Volume XIV • Issue 2/2023 • Online First

INTERDISCIPLINARIA ARCHAEOLOGICA
NATURAL SCIENCES IN ARCHAEOLOGY
homepage: http://www.iansa.eu

A look at the region

Archaeometry in Serbia: Where we are and where we should go next?

Roman Balvanović[1*], Maja Gajić Kvaščev[1], Velibor Andrić[1], Ivanka Holclajtner-Antunović[2], Milica Marić Stojanović[3], Daniela Korolija Crkvenjakov[4], Snežana Vučetić[5], Emilija Nikolić[6], Aleksa Jelikić[7]

[1]*Vinča Institute of Nuclear Sciences – National Institute of Serbia, University of Belgrade, Mike Petrovića Alasa 12–14, 11351 Vinča, Belgrade, Serbia*
[2]*Faculty of Physical Chemistry, University of Belgrade, Studentski trg 12–16, 11158 Belgrade, Serbia*
[3]*National Museum of Serbia, Trg Republike 1a, 11000 Belgrade, Serbia*
[4]*Department of Fine Arts, Academy of Arts, University of Novi Sad, Đure Jakšića 7, 21000 Novi Sad, Serbia*
[5]*University of Novi Sad, Faculty of Technology, Department of Materials Engineering, Boulevard cara Lazara 1, 21101 Novi Sad, Serbia*
[6]*Institute of Archaeology, Belgrade, Kneza Mihaila 35/4, 11000 Belgrade, Serbia*
[7]*Institute for the protection of cultural monuments of Serbia, Radoslava Grujica 11, 11118 Belgrade, Serbia*

ARTICLE INFO

Article history:
Received: 1st February 2023
Accepted: 6th June 2023

DOI: http://dx.doi.org/10.24916/iansa.2023.2.6

Key words:
archaeometry
Serbia
laboratories
institutions
community
projects

ABSTRACT

The paper presents a short history of archaeometry investigations in Serbia, from the first published work in 1932 until today. It then describes the most important laboratories and institutions that perform archaeometry investigations in Serbia today, their teams, equipment, projects, and cooperation: Institute for the Protection of Cultural Monuments of Serbia, Vinča Institute of Nuclear Sciences, Faculty of Physical Chemistry, National Museum of Serbia, Institute of Archaeology, the Heritage Lab, Gallery of Matica Srpska Novi Sad, and City Museum of Subotica. The paper describes plans for the future and proposes forming of Serbian Society for Archaeometry with several goals: to further interconnect research disciplines; to facilitate better use and purchase of equipment, to establish a dedicated laboratory for archaeometry; to introduce archaeometry study programs at different levels of teaching; to introduce archaeometry into scientific plans of Serbia; to start a domestic archaeometry journal, and to promote the awareness of the potentials and benefits of archaeometry to institutions dealing with cultural heritage and to the general public.

1. Introduction

The article before the reader was initially intended to report on the activity of the archaeometry group from the Vinča Institute for Nuclear Sciences, but it was soon realised that, because of the interconnectivity and overlapping of the archaeometry research, this was not adequate. Therefore, the original scope was widened to include other institutions in Serbia participating in archaeometry projects. In addition, besides the main laboratories described here, a not inconsiderable number of people from other institutions also occasionally perform archaeometry work and publish archaeometry papers. To mention them all individually would greatly exceed the scope of this small overview: suffice it to say they comprise an important part of the work in archaeometry in Serbia.

*Corresponding author. E-mail: broman@vinca.rs

Archaeometry in Serbia is not "the new kid on the block". Most likely the first scientific investigation of cultural heritage artifacts in Serbia is the chemical analysis of red colour from a stone plate from the Neolithic Vinča culture. The renowned Serbian chemist Milivoje S. Lozanić determined that the red colour derives from cinnabar (Vasić, 1932). After the Second World War, *Chemistry and cultural heritage*, published in 1956 by Vera Vulović from the Institute for the protection and scientific research of the monuments of the People's Republic of Serbia (Vulović, 1956) reported on cleaning fresco paintings from several medieval monasteries in Serbia, and the chemical analysis of mortars used for frescos in the church of Bogorodica Ljeviška from Prizren (built 1306–1307) in Metohija, southern Serbia, the endowment of the Serbian king Stefan Milutin and a UNESCO World Heritage site. The chemical analysis determined that the composition of samples from different parts of the church walls was similar, hinting to a similar date for their painting,

with the caveat that the same materials for their production were in use for centuries.

In 1956, the archaeologist Miodrag Grbić from the Institute of Archaeology, former custodian of what is today the National Museum of Serbia, led a study of biological and ceramic material from different sites of the Neolithic Starčevo culture (6200–4500 BCE). He performed pollen analyses and radiocarbon dating at the University of Groningen in the Netherlands (Grbić, 1969), later publishing the "Neolithic period and Chronology" (1969) in the journal of the Institute of Archaeology named Starinar. In 1979, Borislav Jovanović gave an extensive overview of methods from the natural sciences that can help in the interpretation of results from archaeological research (Tasić and Jovanović, 1979). Over the next decades, many researchers from the Institute of Archaeology (in cooperation with Serbian and foreign laboratories) participated in the archaeometric investigation of stone and metal artifacts, wall paintings, pottery, brick, and glass.

2. Main laboratories participating in archaeometry studies

2.1 Institute for the Protection of Cultural Monuments of Serbia

The Institute for the Protection and Scientific Research of Cultural Monuments of the People's Republic of Serbia was established soon after WW II in 1947. It was later renamed the Republic Institute for the Protection of Cultural Monuments of Serbia – Belgrade (1960). The precursor of what is today the Laboratory for Physical and Chemical Investigations of the Institute, was an atelier with a chemical laboratory, established in 1947. In 1954, the chemical lab was equipped with the same scientific instrumentation as found in the Fogg Museum. In the same way, the laboratory continued building its analytical capacities, filling its laboratory library with specialised books, and sending its scientists to specialisations abroad – and soon the laboratory had become one of the best laboratories in the world. A part of the scientific equipment from that period is still kept for exhibition purposes.

Experts from the laboratory have conducted investigations of the most important monuments from across Serbia and the former Yugoslavia, as well as in Egypt, ancient Nubia, Pompeii, and other places. They have been engaged in forming similar labs in several countries of Latin America. Some of the widely-accepted procedures of conservation have been devised in this laboratory. One example is the extraction of salt from wall paintings. Since 1971, this laboratory has been integrated with the laboratory of the Institute. Today the laboratory performs all kinds of physical and chemical investigations of various samples from movable and stationary cultural heritage objects, such as painted layers, wall and canvas paintings, guilds, mosaics, icons, monument-building materials, binding materials, salts, and microscopic samples. An important part of investigations is related to the monitoring of micro-climate conditions, determination of moisture concentrations, and provenance. The team consists of two chemists and a technologist and is led by Aleksa Jelikić (Figure 1 shows the co-authors of this review).

2.2 Vinča Institute of Nuclear Sciences

The first impetus for archaeometry research for the Institute of Nuclear Sciences Vinča came from IAEA Technical Cooperation Projects related to the application of nuclear analytical methods for the characterisation and preservation of Cultural Heritage Objects that started in 2004. A group

Figure 1. Contributors to this article. Upper row from left to right: Velibor Andrić, Maja Gajić-Kvaščev, Daniela Korolija Crkvenjakov, and Roman Balvanović. Lower row from left to right: Aleksa Jelikić, Milica Marić Stojanović, Bojan Miljević, Snežana Vučetić, John Milan van der Bergh, Jonjaua Ranogajec, Mladen Jovičić and Emilija Nikolić.

from the Vinča Institute of Nuclear Sciences, Velibor Andrić and Maja Gajić Kvaščev from the Laboratory for Chemical Dynamics and Permanent Education, participated in five consecutive IAEA Projects. The project strengthened the Institute's capacities regarding laboratory equipment and knowledge, and established connections among scientists from the natural sciences and humanities in Serbia and abroad. The laboratory uses portable equipment such as an Energy Dispersive XRF Spectrometer (EDXRF), Fourier-transform infrared spectroscopy (FTIR), and X-ray diffraction spectrometer (XRD). In addition, several destructive analytical techniques are available, such as Flame Atomic Absorption Spectroscopy (FAAS), Graphite Furnace Atomic Absorption Spectrometry (GFAAS), Ion Chromatography (IC), and Ultraviolet-visible-near infrared Spectrophotometry (UV VIS). The team organised the first domestic conference on archaeometry, LANTERNA 2014.

In the Laboratory of Physics of the Vinča Institute, the construction of two channels for the analysis of materials with ion beams is underway. The channel for analysis in-air will be dedicated mostly to archaeometry. It will employ proton-induced X-ray emission (PIXE) and proton-induced gamma-ray emission (PIXE) methods, enabling sensitive and precise non-destructive measurements of the elemental composition of cultural heritage objects. Investigations in archaeometry started in 2017 and are led by Roman Balvanović. In collaboration with the National Museum Belgrade and Jožef Stefan Institute in Ljubljana, the team investigated a significant number of glass fragments from several archaeological sites in Serbia, dated from 2nd to 6th century AD. The team determined elemental compositions, base glass types, the technology of production, and provenance, and gave interpretations regarding commercial patterns of glass in those epochs in Serbia and the Balkans. The Laboratory of Physics of the Vinča Institute in collaboration with the National Museum of Serbia organised the Eighth Balkan Symposium on Archaeometry, held in October 2022 in Belgrade (Figure 4).

2.3 Faculty of Physical Chemistry, University of Belgrade

Pioneering work in archaeometry research at the Faculty of Physical Chemistry was done by Professor Ubavka Mioč, resulting in the scientific paper published in 2004 determining pigments used for decoration of Neolithic pottery. The systematic investigations of archaeological artefacts began in 2006. In collaboration with several domestic and foreign institutions the group employed methods of atomic emission spectroscopy (AES), absorption spectroscopy, infrared spectroscopy (IR), Raman spectroscopy, X-ray diffraction, Scanning Electron Microscopy with Energy Dispersive Spectrometry (SEM-EDS), X-ray fluorescence (XRF), and petrographic analysis. Participating in the project "Processes of urbanisation and development of medieval society", headed by the Institute of Archaeology in Belgrade, the group conducted the first systematic archaeometry investigation of Byzantine ceramics in Serbia. The investigation determined the chemical and mineralogical composition of ceramics and glaze, technology of its production, provenance and dating, which enabled interpretation of commercial routes of the epoch. The second direction of the investigation was frescos from the walls of Medieval churches and monasteries in Serbia. Using mostly micro-Raman spectroscopy (micro-destructive method), the group investigated the surface layers and cross-sections (where possible) of frescos and found natural earth pigments like red and yellow ochre, green earth, lapis lazuli, and vermilion. On the aureoles of saints, the team established that the thin foils were of gold and tin.

Among many international collaborations, the Faculty participated in the FORCA SPECLAB project (Reinforcement of the Research Capacities of the Spectroscopy Laboratory for Archaeometry) in the period 2007–2009, where the organisation of the First Balkan Symposium on Archaeometry was initiated (it was held in Ohrid, Macedonia in 2008). In addition, the project initiated the creation of the Balkan archaeometry database network, supporting cooperation between scientists, archaeologists, conservators, laboratories, and conservation centres working in the field of archaeometry. The earlier leader of the archaeometry research group was Professor Ivanka Holclajtner Antunović. Currently it is led by Professor Ljiljana Damjanović-Vasilić. There is an elective course at the Faculty of a Master's academic study programme "Physicochemical methods in archaeometry", and 18 diploma theses and 5 masters' theses have been defended so far.

2.4 National Museum of Serbia

The laboratory for physical-chemical investigations of the National Museum of Serbia, Belgrade, headed by Milica Marić Stojanović, has been developing since 2004. The laboratory has a metallographic microscope, portable EDXRF, Hyperspectral Imaging Camera (HSI) and sensitive infrared camera. Materials investigated in the lab are painted layers, ceramics, metal, glass, wood, textile, amber, and leather. Additional methods like Raman spectroscopy and Scanning Electron Microscopy (SEM) are used in collaborations with other institutions, both domestic and from abroad.

The laboratory investigated the coloured layers of paintings in the preparation of several exhibitions of important Serbian painters, including Nadežda Petrović, Paja Jovanović, Katarina Ivanović, Vlaho Bukovac, and Ignjat Job. During the recent preparation of the permanent exhibition of Flemish painters, the laboratory analysed the painting techniques of Nicolaes Berchem, Peter Rubens, Abraham van Beren, Jan van Goyen, Jan Victors, and Jan Sanders van Hemessen. The laboratory is planning to continue the analysis of fragments of 12th–16th century frescos from Serbia in preparation for restoration and conservation work and to investigate the icon "Birth of Christ" by Lorenzo Venetiano.

2.5 Institute of Archaeology

The Institute of Archaeology led the project MoDeCo 2000 (Mortar Design for Conservation – Danube Roman Frontier

2000 Years After)[1] in collaboration with the Institute for Testing of Materials Belgrade and the Faculty of Technology Novi Sad in the period from 2020 to 2022. The project researched Roman mortars from structures dated from the 1st to 6th century AD along the Roman Danube Limes in Serbia. The aim was to obtain knowledge on used raw materials and technologies of production, and to apply it in the design of compatible mortar models that should be recommended for conservation use. More than 120 samples originating from legionary fortresses, auxiliary forts, and associated civil settlements were characterised using optical and digital microscopy, spectrophotometry with colourimetry, XRF, XRD, FTIR, SEM-EDS, Raman, ICP-OES, and other laboratory techniques. The First International Conference with Workshop – Science for Conservation of the Danube Limes, was organised in Viminacium in 2022.

The project RACOLNS (Regional Absolute Chronologies of the Late Neolithic in Serbia)[2], led from 2020 to 2023 by the Institute for Balkan Studies SASA, with the Institute of Archaeology and the Faculty of Philosophy, Belgrade as partners, was conducted using the results of radiocarbon dates of organic samples and statistical seriation of ceramic assemblages.

Currently, the FLOW project (Interactions-Transmission-Transformation: Long-Distance Connections in Copper and Bronze Age of the Central Balkans)[3] is led by the Institute of Archaeology, with the Vinča Institute of Nuclear Sciences and Faculty of Philosophy – University of Belgrade, as partners. It studies the origin and potential circulation mechanisms of Copper and Bronze Age artifacts in the Central Balkans, using methods of archaeological science, focusing on provenance, spatiotemporal distribution, and Network Analyses. The analyses will include hundreds of samples of pottery, bronze, copper, obsidian, deposits of clay and copper, originating from sixty-seven archaeological sites and their surroundings.

2.6 Laboratory for Materials in Cultural Heritage – the Heritage Lab

The first regional scientific meeting on problems of humidity in cultural heritage, held in Novi Sad in 2004, has revealed the emerging need for modern equipment and easily-accessible specific knowledge for both conservators and scientists. It was an initial spark that led Prof. Jonjaua Ranogajec to create the Laboratory for Materials in Cultural Heritage – the Heritage Lab, at the Faculty of Technology, Department of Materials Engineering, today led by her and Snežana Vučetić. It investigates historical and contemporary building materials, develops novel materials for the cleaning and protection of cultural heritage artifacts, and develops new testing methods for the functionality of materials. The lab has developed considerable expertise in cleaning and protective materials that use natural phenomena: self-cleaning (UV and VIS), photocatalysis, bacterial activity, denitrification, hydrophilicity, and self-healing. It provides a consultancy service to conservationists in the diagnostic assessment of historical objects, selection of optimal conservation approaches, materials healing and protection, and long-term in-situ monitoring.

The Heritage Lab participated in the European FP7 project HEROMAT (2011–2015), which strengthened the expertise of the team and enabled the purchase of state-of-the-art equipment. It performs laboratory and in-situ analysis using XRF, XRD, SEM-EDS, FTIR, UV-VIS, IR imaging, Hg and low-temperature gas adsorption porosimetry, and micro-indentation. The laboratory performs surface and mechanical characterisation, thermic and microbiological analysis, including artificial weathering tests, and particle size measurement. The Laboratory is part of the consortium that was awarded the prominent European Prize for Cultural Heritage / Europa Nostra Awards for the conservation project of the Bač Fortress.

2.7 Gallery of Matica Srpska Novi Sad

The initiating work was the collaboration with Italian conservators and scientists on the conservation of a renaissance panel painting in 2006. The analysis of materials (mostly pigments) started in 2007, using equipment and resources from the University of Novi Sad (SEM-EDS). In 2010, a multidisciplinary group comprising scientists from the University of Novi Sad and the Vinča institute tested the in-house constructed portable EDXRF and performed a non-invasive analysis of pigments of the iconostasis of the Serbian monastery Krušedol. Daniela Korolija from the Gallery and collaborators (Figure 2) continued the work and analysed various paintings at the Gallery of Matica Srpska Museum by imaging techniques (VIS, UV and IR photography, IR reflectography, and X-ray imaging), XRF spectroscopy, and FTIR. For the analysis of cross-sections, the group uses optical microscopy and SEM-EDS.

Their recent research has included collaboration with physicists using Raman spectroscopy for pigment identification, and testing the possibility of using a medical CT scanner for the analysis of the wood of panel paintings. The group collaborates with image engineers in the use of neural networks and AI in the study of the crack maps in the paint layer. The group is active in the promotion of science in cultural heritage, organising conferences at the museum, inviting distinct scientists to present their work, and giving lectures about the principles, the benefits of science in conservation, and the role of conservators in the multidisciplinary teams of scientists.

2.8 Provincial Institute for the Protection of Cultural Monuments of Vojvodina

In the network of heritage institutes in Serbia, the Provincial Institute from Petrovaradin (Novi Sad) actively includes the

[1] Funded by the Science Fund of the Republic of Serbia through the program PROMIS.

[2] Funded by the Science Fund of the Republic of Serbia through the program PROMIS.

[3] Funded by the Science Fund of the Republic of Serbia through the program Ideas.

Figure 2. A multidisciplinary group of researchers and students, led by Daniela Korolija (in the centre) at the Gallery of Matica Srpska on the occasion of a painting authentication.

analysis of construction materials of built heritage, as well as analysis of materials of easel and wall paintings in all major conservator projects. The senior conservators, architect Slavica Vujović and painting conservator Olivera Brdarić, are the main promoters of heritage science: a necessary part of modern conservation work. The Institute is equipped with imaging techniques (UV, IR, and RX), while collaborating with the Heritage Lab from Novi Sad for other types of analysis. The Provincial institute is the editor of the dedicated annual journal which includes texts about archaeometry research, mostly regarding Vojvodina autonomous province of Serbia.

2.9 City Museum Subotica

The city museum Subotica is dedicated to the research, conservation, and presentation of the Baroque-painted heritage of Hungarian painters in Catholic churches in Vojvodina. Senior paintings conservator Zsuzsana Korhec Papp has led research projects dedicated to the study of Baroque painting techniques for over ten years, collaborating with both Serbian and Hungarian laboratories for the material analysis. The results are published in books and scientific papers.

2.10 Network of other institutions collaborating in archaeometry projects

The mentioned archaeometry groups collaborate on various projects mutually and with quite a few other institutions and laboratories in Serbia and abroad. These institutions provide either specialised analysis, or artifacts for study, or specific conservation and restoration demands. The Faculty of Mining and Geology, Belgrade University, is very important for archaeometry investigations. Besides the SEM-EDS Laboratory, it has experienced geologists Kristina Šarić, Suzana Erić and Vladica Cvetković. The faculty offers two elective courses, "Mineralogical and petrographical research in archaeometry" in undergraduate studies (led by Kristina Šarić) and "Durability and conservation of stone" in doctoral studies (led by Vesna Matović). Other institutions include the Faculty of Technology and Metallurgy, the School of Electrical Engineering, the Department of Archaeology of the Faculty of Philosophy, all from the University of Belgrade, Faculty of Applied Arts of the University of Arts in Belgrade, Institute for Testing of Materials (IMS Institute) Belgrade, and several regional museums across Serbia. Collaborative institutions from Novi Sad include the Faculty of Sciences, Faculty of Technology, and Academy of Arts.

From abroad, collaboration has been established with Institute Jožef Stefan (Slovenia), National Centre for Scientific Research Demokritos (Greece), University of Perugia and La Sapienza University (Italy), Ars Mensurae company (Italy), Joint Institute for Nuclear Reactions (Dubna, Russia), Laboratoire Dynamique, Interactions et Réactivité (LADIR) in France, and the Institute of Chemistry of the Cyril and Methodius University in Skopje (North Macedonia).

In addition, several domestic conferences which have included archaeometry presentations have been organised. The Centre for Museology and Heritage of the Faculty

of Philosophy, University of Belgrade, organised the Third Annual Conference of Museology and Heritage Science "Science and Heritage" in 2013. The Bulletin of the International Colony of Conservators, Restorers and Museum Workers, organised annually since 2016 (apart from 2022), also includes archaeometry papers. The SmartArt conference, organised by the Faculty of Applied Arts of the University of Arts in Belgrade, also publishes its book of abstracts with some archaeometry presentations.

Within the Serbian Archaeological Society (founded in 1883), there is a Section for Archaeometry, Archaeotechnology, Experimental Archaeology and Geoarchaeology, and papers on these topics are presented at the Society's annual meetings. The Section organised its first conference in 2020 and has published the proceedings.

3. Vision of the future

The science of archaeometry in Serbia is maturing – and the community is productive and growing in terms of scientific methods and equipment used, the number of participating specialists and projects, complexity of endeavours, and the increasing awareness of cultural and heritage institutions in terms of their existence and the possibilities they offer. The moment is therefore appropriate for the next phase, namely to give archeometry in Serbia a firmer structure and better interconnectivity. It would be very beneficial if the community would form a Serbian Society for Archaeometry. The goals of such an entity would be manyfold: to further interconnect research disciplines; to facilitate better use of existing equipment and coordinate the acquisition of new equipment and avoid redundant purchases; to establish a well-equipped dedicated laboratory for archaeometry; to introduce archaeometry study programs at different levels of teaching to more faculties; to introduce archaeometry as a science into the scientific research documents and plans of Serbia; to start a domestic archaeometry journal, and to further promote the awareness of the potentials of archaeometry to a wider circle of institutions dealing with cultural heritage and to the general public, thus increasing its own development possibilities.

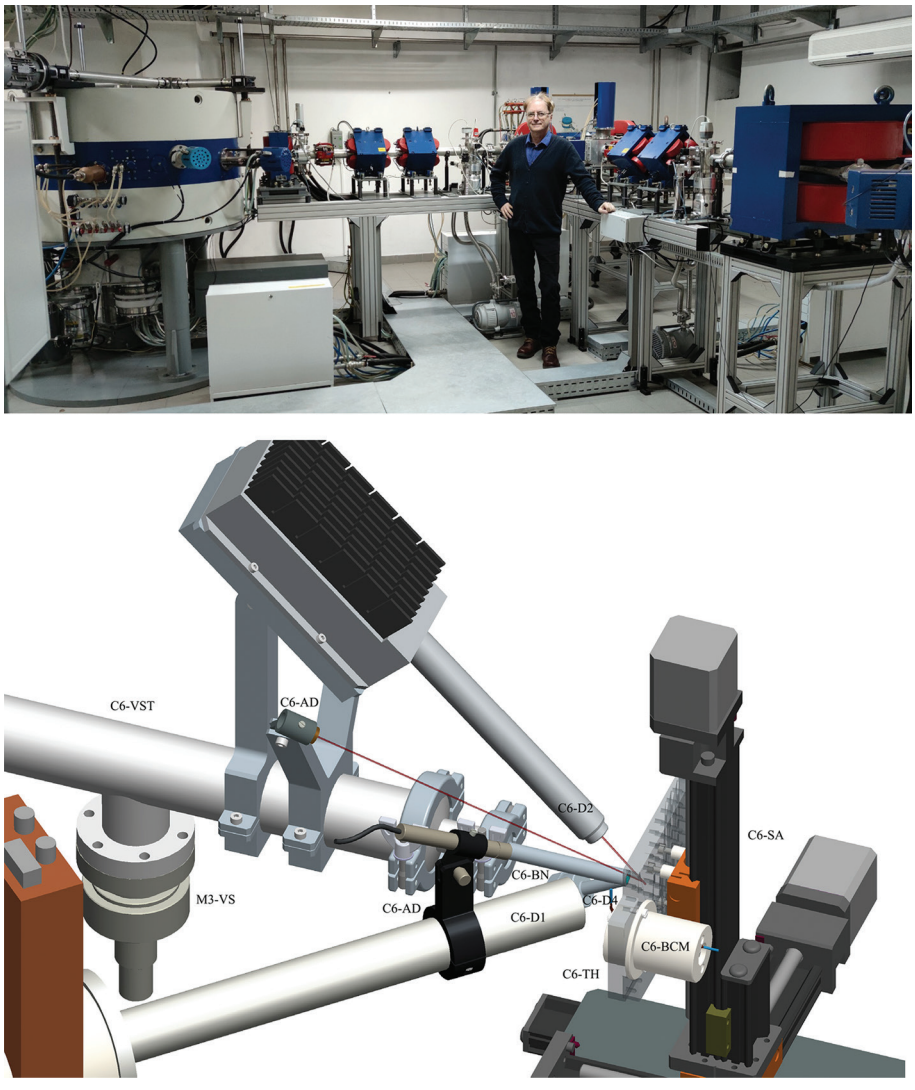

Figure 3. Upper photograph: The proton cyclotron complex (1–3 MeV, 10–100 nA) of the channels C5 and C6 for ion-beam analysis of materials of the FAMA, Institute Vinča (R. Balvanović). Lower photograph: The target area of the channel C6 for analysis in-air (in construction). The Si(Li) Detector C6-D1 is for trace elements detection, the SDD detector C6-D2 is for matrix elements, and the C6-D4 is for dose measurements. The portable gamma detector, for ultra-light matrix elements (not shown), is shared with channel C5. The samples are placed on a target holder assembly (C6-TH), equipped with x and y motors for scanning samples with proton beams.

Figure 4. Participants of the Eighth Balkan Symposium on Archaeometry, Belgrade, 3–6 October 2022.

There is already a basis for the dedicated archaeometry laboratory. In the Vinča Institute, besides the described archaeometric equipment (and other equipment not mentioned in the text), there is the Facility for Modification and Analyses of Materials with Ion Beams (FAMA) which will (after the upgrading) include proton-beam analyses methods PIXE, PIGE (both in-air and in vacuum), and RBS (Figure 3). In-air PIXE/PIGE measurements are non-destructive and are suitable to form the backbone instrumentation for an archaeometry laboratory (Balvanović, 2014). At a later stage, it will be additionally upgraded to include scanning proton micro-beams. The laboratory should be further equipped with complementary analytical techniques such as Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS), radiocarbon dating, and advanced computer applications, to mention but a few. The rich cultural heritage of Serbia undoubtedly deserves this.

References

BALVANOVIĆ, R., 2014. Kanal C6 postrojenja FAMA kao nedestruktivni alat za analizu u nauci o konzervaciji. In: M. Gajić-Kvaščev, ed. *LANTERNA 2014. I nacionalni naučni skup – nuklearne i druge analitičke tehnike u izučavanju kulturnog nasleđa.* Novi Sad: Univerzitet u Beogradu, Institut za nuklearne nauke Vinča, pp. 9–18.

GRBIĆ, M., 1969. Neolit i hronologija. *Starinar*, 20, 139–141.

TASIĆ, N., and JOVANOVIĆ, B., 1979. *Metodologija istraživanja u praistorijskoj arheologiji.* Beograd: Balkanološki institut SANU.

VASIĆ, M., 1932. *Preistoriska Vinča I. Industrija cinabarita I kosmetika u Vinči.* Beograd: Državna štamparija.

VULOVIĆ, V., 1956. *Hemija I kulturno nasleđe, Saopštenja, Knjiga 1.* Beograd: ZZNPSK.