaching* before you encompasses papers presented at the international conference *Teaching STEM in Heritage*. The conference was held in November 2022 at the Faculty of Philosophy, University of Belgrade as the final event of the Erasmus+ Strategic Partnership Project *STEM in Heritage Sciences (HERISTEM)*.

The volume explores the application, learning, and teaching of STEM in heritage disciplines, primarily in Southeastern Europe. The first chapter represents a summary of activities carried out a part of the HERISTEM Project, aimed at university students, staff, and young professionals, as well as the general public (Vuković). Several papers address issues related to STEM teaching: the representation of STEM within university cirricula in Europe (Novaković), within the subdiscipline of archaeology and the public (Cvjetićanin), and within the curriculum of the Conservation-Restoration study program (Korolija Crkvenjakov); the history of archaeozoology at the University of Belgrade (Dimitrijević et al.); relationships between design tools, research strategies, and university courses related to architectural heritage (Milovanović et al.); and relations between "hard sciences," i.e. STEM, and archaeology as a humanistic discipline (Babić). Issues related to various methods and their application in archaeological fieldwork, laboratory analyses, and data processing are also discussed in the volume: the construction of archaological heritage using remote sensing and geophysics (Mlekuž); the use and significance of geoarchaeology both in research and heritage management (French and Rajkovača); geoarchaeological sampling, soil micromorphology, and related laboratory procedures (Rajkovača); the history and current use and importance of GIS (Mori); the application of UAVs, geophysical surveys, laser scanning, and LiDAR in Bosnia and Herzegovina (Kaljanac and Hadžihasanović); and the benefits of using photogrammetry in archaeological documentation (Tresić Pavičić and Burmaz).

We would like to thank all of the contributors for their presentations at the Conference as well as their valuable articles, and the reviewers who read all of the papers promptly and shared their opinions. Out gratitude is extended to our Institution, the Faculty of Philosophy, for supporting the conference and this publication, as well as Tempus Agency for their help during the course of the HERISTEM Project.

Jasna Vuković

THE HERISTEM PROJECT: TEACHING, LEARNING, AND COMMUNICATING STEM IN HERITAGE

Jasna Vuković

Aims and goals of the Project

STEM in Heritage Sciences (HERISTEM) is an Erasmus+ strategic partnership project aimed at implementing STEM sciences and enhancing the university curricula of heritage disciplines. The Project's main goal was to provide an effective transfer of knowledge, skills, and good practices, primarily to students of heritage disciplines, in order to improve their chances in the job market by mastering new STEM-related methods and techniques and gaining experiences in professional working environments. The Project is based on student and staff mobility, and on providing intensive courses to higher education learners.

The partners are universities in Belgrade (Lead Institution), Zagreb, Ljubljana, Sarajevo, and Cambridge, as institutions where young archaeologists receive training. The remaining four partners – the National Museum in Belgrade, the Institute for the Protection of Cultural Heritage of Slovenia, and two private enterprises, Arhej and Kaducej – were selected as the most likely types of institutions for students' further professional careers and training in actual working environments.

The Project started at the end of 2019, with the first activities planned for 2020, including intensive courses, student stays, and staff visits to foreign universities.

Seminar for teachers in online education

The aim of the three-day seminar (Fig. 1) for teachers in online education was to train teachers to efficiently use the e-learning platform designed by the University of Zagreb using a Learning Management Sys-

Figure. 1. Seminar for teachers in online education

tem (LMS)[1] based on open-source MOODLE LMS. All of the lectures were recorded and are available as a webinar. Several lectures were held over the course of the three-day seminar. Bearing in mind that the majority of teachers – participants of the seminar – were unfamiliar with e-learning possibilities, the exercises and practical work during the seminar were of great importance. At the time, the seminar participants had no idea that they would soon have to apply their newly-acquired knowledge due to the COVID-19 outbreak.

Intensive Course in Remote Sensing

Figure. 2. The Intensive Course in Remote Sensing

The Intensive Course in Remote Sensing was held at the University of Zagreb (Fig.2), with teachers from Ljubljana and Zagreb. The topics included aerial archaeology and reconnaissance, LiDAR, the use of satellite images, and the integration of data in geographic information systems. The students also had practical exercises: they worked in groups on assigned projects and presented them on the final day of the workshop.

COVID pandemic and its impact on the Project

Immediately after the conclusion of the Remote Sensing workshop, the COVID-19 outbreak emerged. All areas of life had to change on a global

1 http://omega.ffzg.hr

scale, and this new situation heavily impacted professional and scientific practice as well. Severe lockdowns, and especially travel restrictions, posed a challenge to further Project activities, exclusively based on different types of mobility. The situation required adjustments, such as turning to communication with the scientific and general public (Vuković et al. *in press*) on the one hand, and implementing online training and learning activities on the other. Introductory online lectures for intensive courses in bioarchaeology (zooarchaeology, archaeobotany, physical anthropology, and ancient DNA analyses) (Fig. 3) and geoarchaeology were organized, while the intensive Course in Data Science was completely held online. Student and staff mobility, an essential part of the Project, was affected the most severely by the pandemic, due to travel restrictions and other special measures. After the pandemic ceased, the global political and economic situation made it further difficult for mobility to take place, and unfortunately, many trips did not occur in the end.

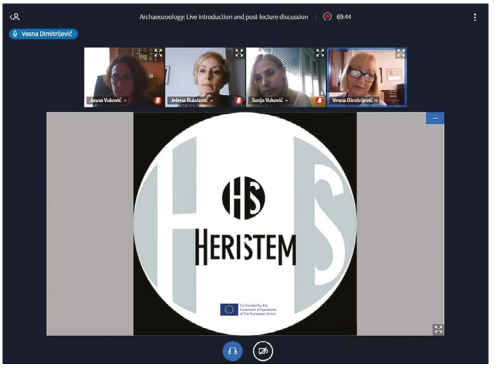

Figure. 3. Online introductory lectures for the Intensive Course in Bioarchaeology

Archaeological Dialogues without Isolation (ARDIZO)

Following the COVID-19 outbreak, project activities were halted. As soon as the global lockdown was put in place, the Project team organized an online conference titled *Archaeological dialogues without isolation*, aimed at scholars, researchers, and the scientific public (Fig. 4). From March to June 2020, 21 lectures were given, followed by fruitful discussions on a wide range of topics – from the history of archaeology to considerations about the state of archaeological heritage to archaeological views on the pandemic. All of the lectures were posted on the newly launched HERISTEM YouTube channel[2], and more than 30 hours of recorded videos have received more than 1500 views to date.

Because of the HERISTEM's prompt response to the new, pandemic situation, *Archaeological dialogues* were recognized as an important strategy during the altered circumstances caused by the COVID-19 outbreak.

2 https://www.youtube.com/playlist?list=PLPveCfyN5lZz2rrqC7gvNZg4lpTM_utgm

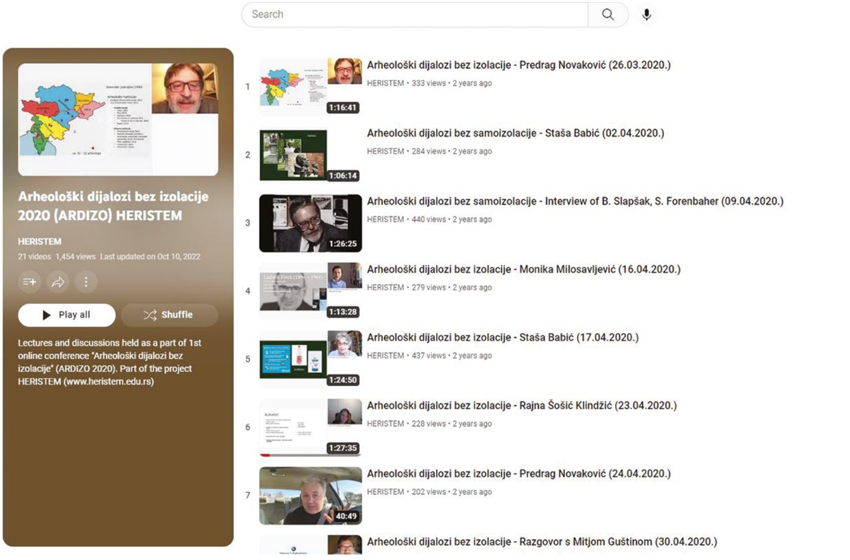

Figure. 4. *Archaeological dialogues without isolation* on YouTube

As a result, *Project HUMAN: Digital transformation in Humanities*[3] *included Archaeological dialogues without isolation* among examples of good practice in communicating archaeology in a digital environment.

Figure. 5. Short videos made for European Researcher's Night 2020

European Researcher's Night 2020

Due to the pandemic, the European Researcher's Night was held online in November 2020. One of HERISTEM's partner institutions, the Department of Archaeology, University of Ljubljana hosted the joint program.

3 https://www.digihuman.eu/case-studies/

The content was presented through a webpage in two languages (Slovene and English)[4]. The general topic was *From earth to table and back*, and it focused on presenting research about human food and diet in the past. This field of research was appealing to the general public while also educating on many interesting topics, including STEM. The webpage, featuring 72 videos (Fig. 5) lasting 4 hours and 18 minutes, three quizzes, and one live event proved to be very interesting to the public, with 550 visits in three days. However, the website was very popular in the following months, with more than 3000 visits by March 2021 (Vuković et al. *in press*).

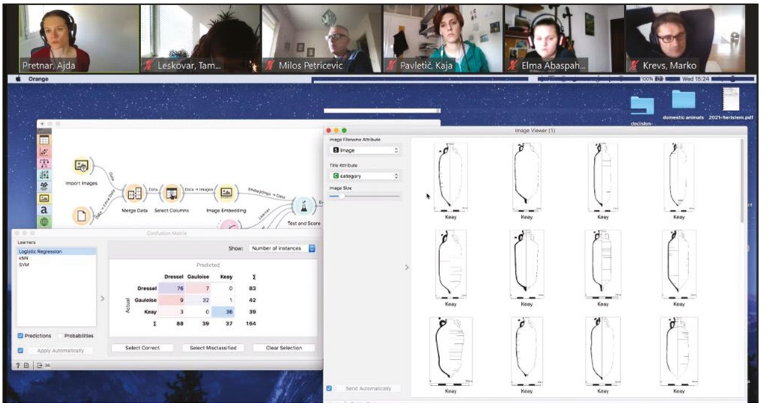

Figure. 6. Online lecture for the Intensive Course in Data Science

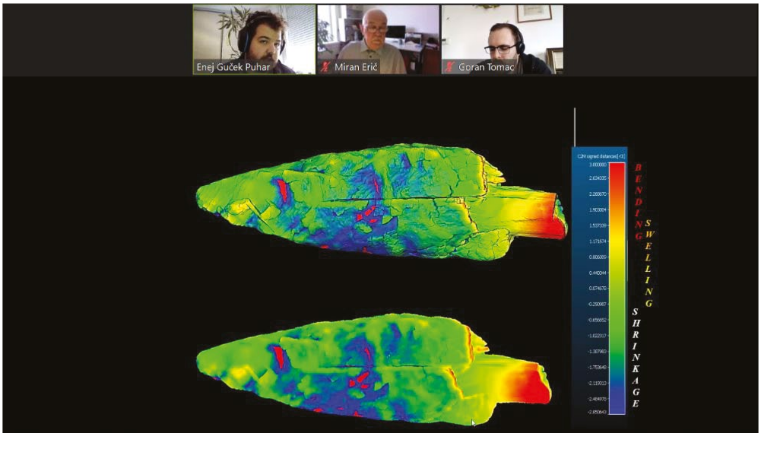

Figure. 7. Online lecture for the Intensive Course in Data Science

4 https://arheolog.eu/domov-english/

Intensive Course in Data Science

The course was organized online in March 2021 by the University of Ljubljana (Figs. 6–7). The covered topics included big data, data classification, data clustering, predictive modeling, 3D modeling, text mining, and image analytics. The participants engaged in exercises in statistics, predictive modeling, data clustering, and other topics.

Figure. 8. Exercises in human and animal bone analysis during the Intensive Course in BioarchaeologyResearcher's Night 2020

Intensive Course in Bioarchaeology

The course in bioarchaeology was organized in person by the University of Belgrade in March 2022. The attendees took part in several short lectures, but the focus was on the exercises in human and animal bone analyses (Fig. 8).

Figure. 9. Field exercises during the Intensive Course in Geoarchaeology

Figure. 10. Field exercises during the Intensive Course in Geoarchaeology

Figure. 11. Field exercises during the Intensive Course in Geoarchaeology

Intensive Course in Geoarchaeology

The in-person part of the Course in Geoarchaeology was organized by the University of Zagreb, Cambridge, and Arhej, and was held in spring 2022 in Đakovo, Croatia (Figs. 9–11). The covered topics and exercises included the goals of geoarchaeological fieldwork, mechanical coring, augering, soil sampling and sample processing, and physical analyses (see also French and Rajkovača, this volume). The students discussed what they had learned and why they wanted to learn about geoarchaeology.[5]

Figure. 12. The Intensive Course in Museum Studies

5 https://www.youtube.com/playlist?list=PLPveCfyN5lZw8-hDkpO0BMIG4vOcEifeG

Figure. 13. Seminar in Entrepreneurship in Archaeology

Intensive Course in Museum Studies

The course was organized by the National Museum in Belgrade and was held completely in person in October 2022 (Fig. 12). The participants learned about the nature of the archaeological record, various analyses of artifacts (archaeometric, macroscopic), and the application of STEM in preventive and curative conservation. They also took part in various exercises including exhibition design.

Figure. 14. The exhibition HERISTEM – STEM in Heritage Sciences at the National Museum in Belgrade

Seminar in Entrepreneurship in Archaeology

The seminar was held at the Faculty of Philosophy, University of Belgrade, and was aimed at young professionals (Fig. 13). Among the covered topics were experiences in entrepreneurship in archaeology in various countries, legislative conditions and prerequisites for entrepreneurship in archaeology, management of field projects, and budget planning, among others.

The HERISTEM exhibition

The National Museum in Belgrade hosted the poster exhibition HERISTEM – STEM in Heritage Sciences (Fig. 14). The exhibition was primarily aimed at the general public to show how STEM is used in the understanding and analysis of the past, as well as in the development of strategies for responsible management and protection of cultural heritage. All of the partners took part in the creation of content for 24 posters. In

10 days, more than 1000 visitors saw the exhibition. It will open at the Faculty of Philosophy at the end of 2022, and it is also planned to go on display at partner institutions and several museums in the following year.

Conclusion

Although faced with a difficult situation caused by the pandemic, it can be concluded that the Project achieved its main goals. As planned, many higher education learners engaged in the Project's activities: around 100 participants from partner universities participated and were trained in various STEM-related fields through intensive courses. Although the *online mode* of teaching made conducting Project activities more difficult, its benefits can be observed in the doubled number (approximately 200) of attendees who were able to listen to online lectures. Around 50 teachers were engaged in delivering lectures and training, but the online mode also allowed teachers from partner universities to join the lectures as listeners.

The evaluations conducted after each intensive course can be used to assess the Project's achievements. Although a detailed analysis is still in progress, the main tendencies can be observed. The majority of participants in all courses were undergraduate students, with little or no experience in STEM-related fields. Generally, all of the workshops were rated as excellent by attendees, with newly acquired knowledge and an inspiring working atmosphere especially emphasized. Many participants found the topics of intensive courses inspiring and important for their future careers. The majority of participants said that they would recommend similar programs to their colleagues, and several of them even commented that the courses should have been longer. In sum, the Project's teaching and learning activities confirmed its main goals were achieved.

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Vuković, Jasna, Rajna Šošić Klindžić, Staša Babić, and Predrag Novaković. *in press* The HERISTEM (STEM In Heritage Sciences) Project: Communicating Archaeology during the Pandemic.

THE LANDSCAPE OF STEM TEACHING IN HERITAGE SCIENCES IN EUROPE

Predrag Novaković

This paper presents the findings of a survey of STEM content in higher education curricula of heritage-related disciplines[1] in several European countries. We aimed to "reveal" the STEM-related "educational landscape" in the field of heritage sciences in order to observe the content and quantity of STEM courses in these disciplines' curricula.

However, after conducting preliminary surveys of the curricula, we decided to exclude architecture because it is, in many respects, an engineering discipline and thus inadequate for the purposes of our survey. Preliminary surveys revealed several important things. It is not news that archaeology includes, by far, the biggest amount of STEM content. However, two other findings were even more striking: the heterogeneity of STEM content in archaeology and the virtually complete absence of any STEM content in art history, ethnology, and history. While subjects associated with visualization and the application of audio-visual media can occasionally be found in art history and ethnology departments, the technological aspects and possibilities for implementation remain secondary. The history curricula, as a rule, do not contain any STEM at all. For these reasons, we have limited our survey to archaeology as essentially the only heritage-related discipline that systematically includes STEM in its curricula. On the other hand, students of other heritage-related disciplines can still study STEM and can individually choose various STEM subjects as optional courses, which is not visible in the curricula. Furthermore, in some countries, Classical Archaeology (as a separate subject or as part of Classical Studies) can be studied independently of archaeology; STEM content is also absent from these curricula.

1 By heritage-related disciplines we primarily mean archaeology, art history, ethnology, history, and architecture, which are disciplines that study various forms of (mostly) material remains from the past that are considered heritage and thus potential objects of protection.

We are fully aware that our survey is incomplete because it does not include Ph.D. curricula and associated research activities, where the situation with STEM can be quite different when compared with undergraduate and graduate levels, even within the same university. In general, Ph.D. curricula offer more individualized or customized research tutorship and education-through-research, and they are much more difficult to present in the same details as pre-Ph.D. curricula. Moreover, research is institutionalized differently in each country. Some have specialized research institutes or centers (e.g. CNRS in France or Italy, institutes within academies of sciences in Poland, Hungary, Slovakia, and Slovenia), whilst in others, the principal research centers are located within universities (e.g. the UK, Ireland, Netherlands, Belgium).

Survey

Before presenting and interpreting the findings of the survey, several remarks are required in order to properly understand and contextualize the collected data. First, all of the data was collected online by looking into each university's undergraduate and graduate (BA/BSc and MA/MSC) study programs. A total of 163 curricula (74 BA/BSc and 89 MA/MSc) were examined from 78 universities in 27 European countries (Fig. 1). This method was quite efficient; however, sometimes we did not get complete data. Based on data from the QS University Ranking and Times Higher Education rankings, we estimate that the surveyed universities represent 25–30% of all European universities with archaeological curricula.

Which universities were selected? First, we divided Europe into six regions based on cultural criteria proposed by the Permanent Committee on Geographic Names. We chose this type of regionalization because national education systems vary greatly depending on cultural and intellectual backgrounds, particularly in humanities.

In general, three universities were selected from each country. This figure was lower in some cases, such as for smaller countries. We did our best to cover the whole of Europe. Despite our best efforts, at this stage, we were unable to include Finland and Hungary, as we could not find translations of their programs. We also excluded Belarus because we could not find any relevant data on the internet. Russia is underrepresented (only one university) because there was not much relevant data on the internet (or at least we could not find it). The sample of universities observed is not very systematic. In the case of larger countries, we aimed at large or more renowned universities in the archeology field. Our selection was sometimes limited because not all universities make their curricula available on the internet.

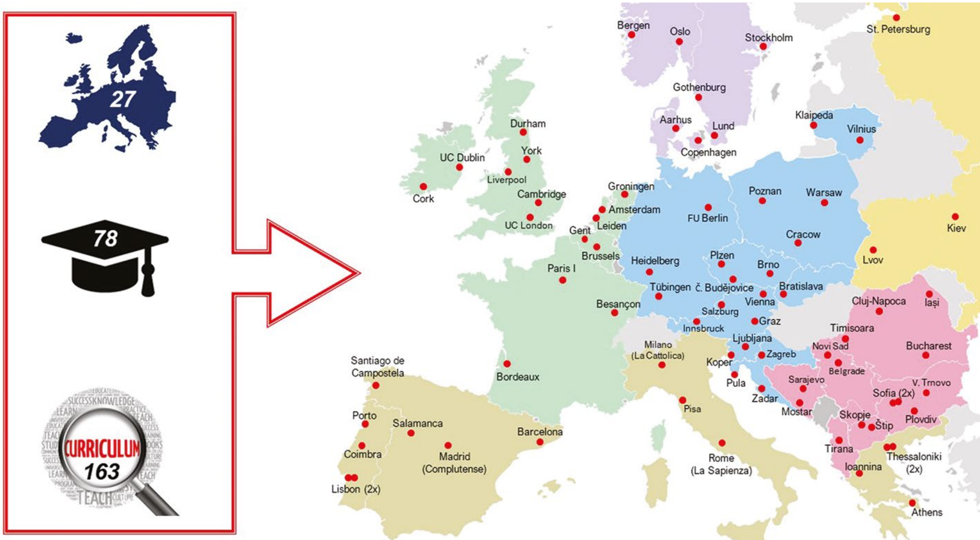

Figure 1. Map of the surveyed universities in six European regions (Southern Europe, South Eastern Europe, Central Europe, Eastern Europe, Western Europe, and Northern Europe; regionalization is based on the cultural-historical criteria of the Permanent Committee on Geographic Names).[2]

As a result, while in smaller countries the STEM content is properly reflected in the humanities program of the selected universities, this may not be the case in larger countries with more universities.

Although the Bologna system attempts to unify higher education systems across Europe to a certain degree, differences between the countries remain substantial, making it hard to “normalize” the data. Currently, the most common features are two-level study programs (undergraduate and graduate) and the ECTS credit system (normally 60 credits per year), with the rest being more heterogeneous. Moreover, the ECTS system is not applied uniformly. For example, individual subjects may have the same ECTS credits but a significantly different number of teaching hours. For this reason, we attempted to present individual subjects in teaching hours rather than ECTS credits. In cases where the exact number of teaching hours was not mentioned in the curriculum, we made estimations based on other data.

The survey revealed that it is possible to study archaeology in a variety of ways and programs, including at the same university (as a single subject, combined subject, in BA/BSc or MA/MScprograms, or as a spe-

2 Peter Jordan, A subdivision of Europe into Larger Regions by Cultural Criteria. United Nations Group of Experts on Geographic names, Working Paper 48, Vienna 2005.

cialization within other programs, such as history). To maintain as much coherence as possible, we examined STEM subjects in all archaeological curricula within the same university, faculty, or department, regardless of program specificities. In short, students in various archaeological programs at the same university are offered the same or a similar corpus of optional courses (STEM courses included).

We established a database of archaeological curricula that focuses on STEM or STEM-related courses, so we excluded other subjects. We were primarily interested in the themes of the subject and the number of teaching hours. It was, however, impossible to cover all STEM-related courses. Some STEM content is "hidden" within broader courses such are Archaeological Methods, Research Methods, Field Methods, etc. A detailed examination of these subjects would be laborious and may not yield conclusive and comparable results because the ratio and teaching hours of each "sub-subject" would not be possible to determine. For this reason, we omitted these courses.

Moreover, when comparing different BA/BSc or MA/MSc programs for their STEM contents, one should consider that undergraduate and graduate programs are not identical in length. For example, undergraduate programs last three to four years, while graduate ones last one to two years; such differences may exist even in the same country.

Our paper did not intend to give definite statistics but rather descriptive ones. The reasons for this were incomplete and fragmented data, which were difficult to "normalize" and compare, and also, the selection of universities was relatively arbitrary in cases of larger countries. Nevertheless, the intention was to identify the general structure and differences between various teaching systems, which can serve as an initial step for further, more detailed analyses.

From these "warnings" alone, it is quite clear how complex and heterogenous the educational landscape in Europe is, even for such a narrow area as archaeology. The organization of studies and the structure of their curricula reflect the influence of many factors, ranging from cultural (national) traditions, disciplinary traditions, the organizational structure of the universities or faculties, infrastructural capacities of the institutions, to personal preferences and influences of the leading scholars in academia. We are completely aware that our sample is not particularly representative, but the results provide us with at least a good preliminary assessment.

RESULTS

The results are presented from several perspectives of observation: a) geographic perspective (European, regional, national); b) disciplinary perspective (STEM content); and c) organizational perspective (how STEM is structured in curricula). These perspectives are intertwined, and the result is an interplay of factors from all three perspectives.

General overview

1. STEM content (and subjects) are present in archaeological curricula in all of the surveyed countries, but vary considerably (see "Regional situation" for more details). However, some countries have universities with archaeological curricula that do not, at least nominally, contain STEM content. In our survey, we encountered a few such cases.

2. STEM content and subjects are very heterogeneous. We are dealing with probably more than 60 different subjects here, which cover a wide range of STEM: physics, chemistry, biology, geodesy, physical geography, ecology, statistics, computing and informatics, remote sensing, and several engineering subjects. To simplify our survey's findings, we divided them into 11 major groups:[3]

1. (A-ENV), Environmental group of subjects (environmental archaeology, ecological archaeology, etc.)
2. (BIO-A); Bioarchaeological group of subjects (i.e. study of various aspects of plant, animal, and human remains)
3. (GEO-A), Geoarchaeological group (geology, geomorphology, physical geography, geophysics, etc.),
4. (ANTHR), Anthropology (Physical Anthropology, Palaeoanthropology, Human Osteology). We separated this group from Bioarchaeology for "historical" reasons. Physical anthropology (basically osteology) has been present in most curricula for many decades, while bioarchaeology is of much more recent date and includes other topics and aspects of human biology.
5. (A-MET), Archaeometry
6. (A-QUANT), Quantitative methods (data science, statistics, etc.)
7. (A-REM), Remote sensing (aerial archaeology, satellite imagery, LIDAR...)
8. (GIS), (Geographic information systems, digital cartography, CAD)
9. (A-MATER), Study of materials and ancient technologies
10. (COMP), Computing (general, image processing, 3D modeling, etc.)
11. (OTHER), Other subjects

3 One could rightfully argue that some of the groups overlap but in many cases the overlap is incomplete, and merging two or three groups into one would still leave certain areas unclassified.

3. Regarding teaching hours, STEM content is generally more frequently taught at the graduate level (MA or MSC programs). According to data from our survey of 78 universities, there are, in total, 7.000–8.000 teaching hours at the undergraduate level (three to four years) and 10.000–12.000 teaching hours at the graduate level (one or two years) (Fig. 2).

However, roughly 20% of universities have more STEM content (i.e. teaching hours) in undergraduate programs. The reason for this seems to be the length of undergraduate and graduate studies. In the 4+1 system, the undergraduate level has more room for STEM. In contrast, curricular space at the graduate level is more restricted since a large part of graduate studies is dedicated to a MA/MSc thesis. There are also other reasons; some universities, for example, do not provide graduate courses in archaeology but include STEM content in undergraduate programs. Nevertheless, STEM is generally taught more frequently and systematically in archaeology at the graduate level, most often because the graduate level is considered a specialized study in archaeology (specialization in STEM subjects included).

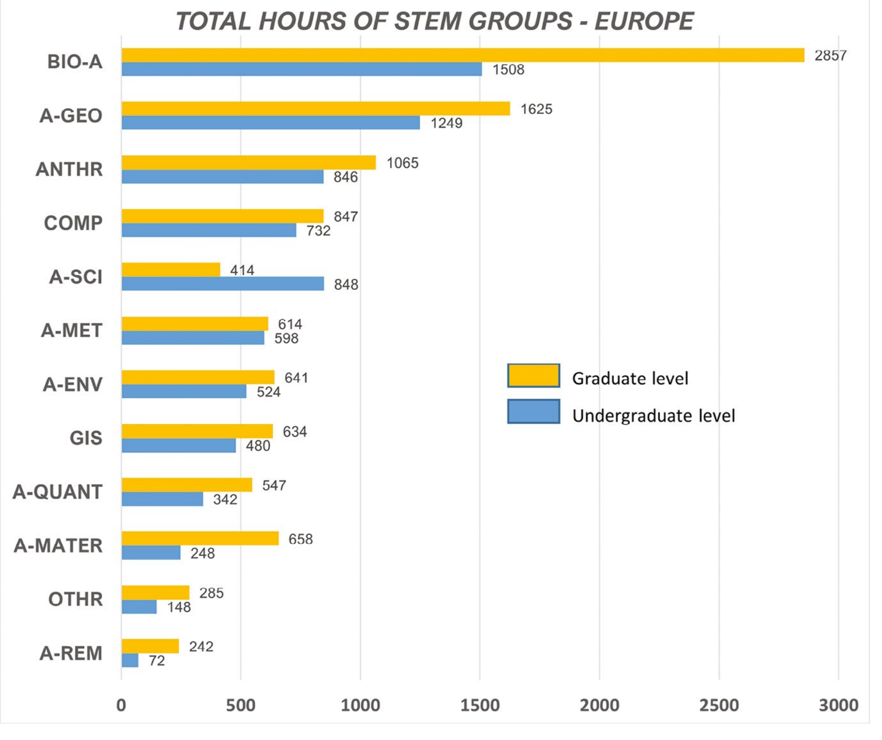

Figure 2. STEM subjects in teaching hours at undergraduate and graduate levels.

4. If we combine data for undergraduate and graduate levels, two kinds of STEM content or subjects are the most prevalent in archaeological curricula: bioarchaeological and geoarchaeological (Fig. 2). The dominance of bioarchaeological content is even greater when combined with physical anthropology, which ranks third on its own. One reason for this is the broad area covered by bioarchaeology (humans, animals, plants), but also the evident rise in the importance of the "bioarchaeological" agenda in archaeology in recent decades. Similar reasons could be thought of in the case of geoarchaeological content. Other groups of content are more or less equally common, with the exception of remote sensing which is the least common content.

Another important finding from our survey is the heterogeneity of STEM content. The range of STEM content in archaeology is indeed extraordinary. One could hardly find a STEM discipline that is not represented in archaeological curricula in Europe, making archaeology by far the most interdisciplinary of the humanities and social sciences. Despite regional differences (see below), in today's circumstances of much faster and easier communication, increased student and research mobility, and research collaboration, there is a great potential for the specialization of archaeology students in many different fields, as well as collaboration with other sciences.

Regional situation

The survey revealed significant regional differences in the teaching of STEM content in archaeology. Though the figures are not entirely accurate, they still reveal some important facts. Two regions, specifically Central and Western Europe, stand out in terms of teaching hours. Northern and Eastern Europe come third and fourth place with a similar number of teaching hours, followed by Southeastern Europe and South Europe (Fig. 3). However, the data for Eastern Europe and, to some extent, Northern Europe should be taken with caution due to the small number of surveyed universities.

The regional distribution reflects at least two factors: archaeological academic traditions, and, to a lesser extent, the relative "richness" of regional archaeology. The results were expected given the archaeological traditions and high values in Western Europe. The universities in this region have a long tradition of including STEM subjects in curricula, especially in their research activities, with several significant "centers of excellence" being developed in the last decades. STEM teaching and research are probably the most expensive in archaeology and require costly infrastructure, equipment, and numerous experts outside the core of archaeol-

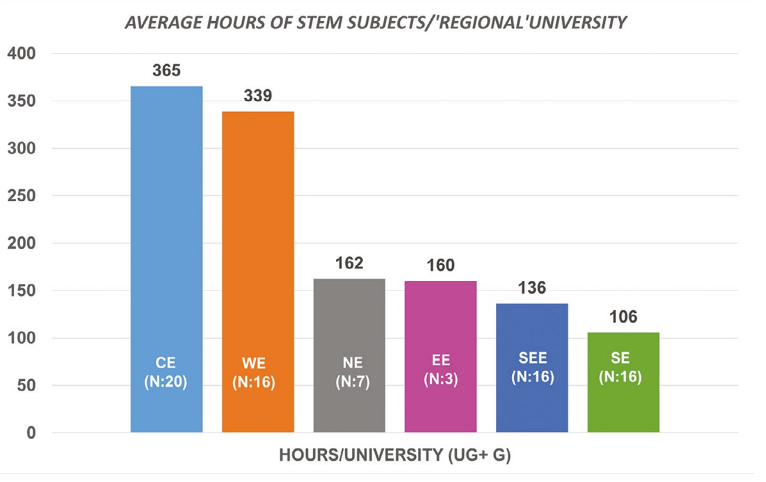

Figure 3. Regional distribution of STEM teaching hours at undergraduate and graduate levels combined. The figures are "normalized" (the mean values/university).levels.

ogy. For these reasons, it seems reasonable to assume that the high relative frequency of STEM in teaching and research is also associated with the wealth of a country, region, or even a single university. But this can only be partly true, and it is more true at the regional than the national level.[4]

The very high values for Central Europe were surprising. Traditionally, Central Europe was home to a culture-historical tradition in archaeology, which was not particularly STEM-oriented. However, in recent decades, a change in the nature of archaeology, or better put, a change in its agenda in Central Europe, has to do with the general globalization of archaeology, the highly increased mobility of scientists (and ideas), and the large intensification of communication, which, among other things, has brought an increase in STEM-related issues and technologies in Central European archaeology as well.

The other three regions – Northern, Southeastern, and Southern Europe – have, in general, two to three times fewer STEM teaching hours in their undergraduate and graduate curricula combined. These regions traditionally developed culture-historical approaches, but they differ between themselves. For example, in the Northern and Southeastern regions, archaeology is similar to the one taught in Central Europe, while

4 We attempted a simple linear regression test. The average wealth of an adult person (per country) was considered an independent variable while the number of STEM teaching hours per country was the dependent variable. The results not only revealed the absence of any relationship between these two variables but strongly suggested that other variables must be at play.

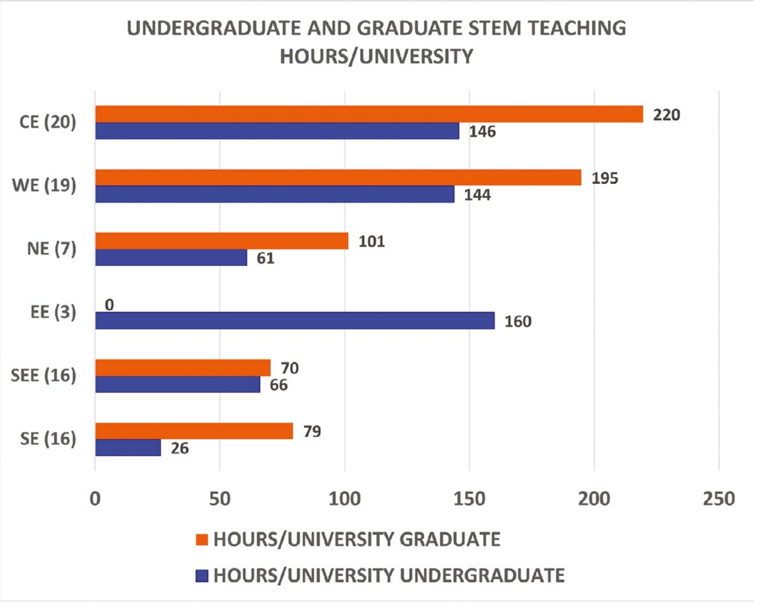

Figure 4. Regional distribution of STEM teaching hours at undergraduate and graduate levels. The figures are "normalized" (the mean values/university).

in Southern Europe, archaeology is more closely associated with classical studies, making its humanistic orientation even stronger. In addition to this, in Southern European countries, the undergraduate curricula that include archaeological courses are more general in their orientation. They include ancient and modern history, Latin and Greek languages, ancient art history, geography, and similar, so they do not have much space for more specialized archaeological courses or methods. Nevertheless, in the last three decades, the development of archaeology has pushed the discipline to the STEM agenda. On the other hand, the revealed differences between Western/Central and Northern/Southeastern/Southern regions also reflect the core-periphery relationship, not in overall archaeology but in STEM-oriented archaeology.

A good illustration of the regional situation is presented in Fig 4. where values for undergraduate and graduate levels are displayed separately. Besides the general trend of more hours spent at the graduate level, one can also see other regional differences. Again, the same regional trend occurs, but with some additional information, such as the low value for undergraduate studies in Southern Europe. The principal reason for this could be found in the tradition of teaching archaeology at this level. For example, in Italy, archaeology at the undergraduate level is part of a more general curriculum in humanities and the classics, and archaeology can be

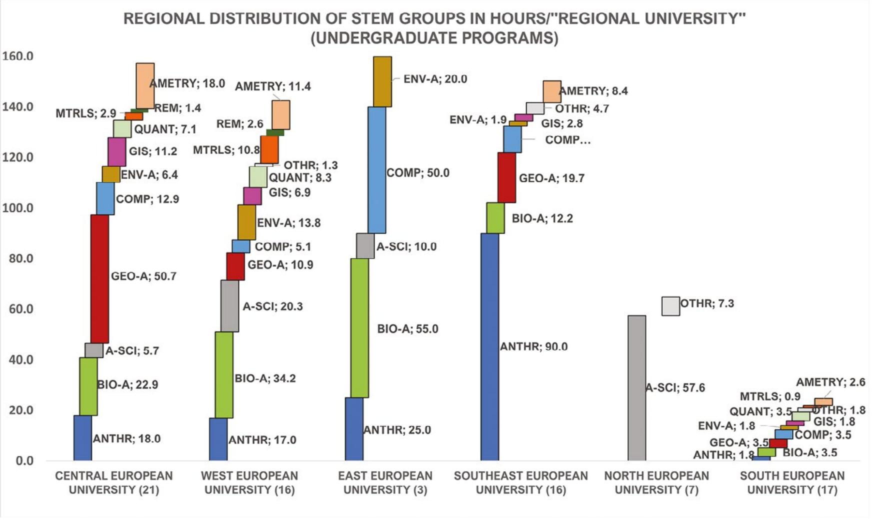

Figure 5. Regional distribution of the types of STEM subjects in teaching hours at undergraduate level. The figures are “normalized” (the mean values/university).

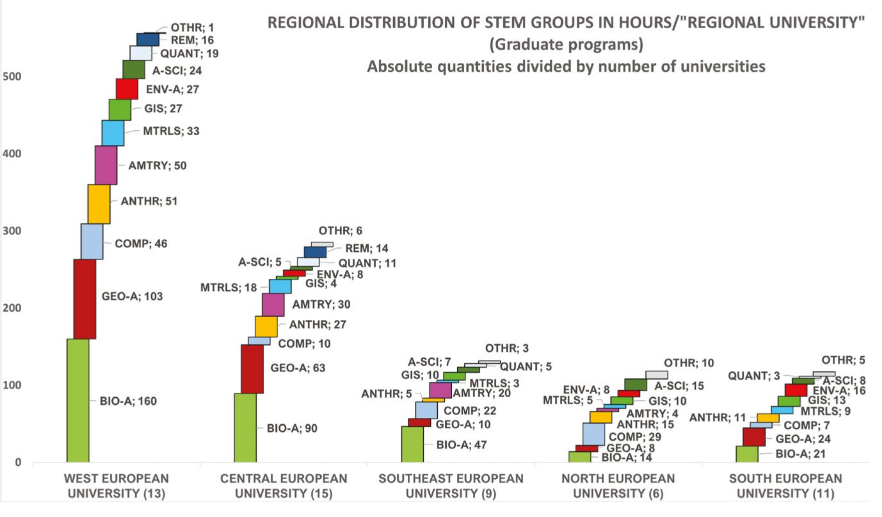

Figure 6. Regional distribution of the types of STEM subjects in teaching hours at the graduate level. The figures are “normalized” (the mean values/university).

specialized only at the graduate level. Moreover, in Spain and Greece, archaeological subjects in BA curricula are frequently combined with other classical and humanities subjects (i.e. Greek, Latin, History, Art History, etc.). It is therefore not surprising that the value of STEM subjects is three times higher at the graduate level.

The regions also differ in the types of STEM courses their universities offer (Figs. 5 and 6). Here again, Western and Central Europe stand out in terms of the "total coverage" of STEM fields. As for Northern Europe, it should be noted that in most curricula, STEM is part of general courses (e.g. Archaeological Science), making it difficult to find individual courses like in other regions.

The situation is much clearer at the graduate level. However, all subjects are present in all regions, including South Europe, despite the small numbers for STEM at the undergraduate level. Compared to the undergraduate level, the heterogeneity of STEM courses at the graduate level is greater. Practically all regions' curricula contain all 11 groups of STEM disciplines.

STEM-oriented graduate degrees

The map with STEM-oriented degrees is presented in Fig. 7. At the undergraduate level, such degrees are possible only in Great Britain at all of the five universities surveyed.

The number of STEM degrees is much higher at the graduate level. These degrees are available in seven countries. Great Britain has very specialized STEM-oriented degrees. However, if one university offers various MSC courses in "STEM-oriented archaeology" they normally have up to half of the subjects in common.

In contrast, in other countries, these degrees have more general names but can include numerous modules covering many STEM areas

WU Timisoara	Archaeology and Environment in the Context of Sustainable Development
Durham	MSc Forensic Archaeology and Anthropology
	MSc Human Bioarchaeology and Palaeopathology
	MSc Bioarchaeology
UC London	MSc Archaeological Science
	MSc Bioarchaeological and Forensic Anthropology
	MSc Computational Archaeology: GIS, Data Science and Complexity
	MSc Environmental Archaeology
	MSc in Palaeoanthropology and Palaeolithic Archaeology
Liverpool	MSc Archaeology
York	MSc Bioarchaeology
	MSc Digital Archaeology
	MSc Digital Heritage
	MSc Funerary Archaeology
	MSc Material Culture and Experimental Archaeology
	MSc Zooarchaeology
Cambridge	Mphil Archaeological Research
	Mphil Archaeological Science
	Mphil Archaeology
	Biological Anthropological Science
	Mphil Human Evolutionary Studies
Paris I	MA Parcours Archeologie environmentale
	MA Parcours Ingenierie de'l Archeologie preventive et programmée
Besançcn	MA Sciences pour l'archeologie
Sofia	MA Archaeometry
UC Dublin	MSc Archaeology (Remote sensing, GIS)
Heidelberg	MA Geoarchaeology
Tübinghen	MSc - Archaeological Sciences and Human Evolution
Leiden	MSc Archaeological Science
	MA Applied Archaeology

Figure 7. Universities with STEM-oriented degrees in archaeology (survey data).

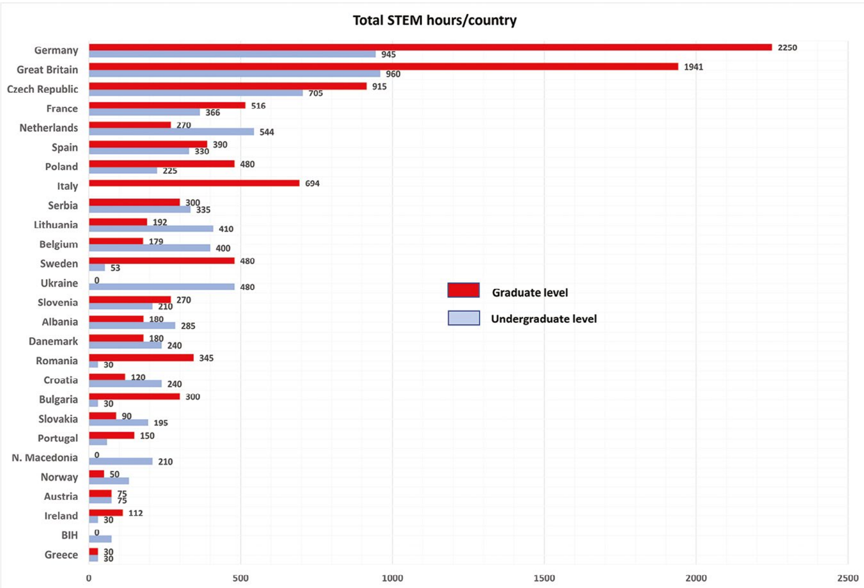

Figure 8. Total STEM teaching hours per individual country (survey data).

(e.g. Tuebingen, Paris I, Leiden). They are mostly found in Western and Central Europe.

Two such degrees exist in Southeastern Europe, but they are more specialized than general.

Distribution by country

Given that the sample size of universities is only partly representative, the ranking and values from Fig. 8 should be regarded with caution. The countries are listed in declining order of the number of STEM teaching hours: some previously observed trends were expected to be confirmed at the national level as well. It seemed logical that the general frequency of STEM content at the national level would reflect tendencies at the regional level.

At present, the first 15 places (top 50% of the countries) are occupied by five universities from Central Europe, four from Western Europe, two from Southeastern Europe, two from Southern Europe, one university from Northern Europe, and one from Eastern Europe.

Conclusion

The primary aim of our survey was to gain an initial understanding of the "educational landscape" in archaeology with regard to STEM-related content. The findings were meant to open a discussion rather than provide definite conclusions. Although the sample of universities is not particularly systematic, we believe it is large enough to allow for some general ideas based on the discovered educational landscape.

Firstly, of all of the "core" heritage disciplines, archaeology has by far the most STEM content in terms of both the quantity and diversity of such content. This clearly demonstrates how interdisciplinary archaeology was and continues to be, and how flexible it is in including methodologies and techniques from other sciences in its teaching and research processes. One of the primary reasons for this is the nature of the object of archaeological research – material remains and material contexts in which these remains exist, from micro to macro levels of observation. In order to understand the structure, origin, technology, function, effects, relationships, and all other pertinent aspects of the observed (material) objects and phenomena, archaeology simply had to include knowledge and methods from other disciplines, STEM disciplines included. Another reason lies in the requirements of the archaeological recording process. Pertinent archaeological objects appear in very different forms, sizes, and states, which require the use of advanced recording technology, especially digital technology.

Our second conclusion is about the most recent developments in archaeology. Though we lack comparable data for archaeological curricula from 30 years ago, the change in curricula is obvious, at least indirectly, in the trends and topics in academic publications. It would be interesting to compare today's situation to that of the "pre-digital" period, for example, the 1980s, for which we believe the regional and national differences would be even greater. Nevertheless, the fact is that archaeology has seen a large transformation in recent decades, especially owing to the expansion of its research with STEM knowledge.

If we are interested in the development of a discipline, university curricula are a good place to look for "stability." While the developmental dynamic in research domains is much greater, new ideas come and go at a very fast speed, but the process of changing or upgrading the curriculum is much slower due to various non-disciplinary factors. It greatly depends on factors such as the organization of university studies, infrastructure, tradition, regulations, etc. But once the new topics are included in the curricula, especially at the undergraduate and graduate levels, this means that they have already been in effective use in the research domain and proved valuable, becoming routinized in research practice.

Our fourth conclusion concerns the employability of archaeology students. Though not all students take all STEM courses available at their university or country, they can, in general, obtain a relatively large corpus of specialized knowledge and skills in various STEM fields. In addition to this, they became acquainted with different methodologies, if not epistemologies. By definition, this increases their chances in the labor market, not only within archaeology but also significantly beyond. If we also add to this the specific soft skills obtained during their studies, such as dealing with stressful practical project work, teamwork, logistic and organizational problem-solving abilities, etc., their chances can be very high. However, the principal problem is with the employers. Our survey did not look into this aspect, but based on our experiences, the majority of potential non-archaeological employers do not understand the profile of an archaeological graduate. Their views on archaeologists are still very simplified and traditional. Though this is a separate problem that goes beyond the scope of our survey, it is worth reflecting on when designing curricula. It is about showing and proving the relevance of archaeology at all levels.

Our survey did not compare “typical” archaeological subjects with STEM courses. This would require a significant amount of additional work, and the great differences in the organization of university studies would further complicate the situation, making it even more difficult to understand the influence of all determining factors. At present, this is best done at the national level, where universities are governed by the same legislation and have similar academic traditions.

TRANS-DISCIPLINARY NATURE OF HERITAGE STUDIES

Tatjana Cvjetićanin

The main objective of the *HERISTEM – STEM in Heritage Sciences* strategic partnership project is *to advance the university curricula in heritage disciplines by the systematic incorporation of STEM knowledge in education and research in heritage disciplines*, based on archaeology and archaeological heritag.[1] Leaving aside problems and concerns related to STEM inclusion, I would like to address an issue concerning heritage and heritage studies; specifically, are heritage studies acknowledged as a new discipline and how are they currently taught? The focus is on universities from the Balkans included in the project.

The starting point will be to define heritage. One of the explanations, taken from the UNESCO glossary, states: *Cultural heritage includes artefacts, monuments, a group of buildings and sites, museums that have a diversity of values including symbolic, historic, artistic, aesthetic, ethnological or anthropological, scientific and social significance. It includes tangible heritage (movable, immobile and underwater), intangible cultural heritage (ICH) embedded into cultural, and natural heritage artefacts, sites or monuments.*[2] It is commonly seen as a legacy or inheritance from the past, a bridge between past and future, which we in the present handle in specific ways. But is it really that simple? In yet another UNESCO publication, it is stated: *Cultural heritage is, in its broadest sense, both a product and a process, which provides societies with a wealth of resources that are inherited from the past, created in the present and bestowed for the benefit of future generations* (Alonso and Medic 2014, 130). "Process" is the key word here. Heritage is thus a concept in constant development (Smith 2004; Winter 2013; Abu Khafajah and Badran 2015).

1 https://www.heristem.edu.rs/
2 https://uis.unesco.org/node/3079731

Heritage is a version of the past received through objects and display, representations and engagements, spectacular locations and events, memories and commemorations, and the preparation of places for cultural purposes and consumption. Collectively, these 'things' and practices have played a central role in structuring and defining the way heritage is understood within academic debate, public policy... (Waterton and Watson 2015, 1–17). In short, heritage is constructed as an *object of knowing in cultural, leisure or tourism, and academic practice* (Smith 2006, 13), and as such has conceptual and material consequences. The most influential are heritage concepts of governing bodies and heritage professionals (cf. Smith 2006; Willems 2014), whose added values to particular tangible and intangible elements of the past, often changeable, impact heritage policies and heritage management, public heritage literacy, involvement of various stakeholders, and heritage teaching, including higher education curricula.

Even though heritage studies are recognized as an important disciplinary and educational field, defining heritage teaching programs remains a challenge, and questions such as "what frames the discipline," what should be the focus of heritage curriculum, and how to create a "balance between research and transferable skills" are critical for many in higher education (Willems et al. 2018). An analysis of a number of existing programs – mostly those connected with archaeology as the central discipline of the HERISTEM project – shows that the majority focus on archaeological heritage management education (Willems et al. 2018, 298–300).

In recent decades, the concept of archaeological heritage management (AHM) has grown in importance in archaeology, especially for the safeguarding of archaeological resources/assets. Increased interest in the past manifested itself in the heritage boom, the heritage industry, and cultural tourism, shaping heritage not only as a social but also a vital economic capital (cf. Hewison 1987; Urry 1990; Lowenthal 1998). Managing archaeological heritage has developed into a significant field in its own right, comprising a variety of activities; it is now more than just archaeology. While research and fieldwork are essential parts of AHM, other activities are also included, such as stewardship (entailing responsible and sustainable management and administration, planning, risk and value assessment, monitoring), legislation, conservation, safeguarding, interpretation, presentation, promotion, stakeholder management, community interaction, participatory processes, and tourism (cf. Willems et al. 2018, 298). Among the covered areas are policy development, recognition of political dimensions of heritage, recognition of different dangers to heritage, recognition and inclusion of different perspectives, and ethics. In short, heritage professionals must possess diverse knowledge and skills.

And how is AHM or heritage management taught in Balkan universities involved in the HERISTEM project? Or heritage studies generally? Who are we educating? Who are we creating curricula for?

Most people employed in heritage institutions in the region, particularly those concerned with monument protection, typically have an academic background in archaeology, architecture, art history, and painting conservation, whereas in complex museums, history, archaeology, anthropology, ethnology, and art history prevail. Here are some examples of heritage education associated with those disciplines that illustrate the current situation:

1. University of Belgrade, Faculty of Philosophy

The Department of the History of Art offers undergraduate museology courses. At the graduate level, MA and Ph.D. titles can be acquired at the Center for Museology and Heritology.[3] The Center was established in 2010, *recognizing that the current placing of these studies (problems of heritage and museum practice, comm. by author) within the framework of traditional humanistic and social sciences is ineffective*.[4]

The Department of Archaeology has only one course – Archaeology and the Public – at the undergraduate level where part of the course is dedicated to archaeological heritage and AHM.[5]

2. University of Ljubljana

The Faculty of Arts, Department of Archaeology is the only one of the involved universities to have Archaeological Heritage Management at the graduate level.[6]

The Faculty of Chemistry and Chemical Technology has the Heritage Science Unit at the Centre for Research Infrastructure,[7] which "provides researchers and experts from various domains (natural and other sciences, engineering and technology, arts and humanities) an interdisciplinary approach to solving problems in the field of heritage science."[8]

3 http://www.cmih.rs/o-centru/

4 Issues of archaeological heritage or AHM are very rarely studied, and in the Centre, from 16 specialists, 14 are art historians: http://www.cmih.rs/saradnici/

5 https://www.f.bg.ac.rs/arheologija/silabusi?IID=3466&nivo=1

6 https://arheologija.ff.uni-lj.si/en/2nd-cycle-archaeology

7 https://www.fkkt.uni-lj.si/en/research-infrastructure/enota-za-dediscinsko-znanost-e-rihssi/

8 https://www.e-rihs.si/_Heritage science unit understands their field as the interdisciplinary domain of scientific study of cultural and natural sciences. It can be seen as STEM in the heritage studies.

3. University of Sarajevo, Faculty of Philosophy

The Department of Archaeology from 2022/23 has one course at the undergraduate level – Conservation – covering topics concerned with heritage management, especially safeguarding and preventive conservation.[9]

The Department of the History of Art offers the course Museum Theory and Practice, also at the undergraduate level.[10]

4. University of Zagreb, Faculty of Philosophy (Humanities and Social Sciences)

The Department of Information and Communication Sciences has the course Museology and Heritage Management at the graduate level.[11]

This overview of heritage-related courses reveals how heritage is viewed, and how heritage studies are typically recognized and assigned to archaeology (sites, immovable structures, movable finds) and/or art history (immovable edifices, monuments, museums), in accordance with former – outdated – academic traditions. The exception is the University of Zagreb, where heritage studies are treated as a communication discipline, probably recognizing the important role of mediation for heritage professionals. Courses mostly cover museology, to a lesser extent heritage governing, and occasionally conservation, cultural economy, and heritage tourism. Even the more common heritage management education is clearly lacking in curricula. Only one university – the University of Ljubljana –offers MPhil or Ph.D. in AHM.

Concerning the skills required from current heritage professionals, there is a significant gap between what heritage management, or specifically AHM, requires, and the formal training that students of traditional heritage disciplines, in this case, archeologists, receive (Willems et al. 2018, 302). The need for heritage management education at several Balkan universities is obvious. But what should these programs include? And, to ask the key question of the HERISTEM project, how to overcome challenges and incorporate STEM into heritage studies? If heritage studies do not currently have a defined profile, this can actually be an opportunity rather than a setback.

Looking into existing heritage studies outside the region, two approaches generally dominate: one emphasizing the social and political

9 https://www.ff.unsa.ba/files/22_23/silabusi/Arheologija-sy.pdf

10 https://www.ff.unsa.ba/files/22_23/silabusi/Historija-umjetnosti-sy.pdf

11 https://inf.ffzg.unizg.hr/images/Programi20212022/StudiesAndCourses_2021_2022.pdf (39-46)

value of heritage, and the other emphasizing STEM application, often titled *heritage science*. The example of the first one are topics pertinent to the Cambridge Heritage Research Centre, which include subjects such as heritage, identity, and migration, or the role of heritage in conflict and post-conflict situations, or theorizing and applying the tangible/intangible heritage distinction. *The Cambridge Heritage Research Centre brings together Departments and Faculties from a variety of disciplines across the University*.[12] Not surprisingly, there are areas where STEM is easily applied, such as heritage, methodologies, and fieldwork.

On the other hand, the definition of heritage science accentuates that it is *the interdisciplinary domain of scientific study of cultural or natural heritage*.[13] Does this imply that heritage studies are not scientific, or that science is reserved just for STEM? It seems like a division into those who know how to conduct research and those who simply use results, without a real understanding of the multidisciplinary and trans-disciplinary potentials of heritage research.

For me, the approach and model of a heritage research center that supports and enables heritage studies from the standpoint of various disciplines, but under one umbrella/authority, is heritage education that does not lose sight of the complexity of heritage and, especially, the conceptual and material consequences of selected research theories and methods. These are thus heritage studies that build upon the knowledge of various disciplines, those traditionally associated with heritage as well as those that have recently been recognized as valuable for a deeper understanding of heritage features and the betterment of heritage. Trans-disciplinary heritage (management) education and the development of new professional skills suggest further collaborative practices, such as joint teaching programs. As diversity is one of the potential strengths of archaeology, so are heritage studies.

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12 https://www.arch.cam.ac.uk/about-us/heritage

13 https://en.wikipedia.org/wiki/Heritage_science; https://www.iccrom.org/section/heritage-science

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MAKING ROOM FOR ANIMALS: THE DEVELOPMENT OF ARCHAEOZOOLOGY WITHIN SERBIAN ARCHAEOLOGY

Vesna Dimitrijević
Sonja Vuković
Ivana Živaljević

Introduction

Every discipline benefits from a reflexive stance and an overview of the history of ideas and practices that shaped it. In the case of the emergence and development of archaeozoology in Serbia, this is especially relevant given its later incorporation into mainstream archaeology, its history that is still being written, and its particular object of study which makes it uniquely positioned in the Nature-Culture divide, one of the grand narratives of Modernist thought. To some extent, its later inclusion in this particular context coincides with the so-called "Third Science Revolution" in archaeology (Kristiansen 2014), as well as calls for an intellectually engaged, collaborative, and confident archaeology that does not lose sight of its humanist perspectives and explicitly addresses the epistemologies of such interdisciplinary collaborations (Nilsson Stutz 2018).

As a discipline dedicated primarily to the study of animal remains (bones, teeth, antlers, horns, scales, shells) from archaeological sites, archaeozoology has historically fluctuated between natural sciences and humanities, between empirical and interpretative approaches. Although the establishment of archaeology in Serbia in the second half of the 19th century owes as much to geology, palaeontology, anthropology, and biology as it does to history, architecture, philology, and the history of art (Novaković 2021; Srejović 1992), the later dominance of cultural-historical approaches led to the marginalization of the study of the "natural" world, as opposed and separate from the human domain. Following global trends and the emergence of the science-based "new" or processual archaeology from the mid-20th century onwards, the first archaeozoological reports, mostly by foreign specialists and resulting from international collaborative projects, slowly started to find their way into Serbian archaeology.

Although these studies paved the way for scholarly interest in animals and their remains from archaeological sites, in the early stages they comprised little more than supplements to archaeological monographs, and seldom played a prominent role in the interpretation of the past. The disciplinary divide, based on the strict separation of the human from the non-human, implied that not only should faunal remains be treated and published separately from artefacts, architectural features, and burials, but that such projects should be undertaken by different specialists and communicated in a different scholarly language. Thus, the possibility for interdisciplinary dialogue and mutual understanding were greatly hindered (Žakula and Živaljević 2018; Živaljević 2013).

The last few decades of the 20th century witnessed a greater number of foreign archaeozoologists working on faunal remains from sites in Serbia, the emergence of the first local specialists (mostly from a biological background), and a growing recognition of the importance and necessity of integrating archaeological and archaeozoological research through the education of archaeologists. In this paper, we provide an overview of the fairly short but lively history of archaeozoological research in Serbia and reflect on how local archaeology, historically focused on human societies in its field of study, eventually made room for animals.

The history of archaeozoology in Serbia: theoretical and methodological underpinnings

The first snippets of information on faunal remains, including an observation regarding their relevance for the reconstruction of past environmental conditions, can be found in the 1931 Vinča–Belo Brdo excavations field diary of Miloje Vasić[1], the first professional archaeologist in Serbia and a professor of archaeology at the Faculty of Philosophy in Belgrade. However, there was no further mention of them in any of Vasić's publications, and the animal bones unearthed during his numerous excavation campaigns, considered of lesser or no importance at the time, were entirely discarded (Dimitrijević 2008b). The 1931 excavations of the site of Starčevo-Grad, led by Miodrag Grbić from the National Museum in Belgrade and Vladimir Fewkes from Harvard University, were the first to include the collection of animal bones, which were subsequently transported to the Peabody Museum to be studied (Clason 1980). Yet, such practices were still few and far between, and the archaeological community in Serbia was to wait another 38 years for the publication of the first archaeozoological report.

1 We thank Aleksandar Palavestra for bringing this information to our attention.

According to the prominent Serbian archaeologist Milutin Garašanin, this was due to the evident lack of bone specialists in Serbia, but the osteological material eventually came to be carefully collected "for the better times to come" (Babić and Tomović 1996, 64). It is worth noting that in his later years, Garašanin explicitly singled out archaeobotany and archaeozoology as extremely valuable (although he personally, like many other archaeologists at the time, did not include them in his research), believing interdisciplinarity to be "the basic element of work of every archaeologist" (Babić and Tomović 1996, 44). A greater scepticism about archaeological sub-disciplines stemming from natural sciences was expressed in the works of Dragoslav Srejović, another eminent Serbian archaeologist, who felt that "new" or processual archaeology tends to approach humanity as "a physical fact, knowable only via scientific methods" (Srejović 1992, 9). According to Srejović (1992, 9–10), such approaches marginalize culture (e.g., religion, art, or ideology), and instead produce "archaeological cookbooks," "long lists of plant and animal species and raw materials that man used, statistical tables of the various physical-chemical dating methods," and "reduce the archaeologist to a collector of samples for laboratory analysis," i.e., for other specialists to study and interpret.

It is quite contradictory, then, that archaeozoology was first introduced into Serbian archaeology during the collaboration of Srejović and Sándor Bökönyi, a Hungarian specialist in veterinary science and mammal osteology. A prolific scholar with an international reputation, and one of the leading figures in the establishment of ICAZ[2] (Bartosiewicz and Choyke 2002), Bökönyi was invited to study the faunal assemblage from the Mesolithic-Neolithic site of Lepenski Vir, whose discovery in 1965, in turn, brought international recognition and particular scientific authority to Srejović. Bökönyi's results, in the form of a short report with an overview of the distribution of animal taxa, were published first as a supplementary to Srejović's monograph on Lepenski Vir (Bökönyi 1969), and shortly after as a standalone paper in *Science* (Bökönyi 1970). The two scholars were to collaborate again, in the publication of the monograph dedicated to the 1970–1971 excavations of the Mesolithic site of Vlasac, led by Srejović and Zagorka Letica. The monograph was divided into two volumes, with the first, written by Srejović and Letica (1978) titled *Archaeology*, and the second, including the contribution by Bökönyi (1978) and other specialists titled *Geology – Biology – Anthropology*. The underlying principle was that faunal remains and other features of the "natural" world were to be published separately from architectural features, burials,

2 The International Council of Archaeozoology, https://www.alexandriaarchive.org/icaz/

and artefacts. The lack of interdisciplinary dialogue was palpable, e.g. with structurally deposited animal bones in human burials often mentioned in the first volume (but with no information on the species from which they originated or potential traces of modification), and with detailed descriptions of particular bone specimens (taxonomic identification, skeletal element, taphonomy, biometric data) in the second volume, with no information on their context. The "walls" separating the domains of Nature and Culture still stood firmly.

In the years to come, Bökönyi went on to analyze a number of faunal assemblages in Serbia and former Yugoslavia. The majority of them originated from prehistoric sites such as Ludoš-Budžak, Nosa-Biserna Obala, Mihajlovac-Knjepište, Divostin, Vinča-Belo Brdo, Mokrin, Kalakača, and Gradina na Bosutu (e.g. Bökönyi 1974; 1984; 1988; 1991; 1992; for a more detailed review see Stojanović and Bulatović, 2013), indicating that archaeozoology's major contribution was related to questions about the transition from a forager to a farming lifestyle and the introduction and development of animal husbandry, although some Roman sites were also included in his research (e.g. Dumbovo, Bökönyi 1976; see also Vuković-Bogdanović 2017). Moreover, the inclusion of archaeozoological analyses undertaken by Bökönyi and the subsequent foreign archaeozoologists was closely associated with large-scale international projects (such as Divostin) and the growing internationalisation of Yugoslav archaeology following the "turn" towards the West during the 1950s and 1960s (Novaković 2021).

In the last decades of the 20th century, the number of international collaborative projects and relevant foreign bone specialists working in Serbia proliferated. Particularly noteworthy in this respect were Dutch archaeozoologists Anneke Clason and Dick Brinkhuizen, Canadian archaeozoologist Haskel Greenfield, British archaeozoologist Anthony Legge, American archaeozoologist Nerissa Russell, and, in the first decade of the 21st century, British archaeozoologist David Orton (for a detailed review see Stojanović and Bulatović 2013, and references therein). Following the particular development of archaeozoological research in Serbia and elsewhere, i.e. its particular relevance to prehistory, these authors mainly engaged in the analysis of faunal assemblages from Mesolithic, Neolithic, Bronze, and Iron Age sites. Clason conducted the analysis of animal remains from the Late Iron Age site of Gomolava (Clason 1979) and Mesolithic-Neolithic Padina and the Early-Mid Neolithic site of Starčevo-Grad (Clason 1980), with a particular focus on the diversity of taxa, their habitat, ageing of specimens, and a discussion on the advent of animal husbandry. A greater emphasis on the contextualization of animal remains, their relationship to architectural features and site seasonality in the Early Neolithic, as well as animal mortality profiles indicative of particular husbandry strategies and the emergence of transhumant pastoralism in later prehistory, was notable in the works of Greenfield (Arnold and Greenfield 2006; Greenfield 1986; 1994; 2006; 2008; 2014; Greenfield and Greenfield 2014), who analyzed the assemblages from the sites of Hajdučka Vodenica, Blagotin, Bukovačka Česma, Petnica, Novačka Ćuprija, Ljuljaci, and Vrbica, among others. Russell (1993; 1999) and Orton (2008; 2012) made significant contributions to the study of the Late Neolithic in the region, namely by looking into the economic and symbolic role of wild and domestic animals, patterns of deposition of faunal remains, taphonomy and associated human activities, with case studies from Opovo, Gomolava, and Petnica.

This period also witnessed the emergence of the first local animal bone specialists. Svetlana Blažić, a biologist employed from 1975 in the Institute for Nature Conservation in the Vojvodina Province and a collaborator in archaeological projects of the Museum of Vojvodina in Novi Sad, joined the museum staff in 1990, becoming the first professional archaeozoologist in Serbia. Her work, mainly focused on taxonomic identification and biometric data, included a great number of faunal assemblages from various sites and periods (from the Neolithic to the medieval), such as Golokut-Vizić, Donja Branjevina, Zlatara-Ruma, Feudvar, Đepfeld, Kale-Krševica, Vranj, Ras-Gradina, and many more (Blažić 1984–1985; 1995; 1999; 2005a; 2005b; 2005c). As of 2010, she was succeeded by biologist Darko Radmanović in the position of archaeozoology specialist in the Museum of Vojvodina, who, jointly with Blažić, is credited for providing several synthetic works on the diachronic changes in the taxonomic composition of archaeozoological assemblages (e.g. Radmanović et al. 2014). In addition, two other museum institutions in Serbia – the Museum of Srem in Sremska Mitrovica and the Regional Museum Jagodina – currently employ specialists engaged in the analysis of archaeozoological material: Dragana Nedeljković and Nevena Cvetković respectively, both palaeontologists by education.

At the turn of the century, the need for training archaeozoologists and a greater integration of archaeology and animal bone studies was recognized. This was set in motion by one of the authors of this paper – Vesna Dimitrijević – a specialist with both palaeontological and archaeological backgrounds. Initially employed at the Faculty of Mining and Geology in Belgrade (from 1983) and involved in the analysis of a number of faunal assemblages from Pleistocene cave deposits, she went on to join the Department of Archaeology of the Faculty of Philosophy in Belgrade, first as a guest lecturer (2003) and then as a full professor (2007). Thus, a new phase of Serbian archaeozoology began, one of crucial importance for its further development: its inclusion in the archaeology curricula and the emergence of archaeozoologists with a primarily archaeological background.

Archaeozoology in the curricula of the Departement of Archaeology, Faculty of Philosophy, University of Belgrade

For the development of any science or scientific discipline in a particular region, it is very important that it is included in the educational system. This importance is twofold: firstly, because it provides all students – and therefore future experts and project leaders – with particular specialist knowledge that they can employ as an integral part of the field of research, i.e. archaeology. When this is not common practice, many future archaeologists will not fully recognize that animal remains are important for study, will not collect faunal remains during excavations, and will not include their analysis in projects. Another important benefit resulting from the introduction of archaeozoology into the curriculum is education at higher levels of study, which allows for the formation of experts who will conduct research within the discipline and further develop it. When a particular discipline is not represented in the curriculum, even when represented by high-quality active experts, it does not have the opportunity to expand and develop, and it often shuts down once individual researchers cease working.

The teaching in the field of archaeozoology in Serbia is linked to the Department of Archaeology of the Faculty of Philosophy, University of Belgrade, as the only place where comprehensive teaching in archeology takes place and where a degree in archeology can be obtained. Apart from that, the Department of History of the Faculty of Philosophy at the University of Novi Sad offers only individual courses in archeology. In this respect, Serbia differs from many other countries in Europe and the region in that it has a single center dedicated to teaching archaeology. This certainly has its downsides, but it also has its upsides, namely the concentration of knowledge and expertise which enables the development of subdisciplines. This would hardly be possible in a smaller department, which could only aspire to provide the basic knowledge and skills in archaeology.

Archaeozoology was first introduced into the curriculum of the Department of Archaeology through the course *Environmental Archaeology* at the undergraduate (bachelor) level. This course changed its name several times, first titled *Archaeology and the Natural Environment*, then *Archeology and the Environment*, and finally *Environmental Archaeology*. It was primarily introduced to provide students with the knowledge necessary for Palaeolithic research, with a focus on the chronology and stratigraphy of the Quaternary period, the characteristics of the climate and the living world in the Pleistocene epoch, as well as the methods for studying Pleistocene deposits. Several lectures in this course were dedicated to

Quaternary fauna and the methods for studying animal remains from archaeological sites. As of 2004, *Environmental Archaeology* has become a two-semester compulsory subject, which students take in their third year of study. The first semester of the course retained most of the topics from the previous one-semester course, and the second semester became entirely dedicated to archaeozoology.

This fulfilled the first condition for the development of the discipline, namely that all students become familiar with the subject and the aims of archaeozoology, and that graduated experts treat archaeozoological analyses as an integral part of archaeological research.

The second goal was achieved in the following accreditation cycle, which began in 2006–2007, when doctoral-level teaching under this curriculum began.

Students were given the option of majoring in archaeozoology as part of their doctoral studies. In addition, three optional courses (*Bone Tools*, *Taphonomic Analysis of Archaeozoological Material,* and *Archaeofaunae of Serbia*) were introduced, to provide students who have opted for archaeozoology as a major with a breadth of knowledge and specific skills necessary for studying animal remains, and to allow other archaeology students to become familiar with faunal analysis relevant for their study field.

In the next accreditation cycle, from 2009, archaeozoology was also introduced as the main subject at the master's level (as the course *Methodology of Archaeozoological Research II*). At the undergraduate level, *Archaeozoology* was separated from the two-semester *Environmental Archeology* course, becoming a mandatory one-semester course. In the same accreditation cycle, optional courses were introduced at the undergraduate level, which had multiple positive effects: it provided interested students with an opportunity to become familiar with archaeozoological material and the methods of its study through practical work, and it also attracted a larger number of students who chose archaeozoology as the main focus of their master's and doctoral studies.

The introduction of optional courses at an undergraduate level (*Methodology of Archaeozoological Research* and *Bone Tools*) in the same accreditation cycle, gave students the opportunity to work on the original archaeozoological material, to touch and observe faunal specimens first-hand, and thus learn about and practice the identification of animal bones, determining which animal and which part of the skeleton the fragmented specimen originated from. Since the practical part of the work is considered the most important in these courses, they are organized with a high number of classes, with an emphasis on practice (one hour of lectures and four hours of practice). Such a large fund of lessons was established because it takes time to prepare the material and even to begin archaeozoological analysis. The same formula was more or less applied to the later introduced optional courses in archaeozoology. The main goal of the *Bone Tools* course is for students to recognize anthropogenic and non-anthropogenic changes on bones, to distinguish the type of anthropogenic modification and/or the type of artefact, as well as to recognize the traces of use and manufacture on raw materials and artefacts. The material that students work on during practical classes consists of collections from archaeological sites. The priority is given to sites where the collection includes semi-finished products and fragments discarded during production, i.e. all specimens with traces of manufacture and use, regardless of whether they represent artefacts in a strict sense. Up to this point, the teaching of this course included the collections of bone objects from the sites of Vinča-Belo Brdo, Čurug-Stari Vinogradi, and Viminacium.

The teaching at the undergraduate level was enriched in the 2014 accreditation cycle with three new optional courses (*Application of Biomolecular Analyzes in Archaeozoology: DNA and Stable Isotopes*, *People and Animals in the Past on the Territory of Serbia: the Interpretation of Biometric Data,* and *Palaeolithic Archaeozoology*).

Finally, in the latest accreditation cycle, which started in 2021, the undergraduate compulsory course *Archaeozoology* has been expanded and extended to a two-semester course. In the same year, the first book dedicated to archaeozoology was published in Serbian, titled *Arheozoologija: uvod u studije zajedničke istorije ljudi i životinja* (*Archaeozoology: The Introduction to the Studies of Shared History of Humans and Animals*) (Dimitrijević 2021b), aimed primarily at students and archaeologists interested in broadening their knowledge on the subject.

From 2015 to 2022, eight PhD dissertations in the field of archaeozoology were defended (Sonja Vuković, Stefan Milošević, Ivana Živaljević, Jelena Bulatović, Nemanja Marković, Ivana Dimitrijević, Teodora Radišić, and Teodora Mladenović) and 16 master theses (Stefan Milošević, Jelena Bulatović, Tamara Blagojević, Vuk Koldžić, Nemanja Marković, Igor Marjanović, Teodora Mladenović, Teodora Radišić, Dušan Palić, Jovana Janković, Maja Kokanović, Dimitrije Marković, Mladen Mladenović, Nastasija Radovanović, Bojana Zorić, and Danica Grujić).

Research themes

Archaeozoologists working in Serbia study various topics, which are nowadays firmly incorporated into broader archaeological interpretations. The study of animal bones from the Middle and Upper Palaeolithic sites showed the remarkable diversity of taxa and habitats (Dimitrijević 1991; 1997; 1998; 2021c; Dimitrijević et al. 2014; Dimitrijević et al. 2018;

Roksandić et al. 2011). The taphonomical aspects of research enabled a better understanding of the nature of animal remains accumulation, as well as of hominin behavior (e.g. Borić et al. 2022; Marín-Arroyo 2014; Mihailović et al. 2022; Stiner et al. 2022), while also inciting questions about the competition between humans and carnivores (e.g. Dimitrijević 2011; Milošević 2020). Furthermore, the Pleistocene mammals from cave deposits in Serbia have been taxonomically, morphologically, and metrically well studied, contributing to the knowledge of the taxonomic position and paleobiology of particular species, such as cave bears (Cvetković and Dimitrijević 2014), cave hyaenas (Dimitrijević 2011), and horses (Forsten and Dimitrijević 2004).

The research of animal remains from Mesolithic-Neolithic sites in the Danube Gorges (Lepenski Vir, Vlasac, Padina, Hajdučka Vodenica, Kula, Mihajlovac-Knjepište) addressed questions of subsistence strategies (Bökönyi 1970; 1978; 1992; Borić and Dimitrijević 2005; Clason 1980; Dimitrijević 2000; Greenfield 2008; Živaljević, Dimitrijević, et al. 2017), the seasonality of settlements (Dimitrijević et al. 2016), and local dog domestication (Bökönyi 1975; Dimitrijević and Vuković 2015), while the contextualization of faunal material enabled a better understanding of human activities and the significant features of human-animal relationships (Dimitrijević 2008a; Živaljević 2015). The hypothesis on the crucial importance of fish and fishing in the formation and development of these settlements was supported – amongst others – by archaeozoological analysis of fish remains (Živaljević 2017b; Živaljević et al. 2021), as well as by the use-wear analysis of ornaments made from cyprinid teeth (Cristiani et al. 2014).

Given that the beginning of the Early Neolithic in the region coincided with the advent of farming societies, which is, amongst others, evidenced by the presence of domestic cattle, sheep, goats, and pigs in the faunal assemblages (Blažić 2005c; Bökönyi 1974; 1984; 1988; Bulatović and Spasić 2019; Clason 1980; Greenfield 1994; Greenfield and Greenfield 2014; Živaljević 2017a), archaeozoological research was mainly focused on questions about the economy of Early Neolithic societies. Thus, relevant research topics include the general discussion on herding and hunting strategies (e.g. Grujić 2022; Orton et al. 2016), and the symbolic and social aspects of human-animal interactions have been addressed as well (Živaljević 2017a).

The research dedicated to human-animal relationships in Late Prehistory (Bulatović and Filipović 2022; Radišić 2020; Stojanović and Bulatović 2013), continued to address primarily issues related to the economy. The studies of animal remains from the sites of Vinča-Belo Brdo (Bulatović 2018; Dimitrijević 2008b), Pločnik (Bulatović and Orton 2021), Drenovac, Pavlovac (Dimitrijević 2021a), Belovode (Dimitrijević and Orton 2021), Gomolava (Clason 1979; Orton 2012), Petnica (Greenfield 1986; Orton 2008) and Opovo (Russell 1993) stand out in terms of the vast number of analyzed bones and the relevance of the results, which enabled a better understanding of animal husbandry, hunting, meat diet, as well as social and symbolic roles of animals in the Late Neolithic (e.g. Bulatović 2018; Orton in press; Radovanović 2020). The faunal assemblages from the Eneolithic (Bulatović 2020; Bulatović and Filipović 2022, and the literature therein) and Bronze Age sites (Becker 1991; Bökönyi 1991; Bulatović 2020; Greenfield 1986; 2014), apart from the aforementioned data on animal breeding and hunting activities, provided information on the intensification of secondary products exploitation (Greenfield 1986; 2014), the emergence of transhumant pastoralism (Arnold and Greenfield 2006), the effects of the Neolithic-Eneolithic transition on the food economy and consumption (Filipović et al. 2020), the relationships between the emergence of social hierarchy in the Bronze Age and the faunal record (Greenfield 2006), as well as the roles of animals in the Bronze Age funerary practices (Blagojević 2020). Although the number of analyzed Iron Age faunal assemblages is still fairly small (Radišić 2020, and the literature therein), a recent study on animal remains from the Late Iron Age fortifications and open-air sites in the Vojvodina region (Radišić 2022) shed more light on animal husbandry and hunting strategies in the Late *La Tène* period, and looked into the similarities and differences in animal use between different types of settlements.

The changes in animal husbandry and hunting activities, brought by the Roman conquest of the region, and consequently by the Roman impact on the economy and society, are also evidenced in the archaeozoological record (Vuković 2020, and the literature therein). Although the number of analyzed faunal assemblages from the Roman period is relatively small compared to the number of excavated sites on the territory of Serbia (Vuković – Bogdanović 2017), the archaeozoological analysis of animal remains from different areas of the Roman site of Viminacium enabled a better understanding of the diet of the inhabitants of the city and its surroundings (Vuković – Bogdanović 2018), the meat and animal products supply of the city and the army (Marković 2018a), the supply of horses (Marković and Danković 2020), the symbolic meanings of dog burials (Vuković and Jovičić 2015; Vuković et al. 2021), the emergence of exotic camels in the Balkan provinces of the Roman Empire (Vuković–Bogdanović and Blažić 2014; Vuković and Bogdanović 2013), the significance of fish and fishing (Živaljević, Vuković – Bogdanović, et al. 2019), as well as the questions of the use of wild beasts in the Roman amphitheater games (Vuković 2015). The analysis of the large faunal assemblage from the Early Byzantine site of Caričin Grad (Baron et al. 2019; Marković

2018b; Marković, Reuter, et al. 2019) significantly contributed to the comprehension of the economy, specifically the features of animal management and subsistence strategies during the Early Byzantine period, while also shedding more light on the camel caravan trade networks (Marković et al. 2021) and the provisioning of early Byzantine cities in exotic fish (Baron and Marković 2020). Jointly with a recent analysis of faunal remains from the site of Gamzigrad (Mladenović 2020a), these studies significantly broadened our knowledge of the changes in animal management brought by ruralization in the region, which occurred after the fall of the Western Roman Empire.

The studies of human-animal relationships in the medieval period, inferred from animal remains (Blažić 1999; Marković and Bulatović 2021; Mladenović and Mladenović 2020, and the litterature therein) have proliferated in more recent years. The recent studies of faunal remains from the medieval settlements in the Southwestern Banat region (Mladenović 2020b; 2022), as well as the settlements of Braničevo (Zorić 2021) and Rudnik (Bulatović and Marković 2019), provide insight into the daily life, animal management, and meat diet in medieval times. Furthermore, the analysis of animal remains from the Monastery of Studenica provides a general overview of the monastery diet (Marković 2015), but also addressed issues of the significance of poultry (Marković et al. 2016) and fish consumption and long-distance fish trade (Živaljević, Marković, et al. 2019), relevant for the understanding of the economic, social, and religious practices in medieval Eastern Orthodox monasteries. The foundations of the archaeozoology of the modern era have recently been established with the analysis of animal remains from the 16th’17th centuries’ features excavated at the *El Kal Vež* Synagogue in Belgrade (Kokanović 2022).

Given that archaeozoology has a strong interdisciplinary potential, specialists in Serbia are collaborating with a number of scientists of non-archaeological background in order to gain a better understanding of various aspects of human-animal relationships in the past. Stemming from the cooperation of archaeozoologists and veterinary medicine scientists, the discipline of animal paleopathology started to develop in recent years (e.g. Bulatović et al. 2022; Bulatović et al. 2016; Marković and Bulatović 2013; Marković et al. 2022; Marković, Stevanović, et al. 2019; Marković et al. 2018; Marković et al. 2014), shedding more light on animal health and diseases in the past, as well as the scale of environmental and human influence on the development of pathologies. Joint efforts of Serbian archaeozoologists and archaeogeneticists unraveled important aspects of the history of animal domestication (e.g. Bergström et al. 2020; Frantz et al. 2019; Krajcarz et al. 2022; Verdugo et al. 2019), as well as the significance of prehistoric fishing and aquatic ecologies (Živaljević, Popović, et al. 2017). The studies of stable isotopes in animal bones and teeth shed more light on human diet (e.g. Jovanović et al. 2019) and seasonal calving of domesticates (Balasse et al., 2021), jointly with lipid residue and dental calculus analysis focusing on milk exploitation and its availability in the Early Neolithic (Balasse et al. 2021; Stojanovski et al. 2020), while such studies also provided insight into animal diets and herding strategies in the Late Neolithic period (Gillis et al. 2021).

Although the vast majority of archaeozoological studies focus on vertebrate (mammal, bird, and fish) remains given their prevalence in faunal assemblages, it is important to note the advances in the field of archaeomalacology. For example, the analysis of remains of shells and snails provided additional insights into Late Neolithic diets (Dimitrijević and Mitrović 2016), while studies of marine shell ornaments from the Balkan Late Neolithic sites (e.g. Dimitrijević 2014; Dimitrijević et al. 2021; Dimitrijević and Tripković 2006) revealed important information on the provision, production, and exchange of prestigious items and materials in prehistoric Europe. The studies of other objects made from osseous materials, mainly focusing on the provenience of raw materials, manufacturing techniques, the typological repertoire, and the interpretation of their function, also intensified in the last two decades (e.g. Cristiani et al. 2016; Stefanović et al. 2019; Vitezović 2016; 2017; 2020; Vitezović 2021).

As of 2012 and the conference in Valjevo, the Annual Meeting of the Serbian Archaeological Society was enriched with the addition of the Section for Bioarchaeology (Miladinović-Radmilović and Vitezović 2013), in which archaeozoologists regularly take part. They have also actively participated in the aforementioned ICAZ conference and its various working groups, as well as many other high-profile meetings such as the EAA (European Association of Archaeologists). In 2021, doctoral and master's students of archaeozoology in Serbia organized and hosted the international 9th PZAF (Postgraduate Zooarchaeology Forum) meeting (Marković and Mladenović 2021), a further testimony to the stimulating and vibrant working environment for early career researchers, their initiative, and their competence.

The important contribution of archaeozoology to contemporary archaeology in Serbia is also evidenced in the number of relevant archaeological projects involving archaeozoological research. Within the ERC project BIRTH[3] (2015–2020), faunal analysis was undertaken in order to explore the effects of the emergence of new foodstuffs (domestic animals and cereals, dairy products) on human health and fertility in the Early Neolithic Balkans. As of 2022, the Science Fund of the Republic of Serbia within the program IDEAS funds two scientific three-year projects which heavily rely on the analysis of archaeological animal remains. The project

3 https://www.ercbirth.com/

NEEMO[4] involves the analysis of faunal remains from the Middle/Upper Palaeolithic sites to understand early human evolution and behavior. The project ARCHAEOWILD[5], which studies human-wildlife interactions in the Central Balkans throughout the Holocene era, is particularly focused on archaeozoology. By providing the baselines of wild mammal distribution, extinction, and introduction in the Holocene, as well as changes in wildlife diet and genetics through time, the ARCHAEOWILD project is relevant for the understanding of human-animal interactions in the past, but it also aims to provide a temporal framework for addressing current environmental issues on a global scale.

Concluding remarks: the future of archaeozoology in Serbia

Archaeozoology in Serbia has gone a long way, from sporadic reports and short supplements and archaeological monographs, to becoming fully integrated into the curriculum of the Department of Archaeology and commonly included in research strategies. Especially promising is the number of researchers specializing in particular cultural contexts (from the Palaeolithic to the modern period) and pursuing specific research questions. This suggests the discipline is developing towards more interpretative approaches, rather than being a source of specialist knowledge whose practitioners are solely expected to provide the raw data and easily shift from assemblage to assemblage, from one cultural context to another.

While there are many reasons for optimism, archaeozoology and archaeology in Serbia are not exempt from the challenges the academia is facing globally – namely the precarious work prospects for early career researchers (Brami et al. 2022), the increasing marginalization of humanities, and neoliberal demands for unambiguous, marketable results, mainly associated with applied sciences (Nilsson Stutz 2018). What can be taken from the development of archaeozoology in Serbia is that some of these challenges can be addressed by acquiring new skills, experiences, and ideas, while retaining a strong archaeological and humanist stance.

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4 https://neemoproject.com/

5 https://archaeowild.org/

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MIND THE GAP! CHEMISTRY IN THE CURRICULUM OF THE CONSERVATION--RESTORATION STUDY PROGRAM – THE EXPERIENCE OF THE ACADEMY OF ARTS NOVI SAD

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Introduction

Conservation-restoration is a discipline traditionally associated with manual dexterity. In the past, conservators were often skilled artists or craftspeople, with vast knowledge of art materials and techniques. However, today's knowledge of conservation and restoration must be at an academic level, and hence theoretical knowledge from various fields is included in the curriculum.

In Serbia, as in many other countries, conservation studies are associated with art academies (Korolija Crkvenjakov and Đukanović 2021). As art academies and faculties do not always have the necessary internal scientists, the need for teachers in scientific fields that are included in the conservation curriculum is met by professors from other relevant faculties, usually within the same university. Although they are undoubtedly experts in their fields, it can be challenging to teach students from a very different discipline with very specific requirements. Conservators are tasked with understanding the materials of the treated object as well as the degradation processes and performing treatments. The conservation of objects of artistic, historical, and cultural interest is a highly interdisciplinary activity. Conservators undoubtedly need scientific expertise and they often employ scientific reasoning in various stages of their work. The first expected outcome of teaching science to conservation students is thus the ability of students to apply science-based logic in various phases of conservation treatment.

The importance of chemistry to conservators

We will take chemistry as an example of a scientific field that is highly important in the conservation of art objects. Degradation processes are often associated with oxidation, hydrolysis, salt formation, and other chemical interactions of an art object's materials with the environment. Due to these interactions, the art object's surface needs to be cleaned. Removing degradation products from the surface of the art object is one of the most common tasks performed by conservators. In the case of paintings, this involves removing dirt and grime or removing discolored varnish and any traces of prior restoration. This is performed by putting the painting's surface in direct contact with solvents and is considered to pose a risk to the original surface, which has to be preserved in its integral state. The mistakes could result in irreversible damage and a reduction in the significance of the heritage object.

Conservators must deal with solvents, chemical tests, neutralization, and toxicity daily while working on valuable surfaces. Considering the importance of chemistry to conservators, this field has been rapidly developing. Since 2000, many books on chemistry applied in conservation have been published in various languages. The most relevant authors are chemists with conservation experience and extensive knowledge of art materials. Such scientists are rare. When it comes to chemistry, specifically chemistry expertise applied in conservation, the best teachers are those scientists who work with conservators on a daily basis and have accumulated experience working on various cases and situations in heritage conservation. Only a few people with scientific backgrounds work in heritage institutions (museums and conservation institutes) in Serbia: chemists, materials scientists, and physical chemists, and their number has not changed for decades. Those scientists possess precious interdisciplinary knowledge, but they do not teach. Different administrations, with separate ministries, laws, and budgets, are in charge of education. Because of these formal restrictions, it is very complicated to be both a scientist in a heritage institution and a university teacher.

Developing a curriculum for the MA in conservation and restoration at the Academy of Arts Novi Sad

Bearing in mind the relevance of science for conservators, the method for teaching students the principles, theory, and practice for the cleaning of paintings, developed for the needs of conservation students at the Academy of Arts Novi Sad, will be discussed. The conservation-related lectures and laboratory work are taught in two courses that run concurrently during the semester. One course is taught by a chemist and covers theoretical principles of chemical bonds, solvent properties, solubility, toxicity, etc., as well as laboratory exercises where conservation students learn how to use laboratory equipment. The other is taught by a conservator, with lectures combining ethical principles, techniques, and aesthetics in the cleaning of paintings. The technical aspect of cleaning paintings is closely tied to the theoretical chemical lectures. In the conservation lab, the students prepare solvent tests and mixtures themselves under the supervision of a teacher and then apply them in the cleaning while working on different examples (Figs. 1, 2, 3). This learning process is filled with discussions and estimations. Students learn through examples and by solving problems. There is no strict set of rules, as each painting is different. It is important that conservation students acquire scientific reasoning skills during the cleaning process, and understand the interaction of solvents with the painted surface and the layers to be removed from it. They learn principles and procedures that will lead them through the practical work.

Figure 1. Preparing test solutions for cleaning

Figure 2. The beginning of a painting's cleaning

The cleaning of the surface is the task of the conservator, not a chemist. Chemists participate in the discussions, answer questions, and conduct analyses, but working on the art object is solely the conservator's responsi-

Figure 3. Supervision during practical work

bility. Besides using chemicals as a technical part of the cleaning, conservators must estimate the ethical and aesthetic aspects of the treatment before and during the process. This combination of necessary expertise from different fields is what makes conservation so multidisciplinary.

Conservation studies at the Academy of Arts Novi Sad are organized in collaboration with museums and conservation institutes in Novi Sad and other cities, where students get the opportunity to work on selected cases. This contributes to the high quality of the learning process. Moreover, although publications about cleaning paintings in various languages do exist, we were aware that a textbook in the Serbian language would be useful. Therefore, a book dedicated to cleaning paintings was published (Korolija Crkvenjakov and Gadžurić 2020) as a result of the close collaboration of a chemist and a conservator, and following the method used in Italian conservation schools.

There are different approaches to teaching conservation, which are discussed in various conservation conferences and journals (Fuster-López and Krarup Andersen 2014). The Academy of Arts Novi Sad also hosted a conference on education in art – Artn'Edu, with lectures on teaching conservation (Academy of Arts Novi Sad, n.d.). International organizations such as ICCROM are actively developing courses on various aspects of teaching conservation and related sciences. Particularly interesting for the issue of teaching STEM in heritage studies is the summer school "Communication and Teaching Skills in Conservation and Science," which introduces science and teaching methods in a fresh, non-traditional way, with a lot of fun (ICCROM, n.d.).

To describe the steps we take in teaching chemistry applied in conservation procedures such as cleaning paintings, a scheme that presents the general learning process is useful. The scheme divides this process into four stages. The first stage, named *Unconscious Incompetence*, describes the student at the beginning of learning: they do not know what they do not know. The teacher's task in the first stage is to provide direct instructions. The second stage is defined as *Conscious Incompetence*: students often feel that it is harder than they thought as they discover the complexity, they are insecure, and doubt if they will ever learn. This describes the phase where conservation students are at the beginning of the practical experience in cleaning paintings and encounter challenges related to real examples of paintings from museum collections. The teacher's task is to remain highly supportive while also providing a safe space for students to practice. The third stage is *Conscious Competence*. Students have now gained some experience and a measure of confidence, although they are still unsure about their competence. They need assurance that a teacher is always available for a check. We would like to think that students at the end of their master's studies are in the third stage, but they usually describe themselves as having lower competence. The fourth and final stage of the learning process is the expert stage: *Unconscious Competence*. It is a point at which someone can teach others.[6]

Conclusion

The four stages of learning are similar to the old master-apprentice tradition of teaching and learning in arts and crafts. Given the character of conservation as a heritage-related profession, which requires manual dexterity and strong craft skills along with theoretical knowledge, this scheme seems appropriate. Moreover, it can be extended to the process of teaching STEM, in our example chemistry, to conservation students. Being aware of the progress students make at various stages of their studies might inspire teachers to refine the teaching process.

It is necessary that chemists (or experts from any other STEM field) and heritage experts work together. Teachers from both disciplines need to leave their "comfort zone" as a critical step towards interdisciplinarity.

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6 There are numerous authors, books and websites that use this learning scheme, which started with Martin Bromwell in 1969. A short explanation of the model can be found at https://leadershipmanagement.com.au/understanding-4-stages-learning/.

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REVIEW OF ANALYTICAL TOOLS AND DESIGN APPROACHES IN ARCHITECTURAL HERITAGE HIGHER EDUCATION: SHARING HERSUS PROJECT EXPERIENCES

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Introduction

In higher education in architecture and urbanism, the theme of cultural heritage is traditionally encouraged within study programs and various educational extracurricular initiatives. In the context of multiple influences affecting the development and transformation of cities – such as climate change, green challenges, and social transformation – the problematization of heritage issues in the setting of the city and landscape becomes a priority topic. For this topic to have far-reaching implications in the practical sense, its integration into existing study programs as well as new study programs is of immense importance. The General Consideration of *UNESCO/UIA Charter for Architectural Education* (UIA 2017) highlights that architectural heritage education is essential for "understanding sustainability, the social context and sense of place in building design, and transforming the professional architectural mentality so that its creative methods are part of a continuous and harmonious cultural process" (Appendix X, UIA paper on Heritage Education, of UIA Education Commission Reflection Group 7, on Heritage Education, Torino 2008, cited in UIA 2017). Following this consideration, understanding heritage issues in the built environment within the framework of cultural and artistic studies in architectural education is listed as part of mandatory knowledge (UIA 2017).

Although the subject of cultural heritage is already deeply rooted in architectural education, it has grown in importance in the last decade, taking a priority position in architectural education, practice, and policy. Within this context, a number of authoritative networks and bodies at the European level (both professional and educational) emphasize the role of heritage in creating a contemporary agenda of architectural action through declarations, charters, strategies, and policies. ACE's Policy Position on *Urban Regeneration: Renovating the Existing Building Stock* defines architectural heritage as "a capital of irreplaceable spiritual, cultural, social and economic value," and accordingly, advocates for the architectural profession's key role in the preservation of heritage through conservation and appropriate intervention (ACE 2016, 2). In the context of the European Conference for Architectural Policies, the vitality of architecture is explained through its connection with heritage – "Architecture is one of the layers of cultural heritage that speaks of who we are and where we are going, with a strong impact on creating the local and national identity" (Goagea et al. 2019). Moreover, research on architectural policies conducted between 2013 and 2020 revealed that built heritage is one of the ten priority thematic areas for achieving the objectives of architectural policies (Goagea et al. 2019). For the current architectural priorities established in accordance with the policy framework to be achieved, a research framework and new architectural strategies that promote circularity as one of the leading drivers of sustainable development must be developed. Consequently, the Statement of the Architects' Council of Europe (ACE 2019) on *Designing for a Circular Economy* indicates the need for introducing a cultural approach directed towards maintaining and re-using cultural heritage (ACE 2019).

Discipline of design and architectural heritage

Over the previous decade, there has been an immense growth of research and work on the principles of sustainability, particularly the preservation of cultural heritage in all domains and in the broadest sense. In this context, it is especially important to examine the relationship between the built environment and heritage in general, having in mind that recognizing and instilling built heritage values has become a critical theme in both the education and the practice of architects. As a result, a new profile of architects/urban designers is needed in the wider architectural field, and design education faces new challenges that demand fresh didactic perspectives and tools. A new professional profile, with specific technical, technological, socio-humanistic, and artistic skills is needed to respond to these challenges. Accordingly, a new profile of architectural educators is required, one who may be in charge of improving didactic methods and tools in architectural design and heritage education. Therefore, it is necessary to emphasize the importance of critical thinking as well as the complexity of developing an adequate methodological framework for addressing sustainability and heritage in architectural higher education and the design discipline in order to enable future professionals to meet the expectations of 21st-century societies for a sustainable and value-based built environment in a variety of cultural settings.

Objectives and paper outline

The primary goal of this paper is to develop a methodological framework for addressing tools in the context of sustainability and heritage, thereby enriching curricula and broadening the scope of tools to be used in the design process. By defining the group of terms perceived as engaging learning contents (Notions, Heritage Types, Design Approaches, Design Actions, and Tools) with a focus on tools within various design approaches, the paper reconsiders the current educational framework (which includes, among other things, multiple scales, thematic scopes, course types), thereby contributing to the integration of three elements of research: value, method, and instrument. The specific objective of this paper is to analyze the relationship between tools and (1) research strategies, (2) spatial scales, and (3) educational frameworks and course types, to conceptualize them as supporting structures around which future curricula in architectural schools can be built, and as guiding frameworks for case study analysis in research and professional contexts. Following these objectives, two research questions arise: (1) what is the importance of tools in the analyzed domain of heritage and sustainability concerning high-quality standards of architecture and urban design higher education, and (2) what is the relationship between specific tools and research strategies, scales, and course types, i.e. what are the prerequisites needed to identify specific starting points and the role of specific tools.

The first part of the paper presents the research context. It provides insight into the Erasmus+ Strategic Partnership – Enhancing of Heritage Awareness and Sustainability of Built Environment in Architectural and Urban Design Higher Education (HERSUS) and HERSUS Intellectual Output 3. The second part of the paper presents a research framework for establishing correlation links between tools and research strategies, spatial scales, and course types for creating a methodological framework addressing the role of tools in sustainability and heritage in architectural higher education. The conclusion summarizes the findings and highlights essential aspects to be addressed in the further development of the remaining intellectual outputs within the HERSUS project.

Research context: HERSUS Strategic Partnership

1. HERSUS project

The HERSUS project (Enhancing of Heritage Awareness and Sustainability of Built Environment in Architectural and Urban Design Higher Education) is developed and implemented as an Erasmus+ project within the Strategic Partnerships for higher education action scope. The project started in 2020 and is developed by five higher education institutions (HEIs) from five different European countries: 1) the University of Belgrade, Faculty of Architecture as the Lead Organization (Serbia), 2) Iuav University of Venice (Italy), 3) The University of Cyprus, Department of Architecture (Cyprus), 4) The Aristotle University of Thessaloniki, School of Architecture (Greece), and 5) the University of Seville, the UNESCO Chair on Built Urban Heritage CREhAR in the digital era (Spain).[1] To create a multi-contextual research platform, HERSUS consortium members give distinct reflections and contextual knowledge deriving from their unique socio-economic and cultural backgrounds, following the geographic line of Southern European schools of architecture. The project is structured around five types of activities: (1) Design and development of Intellectual Outputs (IO) – six results with tangible and meaningful outcomes, specifically publications, book of courses, an interactive platform, and a handbook (2) Learning, Training, and Teaching (LTT) activities – one seminar for teachers, three student workshops, and one training for teachers, (3) Multiplier Events (ME) – nine events for the dissemination of intellectual outputs and the overall results in the form of public presentations, and Open Houses at participating higher education institutions; (4) Transnational Project Meetings (TPM) – six design and development meetings of consortium members; and (5) Project Management and Implementation activities (PMI) – communication, dissemination, and creating a sustainable framework for implementing results. Learning, training, and teaching activities with intellectual outputs are at the core of the HERSUS project's implementation, with all other activities supporting and supplementing their design and development. LTT is a platform for testing principles and methodologies developed from intellectual outputs, ME is a platform for the dissemination and public presentation of intellectual outputs, and TPM promotes the discussion, creative development, and critical reflection of intellectual outputs. As part of the project, four intellectual outputs, along with three student workshops and one seminar, were finished by November 2022 (Fig. 1).

1 For more information, see: https://hersus.org.

Figure 1. HERSUS Completed Results until November 2022 (IO1 - Review of the Best Practices on Educating Sustainability and Heritage (developed from November 2020 – May 2021), IO2 - Questionnaire for the State of the Art (developed from January 2021 – June 2021), IO3 - Statements for Teaching through Design for Sustainability of the Built Environment and Heritage Awareness (developed from February 2021 – December 2021), IO4 - HERSUS Sharing Platform (development started in December 2020, published in November 2021, updating and maintenance until the end of the project), LTT1 - Workshop 1: Sustainable Reconstruction in Urban Areas (Venice, Italy - 22nd–26th November 2021 (onsite), LTT2 - Workshop 2: Adaptive Reuse (Nicosia, Cyprus - 2nd–6th May 2022 (onsite), LTT3 - Workshop 3: Resilience and Future Heritage (Thessaloniki, Greece - 17th–21st October 2022 (onsite). (Figure by authors)

Over the previous two years, the project was gradually implemented, offering a wide scope of activities for cooperation between the research, private, and public sectors, securing both local and regional support for cooperation within higher education and the practical arena. With its research activities and the establishment of high-level expert groups, the project strives to analyze critical issues for the modernization and development of higher education in architecture and urban design across Europe, with an emphasis on the social and educational value of European cultural heritage. The HERSUS project is specific in that there is a visible conditionality between the six intellectual outputs (IO), which are conceptualized both as inputs for each other and as an integral result of the project that is gradually evolving and establishing a conceptual framework for improving higher education in architecture and urban design with a focus on heritage and sustainability.

2. Statements on teaching through design for sustainability of the built environment and heritage awareness

"Statements on Teaching through Design for Sustainability of the Built Environment and Heritage Awareness" are part of HERSUS' third intellectual output (IO3), coordinated by the University of Belgrade – Faculty of Architecture, and aimed at reaching an agreement among the HERSUS consortium on the concepts and fields of action relevant to sustainability and heritage (Djokić et al. 2022, 7). The results from IO3 have been prepared in the form of Teaching Vademecum: Statements on Notions, Ideas, Design Strategies, Design Tactics, Tools and Techniques, and Heritage Types relevant to the HERSUS scope. The IO3 findings led to the development of a strategy containing: (1) the requirements for an architect to be qualified in architectural and urban design, and (2) up-to-date qualifications an architectural educator must obtain to advance their teaching about the sustainability of the built environment and heritage awareness (Djokić et al. 2021). Vademecum provides insight into the above-mentioned analyzed terms along with their definition (explanation) and information regarding the content, methods, goals, course type, scale, learning outcomes, and teachers' competencies most suitable for the education of future professionals in the field. The general structure and instructions for reading Vademecum, as a system of terms relevant to the study of heritage and sustainability in architectural and urban design, is presented in Figure 2.

An important part of this publication is the HERSUS Glossary, which the project's target groups (students/teachers/trainers/tutors) can use to get a clearer picture of specific training and teaching activities that help to align the needs of the practice and teaching of urban and architectural heritage sustainability. The Glossary was developed to help the project consortium establish consensus on concepts and fields of action relevant to the project, and it has specificities and limitations as a result of the expertise and views of individual researchers and experts involved in its development.[2]

The overall focus of IO3 was on a set of recommendations that aim to define and elaborate on professional competencies that need to be developed by both architects/urban designers and architectural educators in a dual perspective by (a) developing statements on the relevant notions, ideas, design strategies, design tactics, tools, techniques, and heritage types, and (b) developing statements on their importance for education (Djokić et al. 2022, 9).

Research framework: Review of analytical tools and design approaches

Based on previous HERSUS IO3 findings, a specific research framework was developed to test the applicability of tools as a driving and operational element of a design process that should be applied systematically to achieve a design goal and solve a design problem. By analyzing the group of terms used to cover all analytical and problem-based approaches in the design process and to treat and preserve a particular category of heritage, specific design approaches were identified.[3] Accordingly, a set of distinctive tools that are currently used or are in the domain of the expertise of researchers participating in the HERSUS project were analyzed following the predefined structure (Fig. 2).[4] Nevertheless, the established list of tools is by

2 The overall methodology of the HERSUS glossary design and development has been previously elaborated (Đorđević et al. 2022).

3 While focusing on individual aspects in the fields of heritage and sustainability, the HERSUS project identifies several different approaches aimed at (1) preserving and emphasising inherited socio-cultural, spatial, and ecological values (Community Building and Representation, Historic Urban Landscape (HUL), Design For All In Cultural Heritage, Multi-scale Design Approach), (2) increasing ecological performance of buildings/places (Environmentally Responsive / Energy – Conscious/Climate-Sensitive/Whole-Lifecycle/Carbon-Neutral/Passive/Active Sustainable Design, Thermal/Visual/Acoustic Comfort Design, and Green Blue Infrastructure), and (3) investigating architectural programs capable of generating a sustainable use of heritage (Heritage Reprograming)

4 The HERSUS project identifies various tools in the field of heritage and sustainability: Image Rectification, 3D Printing, As Built / as Found Recording, Space Syntax, Morphogenesis Study, Mapping, Documenting, Cataloguing, Use of GIS Technology, Heritage Building Information Modelling HBIM, Collaborative cartography, Collab-

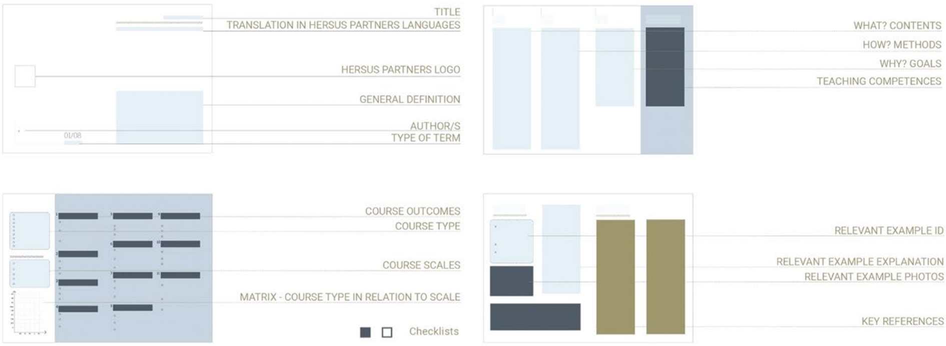

Figure 2. How to read HERSUS Vademecum Statements. (Figure by authors)

no means complete and it needs to be constantly upgraded in line with the ever-changing nature of tools used in architectural and urban design.

1. Role of tools in architectural and urban design

The constant evolution of design tools from perceptual (concrete) to conceptual (abstract), from static (the practice of representation) to dynamic (the practice of simulation), is adding new layers to already complex operations (Đorđević et al. 2022).

Tools in relation to research strategies and design processes

When referring to the design process, three phases are commonly highlighted: (1) the analytical phase characterized by systematic observation, inductive reasoning, experience, and measurement, (2) the creative phase characterized by assessment, deduction, reasoning, and decision making, and (3) the executive phase consisting of describing, translating, and transmission. The design process, perceived in this manner, enables one to understand when a specific tool is applied within the design process. Simultaneously, linking tools to research strategies enables one to understand the rationale behind applying specific tools. In this research, seven types of research strategies were adopted: historical research, qualitative research, correlational research, experimental and quasi-experimental research, simulation research, logical argumentation and case studies,

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orative Workshop CHARRETTE, Creative and Artistic Approaches, Heritage Value Matrix HVM, Thermal Energy Simulation, Lighting Simulation, Post-Occupancy Evaluation POE, Petrography, Conservation Status Evaluation, Archaeometry, Digitization of Heritage

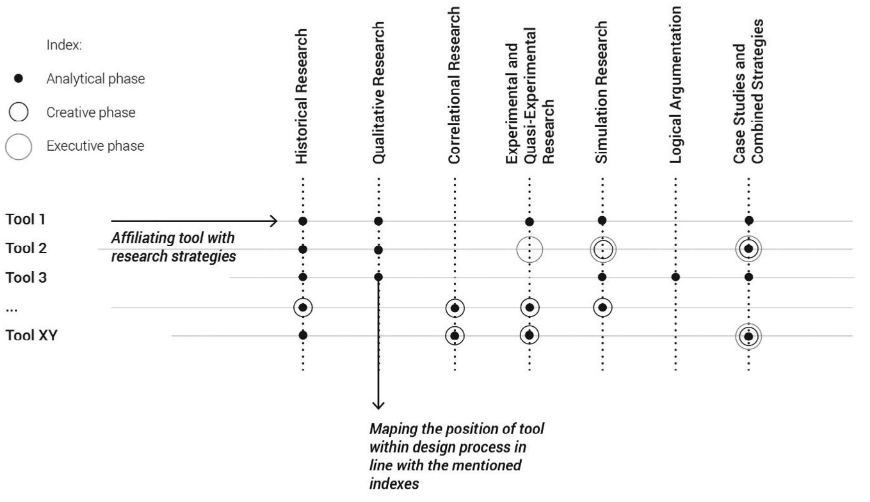

Figure 3. Methodological matrix: Examining the relation in-between research strategies, design phases and design tools. (Figure by authors)

and combined strategies, all of which are elaborated in detail by Linda Groat and David Wang (Groat and Wang 2013).

In this sense, the research framework is based on the methodological matrix (Figure 3) of tools and their affiliation with research strategies. The methodological matrix enables mapping the position of the tool within the design process in line with the mentioned indexes (analytical, creative, and executive phases).

Tools in relation to spatial scales

Considering the multi-scale nature of urban phenomena, spatial scale is of great importance for understanding urban processes and applying design approaches, necessitating architectural education to prepare future professionals to think broadly and act on multiple scales. Accordingly, the spatial scales included within the curricula can be classified as Construction Detailing and Interior Design Scale (XS), Architecture: Buildings Scale (S), Urban Design Scale (M), Urban and Regional Planning Scale (L), and Landscape Scale (XL). Concerning the relationship between spatial scales and design tools, a methodological matrix allows one to map the scope of tools in relation to the spatial scales (Figure 4). Visual representation within the matrix enables additional reading of the applicability span of specific tools (horizontal axes) and the level of tool representation within each scale (vertical axes).

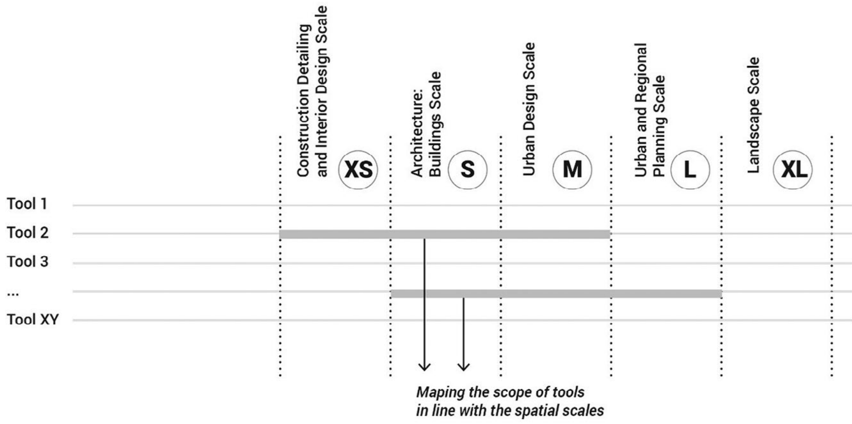

Figure 4. Methodological matrix: Examining the relation in-between spatial scales and design tools. (Figure by authors)

Tools in relation to educational framework and course types

The list of specific course types based on the HERSUS intellectual output 3 (IO3) included the following: Design Studio (DS), Intensive Workshop (IW), Theory Course (TC), Seminar (short comprehensive) (SSC), Laboratory Work (LW), Research Thesis (RT), Field Work (FW), and Internship Practical Training (IPT). The methodological matrix allows one to map the course types within which specific tools can be taught (horizontal axes), while vertical axes helps one to identify the various tools that can be taught within specific course types (Fig. 5).

Conclusions

The conclusions in this paper are conceived as a Concept Note for further research – as a methodological framework for the further critical development of tools and design approaches to heritage. Regarding the importance of tools when dealing with the specific subject of heritage and value-based design, one can recommend their equal use in all phases of the design process – analytical, creative, and executive. Contrary to the most widely held opinion that tools are predominantly used in the analytical phase, the HERSUS project advocates for the equal importance of tools in all phases of the design process. The project's methodological matrix provides a framework for future research and knowledge acquisition: (1) Research strategies and tools – collecting the best examples of good practice of tool application in research and practice which are and will be

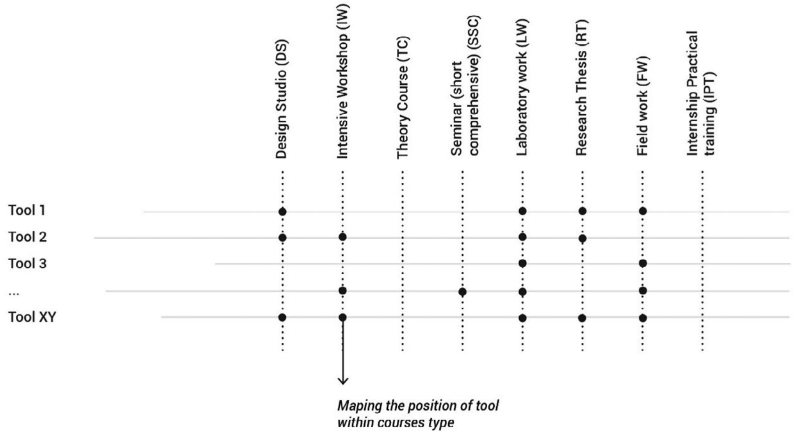

Figure 5. Methodological matrix: Examining the relation in-between course types and design tools. (Figure by authors)

further disseminated through Intellectual Output 4 – Hersus Sharing Platform[5] and used for its upgrade; (2) Spatial scales and tools – developed within IO3 by mapping a wide specter of possibilities and identifying gaps within these relations; this enables the framework for creating new tools and expanding the level of application of existing ones; (3) Course types and tools – tested and promoted through the development of new study courses from the HERSUS book of courses, as part of IO5 findings.

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5 For more information, see: https://hersus-sharingplatform.org.

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TEACHING STEM IN ARCHAEOLOGY – NOTES FROM A DEVIL'S ADVOCATE

Staša Babić

The aim of this volume, and the entire HERISTEM project that generated it, is to work towards the advancement of university curricula in heritage-related disciplines through the systematic incorporation of STEM knowledge and skills in higher education training of heritage professionals. Particularly in archaeology, the rapid developments over the past few decades in the application of various methods and techniques derived from engineering, natural, and computer sciences, aimed at acquiring ever more fine-grained information on the past, have given rise to a wave of optimism, notably expressed by Kristian Kristiansen's proclamation of the *third science revolution* (Kristiansen 2014). Although this firm belief, championed from a position of unquestionable authority, sparked immediate critical responses (*cf.* Chilton 2014, Gonzáles-Ruibal 2014), the claim has gained purchase that archaeology is undergoing a revolutionary *paradigm shift*, predominantly induced by the new technical possibilities for generating and processing data about the past. For example, one of the themes for the 2022 annual conference of the European Association of Archaeologists invited participants to examine the state of the discipline *ten years after the 'Third Science Revolution'*[1] (Babić and Milosavljević 2022), implying that there is no doubt that yet another radical turning point in the development of archaeology has occurred and that the entire field is decisively shaped by the strong influx of ideas from the domain of hard sciences. However, there are still challenges to be resolved, both theoretical and practical, before the *third science revolution* in archaeology can be declared completed (Chilton 2014; Gonzáles-Ruibal 2014). The aim here is not to provide comprehensive coverage of these issues, but rather to point to some of the implications of this situation for the current practices in higher education.

1 https://www.e-a-a.org/EAA2022/Programme.aspx?WebsiteKey=13a70299-9cf2-4cc8-98c2-2862c5c6a8dd&hkey=01dc47f6-68bd-4d87-bcdf-183a7eb484d2&Program=2#Program

There is no doubt that the landscape of archaeology has indeed changed conspicuously in the first decades of the 21st century, to a large extent as a consequence of the vast array of novel techniques from the STEM arena. This broadening of horizons obliges us to reconsider the ways in which young professionals are introduced to the field and what skills are essential for their future success. However, when pondering upon this issue, we should bear in mind that from the turn of the century, other archaeological voices have proposed different agendas, also declaring radical changes in the ways we approach our object of study, but inspired by a different source: concepts and ideas from the domains of anthropology and philosophy (*e.g.* Harris and Cippola 2017; Hodder 2012; Olsen et al. 2012) and engendering lively discussions (Babić 2019). This is certainly not the first time that archaeologists have debated whether their field of expertise is/should be more closely affiliated with hard sciences or humanities, and similar *theory wars* (Chapman and Wylie 2016, 7) have been waged throughout the history of the discipline, without ever reaching a conclusive outcome. Although attempts have been made to advocate a more balanced approach, with the aim of bridging the gap (Jones 2002; Chapman amd Wylie 2016; Babić and Milosavljević 2022), the proponents of the extreme views in these debates have often talked past each other, claiming the exclusive privilege of revolutionizing the field.

Whether any of these contending proposals represents a *paradigm shift* is a moot point (Lucas 2016; Babić 2018, 33–35, 68), but it can hardly be denied that the introduction of an array of methodological procedures heavily borrowed from the field of STEM has made a profound impact on the practices of archaeologists around the world. Many scholars share Kristiansen's enthusiasm that, as a result of this, the science of archaeology is progressively producing a more detailed and accurate knowledge of the past. At the same time, *death of theory* has been announced (Bintliff 2011; Thomas 2015b), at least partially indicating that the matter is settled and that an epistemic consensus has been reached. And yet, there have been moments in the history of archaeology, notably during the 1960s and the 1980s, when parts of the archaeological community expressed their firm belief that the state of *normal science* has been achieved and that the sole remaining task is to apply and refine the determined set of rules of good research. Nevertheless, it can be safely argued that none of these radical theoretical turns have changed the entire field of archaeology and that the majority of researchers around the globe in fact continue to adhere to some kind of hybrid approach, partly adopting novelties while retaining previously deeply rooted practices (Babić 2018). Crucial for the present purpose, this seemingly unruly state of affairs may present particular challenges for university teachers, charged with the task of introducing novices to the field (Babić 2016) and determining the knowledge and skills necessary and sufficient for their incorporation into the disciplinary community (Bourdieu 2004).

Rather than interpret this state of affairs as a sign of an unstable and somehow imperfect field of knowledge, the intention here is to raise the point already stressed by other authors (*cf*. Currie 2018; Lucas 2015; Thomas 2015a, 2015b), that the plurality of approaches present today and throughout the history of archaeology as an academic endeavour is a significant asset of the discipline. Taking advantage of this theoretical and methodological plurality requires constant scrutiny of disciplinary epistemic norms. Useful guidance in this endeavour can be found in the field of *social epistemology*, particularly in the following advice by Melinda Fagan:

> *Purely abstract standards for epistemic justification, lacking any connection to our practices, are at best pretty fictions, descriptions of imaginary science to dazzle the uninitiated and inspire novices. At worst, they mask relations of power and politics that determine what is accepted as scientific knowledge, protecting inequities from critique and lending social biases an appearance of inevitability. To prevent such misuse of epistemic ideals, their connection with scientific practice must be articulated* (Fagan 2010, 103, underlined by S.B.; see also: Longino 2002; Babić 2018: 43 ff.).

In other words, the tenets of any particular theoretical program proposed by archaeologists are literally tested *in the field*, through actual practices of recovering and processing the material remains of the past and constituting the *archaeological record* – a permanent association of specific materiality with the observations and inferences of researchers on its various qualities (Lucas 2012). The massive influx of STEM-derived methods and techniques no doubt significantly increases both the quality and the quantity of data at our disposal. And yet, it has been put very bluntly that *archaeometry has made many people lazy – and justified their laziness* (Gonzáles-Ruibal 2014, 42). Harsh as it may seem, this statement points to a number of important issues worthy of careful scrutiny, especially in the context of training future cohorts of archaeologists. Generating, processing, and manipulating these data requires specific skills that were previously not a standard part of university curricula for archaeology students. Including training in these skills in university programmes may require *excluding* certain other, traditionally taught content, in order to avoid the danger of overcrowding. This raises the problem of priorities and choices to be made by university teachers: what are the core skills and knowledge necessary and sufficient for archaeologists entering the labour market in the third decade of the 21st century, and how do they differ from those required prior to the wave of STEM? What can be safely and justifiably excluded, and at what point do we enter the dangerous zone of throwing the baby out with the bathwater? Following Gonzáles-Ruibal, when do we become lazy and assume that mastering the sophisticated methods of gathering and processing data automatically vouches for *good archaeology*? Ultimately, when do we fall into the trap of *scientism*, putting our faith firmly and exclusively in the power of empirical research (Haack 2017), and forsaking the long humanistic tradition running throughout the history of archaeology? When contemplating these questions, it may be beneficial to reconsider some of the reasons behind the notable increase in STEM-derived elements in archaeological practices, other than their obvious and indubitable potential to increase the viable options for gathering and processing the data on material traces of past human activities. And yet, precisely because these advancements have already immensely extended the scope of our research, it is essential to reconsider both their advantageous impact upon the discipline and the possible dangers of over-enthusiastic expectations. The previous experiences of archaeologists engaging in interdisciplinary dialogue with empirical sciences may serve as a cautionary tale, demonstrating that this rapport may prove to be complex and lead to disappointing results (Babić 2018, 116–120; Chapman and Wylie 2015, 8–10). The disappointment may well have been the result of an insufficiently clear distinction between the *methodological* and *epistemic* domains of research: *what* we do and *why* we do it. This is particularly important when the already existing research procedures are transferred into another domain since their original purpose and rationale rarely precisely match the ones at the receiving end. In this process of "trading with the enemy," (Galison 2010) misunderstandings are frequent, especially concerning the limitations of the "borrowed goods," expected to solve the problems they were not designed to face in the first place. The application of radiocarbon dating is no doubt one of the most successful cases of momentous advancements in the archaeological interpretation of the past enabled by one such transfer of hard-science knowledge:

> *The ambition was to build a body of evidence that could stand as an empirical foundation for absolute chronologies, secure in its own terms, warranted by material postulates drawn from physics that would decisively banish the 'element of conjecture' inherent in existing archaeological dating systems. In the event, the effective application of nuclear science to archaeological problems required an extended process of calibration, often against the very lines of evidence 14C dating was meant to displace* (Chapman and Wylie 2016, 144).

Hence, it is not necessary to subscribe to the fervent critique aimed at the processual program for its excessively positivistic postulates (Babić 2018, 68 f.) in order to point out that *archaeological* knowledge cannot be achieved solely by the means of *physics.* The radiocarbon dating cautionary tale aptly illustrates that, even when successfully adapting the findings, methods, techniques, and skills of the very model of exact science, archaeologists need to refer back to their own specific mode of *evidential reasoning* in order to meaningfully benefit from the trans-disciplinary exchange (*sensu* Chapman and Wylie 2016). This in turn means that the *epistemic goods* – new knowledge on the phenomena we investigate (Currie 2018) – may not be achieved by abandoning our own epistemic concerns in the hope that this neglect can be compensated by the application of sophisticated *scientific* procedures (*cf.* Haack 2017). And yet, the discipline periodically comes dangerously close to this turning point, when a *paradigmatic* shift is announced based largely on the reliance upon the *epistemic norms* coming from the domain of hard science. In many instances, most notably in the most recent influential programmatic text of this kind – that of Kristiansen (2014) – this argument is framed largely in terms of listing the vast possibilities of applying ready-made solutions, while a reflexive discussion on the complexities of interdisciplinary transfers is largely absent. The underlying assumption appears to be that all research is and can only be conducted according to a unified set of *scientific* principles. This, however, is a highly contestable position, with a long history of debate, dating at least to the 19th century (Babić 2018, 57–62, *passim*).

The reasons for the eagerness to comply with the principles of hard science as the only legitimate way of generating true knowledge can be sought in various directions and from various starting points, and a detailed discussion of this topic far exceeds the intentions and possible scope of this text. However, one important rationale behind the periodical searches for the legitimacy and security of *exactness* may lie in the desire of archaeologists to overcome the discipline's subservient position in relation to other fields of inquiry into the past, especially its complex relationship to history (Babić 2018, 49 *ff.*), and to seek "*a better position at the table of human sciences*" (Lucas 2012, 133). This tendency may be brought into perspective by the fact that even Sigmund Freud claimed analogies with physics when formulating the basis of psychoanalysis, in order to gain respect and trust for his revolutionary theory of the human mind (Weinert 2009, 191–209). The irresistible pull of the procedures and protocols deemed *objective, exact, robust,* and thus *properly scientific* and worthy of social esteem is smartly summarized in the title of an essay by Bruno Latour: *Give Me a Laboratory and I will Raise the World* (Latour 1983), examining the ways in which Louis Pasteur profoundly transformed the French society, its attitudes towards public health, the human body, animals, food, housing, and, finally, the procedures and mechanisms of governance. Setting out to change the world, for the benefit of all and according to what was perceived as a *neutral scientific discovery*, the famous microbiologist in fact engaged in a number of eminently social activities to convince many actors in the public arena, including other researchers – medical doctors and veterinarians – that his conclusions are sound. "*How has Pasteur succeeded in capturing the interests of other indifferent groups? ... He transfers himself and his laboratory into the mist of a world untouched by laboratory science*" (Latour 1983, 144). In this intricate interplay, all actors are constantly changing in relation to one another, including strategies of negotiation and concessions, which are familiar to any practicing researcher in search of funds, today certainly no less than during the time of Pasteur. The laboratory – the particular locus of scientific discovery, isolated from the outside world in order to obtain the most objective and controlled observations – proved to be influenced in several fundamental ways by the society it was embedded in.

Pasteur is one of the most celebrated scientists for good reason, and the significance of his work for the health of the human population can hardly be overestimated. Along with his breakthrough inferences about the microorganisms that cause human and animal illness, there is also reason to celebrate his prowess in navigating the world outside his lab and securing social relevance and adequate action from decision-makers of his time – a feat not fully matched by the success of the current scientific community in warning the public about climate change. Public opinion on and confidence in science – whatever is colloquially encompassed by the term – has changed in profound ways from the time of Pasteur (Haack 2017), and communicating research results to the community and inducing social action in accordance with them is now even more difficult than it was at the end of the 19th century. The strategy advocated by a number of archaeologists – to assume the position of objective observers of facts, in order to secure a more influential role in society – may be less efficient in a world fraught with scepticism and denial of disturbing realities. It may be much more productive to devote our energies to articulating our unique position as researchers straddling the divide between natural and social sciences and humanities, equally capable of discerning all aspects of human life, both those observable by STEM-derived skills and those not readily accessible by such approaches. In the words of Elisabeth Chilton:

> *... as a child of the 1960s I optimistically consider humans to be capable of using scientific and technological methods to solve any number of pressing global problems (disease, war, violence, food stress, global warming, etc.). But as a social scientist I also strongly believe that we need first to work on issues that will not be solved by data alone: social inequality, the sustainability of our natural resources, equitable decision-making*

and priority setting, and an understanding of the politics of science and funding mechanisms (Chilton 2014, 39).

Fully embracing this stance, as a university teacher tasked with introducing new professionals to the field of archaeology, I strongly believe that our main goal should be to present to them the full range of archaeological reasoning. Some of the epistemic demands before us are similar to other fields of inquiry, searching for explanations of the deep past from the naturalistic angle, such as paleontology or evolutionary biology (Currie 2018). Nevertheless, there is also a long and highly relevant tradition of archaeological thinking that leans heavily on the humanities (Babić 2018), which may be obscured by the new wave of enthusiasm generated by STEM-driven advances. This *methodological omnivory* has been the source of *epistemic optimism* (Currie 2018), but in order to fully embrace the potential, just like in the case of radiocarbon dating, archaeologists – experienced researchers as well as novices – would be wise to constantly and carefully consider both the *possibilities* and *limitations* of the ideas, concepts, and methods we find useful in other fields of research, regardless of their provenance (Babić 2019). Necessary in this endeavour is the skill of engaging in critical and reflexive interdisciplinary dialogue, profoundly informed by the social relevance of archaeologically produced narratives of the human past. In these exchanges, questions about *why* we choose certain methodological steps should come before concerns about *how* we actually perform certain procedures. It is our duty to teach students how to pose these questions, always bearing in mind the specific quality of our data sources – the materiality of human lives.

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THE CONSTRUCTION OF ARCHEOLOGICAL HERITAGE

Dimitrij Mlekuž Vrhovnik

Archaeological heritage is constructed

Archaeological heritage is not something given in advance. It does not exist in and of itself; rather, it is constructed through the research process. Archaeological traces are, by definition, fragmentary, obscured, and difficult to identify. For a trace to become archaeological heritage, it must go through the stages of identification, registration, documentation, interpretation, and evaluation.

Processes of heritage recognition are historically contingent. They are embedded in the larger theoretical, social, and ideological contexts of reflections and ideas about what heritage is, how to recognize it, and how to protect it. These considerations set the framework for understanding and constructing archaeological heritage. Which archaeological trace is recognized as archaeological heritage and which is not primarily depends on material possibilities, considerations, doctrines, and theories. Archaeological heritage is thus a product of its time.

The protection of archaeological heritage was previously based on the rescue of isolated rare and exceptional monuments, important finds and sites. However, recent decades have seen the emergence of preventive archeology (or *development led archeology*), based on the assumption of archaeological traces as a limited resource that must be managed sustainably, primarily through the avoidance of interventions, particularly spatial planning.

Archaeological traces are under threat of being destroyed, processed, or covered (Solli 2011) as a result of increasingly intensive interventions in space that are characteristic of the Anthropocene. These conditions call for different approaches to protecting archaeological heritage, since "rescue," or the act of documenting traces during interventions in the space, is unproductive for both the heritage and the investors.

The concept of preventive archeology in Slovenia dates back to the late 1980s, when Slovenian archeology developed a number of conceptual and methodological innovations, especially in non-invasive methods of landscape observation such as systematic surface surveys, aerial photography, and geophysics. For the first time, new ideas and methods were put into practice on a major highway construction project, resulting in a dramatic increase in the number and density of new sites, i.e. archaeological heritage. The experience of conserving archaeological heritage during the highway construction project also significantly contributed to the change in the doctrine and organization of archaeological heritage protection. It was this experience that led to the development of preventive archaeology, its implementation in legislation, and the establishment of the Center for Preventive Archeology (Djurić 2007).

This development was the result of larger changes in the understanding of archaeological heritage and the role of archeology in its production. The change in doctrine is reflected in the Le Valetta Convention on the Protection of Archaeological Heritage, adopted in 1992 and ratified by the Republic of Slovenia in 1999. The main points of the Convention are the inclusion of archaeological research in the spatial planning process and the "polluter pays" principle. They are also the foundations of preventive archaeology where archaeological heritage is threatened by intervention.

Preventive archeology is thus a conceptual innovation that incorporates archaeological research into the process of planning interventions in space. Archaeological heritage becomes a feature of the space and archeology one of the partners in spatial development planning as a result.

Heritage is produced through cycles of accumulation

For something to be recognized as archaeological heritage, knowledge must be produced through the arc of research. The process of protecting archaeological heritage is therefore nothing more than a process of knowledge production. And if we reflect on the process of knowledge production, especially through the perspective of Science and Technology Studies (STS), we can identify some key stages of the process of constructing heritage.

One key aspect of knowledge production is cycles of accumulation. Knowledge is created through layering, addition, and multiplication. Thus, in cartography, for example, the cycle of accumulation begins with a researcher being sent to an unknown part of the world. The explorer

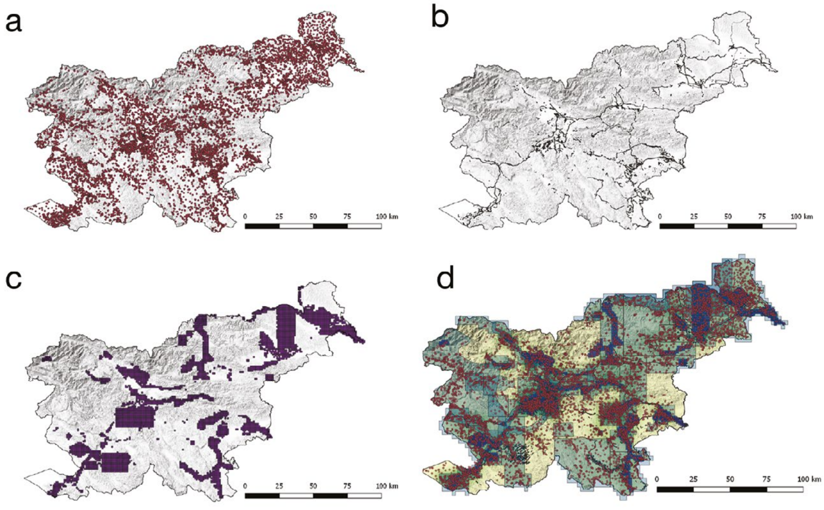

Figure 1. Some visualization of the data from the archaeological heritage information system of the Centre for Preventive Archaeology (CPA): a) archaeological sites, b) archaeological intervention, c) systematically mapped records of the airborne laser scanning (ALS); and d) "white spots" (light) and archaeologically better known areas in Slovenia (dark).

then returns with notes and a map of the area. The next explorer does not venture there bare-handed but is already equipped with the map that the first explorer has made. He returns home with a new, improved, and more accurate map. A new card has therefore been added to the pile. Science, including archaeology, is nothing but repeated accumulation cycles of accumulation (Latour 1987, 225–2267).

In preventive archaeology, cycles of accumulation are formalized through the arc of research, from preliminary research to excavation. The arc of research establishes different forms, statuses, or aggregate states of heritage. The practice of preventive archeology is thus based on the arc of increasingly intensive research, which is divided into three phases. The first phase includes research to assess the archaeological potential (archaeological potential assessment), followed by research to determine the content and composition of the site, and finally, excavation. Surveys for the assessment of archaeological potential are often extensive, covering large areas with methods that do not require significant time and costs per unit area.

A key innovation is the concept of archaeological potential, or the potential of a space to contain archaeological heritage. Archaeological potential is understood as something that is not (yet) archaeological heritage but has the potential to become one.

Archaeological potential cannot, therefore, be simply equated with concrete archaeological traces such as finds or structures. The map of archaeological potential is not a map of archaeological sites, nor of archaeological traces. Archaeological potential speaks only about the property of the space, and refers to the fact that there are archaeological traces there, which may or may not become archaeological heritage. Archaeological potential is thus a step toward the actualization of archaeological sites and archaeological heritage. Unactualized potential resists actualization and requires effort, work, and research to be actualized (Dimitrij Mlekuž et al. 2016).

The idea of potential, of course, does not deny that concrete physical traces in the landscape exist before research. However, for these concrete physical traces to become archaeological heritage, they must first be discovered, identified, analyzed, and interpreted. Archaeological traces will be actualized only through research, when the traces have actually been discovered, when we have recognized their extent and the stratigraphic relationships between them and the image. The idea of potential thus assumes that archaeological potential is actualized in the process of research into concrete archaeological remains or archaeological sites. An updated archaeological site can be understood as archaeological remains, whose extent, structure, stratification, chronology, and finds we know.

The foundation for the assessment of the archaeological potential is cabinet research, particularly "historical analysis," or the compilation and critical examination of existing data available in the archaeological literature, as well as "grey literature" such as various unpublished reports, studies, and expertise, as well as other mentions in the public media, in oral tradition, toponymy, and the like.

An important innovation of preventive archeology in Slovenia is the systematic application of meta and remote sensing, which enables us to observe the Earth's surface from afar. This includes aerial photography, satellite images, laser recording, thermal recording, and others.

The spatial scope of the methods for determining the archaeological potential includes the entire area of Slovenia, despite the fact that in practice it is limited to the areas of individual projects. This is precisely why standardized sampling, which allows for the comparison of individual project findings, is key.

Methods for determining the extent and structure of archaeological traces are more thorough than methods for determining archaeological potential; their purpose is to define archaeological traces more precisely, in terms of their age, preservation, functionality, structure, extent, and stratification. The spatial extent of research is usually limited to areas with high archaeological potential. These include intensive field inspections (of open and closed areas), geophysical surveys, drilling of core wells, digging of manual test probes, and mechanical excavation of test trenches. The selection of individual methods depends on the circumstances and expected results, and similarly to the method for determining the archaeological potential, the key is standardized sampling, which allows for quantitative comparisons between surveys and the integration of surveys across the country. Through this kind of research, potential can be actualized into heritage.

Archaeological excavations result in the destruction of the material integrity of archaeological traces. It is the most complicated, intensive, costly, and invasive archaeological method that requires large organizational and logistical inputs, and produces large amounts of data that require complex and demanding post-excavation processing and interdisciplinary cooperation of specialists from many fields. Precisely because of its destructiveness and cost, excavation should only be used as a last resort, especially in cases where the destruction of archaeological traces is unavoidable; the Valletta Convention already recommends the preservation of archaeological traces *in situ*.[2] Nevertheless, archaeological excavations are still an important and frequently used method in practice.

We produce archaeological heritage with inscription devices

Another significant aspect of knowledge production – if we return to the example of cartography – is that explorers return from distant lands with notes, plans, and maps. When we look at scientists, including archaeologists at work, we notice that most of their time is spent making records, pictures, images, graphs, plans, forms, sketches, photographs, and so on. In short, the majority of their time is devoted to coding reality and then manipulating these codes. In science and technology studies, these are called *inscriptions* (Latour 1987, 63–103). Inscriptions refer to all records (texts, maps, sketches, illustrations, graphs, photographs, point clouds, etc.) that document particular real-world relationships and so consolidate and stabilize them while neglecting the majority of others.

Bruno Latour thus describes inscriptions as immutable and mobile (*immutable mobiles*) as they allow for the movement and dissemination of information (hence mobile), which nevertheless remain coherent (hence immutable).

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2 Which in the Slovenian archaeological heritage profession is often understood as the *presentation* of remains at any cost, even as aliens in a new environment, but not preservation in the original context.

Thus, an archaeological site's floor plan can be duplicated, reduced, and combined with other plans, which cannot be done with the site itself (also because it no longer exists as a coherent material entity). The floor plan can be used as an illustration in a book, it can be simplified and compared with other site plans, and thus with the actual sites. Despite these manipulations, it retains the composition of the original situation, as well as shapes and the spatial relationships between elements such as the boundaries of stratigraphic units, the position of artifacts, and so on.

Unlike real phenomena, inscriptions allow us to compose, confront, combine, and simplify them. In this way, we create more and more abstract hybrids as the result of changing, transforming, simplifying, and combining an increasing number of inscriptions, which Bruno Latour calls a cascade of inscriptions (Latour 1990).

The process of knowledge production is thus a process of creating inscriptions, a process of combining, confronting, and assembling inscriptions making them increasingly abstract and universal. With each step of the transformation, we lose "locality, particularity, materiality, multiplicity and continuity" – which are the characteristics of the material world – but we gain in return "compatibility, standardization, texts, the possibility of calculation, dissemination and relative universality," which are the qualities of documentation. The process of creating inscriptions is thus one of creating knowledge (Latour 1999, 70) from observations and interactions with reality.

Another aspect of inscription production is the use of inscription devices (Latour 1987, 67). They, like all artifacts, are also scientific records, inscriptions compiled with the help of machines or devices. Machines, or inscription devices, play a key role in the researcher's contact with reality, as they condition what we write down, what we stabilize, and how. Tools, or inscriptional devices, determine how we approach reality. Tools such as a meter, a spectrometer, or, for example, Munsell soil charts allow us to record aspects of reality in a more or less universal way. In reality, the difference between a scientist and a non-scientist lies precisely in the use of tools, or inscription devices. Inscription devices allow for the observation of phenomena that cannot be perceived by humans alone and help to formalize the observation, most often through mathematization, or the quantification and transfer of the phenomenon into a mathematical space. These devices and tools transform a concrete material phenomenon into a set of coordinates.

Archaeological traces are often invisible, fragmented, and buried. To find and identify them, we need inscription devices, which often determine which types of traces we perceive and which become heritage. The choice and use of tools often determine our understanding of archaeologi-

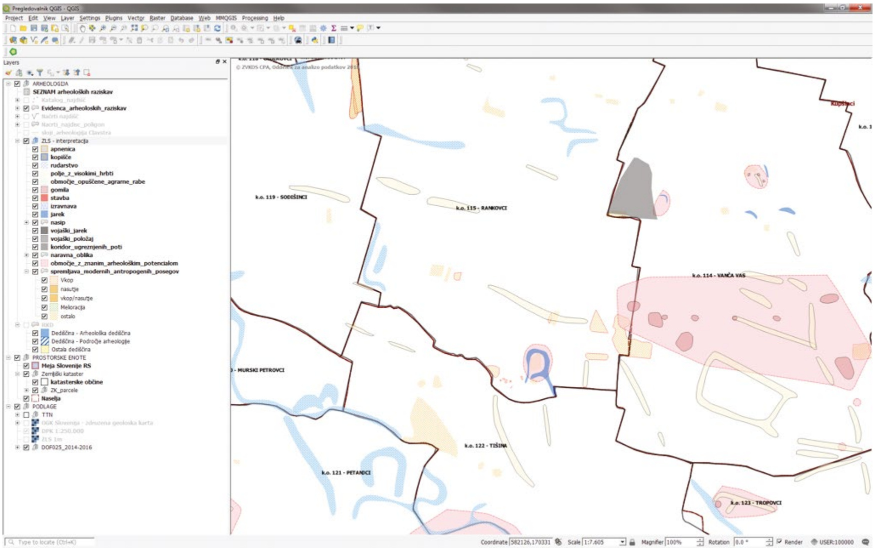

Figure 2. Standardized inscriptions of the systematically mapped ALS records in the archaeological heritage information system.

cal heritage. With geophysical methods, such as laser scanning and other remote sensing methods, we can detect completely different aspects of archaeological traces.

Remote sensing methods are a fast, systematic, non-invasive, and relatively accessible way of obtaining data on archaeological traces in the landscape. This includes aerial photography, satellite images, laser recording, thermal recording, and others. Aerial observations are a way of obtaining data on archaeological potential. Most importantly, aerial photography has significantly contributed to the discovery of new archaeological sites and the understanding of the time depth of the landscape since the 1920s. Aerial photography is based on the observation of signs such as different soil colors (color signs), differences in crop growth (vegetation signs), and shadows (topographic signs) that may indicate archaeological traces below the surface (Grosman 1998).

Unfortunately, aerial photography had little influence on the archaeological practice and heritage protection in Slovenia. There are several reasons for this. The first is that the majority of Slovenia – around 60% – is covered in forest, with a vegetation cover on the ground. For systematic observation, large areas planted with monocultures are best suited since the landscape can be observed as a whole, and differences in the color and texture of the soil and crops between possible archaeological structures and the surroundings can be more easily detected. In Slovenia, which is characterized by rugged topography, a heterogeneous geological base, and fragmented land division, with different crops, each with its own growth cycle, observing vegetation and color signs can be difficult. Thus, it is not surprising that the only great successes of aerial photography have occurred in Prekmurje, where the landscape is more suitable for observation (Kerman 1999).

On the other hand, the method of aerial laser scanning (ZLS) of the surface has been extremely successful in Slovenia. The phrase "laser scanning" describes any technology that measures accurately and frequently the distance from a device to a target using a laser. It collects these measurements as a set of coordinates, or a cloud of points, from which it is possible to obtain information about the shape of the object being scanned. Aerial laser scanning, which often goes under the term lidar (LiDAR, *Light Detection and Ranging*), is a remote sensing method that can be used to measure the Earth's surface very accurately. A laser mounted on an airplane or helicopter illuminates the Earth's surface with laser beams, which are reflected to the receiver. Based on the travel time of the laser pulse from the transmitter to the receiver, the distance to the ground is calculated. With the help of the differential global positioning system (GPS) and inertial meters, it calculates the three-dimensional coordinates of the measured point on the Earth's surface. The device on the plane sends up to hundreds of thousands of laser beam pulses per second, which allows one to cover large areas very quickly (Opitz 2012).

Lidar has proven to be an extremely successful method due to its ability to observe ground covered by forest. Large areas that were previously closed to systematic observation now became visible. Forests are places where archaeological traces have been well preserved due to limited human interventions.

Using remote sensing techniques, we discovered and accurately documented a multitude of new traces of human activities in the past, such as sunken paths, cultural terraces, cemeteries, plot boundaries, limestone, mounds, quarries, fields, and the like. All of these traces are not archaeological sites in the classical sense of the word, at least not as understood by the current practice of archaeological heritage protection. Landscape seems to be full of these traces (Mlekuž 2013).

Heritage is produced in centers of calculation

The key areas within which knowledge production occurs are centers of calculations, a concept developed by Bruno Latour in his seminal work *Science in Action* from 1987 (Latour 1987, 215–45). Centers of calculation are the points from which cycles of accumulation are initiated and where the obtained inscriptions are accumulated. Centers of calculation are either individuals, institutions, countries, or even regions that systematically enable, organize, and direct cycles of accumulation. Returning to the example from cartography, the calculation center has an overview of the white spots on the map, decides where to send explorers, and compiles and completes the maps.

Calculation centers combine acquired inscriptions, combine and duplicate information, and create new, more abstract and more universal inscriptions and knowledge from acquired inscriptions. Centers of calculation are thus venues where knowledge is multiplied through cycles of accumulation.

If the main centers of calculation were primarily scientific and research institutions, which coordinated larger cycles of accumulation of archaeological knowledge, such as the project of archaeological topography of Slovenia or the project of archeology on highways, this is now changing with the introduction of preventive archaeology.

The introduction of preventive archeology in the protection of archaeological heritage was a revolution for the discipline itself. Archeology was primarily an academic science decades ago. Now, with the introduction of preventive archeology, preventive archaeology has became a main task of the discipline. Most accumulation cycles in archaeology are organized and implemented by preventative archeology. An overview of archaeological research in the last decade shows that the majority of it takes place within the framework of preventive archaeology, with only a handful of pure exploratory research. Preliminary archaeological research is thus the main source of archaeological information, and most archaeological research is embedded in accumulation cycles of the arc of research, which is primarily driven by spatial planning.

The emergence and development of preventive archeology in Slovenian archaeological heritage protection coincides with the introduction of new geoinformation technologies. Managing large amounts of information and large areas of research requires the use of modern computer tools, particularly geographic information systems (GIS) and databases. Only in this way can a large number of inscriptions obtained in a variety of ways, with various methods, in different periods... be combined, upgraded, maintained, and managed in the long term.

The Center for Preventive Archeology ZVKDS has developed an information system that gathers all information about archaeological traces and interventions in Slovenian territory (FN differs in this from the Register of Cultural Heritage, which only contains information on registered

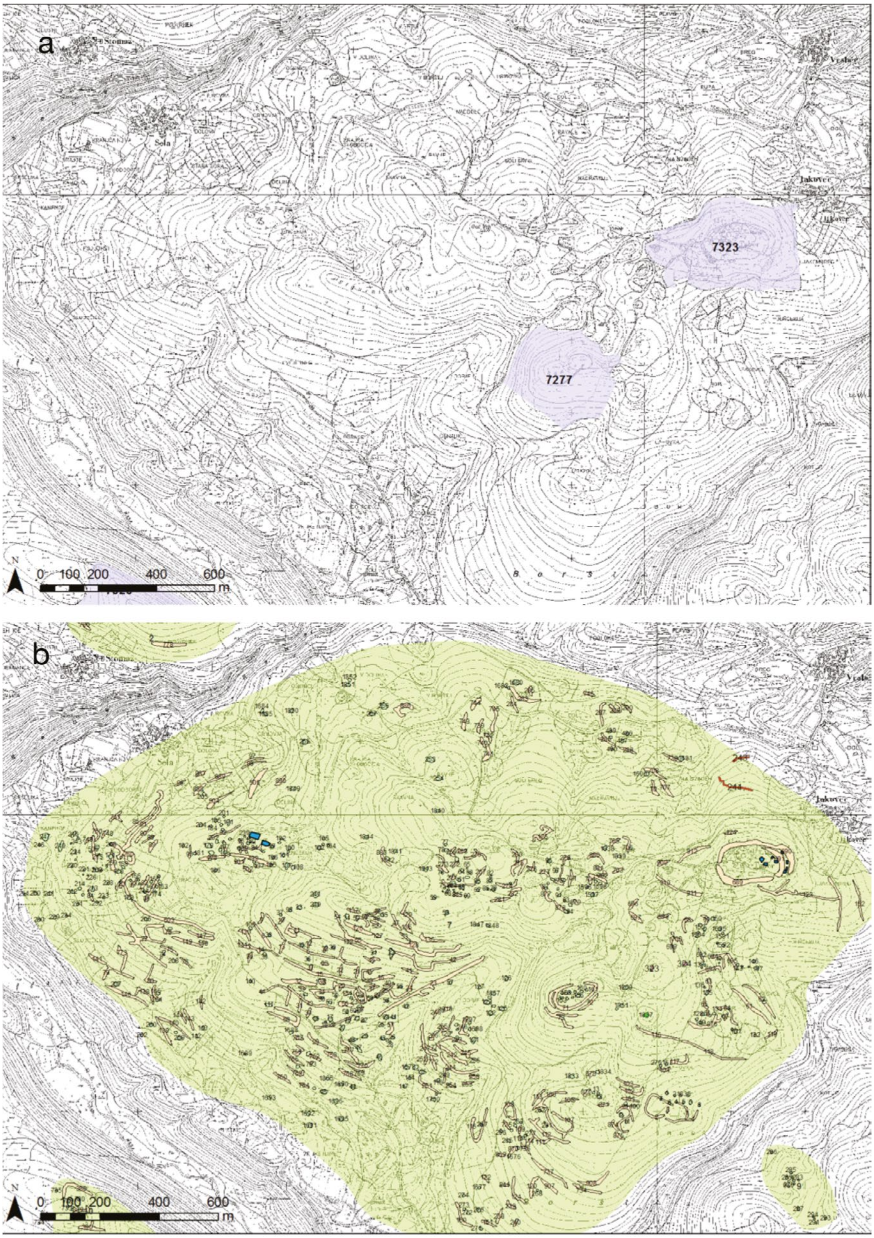

Figure 3. Registered heritage (a) and map of archaeological traces recognized on ALS in the vicinity of Tabor near Vrabče (b).

heritage units, i.e. already constructed heritage). The information system comprises several databases. The first is the catalog of sites, where information gathered through cabinet research of archival sources is collected, and which currently contains around 12,000 located units of known, destroyed, and potential archaeological sites mentioned in various sources. The collection of archaeological sites builds on the project of archaeological topography of Slovenia and was also created by combining other databases (such as Arkas, the collection of the Institute of Archeology ZRC SAZU, and the Register of Immovable Cultural Heritage). The second database contains digitized scale and structure plans of more complex sites (e.g. Emona, Celeia...) and more extensive archaeological traces such as Roman roads or the *Claustra Alpium Iuliarum* system, and is based on published and gray literature. Then, the database of archaeological research documents the extent and type of all archaeological interventions, documented with a report or a written source, and currently comprises around 6,000 entries. In addition to basic information on the type of intervention, time, contractor, and spatial scope of the research, it also contains a link to the digitized report. The record of archaeological research enables the tracking of research and interventions in the territory of Slovenia, the planning of new research, and greater responsiveness in procedures for the protection of cultural heritage.

In the information system, we also collect results of systematic archaeological interpretation of aerial laser scanning data and interpretation of cyclic aerial photography of Slovenia.

The mapping of surface features of ditches, embankments, abandoned paths, former land divisions, various remains of structures, mounds, etc., are all examples of the interpretation of remote sensing images. The mapped traces are classified into several categories and interpreted, becoming standardized entries in the information system.

The heritage information system is based on the combination and re-combination of standardized inscriptions into new knowledge. The archaeological heritage information system provides an overview of the extent, density, and type of archaeological traces and the intensity of research, and also enables visualization of archaeological potential and various types of, even quite complex, inquiries.

The archaeological heritage information system enables the planning of new cycles of accumulation and the management of the archaeological heritage of Slovenia. It has become a key tool for heritage protection, a central tool of the calculation center, and a tool through which we produce new knowledge about archaeological heritage in Slovenia.

The quantity of inscriptions brings a new quality to the archaeological heritage

The Archaeological Heritage Information System is the center of archaeological heritage calculation in the 21st century. The establishment of this center of calculation brought new, unpredictable implications for the understanding of archaeological heritage. Over 80,000 different entries have been amassed in the information system in ten years, while the number of information on archaeological sites has increased by several orders of magnitude. We are currently witnessing a phenomenon where the quantity of archaeological traces, the result of ten years of accumulation cycles at the CPA calculation center, transforms into a new quality, to use Hegel's words. What is this new quality?

Using extensive methods, especially remote sensing techniques, we discover and accurately document a multitude of new traces of human activities from the past, such as sunken paths, cultural terraces, cemeteries, plot boundaries, limestone, mounds, quarries, fields, cemeteries and the like. All these traces are not archaeological sites in the classical sense of the word, at least not as understood by the current practice of archaeological heritage protection. These are traces of activity in the landscape (Mlekuž 2014).

The landscape is no longer an empty space between sites; it is now a space full of archaeological traces. What is more, all of these traces make up the landscape. Archaeological heritage no longer appears as a multitude of isolated scattered points or areas but as a continuum of archaeological traces that cover the area of Slovenia with different densities. It is no longer about individual sites, but about entire landscapes. The multitude of isolated traces became a new quality, which is the landscape.

"Landscape" is now a polyvalent term with many shades of meaning (Mlekuž 2012) (Mlekuž 2011).

In this context, it is best to rely on the definition of landscape as offered by the European Convention on Landscape, which defines it as "an area as perceived by people and the result of the action and interaction of natural and human factors." As a science of long-term change, archeology can contribute in many ways to understanding how people's actions in the past have shaped the present.

Archaeological traces appear in different relationships to the modern landscape. They can be part of the landscape, where the modern landscape organically grew out of them. Later land uses incorporated the older traces, either because of possible continuity of land use or field division or because these traces were so massive and inert. Later uses incorporated

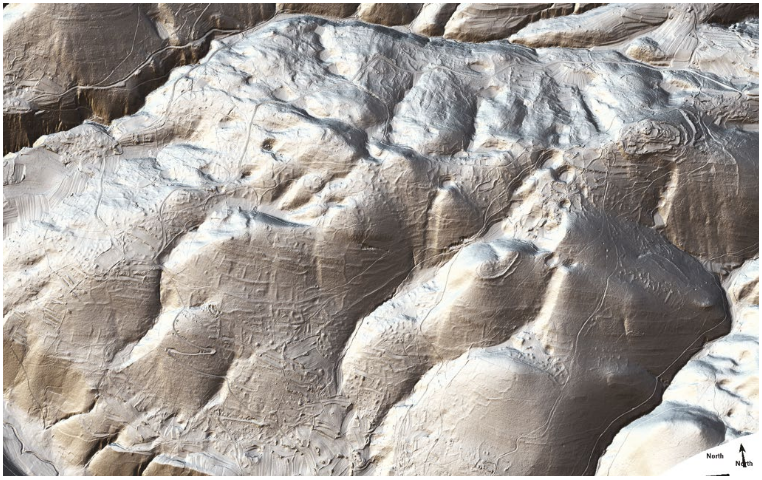

Figure 4. Well-preserved prehistoric fossil landscape around the hill fort Tabor near Vrabče.

these traces, adapting and modifying them. These traces indicate great time depth and the processes of landscape growth and development.

In some places, however, these traces appear in places that were not impacted by later use. The landscape was abandoned and remained in fossil form. Well-preserved patches of fossilized landscapes can be found in marginal areas, such as Karst, or forests that were not destroyed, covered, or processed by subsequent land use (Mlekuž 2015).

Individual protection of all of these traces is unproductive in the great majority of cases. Not only because there are simply far too many of these traces, and protecting them would entail protecting vast numbers of monuments; the main reason is that by protecting them individually, we exclude them from the context of the landscape, freezing and closing them. With individual protection, we also reduce their visibility, as they are less important in and of themselves than the components of the whole, the landscape.

Changes, interventions, and transformations are an integral part of landscapes. Cultural landscapes are cultural precisely because of the long history of changes, interventions, and transformations that took place in them. The landscape bears witness to past changes, it is materialized change and it is changes in the making.

Landscapes are also places where people and other creatures live, work, and visit, where many interests intertwine and collide. Landscapes are shaped not only by those who protect them but also by those who want to change them. The protection of archaeological heritage must, therefore, be included in the democratic process. The main instrument of protection cannot be simply restriction but rather positive spatial planning (Mlekuž 2014, 2017).

Knowledge is a prerequisite for adequate, integrated heritage protection. Without knowing and comprehending traces, their origin, and the ways in which they have transformed and become tied to older traces and features, any protection is futile. However, even this is insufficient if we want to demonstrate the heritage meanings and values of the landscape that we want to preserve.

Heritage is defined by its meaning

Archaeological heritage is not just a collection of recognized archaeological traces or a simple archaeological record created during research. The meaning we attribute to it, its value, is what makes archaeological heritage what it is (Pirkovič 1987).

Values or meaning can only be determined in the context of the wider society, its needs, issues, dilemmas, and opportunities. Evaluation thus also requires sensitivity to society's problems and an understanding of the social role of the discipline (Smith 2006).

The production of heritage is therefore primarily the production of meanings and values; it is the process of evaluating archaeological traces. Of course, archaeological heritage always has inherent scientific value as well, the value of using it to understand the past and answer scientific questions, but is that enough?

The social role of archeology is changing; archeology is no longer just a science that deals with the academic study of the past, but a discipline that actively participates in the democratic process of making decisions about archaeological heritage, as well as interventions in space and the development of the country. The main products of the discipline are no longer monographic publications of individual problem areas, but reports, documents that enable decision-makers to bring decisions about interventions in space.

The role of heritage organization is not only in recognition and protection but above all in recognizing the value of heritage in the process of landscape development. Heritage cannot be protected by prohibitions alone. Heritage can be protected primarily through arguments as to why its individual aspects are important enough to be preserved and to direct spatial development in such a way that they remain in the space.

What can be the values and meanings of archaeological heritage (in addition to the pure scientific value)?

Archaeologists can point to the great temporal depth of the landscape, to the multitude of traces that are forgotten, overlooked, and ignored but make up the landscape and contribute to its identity. To the fact that some landscapes developed shape and basic features deep in the past.

On the other hand, we can point to the long duration, temporality, and slow rhythms that transformed and defined the landscape and continue to define it today. Archaeologists can point to continuities and changes that took place in the past, they can identify areas of steady settlement and much more dynamic areas where settlement changes, breaks, and ceases.

The third aspect we can point to is difference. Archaeology, as a science of others, can point to completely different uses of space, to the presence of anthropological others who lived – perhaps in a radically different way – on the same part of the Earth's surface as us. Archeology can point to the possibility of a different development of landscape and history, to the contingency of historical development and the present, and the possibility of radically different forms of life.

This, of course, requires different approaches to the protection of archaeological heritage. The key is the transition from the protection of isolated sites to the protection of the landscape as a whole. Approaches such as historical landscape characterization or landscape biographies (Fairclough 2006) are used here.

These approaches are based on the idea that the modern cultural landscape represents thousands of years of human action and confrontation with the natural environment, and includes not only archaeological sites but also systems of field distribution, communications, resources, patterns, and use of space... Landscape is a comprehensive and complex spatial system, in which natural and cultural components are intertwined. It is the result of the interaction between natural processes and historical development. Landscapes are thus one of the most important records of human activity in the past and at the same time a living space where the interests, intentions, will, and strength of many participants collided. In the landscape, people write down their identity and life story, while places and landscapes play an active role in their biographies at various time scales.

Conservation must be able to recognize and argue for the value hidden in the landscape. We must also recognize that we cannot preserve all heritage. We need to determine which are important enough to be worth arguing for and which are not. Thus, conservators are mainly in the role of development directors and cultural mediators, representatives of heritage in the process of making decisions about the development of the landscape. In the long term, the most sustainable and productive way to protect landscapes is education and familiarizing people with their depth and complexity. Here, of course, we must cooperate with other disciplines, such as landscape architecture, architecture, ethnology, etc. Archaeologists can recognize the depth of time in the landscape, point to hidden and overlooked aspects, and offer alternative stories about its development, based on concrete scientific evidence and research, which separates archeology from other, increasingly aggressive voices and initiatives that want to give heritage its own meaning.

If the heritage is constructed well enough, it can protect itself

Returning to the initial assumption, archaeological heritage does not exist in and by itself but is constructed through research and evaluation. The definition of archaeological heritage is also constantly changing. Heritage is no longer a collection of isolated monuments but rather part of the landscape. As such, archaeological heritage is often the scene of several conflicting interests. If we want to preserve heritage, our task is to recognize and argue for its value and meaning. Only in this way will we be able to represent it in the democratic decision-making process on landscape development. Our task is to construct heritage as firmly as possible. Because when people recognize something as their heritage, as valuable and meaningful remnants of the past, heritage will have enough allies to defend it against opposing interests. When heritage is sufficiently well constructed, solidly composed, and actualized, it will be able to defend itself (within a functioning system of norms that makes it possible) (Solli 2011). This is the challenge that awaits us in the 21st century.

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THE USE AND IMPORTANCE OF GEOARCHAEOLOGY IN ARCHAEOLOGICAL PROSPECTION, MANAGEMENT, AND CURATION WITH CASE STUDIES FROM THE BALKANS

Charles French
Tonko Rajkovača

The importance of geoarchaeology as a sub-discipline within archaeology

Geoarchaeology is the combined study of archaeological, soil, and geomorphological records and the recognition of how natural, climatic, and human-induced processes alter landscapes (French 2003, 3). The main aim of geoarchaeology is to construct integrated models of human-environmental systems and to interrogate the nature, sequence, and causes of human versus natural impacts on our landscapes. It is equally important at the macro-scale of land-use and landscape change as at the meso– and micro-scale for the use of space and human activities in a settlement context. At any scale, it is possible to investigate the formation and modification of past soils, sediments, and occupation sequences, primarily through the use of soil micromorphological techniques (or the study of the components, features, and fabrics of soils and sediments at the microscopic level in thin section) combined with various physical and geo-chemical techniques (e.g. Blume 2008; Courty et al. 1989; Fleisher and Sulas 2015; French 2015, 2022; Goldberg and Macphail 2006; Kubiena 1938; Macphail and Goldberg 2018; Rapp and Hill 1998; Waters 1992; Wilson et al. 2008). Kubiena (1938) viewed 'micropedology' (or micromorphology) as part of general pedology examining the genesis, morphology, dynamics, and biology of soils. Blume (2008) widened the remit of micromorphology to be a tool that is able to integrate all soil disciplines. Of course, this field of study only benefits from corroborative and complementary sets of other palaeo-environmental data, especially chronological, stratigraphical, palynological, macro-botanical, faunal, and molluscan data. It could be said that geoarchaeology is an over-arching discipline capable of integrating all these types of complementary data to create long-term histories of human landscape development. Without utilising geoarchaeology and its approaches, attaining a better understanding of human contexts of living is generally inadequate.

The contribution of geoarchaeology is integral to archaeology. Indeed, the understanding of stratigraphy in the field, site formation processes, and landscape reconstruction are the most fundamental tenets of geoarchaeology (cf. Butzer 1982; Rapp and Hill 1998; Waters 1992). Having a thorough understanding of the context of a site in its landscape is central to any interpretation of landscape change and the associated human dimensions and influences. The nature of the potential information can contribute at a whole variety of scales, contexts, and levels to the detailed interpretation of archaeological sites and past and present-day landscapes. Increasingly over the past couple of decades, geoarchaeological methods have become a mainstream part of most archaeological projects, although the application of soil micromorphology is not always possible because of time, funding, and too few practitioners and laboratories to meet the demand.

In studying past landscapes, what are geoarchaeological studies trying to achieve? First, it is essential to understand the interaction of topography, climate, soil development, rainfall, run-off rates, and erosion, vegetational change, and human activities, and their combined roles in shaping the landscape system that is observed today (Butzer 1982; De Smedt et al. 2013, 2022; Gerrard 1992; Macphail and Goldberg 2018). Second, one is aiming to develop chrono-sequences and palaeo-catenas that can be used to estimate the age of surficial deposits and relate these to human settlement and living activities in that region, and discern the sequence of how that landscape has developed and been utilised through time (French 2003; Goldberg and Berna 2010; Karkanas and Goldberg 2019; Macphail et al. 2016). It is essential to know how long it has taken to form key properties and deposits in different environments, and/or when major changes/transformations occurred, whether cultural and/or environmental. Third, soils and vegetation types can be used as indicators of long and/or short-term stability or instability, and consequently may be used to show how they have shaped and/or reflect cultural development and change through time. Fourth, is it possible to determine the evidence for and indicators of climatic and/or human impact on land-use change, and discern how these may have influenced landscape development and human activity narratives and biographies? Finally, from these datasets and interpretations, is it possible to understand environmental-human interactions, and give answers as to why any observed change(s) may have occurred?

Geoarchaeological approaches are also an essential component of the microstratigraphic analysis of former settlement sites, whether it is an open air, single occupation structure, or multiple aggradations of many structures and depositionary events in a tell mound. When combined with structural and archaeological analyses, micromorphological and geo-chemical studies can often give specific answers about the sequences of use in the life of structures and open areas on a site, as well as chart the nature and effects of post-depositional processes (Courty et al. 1989; Karkanas and Goldberg 2019; Matthews 1997; Milek 2012a & b; Milek and French 2007; Shillito and Ryan 2013). Geoarchaeological studies of floors, occupation deposits, and construction materials for example, both complement and augment the interpretation of the archaeological record, especially when considered spatially against the available artefact distributions, as well as macro-botanical and faunal remains evidence.

Ethnographic, present-day, and experimental analogues are also very important tools for providing possibilities for the interpretation of geo-chemical results and micromorphological analyses. This might simply be the verification of the microscopic features created by ard ploughing (Lewis 2012) versus spade or hoe (Gebhardt 1992) versus modern ploughing (Jongerius 1983), the recognition of shifting agricultural systems in Maasai herder-gatherer settlements in East Africa (Shahack-Gross et al. 2004), the identification of livestock dung (Shahack-Gross 2011) and construction materials (Gur-Arieh et al. 2018), what is wood ash versus burnt dung (Shahack-Gross 2011; Wattez and Courty 1987) and the type of combustion feature (Mallol et al. 2017), or whether it is calcitic or gypsum-rich plaster (Karkanas 2007), for example. Or the ethnographic analogues could provide possible suggestions as to how social actions and beliefs may have helped to control the formation of the sediment complex as observed and analysed (Boivin 2000; Friesem et al. 2016, 2017; Shahack-Gross et al. 2009).

As multiple sets of descriptive data are regularly obtained from these types of archaeological landscape and palaeo-environmental projects, one of the best ways to manipulate, interrogate, and present these datasets is through GIS (Geographic Information System) modelling applications (Lock and Stancic 1995; Connolly and Lake 2006). These may present possible scenarios of human impact and landscape change, or assess the extent and/or risk of erosion taking place, or attempt to portray the underlying motivations for ecological and socio-economic changes observed in a landscape (Ayala and French 2005; Barton et al. 2010, 2012; Kirkby et al. 1996; Samarasundera 2007; Thornes and Gilman 1983). These objectives are rarely as easy to attain and usually necessitate selecting a few data-rich variables and interrogating these data in multiple combinations. In practice, the different models produced usually give the archaeologist some possible interpretative scenarios with which to either visualise and/or hypothesis test the available data.

In combination with different scales of analysis, targeted questions, and complementary palaeo-environmental techniques, geoarchaeological approaches are one of the best ways of explaining and understanding the development of a site and its landscape through time. Significantly, the study of soil changes within these settings gives us the evidence with which to discern the changing dynamic relationships between human endeavours and their lived-in environments over the *longue durée*. The essence of the geoarchaeological approach is to move away from investigating sites in isolation to viewing them as integral to their contemporary soils and surrounding landscape. This system is dynamic with a number of relationships, often interdependent, between people, climate, and their environment. The concept of 'task-scape' is central to envisaging the enmeshed relationships between people, their activities, soils, and environmental context (Ingold 1993). A geoarchaeological approach is thus central to our ability to decipher and describe possible human-altered and managed landscapes.

The role of geoarchaeology in informing land management strategies should also be considered, and especially aspects of the time depth and lessons already learnt. As Sander van der Leeuw (2018) suggests, geoarchaeology can play a distinctive role in collecting data on the physico-chemical and living environment, which, when coupled with the archaeological record of past societies, can reveal socio-environmental dynamics and explain how shorter-term landscape dynamics may be changing over the longer term. We can also link the past and present, and learn from both for the future, and thus help to extend the value of geoarchaeology as a discipline for all to appreciate.

The geoarchaeological approach to investigating archaeological sites in their landscape is illustrated by brief descriptions of the geoarchaeological fieldwork that took place as part of the *HERISTEM* Erasmus+ project at the Neolithic settlement site of Tomašanci Dubrava near modern Đakovo in south-eastern Croatia, and the site landscape survey that was conducted at Zecovi near Prijedor in the Sana valley of Bosnia and Herzegovina under the *BIHERIT* Tempus programme.

Field case study at Tomašanci Dubrava

Geoarchaeological survey fieldwork was carried out in May 2022 at the Neolithic site of Tomašanci Dubrava near modern Đakovo in south-eastern Croatia by students and staff members from the Universities of Belgrade, Ljubljana, and Zagreb, instructed by three geoarchaeological teams from the Universities of Cambridge and Pula/Pisa, and Arhej (Ljubljana). This was the main Cambridge contribution to the *HERISTEM* project, with Prof. Charles French, Dr. Petros Chatzimpaloglou, and Gian Battista Marras as instructors for this field course.

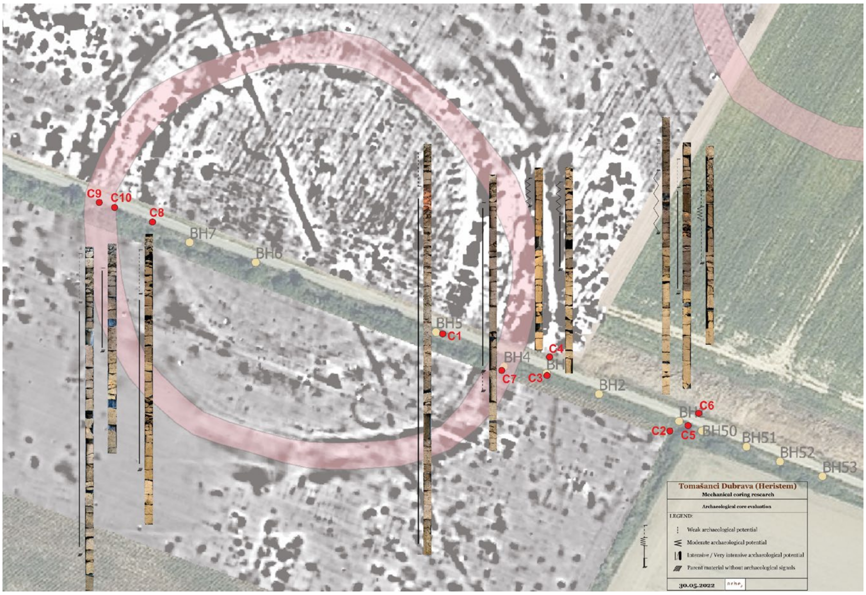

Figure 1. The magnetometry survey plan of Tomašanci Dubrava with superimposed borehole records providing a stratigraphic transect across the site (L. Gruškovnjak and R. Klindzić)

The Neolithic site of Tomašanci Duborava is one of several large circular ditched enclosure settlement sites in the area around Đakovo recently discovered by Dr Rajna Šošić Klindžić and her team from Zagreb. Aerial and geophysical prospection has suggested that these may have one or more substantial circular ditches or enclosure areas with abundant traces of possible structures and pits within (Fig. 1). At Tomašanci, the outer ditch is c. 300 m in diameter, about 10 m across and up to c. 2 m in depth.

The geoarchaeological survey investigation aimed to:

- instruct the staff and students in the use of hand and power augering, as well as soil/sediment description recording and appropriate sampling of the stratigraphy revealed (Figs. 2–3);
- determine the spatial extent and thicknesses of former occupation material present;

Figure 2. Staff and student augering teams at work creating a borehole transect across the Neolithic site of Tomašanci Dubrava (C. French)

Figure 3a. Geoarchaeological field course teaching at Tomašanci Dubrava: Matjaž Novšak explaining a core through the site and its burial sediments (above).

Figure 3b Dr Katerina Gerometta giving an introduction to soil micromorphology (below) (C. French).

- determine whether the site preserved buried soil and evidence of a former landscape, and if so, what that environment may have been like;
- determine the nature of the weathered geological substrate on which the site was constructed;
- determine the nature of the post-Neolithic landscape and the extent of the erosion complex overlying the site.

The borehole survey made a long east-west transect across the middle of the Tomašanci Dubrava Neolithic site (Figs. 1–2). It revealed depths of burial of the archaeological material from about 50 cm to c. 3.5 m as well as several phases of 6000–5000-year-old *in situ* Neolithic occupation. The site appears to have been situated on a former alluvial floodplain developed in a loessic marsh area on Pleistocene continental loess, but which was still prone to seasonal flooding from time to time during and after the occupation period. Later the site was affected by the accumulation of loessic silt soil material and probably hillwash, burying the site with up to another one m of eroded soil. By participating in this field course (Fig. 3), archaeological students and staff alike with no experience of geoarchaeology were exposed to the basics of geoarchaeological techniques for investigating archaeological landscapes and how these may have been modified in the past by human activities.

Field case study at Zecovi

This case study involved both geoarchaeological and archaeological evaluation of the hill-top site of Zecovi in the Sana River valley near Pri-

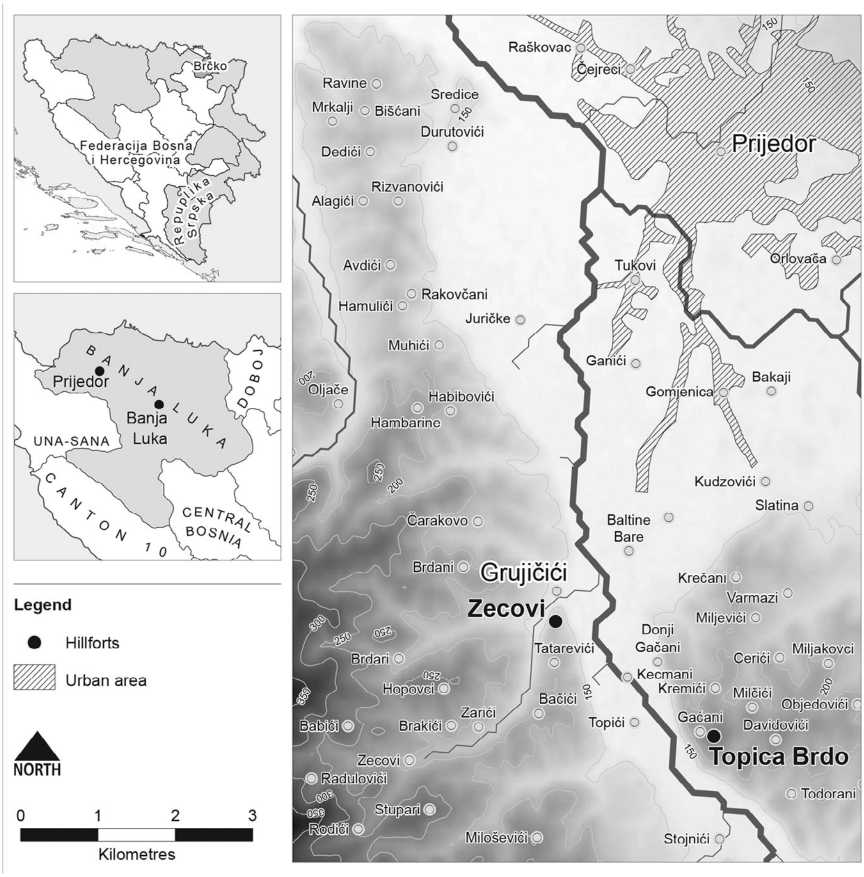

Figure 4a. Location map of Zecovi near Prijedor, Bosnia and Herzegovina (above) (D. Redhouse)

jedor (French et al. 2015). Extensive field survey, augering, test excavation and subsequent analyses were conducted as part of the *BIHERIT* project programme in 2014.

The site of Zecovi is known as an Hallstatt fortified site that was initially excavated and reported on by Benac in the 1950s (Benac 1956) (Fig. 4). The previously excavated area of this site was located on the sloping but more or less flat hill-

Figure 4b The view of Zecovi hill from the floodplain to the northeast (below) (C. French).

Figure 5a. Topographical survey of the hilltop and 'shoulder' area and adjacent Sana floodplain at Zecovi showing the fieldwalked area (D. Redhouse).

top oriented north-south at an elevation of *c.* 200m above sea level which forms a natural elongated tump of land in a prominent position overlooking the Sana valley. Benac (1956) identified Roman buildings with pottery of the mid-4th century AD located above a 1st millennium BC Iron Age oppidum with a *c.* 2.7m maximum thickness of archaeological deposits present. His hill-top excavations also found extensive prehistoric pottery, including diagnostic sherds of the Bronze Age and Neolithic periods.

The project reported on here was an evaluation of the whole hill-top area of Zecovi and its immediate valley surroundings (Figs. 5–6). Specifically, this project aimed to investigate the nature and extent of prehistoric settlement on the hill-top and any evidence of landscape change. The investigations involved an intensive programme of field-walking, test pitting and augering which was supervised by a small team of professional and

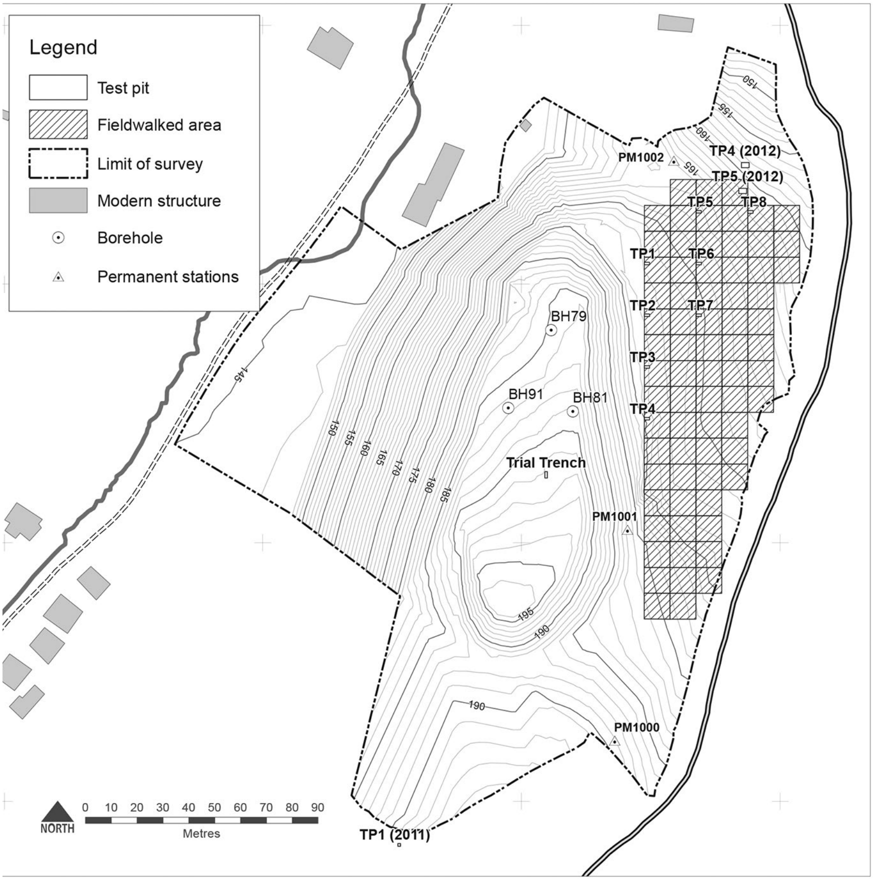

Figure 5b. Test pit and borehole locations (D. Redhouse).

doctoral student archaeologists from the University of Cambridge, with colleagues and students from the Universities of Banja Luka and Sarajevo taking part, as well as assistance from local organisations and museums. The project was kindly hosted and assisted by the staff of the Kozara Museum in Prijedor.

The project had three main aims:

- to define the extent, nature and chronology of the archaeology at the site;
- to set the site in its wider landscape context;
- to use the site and project as a 'field school' to instruct Bosnian students in current field approaches for conducting archaeological site evaluations in northern Europe and the UK. This included

Figure 6a. Two section profiles of the 'shoulder' area of Chalcolithic settlement at Zecovi: with the buried soil, post-hole, and an occupation surface (C. French).

Figure 6b. Hillwash over midden debris and a hillwash thickened buried soil (C. French).

the use of geophysical, auger and topographical surveys, as well as context-based archaeological recording using the *Manual for Archaeological Excavation* (Rajkovača 2010) as a guide.

Archaeologically the key questions were:

- what was the date range of human use of the hill-top and 'shoulder' areas of the site?;
- how did the use of the 'shoulder 'area relate to the hill-top oppidum?;
- what was the nature and extent of prehistoric and Roman activity of the 'shoulder' area?
- what were the changing landscape contexts throughout prehistoric and historic times?

In order to answer these questions the work formed five separate stages, each designed to contribute information to the wider picture:

- intensive surface fieldwalking of the Zecovi hill-top and southwestern slope for artefact recovery;
- intensive hand auger survey to determine the deposit sequences present both on– and off– the hill-top, including a machine rig borehole transect across the adjacent floodplain to the modern Sana River;
- comprehensive topographical and magnetometry surveys of the hill-top and 'shoulder' areas;
- small scale test excavations, including the re-location of Benac's trench area on the hill-top, with test excavation and sampling of that deposit sequence;
- targeted judgemental soil/sediment sampling of the stratigraphic and occupation horizons observed in the test excavations for mi-

cromorphological, magnetic susceptibility and multi-element (including phosphorus/phosphate) analyses, with judgemental selection of charcoal samples for radiocarbon assay from the hill-top and 'shoulder' area test pits.

The evaluation of the Zecovi hill-top and its immediate surroundings added significant knowledge and understanding of how the site may have been used in the past. What is clear is that it is not just the site of a 1st millennium BC oppidum and Roman settlement as Benac discovered in the 1950s, but it had been an extensively used settlement area for at least the previous 2000 years. There is the distinct presence of an earlier settlement of later Neolithic and Bronze Age date, with hints of earlier Neolithic material present in the pottery record, both on the hill-top itself as well as the 'shoulder' area on the northeastern side of Zecovi hill. In terms of new radiocarbon dates, the base of the deposits on the hill-top area are certainly of mid-3rd millennium BC or later Eneolithic date (2680–2548 cal BC; GU38006), with settlement on both the hill-top and 'shoulder' area continuing into the later 1st millennium BC (519–384 cal BC; GU38007). In the latter 'shoulder' area, there is a localised area of about 50 square metres of prehistoric occupation deposits preserved beneath a combination of hillwash deposits and later prehistoric (mainly Bronze and Iron Age) midden material. This was a thick, calcareous and much humified, phosphatic-rich deposit composed mainly of abundant, partly charred and partly humified organic remains. In places this is combined with eroded soil and/or buried by *c.* 50–75cm of sandy clay loam hillwash material. Much of this midden is perhaps indicative of plant processing waste, which in places had buried former surfaces which appear to have been formed gravel and sand/silt with quantities of included calcitic wood ash and degraded waste bone. These surfaces are probably earlier Iron Age (6th-4th centuries BC) in date based on the pottery and one radiocarbon date of 519–384 cal BC (GU38007), and appear to represent *in situ* settlement floor/yard surfaces and structures.

In addition, an apparently contemporary later Eneolithic settlement site has been discovered and evaluated at nearby Topica Brdo on the other side of the Sana River valley some 2 km distant to the southeast (Fig. 4a). There, thick midden deposits over *in situ* hearths and clay floors were revealed with a near contemporary mid-3rd millennium BC radiocarbon date of 3968+/-27 BP or 2573–2453 cal BC (at 95.4% combined probability; GU38005).

The evidence from the buried soils and the augering survey of the adjacent floodplain indicates that the Zecovi landscape has been highly modified during the mid-later Holocene period. Initially, weakly acidic, humic, and argillic (or clay-enriched), brown earth soils developed on the hilltops, probably under woodland, as in many other places in Europe and Britain at this time (Bridges 1978). These had already become disrupted by the time of the Eneolithic occupation from the mid-3rd millennium BC, presumably by clearance and associated agriculture. These soils soon became eroded and truncated as a result of human use and activities. In later prehistoric times, most probably in association with the 1st millennium BC occupation of the hilltop and shoulder areas, both soil/organic midden accumulation and soil erosion increased and led to substantial accumulations of either anthropogenic debris and/or hillwash on the eastern flanks of the hill. At the same time, the adjacent floodplain was presumably subject to the aggradation of these eroded soils as overbank alluvial deposits, a process which probably continued throughout historic times. In addition, the deposition of alluvium from human intervention in the Sana catchment probably also led to the burial of an earlier palaeochannel of the Sana River located at the foot of the Zecovi hillslope. More recently, but at a time yet to be discerned, the modern river has become incised into this wide, silty clay-filled alluvial floodplain.

Wider importance

Geoarchaeology is very good at bringing together many strands of evidence to give both specific and extensive ideas about the nature of a site and its environs, and how it has changed through human and natural causes through time. Hand augering survey is a particularly quick and useful method of prospection and assessing the context and burial conditions of any site and its landscape. It can inform where it may be best to excavate and sample to inform the archaeological and palaeo-environmental interpretations of the site and help recognise the sequences of human activities and environmental impacts in that landscape.

In terms of the future stewardship and preservation of these significant archaeological sites, Tomašanci Duborava is relatively deeply buried and below the influence of the modern plough agricultural disturbance, as is the hilltop site of Zecovi. This means that they are largely free of modern physical disturbance and should remain so as long as they are not built on. Both sites have curatorial integrity which can be managed over the longer term for the benefit of the locale and nation. Nonetheless, the soils and deposits associated with the Neolithic settlements in both cases are largely oxidised, and therefore prone to the ingress of oxygen and insect and soil faunal attack, particularly of the organic components of the site from its past. Obviously, the lithics, pottery, and mud– and fired-brick and faunal remains materials of the Neolithic and later periods will survive, but unless charred, the plant and food remains grown and exploited will be much harder to find intact and say anything meaningful about. This then poses a choice – excavate a large sample of these sites in the not-too-distant future, essentially as soon as possible, to retrieve as much information as possible now, or face the greater information return of these prehistoric settlement sites diminishing further over time.

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GEOARCHAEOLOGICAL SAMPLING AND LABORATORY PROCEDURAL WORK IN A BALKANS SETTING

Tonko Rajkovača

Soils and archaeology

Soil science approaches to archaeological sites involve accurately identifying and describing the stratigraphic sequence on– and off-site, identifying and sampling old land surfaces and/or buried soils, as well as possible occupation surfaces and floors (French 2015). The aim is also to discern past land-use where possible, in combination with other approaches, such as faunal, macro-botanical, and palynological analyses.

If the site or landscape that one is working in has a buried soil surviving under either later drift deposits (such as peat or flood silts and clays) and/or upstanding monuments (like banks and barrows), this represents an advantage, and extensive sampling should be undertaken. On the other hand, if there is no sign of an old land surface or buried soil and the site is within modern plough depth, then this is a serious disadvantage and much less can be done from a geoarchaeological standpoint.

For a best case scenario of what to do if a buried soil survives, here are some sampling techniques that can be used:

- Systematic gridded sampling for phosphate and multi-element geochemical analyses (e.g. to test for manuring, middening, ash) and magnetic susceptibility (e.g. to test for burning, hearths, compacted surfaces), at 1/2/5/10/20 metre intervals as appropriate (i.e. closer interval for a possible living surface; wider interval for a field system).
- Excavation of one-metre square test pits into the buried soil profile at regular intervals (e.g. five, 10, or 20 metres) for artefact retrieval, bulk sampling for macro-botanical analysis, stratigraphic recording, and soil/sediment sampling.
- Soil/sediment sampling from either these test pits, and/or sections in the buried soil, and/or upstanding monuments or cut

features should include taking a continuous set of block samples for micromorphological analysis (see below) and associated small bulk samples (of two handfuls of soil), taken either from each horizon or every 10 centimetres (whichever is most reflective of the stratigraphy) for physical analyses (pH, organic content, magnetic susceptibility) and geochemical analyses (phosphates and multi-element). These physical and geochemical analyses will provide information about preservation conditions and inputs on various human activities such as manuring, middening, night soiling, land-use, and metalwork production.

Sampling for soil micromorphological analysis

One of the best ways of retrieving information relevant to the archaeological story of any site or landscape is soil micromorphology (Courty et al. 1989). It is the analysis of soils/sediments in the thin section with a polarizing microscope. This method is particularly useful when applied to buried soils or palaeosols, where it can be used to investigate and discern sequences of past land-use and landscape change, and to floors and occupation surfaces associated with possible structures where the technique can be used to elucidate construction materials and techniques, trampling/compaction, micro-settlement refuse, and use-in-life of the floor/room/structure (French 2015, 2022).

Sampling for a micromorphological analysis requires taking intact soil/sediment blocks, transporting them to a laboratory undamaged, and then using a slow processing technique over a period of four to eight weeks. This briefly entails impregnating the block with a clear casting resin under vacuum, curing it for one month, cutting a thin slice off the impregnated block, polishing the slice and mounting it on a polished glass microscope slide, then grinding it to a thickness of 25–30 microns (μm) and covering the slide with a glass coverslip (French and Rajkovača 2015, app. 3).

The materials necessary to take micromorphological samples include:

1) A role of cling film and/or paper towel.
2) Parcel tape.
3) Trowel and/or strong knife.
4) Containers to hold sample blocks. This can include aluminium Kubiena tins; c. 5–8 centimetres square sectioned plastic downpipe cut into c. 10–14 centimetres lengths with one long side cut off; and clean empty cardboard juice cartons or tin-foil take-away/frozen food containers.

The sampling procedure in the field is as follows:

1) Clean a section to clearly identify major horizons and/or horizon boundaries.
2) Describe, draw, and photograph sections.
3) Sample either as a series of continuous sets of blocks or as discrete blocks, each block about 10–14 centimetres long and 5–6 centimetres thick, or smaller as appropriate.
4) If possible, sample across main layer/horizon/context boundaries.
5) With a knife or trowel, cut vertical slots along the sides of the prospective soil block in order to fit the container from the section face; start out wide and work your way in; place a container over the prospective sample block; cut out a block from behind the section face; trim the sample block as necessary after removing it from the section and remembering which way is up; if the profile is particularly sandy, rubbly, or unconsolidated, several attempts may be needed to cut out an intact block – for these, more 'weathered/crusted' sections are preferable; blocks can also be carved out freehand.
6) Wrap the sample block in a cling film/paper towel and then in parcel tape.
7) Label it with an indelible marker pen, marking the site sample/context numbers, and, most importantly, indicate which way is up using an arrow.
8) Pack the block for transport to the lab in a suitable receptacle, i.e. wooden/cardboard box, or suitcase, using newspapers/sponges/old clothes for cushioning or any other suitable material. It is worth noting that it does not matter whether the samples dry out or not; what is important is that they are kept as undisturbed as possible, that one always know which way is up, and that the samples are well-labelled.
9) If possible, take at least one small (two handfuls) loose soil sample to accompany each soil block for physical/chemical analyses.

Borehole survey – augering

The Borehole survey technique is increasingly gaining importance in preventive archaeology (Figs. 1–3). It can be used on a variety of terrains, regardless of the vegetation and weather conditions, and, notably, it can be used in urban settings. It may be chosen as the survey method if a reasonable case can be made that expected finds (or, in exceptional cas-

Figure 1. Using a Dutch hand auger on Mainland, Orkney, surveying midden deposits at a Neolithic settlement (photo: I. Ostericher)

Figure 2. Using a machine corer for sampling a palaeochannel of the River Sana near Prijedor, Bosnia and Herzegovina (photo: I. Ostericher)

es, contexts) or other indicators will be present and discernible in the borehole at known depths. A Borehole survey may entail working with various boring grids, boring diameters, depths, or observation methods (naked eye, sieving). Borehole surveys can therefore be used not only for mapping and prospecting for archaeological find-spots and sites, but also for landscape surveys to define deposit models and refine the archaeological predictive model.

Augering involves the use of drill-like tools such as various sizes of Dutch augers to take small samples or columns of sub-surface deposits, which are also known as 'cores' or 'boreholes'. The advantage of hand augering is that it is fairly quick and easy to carry out, in comparison to more extensive excavation. It can be used to test the depth of deposits, or to retrieve material for further analysis.

One auger hole may answer specific questions, such as 'how deep is this ditch, and what type of deposit is at the bottom?', but when carried out over an area at regular intervals, an auger survey may give a very useful preview of the types and depths of deposits that may be encountered in subsequent information. These observations can be used to create a 3D computer model of sub-surface layers or the underlying topography, buried soils and alluvial/colluvial sequences. The disadvantage of augering is that it may provide little contextual information about the samples retrieved: for example, an auger may penetrate a grave-cut or the floor deposit of a prehistoric round-house, but a slight smear of different-coloured soil may be all that would be visible in the auger sample.

More elaborate and deeper-probing augers (often used in connection with engineering rather than archaeology) use a cylindrical metal casing which is driven into the ground before the core is removed. These may be either diesel engine percussion or pneumatic pressure driven coring rigs, and in larger cases mechanical 'boring rigs' to drive sleaved cores into the ground. However, these can be of use to archaeologists – the results of engineering surveys (which give soil transect profiles across an area such as a site designated for construction or quarrying) can tell the archaeologist where archaeological deposits are likely to exist within a deposit model of the site in its landscape context (Carey et al. 2018).

Figure 3. Core drilling at Butmir, Sarajevo in 2016. Core-drilling was part of a large (300-hectar) project of assessing the archaeological potential, together with surface surveying, machine trenching, and test trenching (by hand), which took place in the autumn of 2016. This was the first large-scale systematic preventive assessment of archaeological potential in Bosnia and Herzegovina of its kind. The assessment was undertaken by the Institute of Archaeology (University of Sarajevo), Arhej d.o.o (Sevnica, Slovenia) and the Department of Archaeology, University of Ljubljana (Slovenia) (Kaljanac et al. 2016) (photo: T. Rajkovača)

In late 2016, the first large-scale archaeological assessment project was undertaken in Butmir, Sarajevo (Fig. 3). A 300-hectar area is protected as an archaeological monument there (the Neolithic site of Butmir). The local municipality (Ilidža) planned this area for a large housing development. To meet the requirements for assessment, an archaeological consortium consisting of three partners was formed (Institute of Archaeology, University of Sarajevo, Arhej d.o.o., Sevnica, Department of Archaeology, University of Ljubljana). Because deep alluvial deposits were known to exist there, core drilling was one of the main techniques used. This assessment was the first of its kind in Bosnia and Herzegovina to be coordinated by a local team. The Slovene partners acted as expert consultants and supervisors of trial trenching and core-drilling. The project established a standard of good practice and had an important role in training local archaeologists.

Soil science is a complex discipline that greatly contributes to many other fields, including agriculture, engineering, geology, and geography. As such, there are many ways to describe, analyse, and interpret soil. It is recommended that, during archaeological excavations, soil description and recording are assigned to one or several trained individuals for the sake of site-wide consistency. However, all practitioners of archaeology (especially excavators) should be familiar with the principles of soil processes.

Soils are of great importance to archaeology in two ways (French 2003). First and foremost, soils are important because of their effects on the archaeological materials that they contain. Different soil types have different chemical and physical properties, such as pH, texture, wetness, and iron content, to name a few, which will differently affect preservation of archaeological materials. Some soils will readily preserve organic material (i.e. acidic and/or waterlogged), whereas others will completely remove nearly all traces of it (i.e. alkaline, unless charred). In such cases, artefact patterning is not human-caused but rather a factor of the soil's preservation potential, and something which only a detailed understanding of the soil matrix can confirm.

Secondly, soils themselves can be a valuable part of the archaeological record. Buried soils are often evidence of a past stable land surface, because soils need a relatively stable land surface on which to form. In addition to simply giving evidence of a surface, buried soils provide important environmental and land use information and sequence to complement other forms of environmental archaeology. As soils are products of climate and organisms, among other things (see above), they can be used to make inferences about the conditions (e.g. humid or arid; forest or grassland) under which they formed, and by extension, the conditions under which the associated archaeological materials were deposited. The term 'soil' is often used very generally to describe any unconsolidated (i.e. not rock) part of the Earth's surface. This term is often synonymous with 'dirt' or 'sediment'. However, there are more meaningful definitions of 'soil' and 'sediment' that ought to be understood by all.

Some basic definitions

A sediment is any mineral or rock that has been transported and deposited in a different physical location. Sediments and soils can be transported via wind (aeolian), water (alluviation), gravity/general erosion (colluviation), animals, and/or humans. Groups of transported sediments form deposits, and when these are layered, they can show distinct stratigraphic units differentiated by colour, texture, and inclusions, but which are distinct from soil horizons.

Soils are mineral and organic complexes of solid, liquid, and gas that form through processes of physical and chemical weathering and are affected by the climate, the soil organisms and vegetation, the slope or ground relief, the parent material (the sediment and/or weathering rock on which they are forming), time (Jenny 1941), and human activities, and are altered by additions, losses, transformations, and translocations (Soil Survey Staff 1975). As soils form as a function of the above processes, they differentiate into soil horizons, or zones of distinct features such as colour, structure, texture, and organic material (see Table 1 for an overview of the main soil horizons).

Soils can often form on previously deposited sediments such as flood deposits in a valley's floodplain, or anthropogenic deposits on archaeological sites, superimposing soil horizons onto stratigraphic units. It is therefore important for the archaeologist to be able to differentiate these two very different types of sub-surface features.

Soil classification and description

There are many different soil taxonomy systems (e.g. U.S.D.A. Soil Taxonomy, Soil Survey of England and Wales, Russian National soil classification, F.A.O. soil taxonomy) with overlap and differences. The recent World Reference Base for Soil Resources (W.R.B. 2014) attempted to consolidate these systems and provide a framework for moving between local and national systems. It is recommended that archaeologists begin to work within this framework, for soil types and horizon definitions, as it is becoming the international standard for soil scientists working across disciplines. It is also intended to be translational between classification systems, so much of the terminology is transferrable.

Soil classification is based on soil morphological features such as the type of horizon (Table 1) and the order in which it is present, the soil's

Master horizon	***Characteristics***
H	Horizon of undecomposed organic matter that is or was saturated by water. H horizons can occur above mineral horizons or at any depth below surface if buried.
O	Organic dominated in any stage of decomposition.
A	Mineral horizon formed at the surface or below an O horizon that is either dominated by an accumulation of humified organic material mixed with the mineral fraction, or shows evidence of pasturing, cultivation or other kinds of disturbance.
E	Or Eluvial Horizon – Light-coloured (or bleached) horizon formed by the removal of weatherable materials, silicate clay, iron, aluminium, humus or a combination, and which is dominated by the remaining mineral fraction.
B	A horizon of accumulation and alteration by soil forming processes – Subsurface mineral horizon formed by (1) illuvial accumulation of clay, iron, aluminium, humus, etc., (2) removal of primary carbonates, (3) residual concentrations of sesquioxides, (4) distinctive, non-geologic structure and/or (5) brittleness.
C	Mineral horizon, excluding hard bedrock, that has been *little* affected by soil formation processes and lack the properties of O, A, E and B horizons. Most C horizons are mineral soil layers and retain some rock structure or sedimentary structure.
D	Deep horizon showing *no* features of soil formation processes such as leaching of carbonates or oxidation. D horizons retain geologic structure and are often dense and formed in unconsolidated sediments (like C horizons).
R	Hard, continuous bedrock or regolith.

Table 1: Main soil horizon nomenclature (modified from F.A.O. and I.S.R.I.C. 1990)

Structure Type	Description/formation
Blocky	Blocks or polyhedrons, nearly equidimensional, having flat or slightly rounded surfaces that are casts of the faces of the surrounding aggregates. Subdivision is recommended into angular, with faces intersecting at relatively sharp angles, and subangular blocky faces intersecting at rounded angles.
Granular	Spheroids or polyhedrons, having curved or irregular surfaces that are not casts of the faces of surrounding aggregates.
Platy	Flat overlapping peds oriented on a horizontal plane.
Prismatic	The peds are horizontally narrow but vertically long with very clear faces. Prismatic structures with rounded caps are distinguished as Columnar.
Rock structure	Rock structure includes fine stratification in unconsolidated sediment, and pseudomorphs of weathered minerals retaining their positions relative to each other and to unweathered minerals in saprolite (highly weathered rock) from consolidated rocks.
Wedge-shaped	Elliptical, interlocking lenses that terminate in sharp angles, bounded by slickensides; not limited to vertic materials.
Crumb, lump and clod	Primarily from soil mechanical disturbances such as tillage.

Table 2: Overview of soil structure types (after F.A.O. and I.S.R.I.C. 1990)

texture, colour, physical and chemical properties, and spatial relationships between different soil elements (e.g. horizon size, depths at which changes occur). Basic in-field description of soils should be recorded, which includes the Munsell colour, texture, abundance and colour of mottling, presence/abundance/preservation of organic material, soil structure (see below), and consistence (the degree to which soil material retains its shape under pressure both when wet and dry). Soil structure (Table 2) refers to the arrangement of the soil matrix into units called peds or aggregates, which are separated by empty space (voids or pores), though not all soils display structure (apedal soils). These properties of soils are used to identify soil horizons and further to classify the observed soil by taxonomic type (Table 1) (see F.A.O. and I.S.R.I.C. 1990; Soil Survey Staff 1975; W.R.B. 2014).

The essentials of soil sampling

If a site is very plough damaged and associated with thin modern soil cover (i.e. <50–70cm), it is only really possible to sample the fills of cut features. This is generally less useful from a geoarchaeological/soils perspective, but occasionally there are features of interest to sample, such as possible pit linings, organic standstill horizons in ditches, or redeposited soil material, with primary fills usually being the most reflective of 'use in life' of the feature and its immediate surroundings.

Sampling for soil micromorphological analysis

Soil micromorphology is the analysis of soils/sediments in the thin section with a polarizing microscope (Courty et al. 1989).

Intact block samples are collected from the field and brought to the laboratory for drying and impregnation with a crystic polyester resin, and then put under vacuum for up to forty-eight hours (Figs. 4–12). They are then taken from the vacuum chamber to cold cure in a ventilated cabinet for two weeks, or

Figure 4. Samples are placed to air dry in labelled trays on open shelves in the lab (photo: T. Rajkovača)

Figure 5. Blocks are put into labelled plastic containers ready for oven drying and impregnation (photo: T. Rajkovača)

Figure 6. Placing samples in the oven for final drying (photo: T. Rajkovača)

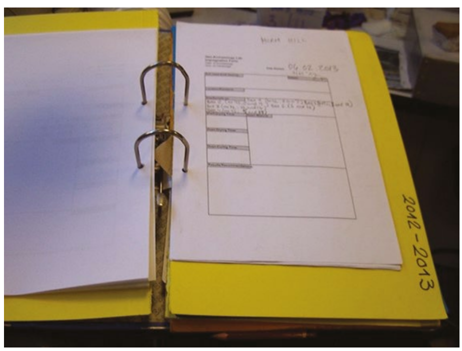

Figure 7. Impregnation and sample records should be kept (photo: T. Rajkovača)

Figure 8. Impregnation with a mix of crystic resin, acetone, and MEKP accelerator/hardener (photo: T. Rajkovača)

Figure 10. Placing impregnated samples in the vacuum chamber for 24-48 hours (photo: T. Rajkovača)

Figure 12. Processing waste bin (photo: T. Rajkovača)

Figure 9. The samples are left to infiltrate with resin by capillary rise for up to an hour within the fume cupboard. The resin level should be monitored, and further topped up if it should drop below the original immersion mark. The date of impregnation should be placed on the outside of the container to monitor the curing time (photo: T. Rajkovača)

Figure 11. Curing cabinet with impregnated samples (photo: T. Rajkovača)

Figure 13. The diamond bladed saw for cutting slices (photo: T. Rajkovača)

Figure 14. Cut blocks and slices cut with a notch to indicate the top of each sample (photo: T. Rajkovača)

up to one month, until they become hardened. The samples are then final cured in the oven for up to three days. At this stage, sample slices are sawed from the hardened blocks to fit microscope slides (Figs. 13–14). The slices are then prepared for final thin sectioning on the Brot multiplate grinding system (Figs. 15–19).

Figure 15. The Brot and its working area with the grinding wheel (left) and slide holder (right) (photo: T. Rajkovača)

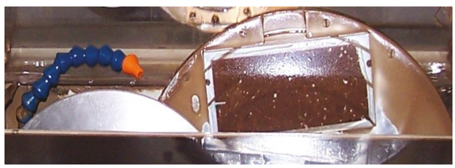

Figure 16. Sequence of beginning grinding after loading slides: 1: Turn the machine from hand to auto. 2: Turn on lubrication, and adjust the blue oil nozzle accordingly. Wind grinding wheel two turns away from the slides, against the arrow direction (Fig. 18). Set appropriate measurement to grind and set the gear. Close the machine's lid. 3: Start the grinding wheel. 4: Start the sample holder, and flick the gear on (photo: T. Rajkovača)

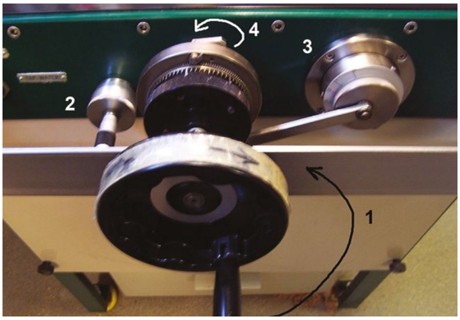

Figure 17. The micrometre for advancing the grinding wheel onto the slides (photo: T. Rajkovača)

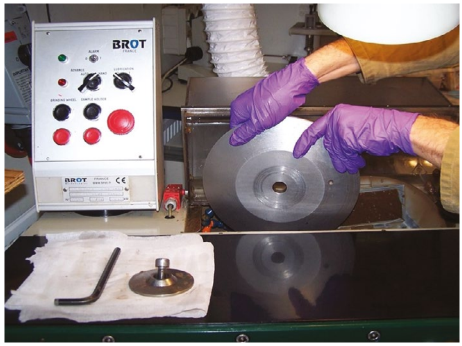

Figure 18. Changing the grinding wheel on the Brot machine (photo: T. Rajkovača)

Figure 19. The author watching slides on the Brot grinding machine (photo: I. Ostericher)

Once slices are cut of about 4–5 millimeters in thickness, they are mounted temporarily on prepared coarse ground glass slides with super-glue gel in sets of three samples. These are then placed on the Brot grinding machine with oil and ground to an even thickness, first with a coarse wheel and then with a fine wheel (Figs. 16–20).

The three slides are then removed, the glass separated from the slice, cleaned and dried, before being re-mounting on a set of polished glass slides of all the same thickness using a 'hot mix' of the same resin recipe used for impregnation. The permanently mounted slices/slides are put in their original order back onto the Brot sectioning machine, and the same process of coarse and fine grinding takes place to achieve finished micron-width thin sections of about 25–30 μm in thickness.

Conclusions

This brief introduction to geoarchaeological methods is not intended to be exhaustive, but rather to provide all archaeologists with an idea of what is possible as well as some basics of sampling, with some greater detail on soil micromorphology.

The finished thin section slides are not only a 'work of art', but contain a wealth of textural and process information to assist in any archaeological or landscape interpretation. Moreover, they form a part of the site archive, along with the impregnated blocks, and may be stored long-term without degradation. In addition, the slides themselves and/or new slices from the block may be used for other scientific techniques such as SEM (scanning electron microscopy) or micro-probe elemental analyses. Thus both the data from these soil/sediment analyses as well as the remaining samples should be treated as part of the site archive, and just as if they were artefacts. Moreover, in future archaeological projects in the Balkans, whether developer-funded or research-driven, the geoarchaeological component should be viewed as just as essential as the retrieval, recording, and analyses of artefacts (Rajkovača 2019).

The second paper on geoarchaeology in this volume by French and Rajkovača presents two archaeological case studies from the Balkans to illustrate what is possible in terms of new and additional information potential on relatively small budgets and timetables using geoarchaeological approaches. For those interested to read further on the full breadth of possibilities available in geoarchaological research, I refer you to the *Encyclopedia of Geoarchaeology* (Gilbert 2017), Macphail and Goldberg's 2018 textbook *Applied Soil Micromorphology in Archaeology*, and Nicosia and Stoops' 2017 textbook *Archaeological Soil and Sediment Micromorphology*.

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LIFE OF ARCHAEOLOGICAL GIS

Matjaž Mori

The Centre for Preventive Archaeology (CPA) is a branch of the Institute for the Protection of Cultural Heritage of Slovenia. Its state-founded activities include archaeological potential assessment, research for non-profit residential housing, and research of state-owned monuments. In practice, we engage in a wide range of archaeological activities, including excavation, post-excavation processing, field surveys, geophysics, remote sensing, and publishing.

CPA was founded in 2009, when CAD software was the primary tool for spatial data generation, management, and publishing. Being a state institution, CPA was involved in large state projects that assessed and mapped archeological potential. CPA was also tasked with running the National Register of Archaeological Research. CAD software was unsuitable for this type of data, prompting the shift toward the geographic information system (GIS).

Digital GIS originated in the 1960s, but many GIS-related methods and concepts predate it. One of the first cases of successful spatial analysis was performed by J. Snow in 1854. He mapped cholera outbreaks and identified water sources responsible for the outbreak based on cluster analysis[3]. The first true GIS was developed in the 1960s for the Canadian government to help with land use management and resource monitoring. The first cases of its usage in anthropology and archaeology date back to the 1980s. The major turning point was the study of the island of Hvar done by Vincent Gaffney and Zoran Stančič (Gaffney and Stančič 1991).

Since the early 1990s, GIS remained restricted to academic use, probably due to high software prices, high hardware demands, and the necessity for highly skilled operators. Spatial data in the archaeological "digital era" was mostly generated and manipulated using CAD software.

As previously mentioned, the initial driving force behind the shift towards GIS in CPA was the type of data involved. Initially, only two experts

3 https://gisgeography.com/history-of-gis/

used GIS for remote sensing and mapping of archaeological potential. The data was still produced and managed in MS Excell and only mapped in GIS. Tasks assigned to CPA resulted in the formation of several databases, which were still in the form of single files, such as .xls, .shp, or a combination of both.

Around this time, three major milestones happened that accelerated the shift toward GIS:

- Open-source GIS software reached a mature stage
- The implementation of the INSPIRE directive
- Advances in photogrammetry

The availability of high-quality free open-source GIS software allowed a far larger range of employees access to GIS tools. Previously limited by several licenses, now anyone could install and start using it, implying that more and more individuals were now at least familiar with GIS. Our chosen open-source GIS software was QGIS[4], which at the time was already on the pair with proprietary software options. QGIS has had good community support since early on; knowledge is shared and easily accessible on various platforms by users for users (e. g. Stack Exchange).

The implementation of the INSPIRE directive provided access to statewide data[5]. Previously, data had to be acquired from project to project for a limited area. With the state's compliance with the directive, numerous data layers for the whole country are now easily accessible. Data is often provided in forms that are not compatible with CAD software (WFS, WMS...).

Advances in photogrammetry algorithms led to the emergence of simple-to-use effective photogrammetry software which caused a big revolution in the way archaeological remains were documented in the field. This changed the type of data that now came from the field. A very sparse point cloud of carefully selected points and a few photos were replaced by large sets of photos that, when processed, produced a wide range of derivatives, from a dense point cloud and textured mesh to high-resolution digital elevation models and orthophotos.

The three milestones had a cumulative effect. Open-source software allowed everyone to install GIS, allowing anyone to view the data as a result. The availability of data made it easier to prepare GIS projects for individual projects since most layers cover the whole country and GIS can manage a huge amount of data. As a consequence, GIS became a data viewer for anyone interested, rather than just a plotting tool for select experts with licenses. This resulted in more and more work being done in GIS, which allowed us to become more skilled at it as well as more ambitious in terms of what we wanted out of it.

4 https://qgis.org/en/site/

5 https://inspire.ec.europa.eu/about-inspire/563

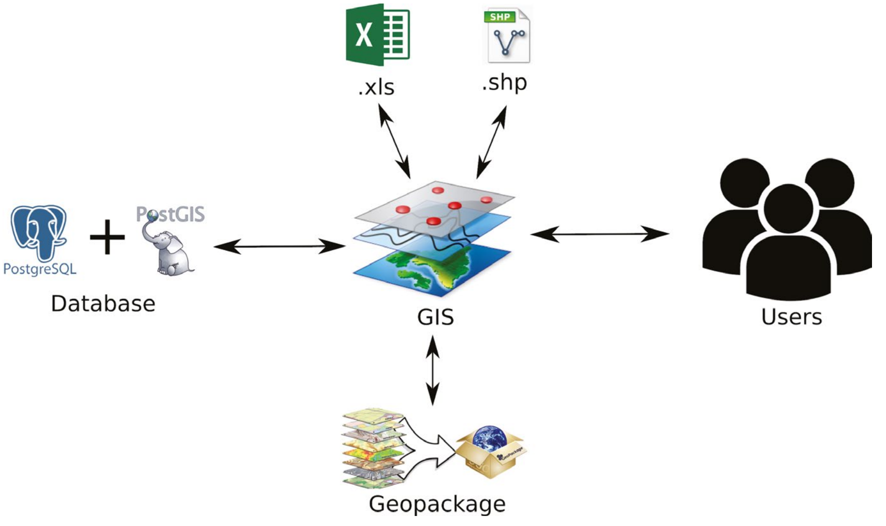

Figure 1. The data infrastructure behind GIS.

At this point, data produced by CPA was still stored in the file system, mostly as .shp, occasionally as .xls, and only viewed in GIS. But once again, the data spoke out and demonstrated that this is not the way to go. There were many issues, including the inability of multiuser editing, a lack of data versioning control, size and text length limitations of shapefiles, and encoding and coordinate reference system (CRS) related issues. The next step was establishing proper data infrastructure. On the server, we installed a PostgreSQL relational database[6] with PostGIS extension and moved our file-based layers to it. We were able to automate some fields that previously had to be manually entered as well as add functions that track changes. Switching to a real database enabled us to maintain data versioning, CRS, and encoding issues under control as well as allowed concurrent multi-user editing of layers with no conflicts or fear of data corruption. Regular users do not see any difference between the file system and database storage other than possible faster loading speeds (Fig.1). The file system is still used for some tasks but we switched to Geopackage, a single file-based database without shapefile limitations which also allows adding functions and storing several layers in one file, including symbology.

When the data was made available through GIS for everyone to see and edit, we started working on input and metadata viewing forms to make them more user-friendly. External data (pdfs, images, etc.) was also linked and made available with one click by using these forms (Fig. 2).

6 https://www.postgresql.org/

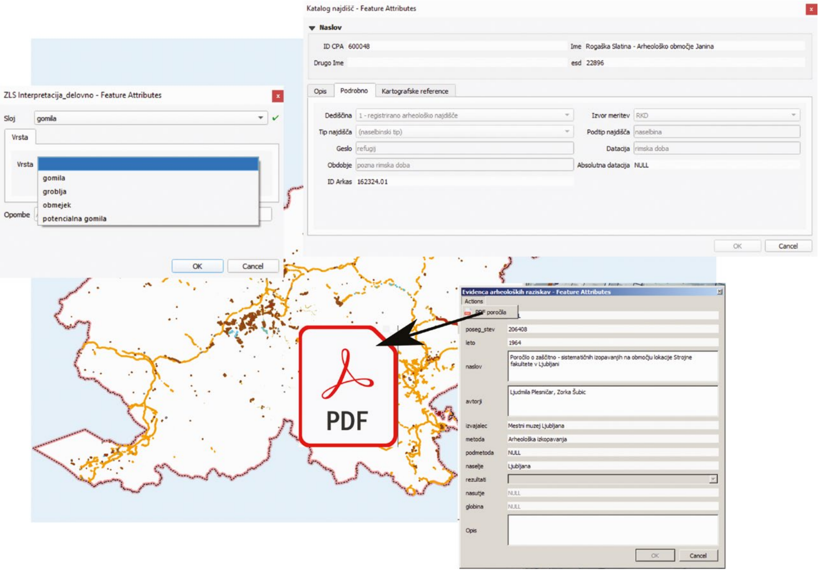

Figure 2. Various input forms with links to external data.

QGIS provides an excellent framework for expanding its functionality or optimizing workflows. There are over 1700 plugins available[7], and they are shared by other users. The development of plugins can be done rapidly, and there is even a plugin for building plugins. After incorporating GIS in our workflows, we soon discovered that it was critical to start developing plugins for our specific needs.

The first plugin that was produced by CPA and published in the official repository was named Archaeological GIS[8]. Its function is to load available statewide layers into GIS (Fig. 3). Each research project starts with this plugin, to set up base layers in the GIS project. The plugin proved to be useful to a far larger audience than expected, with over 23 thousand downloads since its release.

To date, several plugins and simple scripts have been developed to simplify workflows, making it easier for unskilled users to follow established workflows in GIS, reduce clicks, and execute more complex operations. Most of them are currently works in progress or are so specific that there is no use in publishing them. The latest published plugin is ALS Downloader, which provides access to raw aerial laser scanning data for Slovenia and the Netherlands.

Small initial steps in GIS usage created a snowball effect, and we started using GIS more and more for tasks previously done in CAD and

7 https://plugins.qgis.org/plugins/als_downloader/
8 https://plugins.qgis.org/plugins/agis/

Figure 3. Layers loaded into QGIS using AGIS plugin.

various other vector graphics software. We ended up completely abandoning CAD software in all segments of work. Maps and vector images are now produced entirely in GIS without the need for additional vector manipulation software. Together with data acquired using photogrammetry we can prepare and publish accurate representations of documented archaeological remains (Fig. 4).

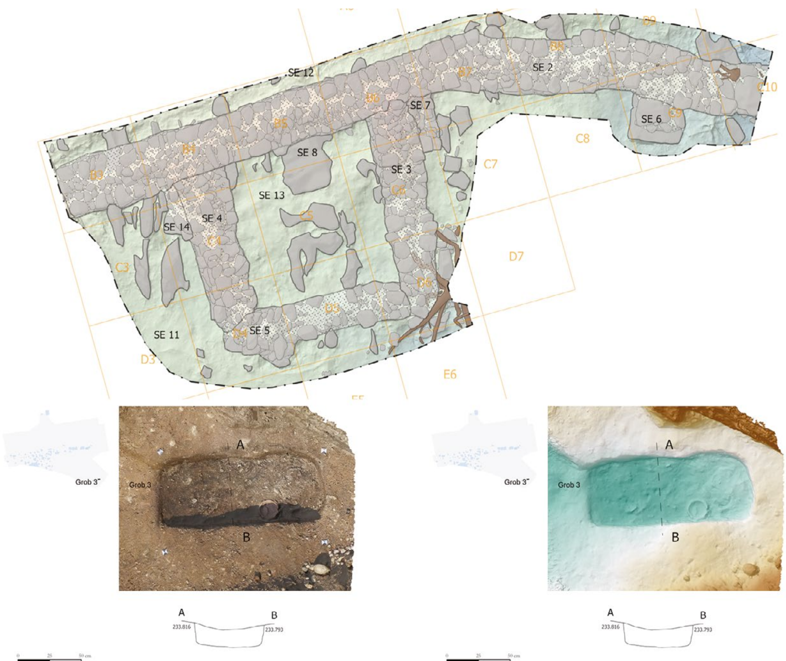

Figure 4. Example of final plan view of excavated roman tower (up) and Roman grave with cross section (bottom).

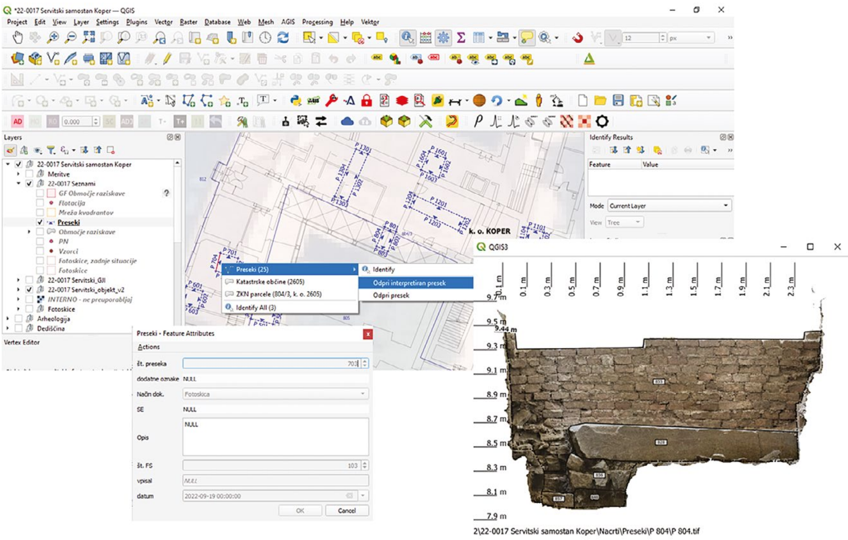

Figure 5. An example of "site database" that includes documented entities with links and actions that allow easy access to all gathered and derived data.

In our experience, many aspects of GIS have proven to be beneficial; the transition brought many improvements in data management, high-quality data derivatives, low-cost automation possibilities, and more. GIS is a ready-to-use database frontend; with little to no effort, all excavation data, both spatial and nonspatial, can be gathered and organized within a GIS project for browsing, analyzing, and report creation (Fig. 5). Interconnecting data, linking it back to its spatial component and attempting to understand it returns us to the origins of GIS. We are drawing dots and trying to figure out what they can tell us.

Today, most archeologists at CPA use GIS regularly; each project starts in GIS with desk assessment and ends in GIS with plotting maps. All field spatial data is produced, processed, and prepared for publishing within GIS. In our experience, GIS was accepted with open arms among users, with some frustrations due to a lack of knowledge on how to use it. Learning to use it takes time and motivation; mastering GIS, like any other skill, demands (but also allows for) constant self-improvement. Its complexity and rapid software development provide opportunities for upgrading, optimizing, and rethinking processes.

References

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EXPERIENCES, RESULTS, AND KNOWLEDGE TRANSFER DURING UNSA ARCHAEOLOGICAL RESEARCH USING GEOPHYSICAL MEASURING DEVICES, LASER SCANNING, LIDAR, AND UAV FROM 2016 TO TODAY

Adnan Kaljanac
Jesenko Hadžihasanović

Less than 10 years have passed since the Institute of Archaeology of the Faculty of Philosophy at the University of Sarajevo (further: Institute of Archaeology) was founded, and that time has not been wasted in vain. To begin, since 2013, the Institute of Archaeology has participated in the implementation of several archaeological research projects in Bosnia and Herzegovina, but it was not until 2016 that these projects gained momentum, particularly those involving UAVs and geophysical measuring devices. Laser scanning and LIDAR, on the other hand, began to be used as research and data collection tools in earnest a few years later, more precisely in 2021 and 2022, respectively. Thus, from 2016 to the present, more than 50 archaeological sites of various periods (ranging from the Paleolithic to the Ottoman period) have been researched, with the Institute of Archaeology as either the leading partner or one of the implementation partners during projects ranging from prospection to systematic research. Now, for the purposes of this paper, a selection from the before-mentioned archaeological research projects that involved the use of UAVs, geophysical surveys, laser scanning, and LiDAR has been made, and they are as follows:

– two archaeological research campaigns at the site of the national monument of Bosnia and Herzegovina Butmir in the vicinity of Ilidža, near Sarajevo (2016 and 2017),

- archaeological prospection of the plateau west of Visočica hill near Visoko (2017),
- archaeological research at the location of the national monument of Bosnia and Herzegovina Ripač near Bihać (2015 and 2017),
- archaeological research at the Brandže site near Bihać (2017),
- geophysical survey of the national monument of Bosnia and Herzegovina necropolis with stećci Šabići near Trnovo (2017),
- aerial survey of the site of Čajangrad near Visoko (2017),
- archaeological research of the national monument of Bosnia and Herzegovina Necropolis with stećci at Stare Kuće in Donje Breške near Tuzla (2017),
- archaeological research at the site Arnautovići near Visoko (2018),
- geophysical survey at the site of Crkvište in Travnik (2018),
- two research campaigns at the site of Kundruci in the hamlet of Hadžići near Visoko (both in 2022),
- two research campaigns at the site of Svibe in Gornje Moštre near Visoko (2018 and 2020),
- geophysical survey at the site of the national monument of Bosnia and Herzegovina and the UNESCO World Heritage Site: the necropolis with stećci Maculje near Novi Travnik (2021),
- archaeological research at the site of Kadića Brdo near Sokolac (2021),
- geophysical survey of a locality in the Jewish cemetery in Sarajevo (2021),
- archaeological research of the national monument of Bosnia and Herzegovina Bjelaj near Bosanski Petrovac (2021),
- archaeological prospection of the route of the highway Koridor Vc on the subsection Putnikovo Brdo-Medakovo near Tešanj (2022),
- archaeological prospection of a locality at the eastern entrance to Travnik (2022),
- two research campaigns at a site in Nević Polje, Lašva near Travnik (2021 and 2022),
- preliminary research at the site of the national monument of Bosnia and Herzegovina Debelo Brdo near Sarajevo (2022).

Before presenting and listing the results and the research methods used in all of the mentioned research projects, it is of utmost importance to present tools that were used during their implementation, as well as modifications and upgrades made to some of the tools as a result of challenges that emerged during their use.

The first tool is the *UAV DJI Flamewheel F550*, with a built-in camera for recording photographic and video content. Even though aerial photography had been used in archaeological research since the 19th century (Ceraudo 2013, 11), it was a costly endeavor before the advent of UAVs, like the one mentioned above. This tool enabled fairly easy and cheap, in comparison, aerial terrain surveys that aim to detect telltale signs of archaeological features and record the research process in order to later use these media for the best possible presentation to the scientific and wider audience. No special software is necessary to process images or videos captured during a *DJI Flamewheel F550* flight.

Figure 1. *DJI FlamewheelFf550* used during the research at the Butmir site with a student holding Flamewheel's remote control and a display that transmits visual information to facilitate the navigation of the UAV.

The next tool is the *Geoscan Resistance Meter RM85*, which can measure soil electrical resistance values by releasing electric current into the ground and measuring resistance at particular points. The resistance is highly dependent on the distribution of moisture in soils affected by drainage, the presence of structures, and soil porosity (Monfort 2013, 154). Thus, by using RM85, it is possible to gauge the position of any underground architectural object, particularly stone ones, but it is also possible to detect other types of buildings, as well as changes in the soil caused by various human activities or natural processes. One of the modular modifications of RM85 made at the Institute for Archaeology is the addition of a SENO114 humidity sensor with a real-time transfer of humidity data to the microcontroller, which allows for the beginning of ro-

Figure 2. *Geoscan Resistance Meter RM85* used during research at the Butmir site.

Figure 3. *Geoscan Resistance Meter RM85* used during the geophysical survey of the Jewish cemetery in Sarajevo with modified spikes to enable recording between individual tombstones.

Figure 4. *Geoscan FM256 Fluxgate Gradiometer* used during preliminary research at the Debelo Brdo site.

tating modulation to compensate for the variability of soil humidity in the location being recorded. Another modification is the adoption of new, longer spikes for use on sites where the height of various features hinders operations with standard-length spikes, as was the case with tombstones at the Jewish cemetery in Sarajevo as seen in Fig. 3. Due to the tool's sensitivity to electrical current, any powerlines above or below ground can interfere with the device, so it must be used with caution. A specialized program, either GeoPlot 3.0 or GeoPlot 4.0, is required to process the data obtained from this device's geophysical survey.

The next device employed by the Institute of Archaeology is the *Geoscan FM256 Fluxgate Gradiometer*. It is used to determine the gradient of local magnetic fields of buried features on a surveyed area in comparison to Earth's magnetic field (Bevan and Smakalova 2013, 133), and thus it is also capable of detecting architectural objects like RM85, albeit of different characteristics. Due to its high sensitivity to environmental magnetism, pieces of clothing made of non-magnetic alloys, and its rather large overlap of the locations of archaeological sites and the battlelines from the 1992–1995 war, it is currently the least used geophysical measuring device at the Institute of Archaeology. As is the case with RM85, a specialized program, either GeoPlot 3.0 or GeoPlot 4.0, is required to process data obtained from a geophysical survey by the FM256 device.

The third geophysical device used by the Institute of Archaeology is *EasyRad Ground Penetrating Radar (GPR)*. It records underground features by transmitting a very short pulse of electromagnetic energy and measuring a reflected signal that is dependent upon the dielectric properties of the subsurface material, and the time delay of the reflected signal is used to estimate the depth range of the target. (Novo 2013, 166–167). Thus, it is suitable for use in environments where it would be difficult to operate other geophysical devices (due to the vicinity of power lines, "pollution" caused by magnetic fields, alloys, etc.). A specialized program, either Voxler 3.0 or Voxler 4.0, is required to process data obtained from this device's geophysical survey.

Figure 5. EasyRad Ground Penetrating Radar (GPR) used during the geophysical survey of a graveyard in Ljubuški.

Figure 6. Topcon IS 9 Total station used during preliminary research at the Debelo Brdo site.

The penultimate device used by the Institute for Archaeology is the *Topcon IS 9 Total station*. Even though total stations are a common occurrence in most archaeological research these days because of their adaptability, this particular series has a feature that works particularly well with georeferenced points in space, namely the possibility of laser scanning of features within the visible range. The term "laser scanning" describes any technology that accurately and repeatedly measures distance using a laser pulse, by precisely measuring the time needed for the laser pulse to travel from the object and back and then transforming these measurements (Mlekuž 2013, 113). The scanning ability of *Topcon IS 9* is useful for recording any standing or aboveground features such as tombstones (mostly *stećci* or *nišani* in the case of Bosnia and Herzegovina) as well as any built or decayed architectural features, and recording excavated features. It can also be used for recording parts of the landscape of research interest.

The last tool to be mentioned is the LiDAR device *Velodyne VLP-16*. The principle behind LiDAR (an acronym for Light Detection and Ranging) is the same as that of the previously mentioned laser scanning device *Topcon IS 9 Total station*. While Velodyne VLP-16 can capture several times the number of points in less time than IS 9 Total station, Velodyne VLP-16 only has lasers and sensors and thus cannot position itself in georeference space, meaning that external points of reference are required for

Figure 7. The first method of mounting the LiDAR *Velodyne VLP-16*, used during archaeological prospection of the route of the highway Koridor Vc on the subsection Putnikovo Brdo-Medakovo near Tešanj.

Figure 8. The second method of mounting the LiDAR *Velodyne VLP-16*, used during the second research at the Nević Polje site, Lašva near Travnik.

the data to be georeferenced. Since acquiring the Velodyne VLP-16, the Institute of Archaeology's staff has experimented with and developed various means of carrying the device for recording an area of interest. Fig. 7 depicts the first generation of devices for mounting the LiDAR that could be carried in the hands, where the sensor would be about a meter away from the person surveying the landscape. However, the device's height and stability were deemed insufficient, so the second way of LiDAR mounting devices was upgraded by putting the sensor puck on a pole of greater height, as seen in Fig. 8. Although this modification proved well in the field test, it was determined that stabilization is more important for the quality of recorded data, and that, although sufficient for surveying, there was still room for improvement. So a third generation of mounting devices with a two-axis gimbal was specifically developed and installed on a backpack, together with an accompanying computer with dedicated software, as seen in Fig. 9. This method has proven to be the most successful so far.

From 2016 to the present, as seen above, the Institute of Archaeology conducted research at numerous sites, and the methodolo-

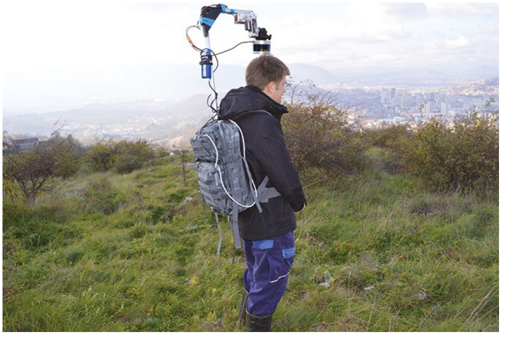

Figure 9. The third method of mounting the LiDAR *Velodyne VLP-16*, used during preliminary research at the Debelo Brdo site.

gy was similar regarding the use of geophysical, laser scanning, LiDAR, or UAV devices, depending on the circumstances and nature of the research, as well as the needs of investors for the specific project in question. When only geophysical surveying was needed, one or more of the above-mentioned devices were used, while in the case of archaeological prospection or rescue archaeology, a combination of geophysical and other devices was used in addition to excavations. In each of the mentioned scenarios, UAVs could have been used as an additional way of collecting data in the field, while in a few instances, only UAV aerial photography was used. In the pages that follow, a selection of research findings will be presented.

Archaeological research at the site of Butmir in 2016 and 2017

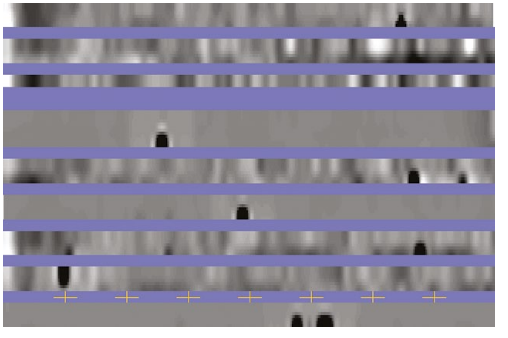

Figure 10. Geophysical data collected from surveying between rows of apple trees in the orchard of the Institute for Agriculture in Ilidža.

The first research that is being discussed was at the site of the national monument of Butmir near Sarajevo, where various methods were used to survey about 30 hectares during the first archaeological research campaign (Kaljanac 2017) and an additional 10 during the second campaign (Kaljanac and Brigić 2020). During both of the campaigns, the RM85 Resistance meter and FM256 Fluxgate Gradiometer were used to collect additional data from the site. One of the challenges during the first campaign for the geophysical survey was recording in the orchard at the Institute for Agriculture in Ilidža with closely spaced rows of apple trees in Section 4, as marked during archaeological research in 2016. This required recording only smaller stretches of land that could be combined in the post-production to get a coherent picture of the surveyed area. This has given results that were consistent with the orchard's position and past land uses as a barracks site post-1945 (Fig. 10).

Aerial survey of the site of Čajangrad near Visoko

The second research presented is an example of an aerial survey (which the Institute of Archaeology has so far conducted on a number of

Figure 11. Aerial photography of the medieval site of Čajangrad near Visoko.

sites) of the Čajangrad site near Visoko. This medieval-period archaeological site is located on a small plateau above a river valley, which was mostly covered in forest in the past. The survey aimed to obtain aerial images to assess the work done thus far and to determine if there were any structures or features that were not visible from ground level. (Fig. 11)

Archaeological research at the site of Kundruci in the hamlet of Hadžići near Visoko

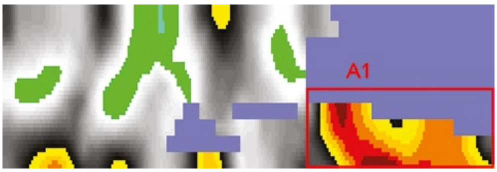

Figure 12. Geophysical recording obtained during a survey of the site of Kundruci near Visoko, with anomaly labeled A1 (Kaljanac and Hadžihasanović 2022).

The next presented case is the research at the site of Kundruci near Visoko, where two separate campaigns took place. During the first one, a geophysical survey using a Geoscan RM85 Resistance meter was incorporated into the research, during which an anomaly in the ground was discovered (Fig. 12) that was not recorded during earlier surveys of the area (Fig. 13) (Furholt 2013). The anomaly become one of the focal points of the second campaign when it was discovered that it was a stone construction (Fig. 14) that could be dated to the Neolithic period based on stone and ceramic artifacts found on its surface (Kaljanac and Hadžihasanović 2022).

Archaeological research at the site of Svibe in Gornje Moštre near Visoko

Another project in Visoko was cooperation with the Museum of Visoko on the exploration of the site of Svibe near Visoko, where a Roman-period building complex of currently unknown size was discovered (Silajdžić 2021; Silajdžić 2022). This case is noteworthy because the geophysical survey aimed to determine the possible positions of the walls in the area under research, which proved successful (Figs. 15–16).

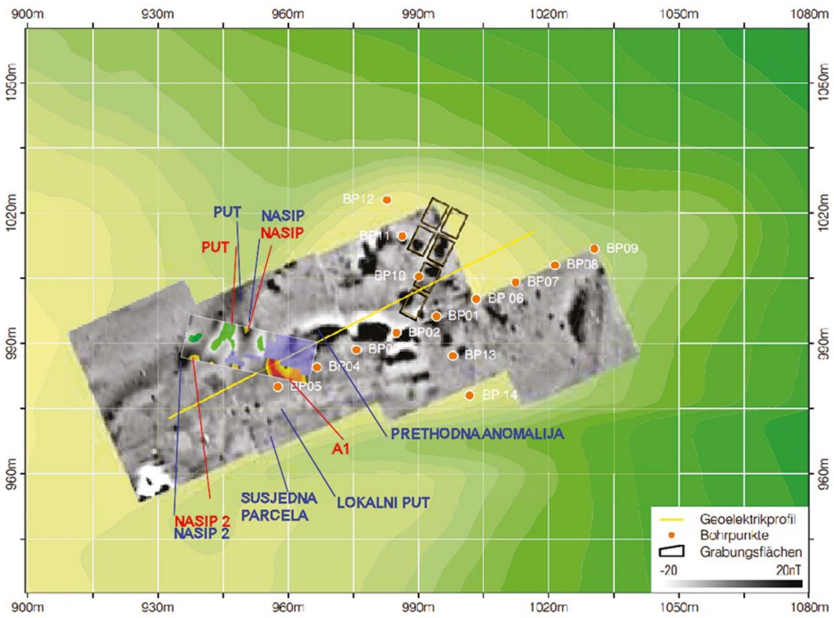

Figure 13. Results of geophysical research conducted in 2020 superimposed on those of research conducted in 2008. The anomalies detected during geomagnetic surveys in 2008 are marked in blue, while the anomalies detected during geophysical surveys in 2020 are marked in red. (Kaljanac and Hadžihasanović 2022).

Figure 14. Aerial photography of the stone construction during excavation at the site of Kundruci near Visoko.

Figure 15. Geophysical recording of the site of Svibe. The excavated positions are marked in yellow, while the anomalies detected during two geophysical surveys are marked in red (modified after Silajdžić 2022).

Figure 16. Aerial photo of the area excavated at the site of Svibe near Visoko (Silajdžić 2022).

Figure 17. Geophysical recording superimposed on the aerial photo of the necropolis with stećci Maculje.

Geophysical survey at the site of the national monument of Bosnia and Herzegovina and a UNESCO World Heritage Site: The historic site of the Maculje necropolis with stećak tombstones, Novi Travnik Municipality.

The next research project illustrates the use of EasyRAD radar to survey the necropolis with stećci Maculje. Anomalies consistent with known building activities (concrete foundations of varying sizes of the table and the site's information board) were found, as well as anomalies that show places where a few stećak tombstones were found during research preceding the road rebuilding. Lastly, anomalies that point to unknown activities near a few of the tombstones were also identified. (Fig. 17).

Geophysical survey of a locality at the Jewish cemetery in Sarajevo

The following research was conducted at the Jewish cemetery in Sarajevo, where it was necessary to modify the spikes in order for the survey

Figure 18. Geophysical recording superimposed on the aerial photo of the Jewish cemetery in Sarajevo.

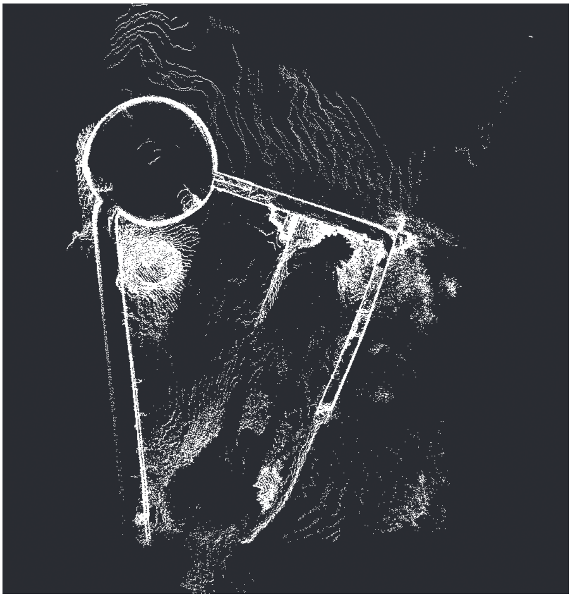

Figure 19. Laser scan of Bjelaj, the medieval town near Bosanski Petrovac, from a bird's-eye viewpoint.

to be carried out at all. Namely, when trying to record between tightly packed graves, the spikes that came with the Geoscan RM85 Resistance meter were too short to touch the ground. As a result, two new spikes, more than double the length of the original ones, were manufactured and the survey was successfully conducted, as can be seen in Fig. 3. The survey has shown us areas where graves were dug and used in religious rites, as was expected (Fig. 18).

Figure 20. A laser scan detail from a bird's-eye viewpoint of the northeastern part of the medieval town of Bjelaj near Bosanski Petrovac.

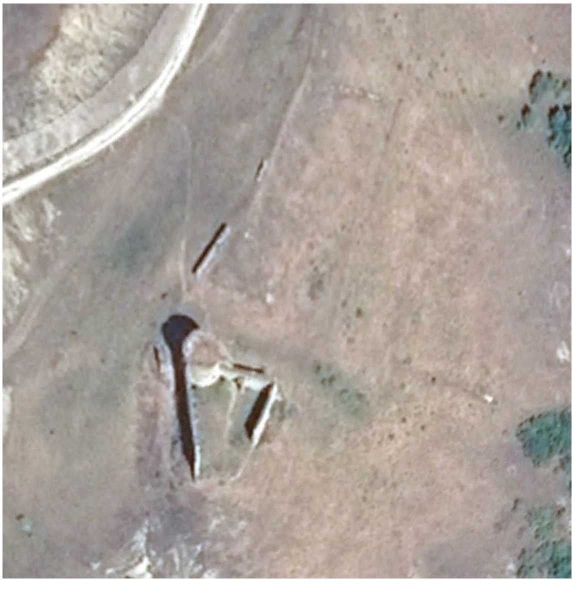

Figure 21. Satellite photo of the medieval town of Bjelaj near Bosanski Petrovac.

Archaeological research of the national monument of Bosnia and Herzegovina Bjelaj near Bosanski Petrovac

During explorations of the national monument of Bosnia and Herzegovina Bjelaj near Bosanski Petrovac, in addition to archaeological excavations, a laser scanning using Topcon IS 9 was done because the walls on the site had survived, providing an opportunity to collect additional georeferenced data, the result of which can be seen in Fig. 19, with a detail presented in Fig. 20 and a comparison with a satellite image in Fig. 21.

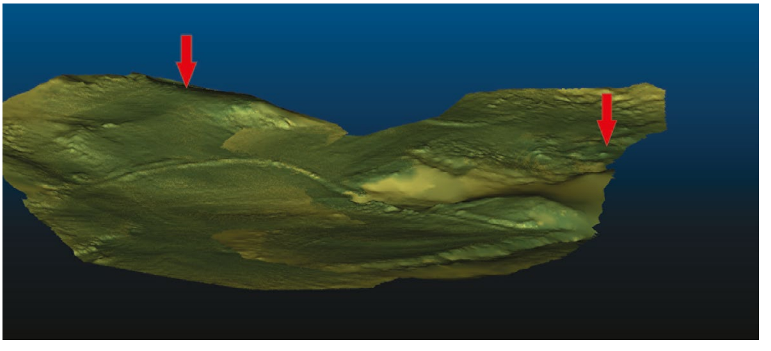

Figure 22. Image of the area surveyed with LiDAR Velodyne VLP 16 during the archaeological prospection of the subsection Putnikovo Brdo-Medakovo near Tešanj.

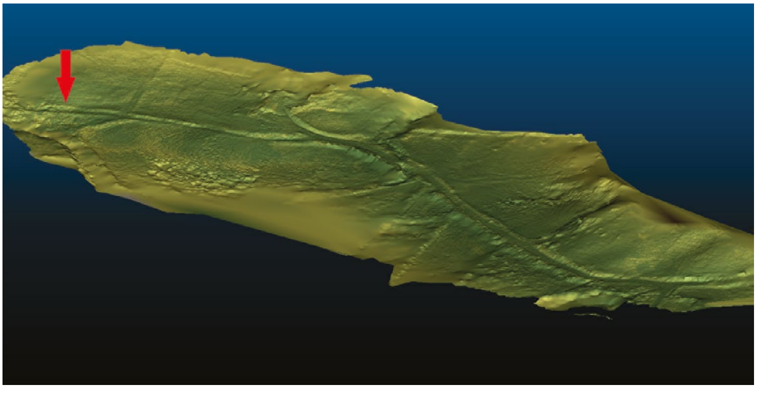

Figure 23. Image of the area surveyed with LiDAR Velodyne VLP 16 during the archaeological prospection of the subsection Putnikovo Brdo-Medakovo near Tešanj.

Archaeological prospection of the route of the highway Koridor Vc on the subsection Putnikovo Brdo-Medakovo near Tešanj

When the archaeological survey of the subsection Putnikovo Brdo-Medakovo near Tešanj was carried out, part of the terrain was covered by forest, and the survey was conducted while the terrain was covered in snow. These factors made archaeological prospection even more difficult than usual. For these reasons, it was decided to survey more difficult parts of the terrain of the area slated for archaeological prospection with the newly acquired LiDAR Velodyne VLP 16, and using the first mounting

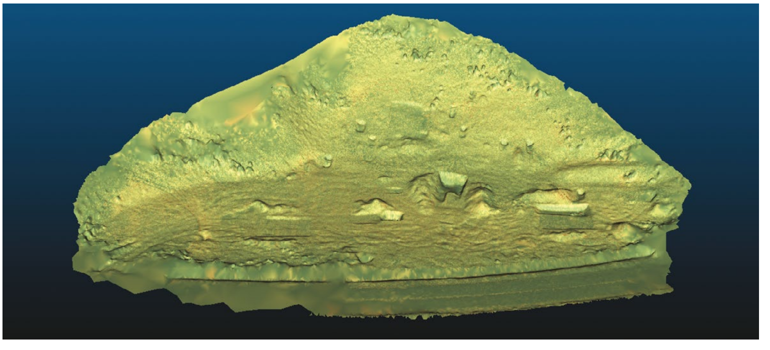

Figure 24. Image of the area surveyed with LiDAR Velodyne VLP 16 during the archaeological prospection of the area at Travnik's eastern entrance .

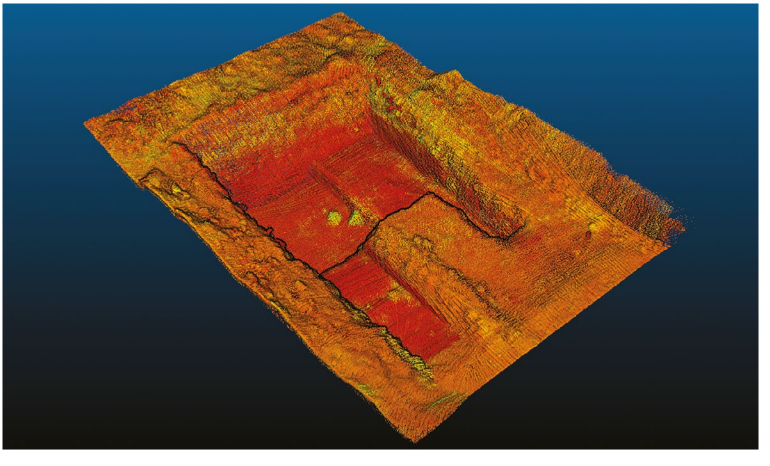

Figure 25. Point cloud of Trench 2 in the area at Travnik's eastern entrance.

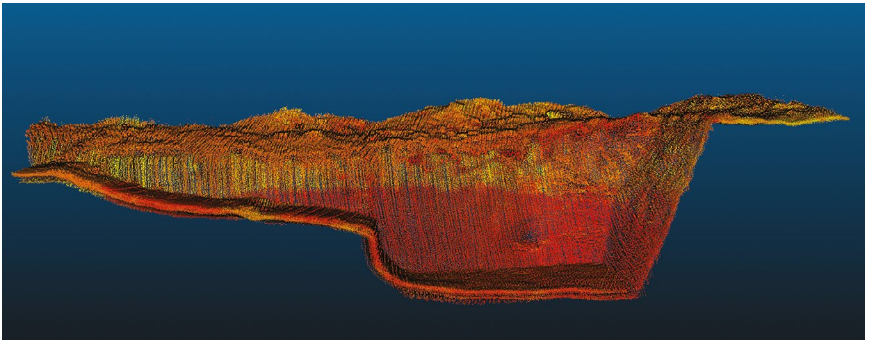

Figure 26. Cross-section of the point cloud of Trench 2 in the area at Travnik's eastern entrance.

method as is seen in Fig. 7 earlier in the paper. The post-processing results of the survey with LiDAR can be seen in Figs. 22 and 23, where road surfaces and other anomalies can be easily identified.

Archaeological prospection of the locality at the eastern entrance to Travnik

Figure 27. Image of Trench 2 in the area at Travnik's eastern entrance.

Last of the Institute of Archaeology's research projects is an archaeological prospection of the area at Travnik's eastern entrance. The site itself has shown to have little archaeological potential, but for the purpose of this paper, the LiDAR scanning performed with Velodyne VLP 16 using the second mounting method as seen in Fig. 8 is significant. Fig. 24 shows how the post-processed survey results can reflect how the site itself looked like at that moment, while Figs. 25–26 show how differences between various soil strata can be observed even on raw LiDAR point clouds (compare with Fig. 27).

In earlier pages, a selection of various methods and the result of their use were presented. But one aspect of this brief presentation of the work of the Institute of Archaeology that could have been discerned by more observant eyes but was not explicitly discussed, is the issue of knowledge transfer. During all of the Institute of Archaeology's previously mentioned research, it was deemed of utmost importance to include students as participants in all of the processes involving the organization and implementation of research projects. As the Department of Archaeology of the University of Sarajevo is the youngest department to teach archaeology as a program in Bosnia and Herzegovina, if not the entire territory of former Yugoslavia, there has always been a concern of providing the students with the opportunity to gain enough valuable field research experience. While the program and some local projects have provided some experience, more is always welcome, and more importantly, none of the methods previously discussed in this article were not used during their implementation. Thus, it was concluded that including students in the implementation of the Institute of Archaeology's project would only be beneficial in the long run. With this in mind, students were given access to various devices to use (as seen in Figs. 1–3, 6 and 11), and were even given an opportunity to pilot an UAV by themselves (Figs. 1 and 11); of course, all of these activities were done under supervision to prevent any adverse effect. After surveying and recording with these devices, students were given the data obtained from these activities, and a chance to make their own observations and interpretations, which were later compared to those made by the staff of the Institute of Archaeology involved in the particular project where the devices were used. In this way, even if the students made wrong predictions or assumptions, they had an opportunity to develop the skills necessary to interpret data obtained during surveying with these devices. Even more importantly, the use of these devices was normalized, or their use became more tangible, and not some highly specialized activity, thereby becoming part of students' basic toolbox, which had already contained mundane tools like excavation of test pits. This will allow them to obtain better findings during various archaeological research, which would otherwise be unavailable due to a variety of different factors.

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HOW PHOTOGRAMMETRY BECAME COMMON PRACTICE IN FIELD ARCHAEOLOGY

Dinko Tresić Pavičić
Josip Burmaz

Archaeological excavation as a destructive process is an unrepeatable experiment since no two archaeological sites are the same (Barker 1993, 1). Therefore, it is imperative to make as detailed an archaeological field record as possible. However, there is a contradiction between the incentive for objectivity and the fact that archaeological interpretation is subjective (Hodder 1997, 691–693). As archeology is a visual discipline, archaeologists have used various visual methods for illustrating and recording the shape, position, size of, and relationship between, different archaeological features or artifacts since the very beginning (Moser 1992, 831; Opgenhaffen 2021, 353). The most common traditional visual techniques used for recording archaeological sites are drawing and photography. While both methods provide a visual record, drawing is by definition an interpretation (Green 2003, 69) and has a central role in archaeological knowledge construction (Morgan et al. 2021, 627); photography, on the other hand, is a more objective representation of reality and is less interpretative (Moser 1992, 832). The latter is also true for photogrammetrically generated representations used in modern archeological field documentation. Although they contain the measurement record in addition to the visual one, photogrammetric representations cannot replace the interpretive value of an archaeological sketch or drawing. Nevertheless, digital photogrammetric methods are precise, detailed, fast, and cost-effective tools that have been incorporated into archaeological field recording procedures (Magnani et al. 2020, 8–12). With the development of 3D technologies, the further integration of photographic, measurement, and drawn archaeological field documentation can be expected.

The authors provide a short overview of photogrammetric techniques used in archaeological field recording procedures while emphasizing that photogrammetry, although useful, is not vital to the archaeological process. The authors have over 20 years of experience in archaeological excavation and field recording techniques with the archeological enterprise Kaducej Ltd. in Croatia.

Analog era

During the analog era, photogrammetric methods (mostly stereophotogrammetry) in archaeology were primarily used within aerial archaeology and for documenting architectural cultural heritage sites. Due to the specific skills and equipmenet needed to apply this technology, it was not widely used as an excavation recording technique, although there are examples where it was successfully applied. (Fant et al. 1978, 143–151).

An essential element of archeological field documentation is the drawn record. Traditionally, sections and plans were drawn on-site during excavation, using a pen and paper with a tape measure and a level to survey elevation data. Although each archaeologist was capable of producing a drawing, for larger excavations drawings were usually made by specialized draughtsmen who spent years refining their drawing skills. This type of visual record can be criticized for its potential lack of precision or detail, although it can be argued that when done skillfully, it provides just the right amount of desired information and precision. One of the issues that eventually led to the abandonment of on-site drawing on paper was that drawing was time-consuming. On the other hand, this slow process enabled close observation of the archaeological record, discussion, and a natural transfer of knowledge.

Photography has been used in archaeology almost since its inception. These beginnings are characterized by the casual use of cameras on archaeological excavations, but soon the full potential of photography was realized, making photography an indispensable part of the archaeological field record (South 1968, 73; Drewett 2001, 138). For the first time, differences in texture and the color of archaeological features could be recorded with an incredible amount of detail. If drawing provided interpretation, photography, in a sense, provided evidence for that interpretation. Although it meets the requirements for objectivity better than a drawing, a photograph cannot be considered objective because it is still up to the individual what and how to photograph. The relative technical complexity of analog photography required specific knowledge and skills, so oftentimes, a professional photographer was in charge of taking, developing, and archiving photographs during excavation. Given the limited number of images that could be captured on film, great attention was paid to framing and lighting, while professional knowledge allowed for the beauty of artistic expression even in technical photography.

Digital era

The adoption of digital technologies in archaeology has been gradual and is not yet complete. Essential for archaeological field recording was the development of digital point-and-shoot cameras and measuring instruments (EDMs and differential GNSS receivers), as well as the development of computer hardware and software, particularly CAD or GIS solutions for drawing and analyzing spatial data. The main incentive for implementing digital technologies was to improve efficiency by reducing time spent on field recording, without losing the accuracy or precision of documentation (Caraher 2016, 430–431). With the advent of digital photography, it became possible to instantly view the quality of the captured photograph and, even more important, to capture and store an almost unlimited number of photographs. On-site drawing on paper was replaced by "drawing" using Total Station or differential GNSS, or by completely replacing on-site drawing with photogrammetry (Olson et al. 2013; Berggren and Gutehall 2018, 128–137; Morgan et al. 2021, 614).

The first widespread application of digital photogrammetric techniques in archaeological field recording was the use of photogrammetric single image techniques for correcting image distortions, primarily certain low-order polynomial rectification methods. These methods are used for geometric transformations between the image plane and the projective plane using control points placed on the

Figure 1. Drawing on paper. Town of Hvar, 2004. (Photograph by Josip Burmaz, courtesy of Kaducej d.o.o.)

Figure 2. Photogrammetric single image technique workflow. Pod, near Bruška, 2011. (Photograph by Dinko Tresić Pavičić, courtesy of Kaducej d.o.o.)

object plane in order to obtain an orthophoto, i.e. a geometrically corrected photograph with a uniform scale (Hemmleb and Wiedemann 1997, 262). Vertical photography in the field was most commonly done by hand, from a ladder, or using various types of stands (monopod, A-stand...) or platforms, while low aerial photography was employed less frequently due to impracticality and cost, and included balloons or kites. This demanding process may require the involvement of several people and the use of complicated and cumbersome equipment. As a result, the method was used only for recording more complex situations or structures (such as walls, floors, etc.), as well as larger excavated surfaces. As data processing and rectification were sometimes performed off-site, it was necessary to keep precise and comprehensible field sketches as an integral part of the measurement record, so that the technician would have a clear picture of what needed to be drawn from the created orthophoto. By applying the method correctly, and understanding its advantages and disadvantages, it was possible to obtain precise and detailed orthophotos as base maps for creating archaeological plans and sections.

Today, digital photogrammetry techniques have developed to the point that anyone, without special equipment and any knowledge of photography, surveying, or photogrammetry, can create detailed and precise 3D models of reality (Magnani et al. 2020, 2). What was once a painstaking manual process of creating orthophoto mosaics by manual rectification of one-by-one vertical photographs is now done considerably faster and with greater precision and accuracy by using software that implements the structure-from-motion photogrammetric technique. The advent and proliferation of drones, which completely replaced cumbersome terrestrial and low aerial camera platforms like stands or balloons, also facilitated the acquisition of photographic data.

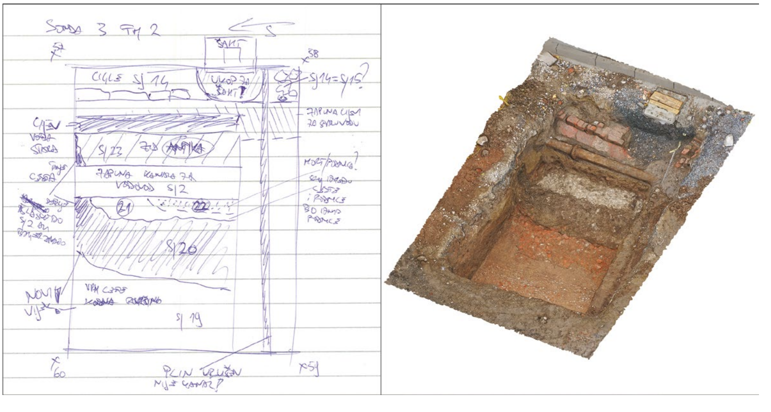

Figure 3. Field sketch and an isometric view of a photogrammetric 3D model of Trench 3. What is a 3D model without a field sketch? Zvonimirova ulica, Sisak, 2022. (Graphic by Dinko Tresić Pavičić, courtesy of Kaducej d.o.o.)

Discussion

The sheer number of papers published in recent years about the use of these technologies in field recording procedures testify to the fact that field archeologists consider these developments nothing less than revolutionary (Magnaniet al. 2020, 1–4). But are they really so?

Processing of gathered photographic and surveyed data is still frequently done off-site, and sometimes even after excavation is completed. For the created 3D models to be comprehensible, sketches and drawings need to be drawn on the field, either on paper or digitally, from scratch or traced from photographs. The created 3D models are realistic, accurate, and detailed, but current computer technologies do not allow practical manipulation, editing, and, in some cases, even visualization of this 3D data. To efficiently analyze and convey 3D information archeologists still depend on 2D representations! From created 3D models we generate raster data, such as digital elevation models or orthophotos, as base maps for drawing plans and sections. This is still a complicated process, and it feels as if the full potential of digital photogrammetry in the digital archaeological field record has not yet been fully realized. On the other hand, archeologists need to better understand the impact these digital technologies have on archaeological field practices, interpretation, and knowledge construction (Berggren and Gutehall 2018, 123; Morgan et al. 2021, 626).

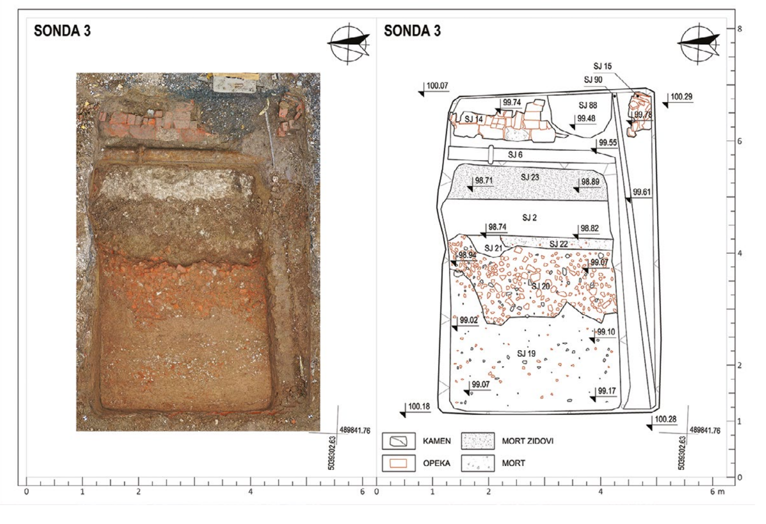

Figure 4. Orthophoto generated from a photogrammetric 3D model, and the final plan for Trench 3, illustrated in CAD software. Zvonimirova ulica, Sisak, 2022. (Graphic by Dinko Tresić Pavičić, courtesy of Kaducej d.o.o.)

As digital photogrammetric methods have immensely facilitated and accelerated on-site spatial and visual data acquisition, their frequent use is encouraged in order to record as "objectively" as possible during excavation. The idea is that this recording approach can provide sufficient 3D data of the archaeological record for post-field archeological interpretation, and the intention is to excavate as quickly as possible without wasting time on thorough observation. Although photogrammetric 3D models have some potential for post-field analysis and interpretation (Magnani et al. 2020, 8), the assumption that observation can be continued after the record is compiled is, to say the least, doubtful (Reynolds and Barber 1984, 98–99). On-site observation is essential for archaeological interpretation (Hodder 1997, 692–695), and only what is observed can be recorded (Barker 1993, 113).

The use of digital technology can lead to some form of de-skilling, as Caraher calls it. Certain efficiencies are achieved by using digital tools, but other processes remain hidden, which can impact archaeological practice and methodology (Caraher 2016, 421,435). This was already seen 20 years ago, with the use of Total Stations, when oftentimes the primary concern was operating the station, while "drawing" with the prism was secondary. At the same time, the gap between on-site data collection with a prism and the final illustration done on the computer in the office often resulted in the misunderstanding that the "prism pole holder" is the one who draws, the interpreter. The use of photogrammetric methods makes this gap even more apparent. Replacing time-consuming on-site drawing with photogrammetric recording methods can transform a crucial step in the documentation process, from one requiring detailed and careful knowledge of the features in a trench and illustration conventions to one requiring the understanding of a digital camera and relevant software (Caraher 2016, 436; Morgan et al. 2021, 614). Because of the accuracy, detail, and visual impact that digital 3D models have, one may falsely presume that archaeological work is completed after photogrammetric recording, and that interpretation will be provided later. But there is more to archaeology than just the passive collection of data from the sides of the trench, followed by reviewing the collected 3D data in the office. To adequately understand and interpret the archaeological record, one has to have a more active role and be inside the trench with the trowel, not outside with the camera (Caraher 2016, 436). This active role also includes time spent observing the site as part of the wider landscape, along with involving and communicating with the locals as an indispensable part of providing context for the discovered archaeological record and understanding of the site.

Although these concerns about the use of photogrammetric methods as part of digital archeological recording procedures are more associated with good archaeological excavations practices than with a particular recording technique (Ellis 2016, 69), we should be aware that digital tools have the potential to transform archaeological field practices and methodology. Perhaps the main issue is the general misuse of technologies; instead of having more time for observation, study, and interpretation, we use digital tools simply to speed up the excavation process. Nevertheless, archaeologists are constantly incorporating new technologies into excavation processes, which eventually become invaluable tools for recording and, ultimately, interpreting archaeological data. There is no reason to believe that it will be any different with photogrammetric techniques. While it is true that on-site hand drawing of plans and sections as a means of recording has been replaced by the use of photogrammetric methods, it should be stressed that field sketches (drawings) are still a necessary part of the photogrammetric workflow, because the created 3D models would not be intelligible without them. Moreover, some form of drawing, either 2D or 3D, will always be necessary as a means of visualizing and conveying specific, interpretative information.

Figure 5. Paper or digital is not important for archaeological discussion. Only time is important. Gundinci, near Đakovo, 2012. (Photograph by Borko Rožanković, courtesy of Kaducej d.o.o.).

Future and conclusion

Digital photogrammetric 3D representation techniques are accurate, precise, and cost-effective recording methods that have rightly become a standard part of archaeological field recording procedures. The methods are mostly used for recording and as visual assistance, while their analytical potential remains undeveloped (Magnani et al. 2020, 1). With the introduction of

Figure 6. Close observation is essential for archaeological interpretation. Erdödy Castle, Town of Jastrebarsko, 2012. (Photograph by Borko Rožanković, courtesy of Kaducej d.o.o.)

photogrammetric methods, traditional photographic and measurement archaeological documentation started to become integrated. Further development of digital technologies including new types of instruments for recording spatial and visual data, along with hardware and software for visualization, manipulation, and dissemination of 3D data, can be expected in the future with the full integration of photographic, measurement, and drawn archeological records.

The process of transitioning from traditional paper-based recording to a digital system provides benefits, but it can come with a price. There is concern that by using digital surrogates, we are losing fundamental skills for understanding archaeology (Morgan and Wright 2018, 14). Although the use of digital technologies has an impact on archaeological practice and methodology, these problems can be addressed and kept in check. The reality is that there is no going back. The digital era is here, and archeological field recording will inevitably become entirely digital. As field archaeologists, we must simply make the best of it.

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