INTERNATIONAL CONFERENCE

10TH BALKAN SYMPOSIUM ON ARCHAEOMETRY

Connecting Minds: Unveiling the Past Together

ABSTRACT BOOK



19–22 October 2026

Budapest, Hungary

Institute of Archaeology, ELTE RCH

Institute for Geological and Geochemical Research, HUN-REN RCAES

HUN REN Research Centre for Astronomy and Earth Sciences CSFK
ELTE | RCH INSTITUTE OF ARCHAEOLOGY
BASES MTA-ELTE HTK Lendület "Momentum" BASES Research Group
MTA Centre of Excellence
NATIONAL RESEARCH, DEVELOPMENT AND INNOVATION OFFICE HUNGARY PROGRAM FINANCED FROM THE NRDI FUND
National Cultural Fund of Hungary

10TH BALKAN SYMPOSIUM ON ARCHAEOMETRY

Connecting Minds: Unveiling the Past Together



ARCHAEOLINGUA

ARCHAEOLINGUA FOUNDATION
H-1067 Budapest, Teréz krt. 13.
Managing Director: Erzsébet Jerem
Desktop editing by Zsuzsanna Kiss
Printed in Hungary by Prime Rate Kft.

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Institute for Geological and Geochemical Research, HUN-REN RCAES

Budapest
2026

BSA
10th • BUDAPEST

This conference is supported by National Research, Development and Innovation Office Hungary (Project Nr. NRDI MEC_SZ_26 156921) and National Cultural Fund of Hungary (Project Nr. 503108/01547), in cooperation with the Institute of Archaeology ELTE RCH, the Institute for Geological and Geochemical Research HUN-REN RCAES, and the MTA–ELTE HTK Lendület "Momentum" BASES Research Group.













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HUNGARIAN ACADEMY OF SCIENCES











Organising Committee:

Bernadett Bajnóczi, Gabriella Kulcsár, Viktória Kiss,
Viktória Mozgai, Eszter Horváth, Ágnes Kolláth

Website design in English/in Hungarian: Gabriella Kulcsár and Viktória Mozgai
https://www.bsa2026budapest.com/

Logo: Réka Fülöpp

Editors: Bernadett Bajnóczi, Gabriella Kulcsár, Viktória Mozgai

Cover design: Zsóka Varga

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ISBN: 978-615-5766-89-3

DOI: 10.62150/10BSA.2026

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FOREWORD



We are delighted to welcome the participants of the *10th Balkan Symposium on Archaeometry – Connecting Minds: Unveiling the Past Together* to Budapest. This anniversary meeting is not only a further milestone in an international conference series spanning almost two decades, but also testament to the fact that collaboration between archaeometry, archaeology and heritage science plays a more important role than ever in research into the past.

Since its inception in 2008, the *Balkan Symposium on Archaeometry* has become one of the leading scientific forums in South-Eastern Europe. From the outset, the conference series has aimed to provide a shared platform for archaeologists, natural scientists, conservators and heritage professionals engaged in cultural heritage research, fostering methodological dialogue, the discussion of new research findings and the development of international collaborations.

The central theme of the anniversary conference in Budapest – *Crossroads of Cultures between the Balkans and Central Europe* – aptly reflects a geographical and cultural region that, for millennia, has been a meeting point for peoples, technologies, raw materials and ideas. Today, the interpretation of archaeological material is inconceivable without modern scientific analysis: scientific methods provide an increasingly detailed understanding of the lives, economies, environments and networks of past communities. The conference presentations reflect this diversity, ranging from dating techniques and materials analysis to bioarchaeology, environmental archaeology, archaeometallurgy and geoarchaeology, as well as the latest advances in digital heritage science.

The conference logo, a central element of its visual identity, features a stylised version of the spiral wave motif found on objects of outstanding importance from the Bronze Age Carpathian Basin, including the Hajdúsámson sword. Evoking the flow of water, the design refers to the close relationship between Budapest and the Danube, while also emphasising the role of rivers in connecting the different regions of the Balkans. This symbolism is further reinforced by the blue and turquoise tones of the logo. The motif thus brings together archaeological heritage, archaeometric research, the conference venue in Budapest and the regions of the Balkans.

The exceptional level of interest in this anniversary conference also reflects the dynamic development of the field. Following evaluation by the Scientific Committee, 112 scientific contributions were accepted for inclusion in the programme, comprising 77 oral presentations and 35 posters. The scientific programme is organised into twelve thematic sessions covering the principal areas of research in archaeometry, archaeological science and heritage science. It is further enriched by six keynote lectures, in which internationally recognised scholars present their latest findings, methodological innovations and wide-ranging syntheses.

The programme also includes two sponsor presentations. The poster presentations and accompanying flash talks will provide a platform for professional dialogue between different generations and offer emerging researchers an opportunity to present their work. Owing to the large number and high quality of the submissions, presentations will take place in two parallel rooms throughout the three conference days. On the fourth day, participants will also have the opportunity to visit some of Budapest's leading archaeological and scientific institutions as part of guided professional programmes, further fostering academic exchange and personal connections.

An important part of the conference's mission is to make the latest scientific findings accessible to a wider audience. Recordings of the presentations will be made available on the ELTE RCH YouTube channel, and we also plan to publish the conference papers as proceedings in a scientific journal. The conference will be accompanied by a series of podcast discussions and a public outreach lecture. In this lecture, László Bartosiewicz will commemorate Sándor Bökönyi, a member of the Hungarian Academy of Sciences who was born a century ago, an internationally recognised pioneer of modern archaeozoology and one of the founders of interdisciplinary research in Hungary. He will also introduce the wider public to current perspectives in archaeozoology.

The organising institutions of this international scientific conference, hosted in Hungary, are the Institute of Archaeology, ELTE Research Centre for the Humanities and the Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, in collaboration with the MTA–ELTE HTK Lendület "Momentum" BASES Research Group.

The conference has been made possible by support from the Scientific Patronage Programme of the National Research, Development and Innovation Office and the National Cultural Fund of Hungary, for which we express our sincere gratitude. We are also grateful to the members of the Scientific Committee for their careful evaluation of the submitted abstracts, and to all speakers and participants, whose willingness to share their research contributes to the success of the conference. The guided visits associated with the conference have been made possible through the support of the staff and leadership of the Budapest History Museum – including the Aquincum Museum and Archaeological Park, Buda Castle and the Budapest History Museum – and the Budapest Neutron Centre. We extend our warm thanks to them as well. We are also grateful to Isotoptech Zrt. and JEOL for their financial support.

We hope that the meeting in Budapest will provide not only an opportunity to present new research findings, but also to forge new collaborations, launch joint research projects and deepen our understanding of the cultural heritage of the Balkans and Central Europe. We also hope that the professional dialogues begun here will continue beyond the conference and, in the long term, strengthen the international archaeometric research community.

Thank you for joining us in Budapest. We wish you an inspiring and fruitful meeting!

The Organising Committee

COMMITTEES

Organising committee

Bernadett Bajnóczi
Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, Budapest, Hungary

Gabriella Kulcsár
Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary

Viktória Kiss
MTA–ELTE HTK Lendület "Momentum" BASES Research Group / Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary

Viktória Mozgai
Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, Budapest, Hungary

Eszter Horváth
Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary

Ágnes Kolláth
Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary

Scientific committee

Alexandra Anders
Institute of Archaeological Sciences, Eötvös Loránd University, Budapest, Hungary

Roxana Bugoi
Horia Hulubei National Institute for Nuclear Physics and Engineering, Bucharest, Romania

Matija Črešnar
University of Ljubljana, Ljubljana, Slovenia

János Dani
Department of Archaeology, University of Szeged, Szeged, Hungary

Dragana Filipović
University of Algarve, Algarve, Portugal & University of Bucharest, Bucharest, Romania

Zsolt Kasztovszky
Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary

Attila Kreiter
Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary

Rovena Kurti
Institute of Archaeology, Albanian Academy of Sciences, Tirana, Albania

Cătălin Lazăr
The Research Institute of the University of Bucharest, Bucharest, Romania

Enikő Magyari
Department of Environmental and Landscape Geography, Eötvös Loránd University, Budapest, Hungary

Ina Miloglav
University of Zagreb, Zagreb, Croatia

Goce Naumov
Goce Delcev University, Shtip, North Macedonia

Mario Novak
Institute for Anthropological Research, Zagreb, Croatia

Eleni Papadopoulou
Ephorate of Antiquities of Chania, Chania, Greece

Hristo Popov
National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria

Milica Marić Stojanović
National Museum of Serbia, Belgrade, Serbia

Anna Szécsényi-Nagy
Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary

Zita Szikszai
Laboratory for Heritage Science, HUN-REN Institute for Nuclear Research, Debrecen, Hungary

Veronika Szilágyi
Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary

Béla Török
Institute of Chemical Metallurgy and Foundry Engineering, University of Miskolc, Miskolc, Hungary

Manca Vinazza
University of Ljubljana, Ljubljana, Slovenia

CONFERENCE PROGRAMME

10TH BALKAN SYMPOSIUM ON ARCHAEOMETRY

Connecting Minds: Unveiling the Past Together

Budapest, Hungary

19–22 October 2026

https://www.bsa2026budapest.com/

Location: Institute of Archaeology ELTE RCH

Research Centre for Human Sciences of Hungarian Academy of Sciences

Conference hall and Room K11/12, ground floor

H-1097 Budapest, 4 Tóth Kálmán Street

10TH BALKAN SYMPOSIUM ON ARCHAEOMETRY

Four-day programme overview

19–22 October 2026 | Budapest

DAY 1

Monday, 19 October 2026

TIME	CONFERENCE ROOM	ROOM K11/12
08:30	Registration	
09:00	**Opening ceremony**	
09:30	**Keynote lecture 1**	
10:20	**Session 2/Ceramics/1–2**	**Session 1/1–2**
11:00	**Coffee break**	
11:40	**Session 2/Ceramics/3–6**	**Session 3/1–4**
13:00	**Lunch break**	
14:00	**Keynote lecture 2**	
14:40	**Session 2/Ceramics/7–9**	**Session 4/1–3**
15:40	**Coffee break**	
16:10	**Session 2/Glass/1–4**	**Session 4/4–7**
17:30	**Poster session with flash talks I**	
19:00	Icebreaker	

DAY 2

Tuesday, 20 October 2026

TIME	CONFERENCE ROOM	ROOM K11/12
08:30	Registration	
09:00	**Keynote lecture 3**	
09:40	**Session 2/Glass/5–6; Session 2/Metals/1–2**	**Session 5/1; Session 6/1; Session 7/1–2**
11:00	**Coffee break**	
11:30	**Session 2/Metals/3–6**	**Session 7/3–7**
13:10	**Lunch break**	
14:10	**Keynote lecture 4**	
14:50	**Session 2/Stone & Marble/1–2**	**Session 8/1–2**
15:30	**Coffee break**	
16:00	**Session 2/Stone & Marble/3–5**	**Session 8/3–5**
17:10	**Poster session with flash talks II**	
19:30	Conference dinner in Budapest	

DAY 3

Wednesday, 21 October 2026

TIME	CONFERENCE ROOM	ROOM K11/12
08:30	Registration	
09:00	**Keynote lecture 5**	
09:40	**Session 2/Others/1–5**	**Session 9/1–5**
11:20	**Coffee break**	
11:50	**Session 10/1–5**	**Session 12/1–5**
13:30	**Lunch break**	
14:30	**Keynote lecture 6**	**Session 11/1–4**
15:00	**Sponsor presentations**	
16:00	Roundtable	
17:00	End of the conference	

DAY 4

Thursday, 22 October 2026

09:00	**Guided visits**
	Aquincum Museum and Archaeological Park
	Buda Castle and Budapest History Museum
	Budapest Neutron Centre

DAY 1 Monday, 19 October 2026 | Morning programme

TIME	CONFERENCE ROOM	ROOM K11/12
08:30	REGISTRATION	
09:00	**OPENING CEREMONY**	
09:30	**Keynote lecture 1 — Elisabetta Starnini:** *Green archaeometry for a green archaeology: A new paradigm*	
10:10	**Technical break & room change**	
10:20	**S2/Ceramics/1** Manca Vinazza et al.: *Miniature ceramic bottles from Eneolithic cave cemetery Ajdovska jama, Slovenia*	**S1/1** Angeliki Kandri et al.: *Resolving structural instability in a cinerary urn and lid from the Isthmia Archaeological Museum utilizing 3D technologies*
10:40	**S2/Ceramics/2** Mădălina Dimache and Mădalina-Florentina Voicu: *Archaeometric characterization of Eneolithic pottery from Bordușani-Popină (Romania)*	**S1/2** Elena Badea and Cristina Carsote: *Enabling cross-collection comparisons in collagen degradation by standardised microDSC and MHT protocols*
11:00	**COFFEE BREAK**	
11:40	**S2/Ceramics/3** Ákos Mengyán: *Ceramic raw material procurement and tempering practices in the Late Bronze Age Maklár: Implications for social dynamics*	**S3/1** Szulamit Emma Horváth and Zsófia Masek: *The conservation process of a Gepidic-period spatha with silver mountings and wooden scabbard remains*
12:00	**S2/Ceramics/4** Csaba Bodnár et al.: *Archaeometric investigation of the chaîne opératoire of Mycenaean stirrup jars through the integration of X-ray radiography, XRF analysis and macroscopic observations*	**S3/2** Violeta Karailieva and Veselina Chakarova: *Manufacturing process revealed through archaeometry and conservation – A case study of a bronze artefacts from the site of "Gerena"*
12:20	**S2/Ceramics/5** Barbara Borgers et al.: *Ceramic technology and craft communities in 1st–2nd century AD: A view from Noricum*	**S3/3** Xanthippi Foulidi et al.: *Material characterisation using non-destructive techniques: The case of the Ephesiou summer house*
12:40	**S2/Ceramics/6** Dorottya Györkös et al.: *Glazed ceramic products of a Late Roman workshop in Pannonia Valeria*	**S3/4** Bojana Savić et al.: *Thin films from liquid-phase exfoliated h-BN as protective coatings for mural paintings preservation*
13:00	**LUNCH BREAK**	

DAY 1 Monday, 19 October 2026 | Afternoon programme

TIME	CONFERENCE ROOM	ROOM K11/12
14:00	**Keynote lecture 2 — Jelena Živković and Vesna Bikić:** *Archaeology and archaeometry in dialogue: Studies of medieval and early modern ceramics in the Middle Danube region*	
14:30	**Technical break & room change**	
14:40	**S2/Ceramics/7** Boglárka Döncző and Marianna Bálint: *Bottles at the crossroads: Archaeometric insights into Árpádian Age ceramic vessels at Hajdúböszörmény-Téglagyár*	**S4/1** Anett Osztás et al.: *From ore to ornament: The life history of Late Neolithic copper jewellery from Alsónyék-Bátaszék (southern Hungary)*
15:00	**S2/Ceramics/8** Veronika Szilágyi et al.: *Medieval whiteware in NE Hungary: Identification of provenance-related and technological features*	**S4/2** Zsuzsanna Siklósi et al.: *The provenience of the Early Copper Age Szeged-Szillér hoard*
15:20	**S2/Ceramics/9** Bálint Péterdi et al.: *Integrating historical clay collections into ceramic provenance studies*	**S4/3** János Dani et al.: *Compositional analysis of the Middle Copper Age hoard of Bagota*
15:40	**COFFEE BREAK**	
16:10	**S2/Glass/1** Kata Dévai et al.: *Glass recycling on the Danube frontier: Preliminary archaeometric results from the Brigetio workshop*	**S4/4** Gabriela Ilieș et al.: *The use of mineral resources of Maramureș in prehistoric metal deposits from Northwestern Romania. XRF analyses*
16:30	**S2/Glass/2** Roxana Bugoi et al.: *Exploring Roman and Late Antique glass finds from Dinogetia, Romania*	**S4/5** Athina Nikolopoulou and Eleni Filippaki: *Copper ingots and axes: Rethinking copper forms in the prehistoric Aegean*
16:50	**S2/Glass/3** Žiga Šmit and Tina Milavec: *Post-antique glass on the territory of Eastern Alps*	**S4/6** Tena Karavidović et al.: *Roman iron semi-products in circulation: Standardisation and variability in production practices — evidence from the Hrvatska Dubica iron-bar assemblage, Croatia*
17:10	**S2/Glass/4** Roman Balvanović et al.: *Provenance of Byzantine glass bracelets from the 11th–12th century Braničevo and Morava (Serbia)*	**S4/7** Gergely Szenthe et al.: *Silver sources in the "long eighth century" of East-Central-Europe*
17:20	**Technical break & room change**	
17:30	**Poster session with flash talks I**	
18:30	End	
19:00–21:00	**ICEBREAKER**	

10TH BALKAN SYMPOSIUM ON ARCHAEOMETRY

Connecting Minds: Unveiling the Past Together

DAY 2 Tuesday, 20 October 2026 | Morning programme

TIME	CONFERENCE ROOM	ROOM K11/12
08:30	REGISTRATION	
09:00	**Keynote lecture 3 — Christina Papageorgopoulou:** *Resilient cities, fragile lives: Diversity, crisis, and survival in ancient Thessaloniki*	
09:30	**Technical break & room change**	
09:40	**S2/Glass/5** Mudit Trivedi et al.: *High boron glass beads in Central European Early Iron Age glass networks: New data from Herzegovina*	**S5/1** Mirela Mihon et al.: *Sample preparation and AMS 14C analyses of wood from Târgșoru Vechi-Holcim*
10:00	**S2/Glass/6** László Előd Aradi et al.: *Unveiling the Monomachos crown: Archaeometric insights into the materials and medieval glassmaking technology*	**S6/1** Dorottya Láng: *From sea to summit: Marine shell beads in the Late Bronze Age hoards of Somló Hill*
10:20	**S2/Metals/1** Todor Valchev and Danail Yovchev: *Non-destructive SEM-EDS analysis of the silver and gold hair-rings from the Early Bronze Age from the Lower and Middle course of the Tundzha River, Bulgaria*	**S7/1** István Major et al.: *Isotopic dietary and palaeoenvironmental reconstruction of a Mesolithic hunter-gatherer from the Hódmezővásárhely-Gorzsa sand mine No. 5 site, SE-Hungary*
10:40	**S2/Metals/2** Monica Dinu et al.: *Beyond typology and upgrading showcase display: Insights into Late Bronze Age / Early Iron Age craftsmanship for museum valorization*	**S7/2** Jelena Jovanović et al.: *Diet and settlement patterns during the Neolithic in the Southern Carpathian Basin*
11:00	**COFFEE BREAK**	
11:30	**S2/Metals/3** Šárka Krupičková et al.: *“Bommelohrringe” between Balkans and Central Europe*	**S7/3** Aurelien Tafani et al.: *Why studying Neolithic mobility in the Eastern Balkans requires crossing modern borders*
11:50	**S2/Metals/4** Eszter Horváth et al.: *A Byzantine masterpiece in the Avar Khaganate: Archaeometric reassessment of the polychrome buckle from Kunbábony*	**S7/4** Christophe Snoeck et al.: *Exploring the potential of isotope analyses in Slovenian Archaeology*
12:10	**S2/Metals/5** Zuzana Borzová et al.: *Archaeometric and technological investigation of a lunula-shaped enamel temple ring from the 10th–11th century burial ground at Hontianska Vrbica (Slovakia)*	**S7/5** Chen Kozulin: *Epigenetics of ancient Pannonia populations*
12:30	**S2/Metals/6** András Török: *Surface treatments on medieval small finds: A case study*	**S7/6** Mackenzie Masters et al.: *At an isotopic crossroads: An intersectional study of a ’mass grave’ from Romano-Byzantine Ibida (Romania) applying archaeothanaotlogy, bioarchaeology, and isotopic proxies*
12:50		**S7/7** Yusuf Can Özdemir et al.: *Genetic contrast and dietary differences between neighbouring elite and low-status burial groups in the Middle–Late Avar period*
13:10	**LUNCH BREAK**	

DAY 2 Tuesday, 20 October 2026 | Afternoon programme

TIME	CONFERENCE ROOM	ROOM K11/12
14:10	**Keynote lecture 4 — László Bartosiewicz:** *Navigating between disciplines: The Bökönyi centenary*	
14:40	**Technical break & room change**	
14:50	**S2/Stone&Marble/1** Kata Furholt et al.: *Tracing the social lives of white stone and serpentinite artefacts in the Balkans and the Carpathian Basin during the 6th and 5th millennia BCE*	**S8/1** Péter Csippán: *Stratigraphical and spatio-temporal analysis of the animal bone finds of the Late Neolithic tell-like settlement of Öcsöd-Kováshalom, Hungary*
15:10	**S2/Stone&Marble/2** Diego Seguí-Fábián et al.: *Archaeometric analysis of high-pressure meta-ophiolitic pebbles from Oligocene conglomerate outcrops near Carrosio (Italy)*	**S8/2** Linoy Namdar and Zsuzsanna Siklósi: *A multi-method dental approach to herd management and paleodietary reconstruction in Copper Age cattle from Hungary*
15:30	**COFFEE BREAK**	
16:00	**S2/Stone&Marble/3** Tamás Sági et al.: *Complex petrographic and geochemical provenance analysis of Late Neolithic polished stone tools made of alkaline igneous raw materials from Alsónyék-Bátaszék (S-Hungary)*	**S8/3** Stella Nikolova et al.: *What went down the well: Animal husbandry and ritual consumption at Emporion Pistiros*
16:20	**S2/Stone&Marble/4** Erika Kereskényi et al.: *Preliminary results of petrographical examinations of polished stone tools from Szeleta Cave, Bükk Mountains, Hungary*	**S8/4** Erika Gál and Gyöngyi Kovács: *Animal bone remains from the Csókakő Castle: Cultural and environmental imprints*
16:40	**S2/Stone&Marble/5** Eszter Melis et al.: *A moment of power? Investigating a Bronze Age composite macehead from Nagycenk (Western Hungary)*	**S8/5** Kata Szathmári: *Bone applications of fishing nets*
17:00	**Technical break & room change**	
17:10	**Poster session with flash talks II**	
18:00	End	
19:30	**Conference dinner in Budapest**	

10TH BALKAN SYMPOSIUM ON ARCHAEOMETRY

Connecting Minds: Unveiling the Past Together

DAY 3 Wednesday, 21 October 2026 | Morning programme

TIME	CONFERENCE ROOM	ROOM K11/12
08:30	REGISTRATION	
09:00	**Keynote lecture 5 — Alexandra Rodler:** *From raw materials to color: Archaeometric perspectives on pigment production and trade*	
09:30	**Technical break & room change**	
09:40	**S2/Others/1** Adina Boroneanț and Monica Mărgărit: *Function and use-wear of Early Neolithic bone spoons: Evidence from SW Romania*	**S9/1** Dragana Filipović et al.: *Finds of flax/linseed at prehistoric sites in Serbia and Romania and the issue of flax seed size*
10:00	**S2/Others/2** Angelina Pirovska et al.: *Technological continuity vs. turnover: A comparative archaeometric study of Neolithic and Chalcolithic ceramic pigments across the Balkan Peninsula and the Carpathian Basin*	**S9/2** Rebeka Solti et al.: *Combining morphometry and organic residue analyses to understand Copper Age pottery use in the Carpathian Basin*
10:20	**S2/Others/3** Dorottya Láng et al.: *Remains of an Early Copper Age burnt house from Noşlac (Romania)*	**S9/3** Mateja Hulina et al.: *Molecular traces of Copper Age life: Lipid analysis of Lasinja culture pottery from Poljana Križevačka 2, Croatia*
10:40	**S2/Others/4** Milica Marić Stojanović et al.: *Fresco fragments from the remains of the 11–13th century church in Senta-Crkveno Brdo, Serbia*	**S9/4** Ines Nabernik Bošnjak et al.: *Lunch at the lake: Organic residue analysis from the pile-dwelling site of Stare gmajne (late 4th millennium BC, Ljubljansko barje, Slovenia)*
11:00	**S2/Others/5** Veronika Nagy and Béla Török: *Color change of pigments characteristic in medieval wall paintings*	**S9/5** Beatrice Ciuta: *Microstructural analysis of carbonized porridge from a Dacian settlement in north-western Romania*
11:20	**COFFEE BREAK**	
11:50	**S10/1** Denitsa Sandeva-Minkova et al.: *In search of the past: Integrated remote sensing and geophysical approaches in archaeological research on the Ludogorsko Plateau, Northeastern Bulgaria*	**S12/1** Laura Dietrich et al.: *Project WEAR: A methodological framework for experimental and computational analysis of stone tool uses*
12:10	**S10/2** Nadezhda Kecheva et al.: *AI ArchaeoTopia: AI-assisted georeferencing and mound-symbol extraction from archival topographic maps of Bulgaria*	**S12/2** Gábor Mesterházy et al.: *Settlement pattern analysis and predictive modelling with a probabilistic approach in the Tiszazug microregion, Eastern Hungary*
12:30	**S10/3** Corina Borș et al.: *Seeing the unseen: The archaeological site of Tărtăria-Podu Tărtăriei vest after more than a decade since its discovery*	**S12/3** Eszter Solnay et al.: *Mapping technological knowledge and social connections: Network analysis of Copper Age pottery forming in the Carpathian Basin*
12:50	**S10/4** Rebeka Mesterházy-Gergácz et al.: *The possibilities and limitations of using various non-destructive investigations on multiperiod settlements in the Vál Valley*	**S12/4** Ioan Gabriel Mircea et al.: *Protocol for interdisciplinary data harvesting aimed at continuous bioarcheological and geological research improvement with machine learning computing techniques*
13:10	**S10/5** Barbora Weissová et al.: *Peak under the canopy. Exploring Osogovo Mountains using LiDAR, remote sensing and ground control*	**S12/5** Ákos Ekrik: *A digital workflow for the documentation and analysis of carved building stones*
13:30	**LUNCH BREAK**	

DAY 3 Wednesday, 21 October 2026 | Afternoon programme

TIME	CONFERENCE ROOM	ROOM K11/12
14:30	**Keynote lecture 6 — Vania Virgili:** *From instruments to interpretation: The new challenges of heritage science*	**S11/1** Alfred Vespremeanu-Stroe et al.: *Large rivers, small rivers and rising seas: Long-term settlement strategies in the Lower Danube and Western Black Sea region*
15:00	Laurent Vasse: *JEOL Scanning Electron Microscopy – Versatility in imaging and analysis*	**S11/2** Nino Sulava et al.: *Reconstructing the Late Bronze Age–Iron Age metallurgical society of Colchis through palynological evidence*
15:20	Anna Szigeti and István Major: *Isotopech Zrt.*: *Providing archaeometry services through isotope analysis*	**S11/3** Miklós Kázmér et al: *Destructive earthquakes in ancient Tomis (Constanța, Romania) – Archaeoseismological and historical data*
15:40		**S11/4** Tena Karavidović et al.: *Workspaces and areas of exploitation – Geoarchaeological record of the iron production environments in altered lowland landscapes*
16:00	Roundtable: *Connecting Minds: Unveiling the Past Together — Integrating Archaeology and Archaeometry*	
17:00	**End**	

DAY 4 Thursday, 22 October 2026 | Guided visits

TIME	PROGRAMME
09:00–14:00	**Aquincum Museum and Archaeological Park** **Buda Castle and Budapest History Museum** **Budapest Neutron Centre**

Keynote lectures



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Monday, 19 October 2026



Elisabetta Starnini

University of Pisa, Italy

Green archaeometry for a green archaeology: A new paradigm

The «green archaeometry» concept will be introduced as a new paradigm for a sustainable method of research in archaeology. Sustainable as aimed at providing the archaeologists with tools for recognizing the combination of the compositional, technological, and typological macroscopical markers, for identifying a specific production without destructive and expensive analyses, as in the case of ceramics. Moreover, in the spirit of «green archaeology» the aim is to recycle and reuse old samples for reanalysis, rather than resample for new analyses and to limit new sampling to the strict necessary. Archaeological deposits continue to be consumed all over the world and in some cases exhausted despite the awareness acquired over the years that excavation is a destructive operation, and that technological progress and scientific methodological advances instead provide us with increasingly less invasive investigation techniques. In many cases, new and groundbreaking information has been achieved simply by restudying old collections of thin sections in the light of new knowledge and with new, holistic approaches. Some case-studies of green archaeometry for green archaeology will be illustrated.

Monday, 19 October 2026





Jelena Živković and Vesna Bikić

University of Tübingen, Germany
Institute of Archaeology, Belgrade, Serbia

Archaeology and archaeometry in dialogue: Studies of medieval and early modern ceramics in the Middle Danube region

During the medieval and early modern periods, the Middle Danube was largely a frontier region that brought different social actors into cross-cultural exchange, as reflected in the ceramic record. While the complex dynamics of cultural continuity and discontinuity have long been recognized in archaeology, the integration of archaeometric approaches into ceramic studies has significantly improved our understanding of the mechanisms underlying these processes.

Research on the transmission of technological knowledge demonstrates the strong impact of political change on local craftsmanship. In Belgrade, the Ottoman conquest in 1521 marked the beginning of new production practices that differed from those of the period of Hungarian rule across all segments of the chaîne opératoire, as demonstrated by petrographic and chemical analyses of ceramics.

New data on ceramic production technologies along the Danube, Sava, and Drava rivers indicate the formation of two technological traditions that emerged in the Middle Danube Region during the Ottoman period. The first concerns the production of tableware and storage vessels formed by wheel-throwing, both glazed and unglazed, typical of Ottoman urban centres. The second tradition centres on pottery formed by hand and hand-turning wheel that was used for cooking and baking. Archaeological criteria indicate consistency in the use of functional vessel classes, as well as uniformity in vessel profiles within each class across the region. Provenance studies and the reconstruction of ceramic, slip, and glaze production technologies reveal the exchange of knowledge among multiple workshops within both technological traditions of the Middle Danube region. These emerging networks of knowledge exchange illustrate connectivity between socially diverse communities shaped by migrations and warfare on the frontier.

Tuesday, 20 October 2026



Christina Papageorgopoulou

Democritus University of Thrace, Greece

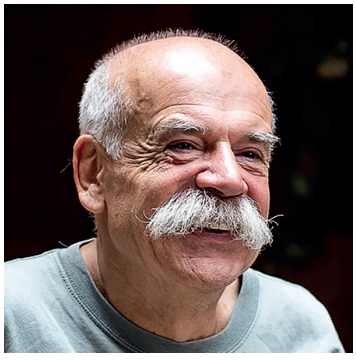
Resilient cities, fragile lives: Diversity, crisis, and survival in ancient Thessaloniki

CityLife is an ERC-funded project that investigates, from a bioarchaeological perspective, how past populations adapted to urban environments and developed resilience to the inherent challenges of urban life. By analyzing human skeletal remains, the project examines the role of biological factors in the durability and sustainability of pre-industrial urban societies. The research focuses on Thessaloniki, a major European urban center that provides a unique opportunity to study urban life diachronically from 300 BC to AD 1500. *CityLife* explores key aspects of past societies, including living conditions, economic structures, population dynamics, pathogen load, and immune responses.

This presentation highlights the use of ancient DNA analysis to investigate how trade, migration, and exogamous marriage practices contributed to increased genetic diversity at the population level in urban environments. At the same time, the formation of social, religious, and neighborhood-based subgroups may have promoted endogamy, reducing genetic diversity within those communities. In parallel, stable isotope analysis, skeletal stress markers and innovative computational tools are used to assess the resilience and sustainability of urban food systems. These approaches help determine how such systems responded to crises and long-term transformations, as well as how population growth and socioeconomic disruptions affected their efficiency.

Preliminary genetic results confirm the diverse and multicultural character of Thessaloniki's population. Demographic evidence points to cycles of prosperity and growth, interrupted by periods of significant stress. Indicators of developmental stress, disease, and mortality – especially among infants and children – suggest that urban life posed substantial challenges from an early age. Ongoing research explores hypotheses related to food inequality, religious dietary restrictions, and shifts in diet before and after major conflicts, epidemics, and periods of social instability.

Tuesday, 20 October 2026



László Bartosiewicz

Stockholm University, Sweden

Navigating between disciplines: The Bökönyi centenary

Sándor Bökönyi, the founder of modern archaeozoology in Hungary, was born in 1926. Holding a degree in veterinary science, he devoted his entire life to archaeological research. Through his investigations in the Balkans and Southwest Asia, he achieved results of international importance in elucidating past animal-human relationships. Notably, he was one of the few, whose approach was truly interdisciplinary in Hungarian archaeology at the time. He played a prominent role in representing archaeology at the level of the Hungarian Academy of Sciences. A generation's time has passed since his untimely death. It is therefore instructive to review the current state of archaeozoology in light of his career and the perspectives of archaeozoological research in Hungarian archaeology.

Wednesday, 21 October 2026



Alexandra Rodler

Austrian Archaeological Institute
of the Austrian Academy of Sciences
Vienna, Austria

From raw materials to color: Archaeometric perspectives on pigment production and trade

Color played a central role in the ancient world, not only as an aesthetic choice but as material expression shaped by resource availability and technological knowledge. Vibrant palettes drew on a wide range of mineral pigments from naturally occurring materials requiring minimal processing – such as ochre and cinnabar – to complex, multicomponent materials produced through high-temperature technologies such as Egyptian blue. Ancient texts emphasize that material quality and provenance mattered, yet the origins of these materials or where they were processed remain poorly understood. Some pigments derived from rare resources and appear sparingly in the archaeological record, while others made from more accessible raw materials were widely used and possibly circulated far.

This keynote presents new insights from the ERC-funded project *Color in a New Light,* which situates pigments within broader frameworks of production, trade, and cultural interaction. Despite their importance, pigments remain understudied compared to materials such as metals: pigment provenance research still needs robust methodologies and comprehensive reference databases. As a result, interpretations of pigment origins and circulation remain challenging.

Focusing on Egyptian blue as a key case study, this keynote traces shifts in supply networks and explores the potential reorganization of pigment industries in the 1st century BCE. Produced in high-temperature workshops from calcium-, silica-, and copper-based compounds with added flux, Egyptian blue exemplifies the intersection of technological knowledge and resource procurement. Its manufacture appears closely linked to glass and metal production, suggesting shared workshops and overlapping trade networks. However, only a few production centers have been identified, and provenance studies remain scarce. The limited data available point to the use of distant copper sources, underscoring the complexity of these supply systems. By reconstructing pigment production and trade, this research sheds new light on ancient connectivity and contributes to a more nuanced understanding of technological and economic organization.

Wednesday, 21 October 2026



Vania Virgili

European Research Infrastructure for Heritage Science, E-RIHS ERIC
Florence, Italy

From instruments to interpretation: The new challenges of heritage science

Instruments produce measurements. Research questions require interpretation. Between the two lies the contribution of heritage science, and its challenges: complex research questions no single technique can answer, data that must stay usable long after a project ends, and research that crosses disciplinary and national boundaries.

E-RIHS ERIC, the European Research Infrastructure for Heritage Science (www.e-rihs.eu), brings together expertise and capabilities across Europe. Through four platforms – ARCHLAB, FIXLAB, MOLAB and DIGILAB – it provides access to state-of-the-art facilities, instruments, archives, collections and digital resources. Researchers can combine them, designing investigations around the research question rather than the capabilities of a single laboratory. This matters in archaeometry, where complementary analytical approaches reveal different aspects of an artefact's materials, manufacture and history. The HS Academy adds doctoral schools, training camps and webinars.

Heritage science is asked today for more efficient methods to interpret heritage in its cultural contexts, and stronger capacity to respond to climate and human-induced pressures. Growing, heterogeneous data change how knowledge is created, while AI opens new possibilities and raises questions of quality, reliability and ethics. The E-RIHS Scientific Strategy 2026–2030 answers in four pillars: scientific and technological advancement for emerging needs; data-driven research within the European digital ecosystem; balanced access, training and community engagement; and enlargement and operational excellence.

In archaeometry, connecting measurement to interpretation is not new: it is integral to the field. What changes is the scale at which it becomes possible, and the degree to which national strengths can become shared European capacity. E-RIHS provides a framework for working at that scale, shaped by those who use it, provide services through it and partner in its development.

Sponsor presentations



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Wednesday, 21 October 2026

Laurent Vasse

JEOL (EUROPE) SAS
Croissy-Sur-Seine

JEOL Scanning Electron Microscopy – Versatility in imaging and analysis

Electron microscopes for material science including heritage sciences from JEOL are developed to support users to investigate large variety of samples with several techniques. We will introduce our portfolio from tabletop JCM-7000 Neoscope to JSM-IT710(HR) and JSM-IT810 FEG SEMs with presenting solutions of particle analysis and automatic functions from JEOL in order to cover several aspects of needs for automative workflow.

Anna Szigeti and István Major

Isotoptech Zrt.
Debrecen, Hungary

Isotopech Zrt.: Providing archaeometry services through isotope analysis

Over the past few decades, the focus of archaeological, anthropological and cultural heritage research has broadened to incorporate a variety of natural scientific and instrumental analytical approaches. The Isotoptech Zrt. laboratory in Debrecen, Hungary, is expertised in isotope analytical methods, and we have decades of experience in the field.

The radiocarbon dating laboratory is equipped to handle a wide variety of archaeological samples, including bone, tooth, cremated bone and plant remains, such as seeds, charcoal and wood. Despite the small amount of sample required for the analysis thereby protecting our common heritage, our measurements are conducted with a low background and high level of precision.

On most of the mentioned sample types, stable isotope ratio measurements (C, N, O, S or Sr) can also be completed. Analysing stable isotope ratios is a widely preferred method for detecting past dietary, mobility and migration habits, as well as environmental conditions and changes over time.

Oral presentations and posters

ABSTRACTS

Sessions 1–12

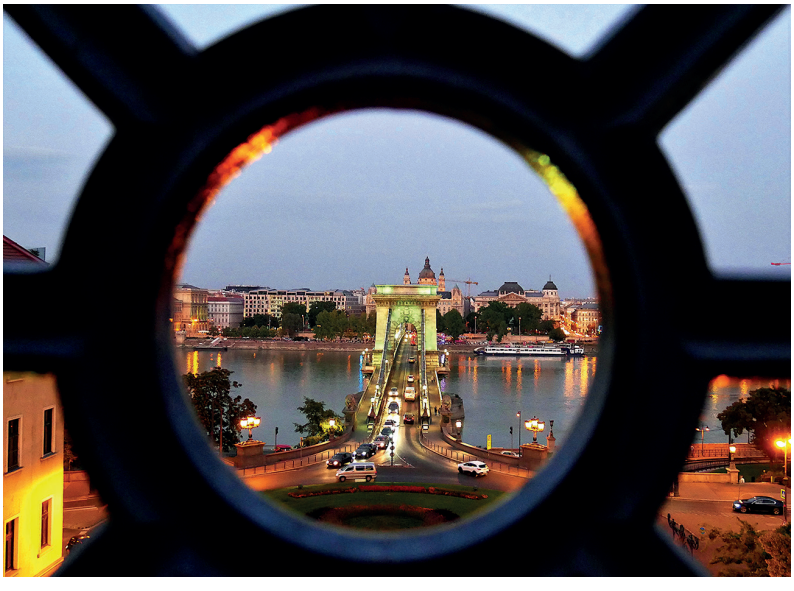


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Session 1

PROBING THE PAST

Advanced analytical toolkits for heritage science



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Resolving structural instability in a cinerary urn and lid from the Isthmia Archaeological Museum utilizing 3D technologies

Angeliki Kandri[1], Theodore Ganetsos[2,3], Antreas Kantaros[4] and Joseph L. Rife[5]

[1] University of West Attica, Athens, Greece, angel_kandri@uniwa.gr
[2] University of West Attica, Athens, Greece, ganetsos@uniwa.gr, ORCiD: 0000-0003-2081-4960
[3] Laboratory for Materials and Cultural Heritage, Faculty of Technology, University of Novi Sad, Serbia
[4] University of West Attica, Athens, Greece, akantaros@uniwa.gr, ORCiD: 0000-0001-7927-1468
[5] Department of Classical and Religious Studies, Vanderbilt University, Nashville, Tennessee, USA

Keywords: *conservation and preservation, 3D scanning, 3D printing, cinerary urn*

Preserving cultural property constitutes a fundamental priority within contemporary heritage science. Given the inevitable degradation of archaeological material, implementing non-destructive documentation and restoration workflows is paramount. This paper evaluates a digital preservation strategy applied to a Roman-era cinerary urn and its matching lid, currently stored in the Isthmia Archaeological Museum. The vessel was unearthed from Tomb 7 on the Koutsongila Ridge, located in the north cemetery at Kenchreai, the eastern port of Corinth, and dates from the 1st to the early 2nd century CE, serving an essential funerary function within a multi-generational household that makes it vital for interpreting local burial customs. Due to severe fragmentation, initial conservation required the structural bonding of all fragments; however, significant material loss along the vessel's upper rim resulted in severe instability, preventing the lid from being properly supported. To achieve stabilization with minimal physical intervention, this research leverages high-resolution 3D structured light scanning and 3D printing. A handheld 3D scanner captured high-fidelity surface geometries, which were post-processed to generate an accurate digital mesh. Through virtual restoration techniques, the missing segments of the rim were digitally reconstructed to match the exact profile of the lid. The missing volumes were then fabricated via desktop 3D printing using compatible polymers. Post-processing operations were applied to refine and color-match the physical inserts, ensuring seamless integration. This non-contact approach leads to the successful restoration of the structural and aesthetic integrity of the archaeological assembly, offering a precise, reversible solution for complex pottery restoration.

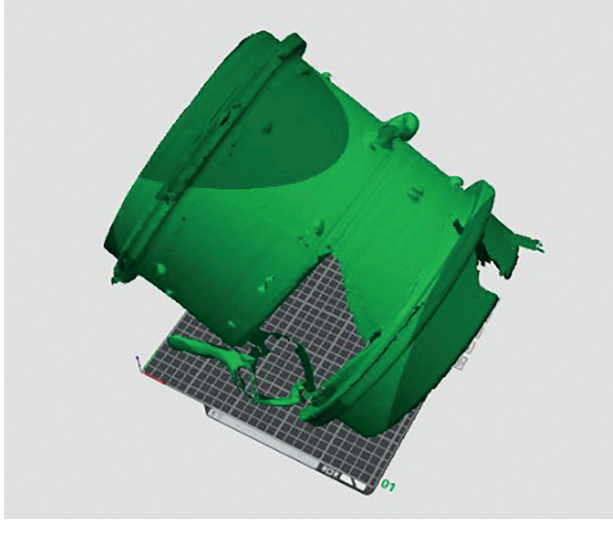
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The cinerary urn vessel during processing in the 3D scanner software

Notes

Enabling cross-collection comparisons in collagen degradation by standardised microDSC and MHT protocols

Elena Badea[1,2] and Cristina Carsote[3]

[1] Department of Chemistry, Faculty of Sciences, University of Craiova, Romania, elena.badea@edu.ucv.ro, ORCiD: 0000-0003-1437-2844
[2] The Research Institute, University of Bucharest, Romania
[3] Centre for Research and Physical-Chemical and Biological Investigations, National Museum of Romanian History, Bucharest, Romania, criscarsote@yahoo.com, ORCiD: 0000-0002-6137-9961

Keywords: *collagen, microDSC, MHT, standardisation, damage assessment, integrated analytical workflow*

Collagen-based archaeological materials, including skin and leather, are highly heterogeneous and sensitive to environmental stressors [1]. Assessing their degradation is challenging. This study introduces standardised protocols for micro-differential scanning calorimetry and micro hot table (MHT) as complementary tools for evaluating collagen preservation. MicroDSC yields quantitative data on collagen thermal denaturation, detecting changes in the heat absorbed or released during a process and transition temperatures associated with structural alterations. MHT measures the temperature at which collagen fibres shrink, a direct indicator of material stability. The proposed standardisation addresses sample preparation, measurement conditions, data processing, and reporting criteria to improve reproducibility across laboratories and materials. Particular attention is given to the challenges arising from heterogeneous specimens, limited sampling, and variability in historic manufacturing and burial conditions. This dual thermal analysis is particularly effective in clarifying the interpretation of complex degradation histories when complemented by attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR) and carbon-13 solid-state nuclear magnetic resonance (^{13}C NMR) [2]. A harmonised analytical workflow facilitates the classification of degradation states, supports comparison between collections, and reinforces the scientific basis for conservation decisions. It is particularly advantageous for studies of collagen-rich artefacts where minimal sample consumption and high sensitivity are required [3]. The rationale, protocol design, and interpretive potential of standardised thermal analysis within a multiscale-, multi-technique analytical platform for archaeological research are discussed [4].

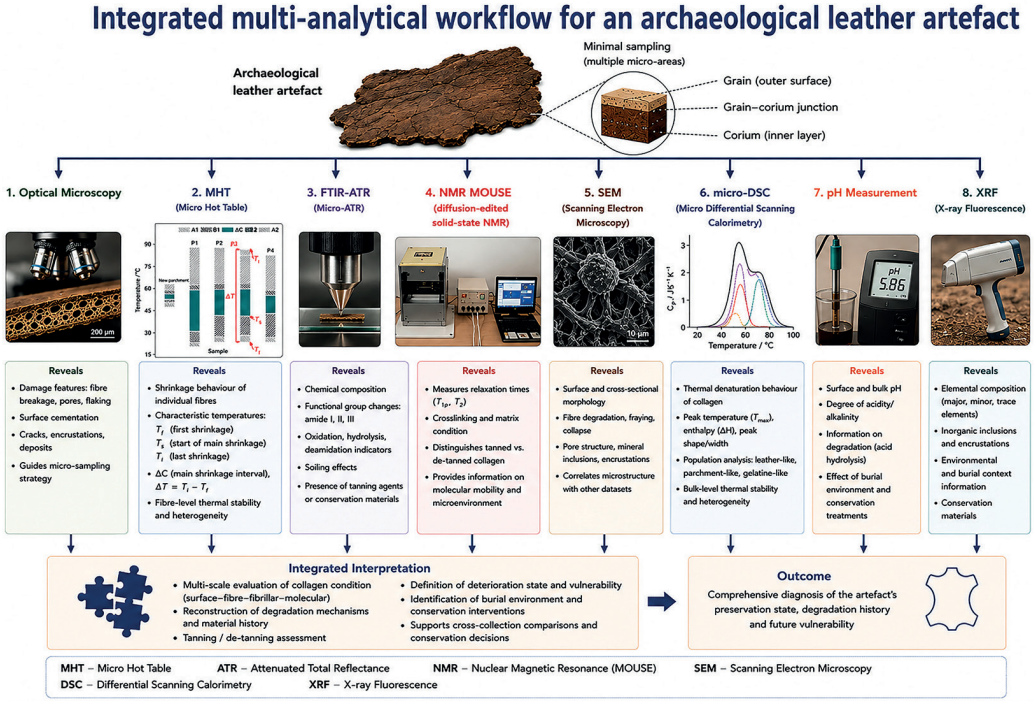
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Integrated multi-scale analytical workflow for archaeological leather, combining microscopy, MHT, FTIR-ATR, NMR MOUSE, SEM, micro-DSC, pH and XRF to characterize collagen preservation, deterioration mechanisms, and burial-related alterations

Notes

Session 2

THE ARTEFACT'S ANATOMY

Deep dives into material characterisation



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Miniature ceramic bottles from Eneolithic cave cemetery Ajdovska jama, Slovenia

Manca Vinazza[1], Lidija Korat Bensa[2], Milena Horvat[3] and Nastja Rogan Šmuc[4]

[1] Department of Archaeology, Faculty of Arts, University of Ljubljana, Ljubljana, Slovenia, manca.vinazza@ff.uni-lj.si, ORCiD: 0000-0002-5261-8473
[2] ZAG – Slovenian National Building and Civil Engineering Institute, Ljubljana, Slovenia, lidija.korat@zag.si, ORCiD: 0000-0002-8209-4308
[3] Trbovlje, Slovenia, milena.horvat@ff.uni-lj.si
[4] Department of Geology, Faculty of Natural Sciences and Engineering, University of Ljubljana, Ljubljana, Slovenia, nastja.rogan@ntf.uni-lj.si

Keywords: *ceramic bottles, archeometry, Eneolithic, cave cemetery*

Ajdovska jama is the only known Eneolithic cave cemetery in Slovenia. Several groups of graves have been identified here, and in some cases, miniature ceramic bottles were found as grave goods. Other ceramic bottles from Slovenia originate from Neolithic and Eneolithic settlements, which makes Ajdovska jama even more intriguing. For this reason, we decided to study the bottles from the perspective of the ceramic *chaîne opératoire* to understand their forming and decoration techniques, as well as their use and function.

To achieve this, we employed a range of analytical techniques. The integration of these approaches enabled a more comprehensive understanding of their use and function by providing insights from both organic and inorganic perspectives. Sampling presented a significant challenge, as the objects are of national importance and therefore required exceptional care during analysis, while their small dimensions further restricted the quantity of material available for sampling.

Beginning with macroscopic analysis, we were able to define the objectives of the study. A broad range of analyses allowed us to use various techniques to investigate several aspects from the production to the use, as we obtained data from both organic and inorganic perspectives. Ceramic thin-section analysis, in combination with micro-CT, provided insight into the clay paste and forming techniques. Later, micro-CT results also helped guide the implementation of sampling strategies for geochemical and organic residue analyses.

The combination of optical microscopy, X-ray powder diffraction, and high-resolution inductively coupled plasma mass spectrometry has provided better insight into the characterisation of ceramic bottles made from local clay without temper. Evidence of surface treatment was also identified, likely resulting from the use of beeswax. The elemental composition of the bottles is associated with increased levels of chromium, copper, phosphorus, lead, titanium, and zinc.

Additionally, our study provides important information on the forming techniques of the ceramic bottles, whose deposition within a burial context suggests a deliberate and potentially symbolic function, which will be explored through the integrated results of the various analyses.

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Ceramic bottle from Ajdovska jama showing the chromatographic profile and X-ray computed tomography results

Notes

Archaeometric characterization of Eneolithic pottery from Bordușani-Popină (Romania)

Mădălina Dimache[1] and Mădalina-Florentina Voicu[2]

[1] National Museum of the Romanian History, Bucharest, Romania, dimachemadalina@gmail.com
[2] National Museum of the Romanian History, Bucharest, Romania

Keywords: *pottery, Eneolithic, Romania*

The Gumelnița culture is one of the most representative expressions of the Eneolithic in the northern Balkan Peninsula, with a range covering vast regions of southern Romania – Muntenia, eastern Oltenia, southeastern Moldavia, and Dobrogea – as well as the southern Danubian territories of Bulgarian and Greek Thrace.

This extension defines the Gumelnița–Kodžadermen–Karanovo VI cultural complex, whose communities evolved between 4600–3900 BC. Among the numerous archaeological sites identified, the Popina-Bordușani Eneolithic tell settlement (Ialomița County, southeastern Romania) represents a key archaeological sequence for investigating the maximum development of this culture (phase A2) north of the Danube. Its extensive stratigraphy reaches, in places, a thickness of up to 8 meters of anthropic accumulation. Essential aspects of daily life at that time included pottery production, a complex workflow involving the careful selection of raw materials, shaping, decoration, and firing in specialized kilns.

To preserve a ceramic artifact's inherent historical integrity and data retention, minimizing post-excavation handling and intervention is paramount. In strict alignment with this principle, treatment of the vessel under study was restricted to gentle cleaning and structural reassembly. By deliberately omitting chemical consolidation, the artifact's pristine material matrix remains completely uncompromised, thereby expanding the scope and viability of prospective archaeometric investigations.

Consequently, the petrographic, optical microscopy, and chemical analyses carried out on the ceramic samples from Popina-Bordușani have provided essential information on manufacturing technologies, raw material provenance, and the dynamics of craft traditions. The results of this research indicate a persistence of traditional manufacturing and utilitarian customs, suggesting a cultural continuity deeply rooted within the local community.

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Notes

Ceramic raw material procurement and tempering practices in the Late Bronze Age Maklár: Implications for social dynamics

Ákos Mengyán[1,2]

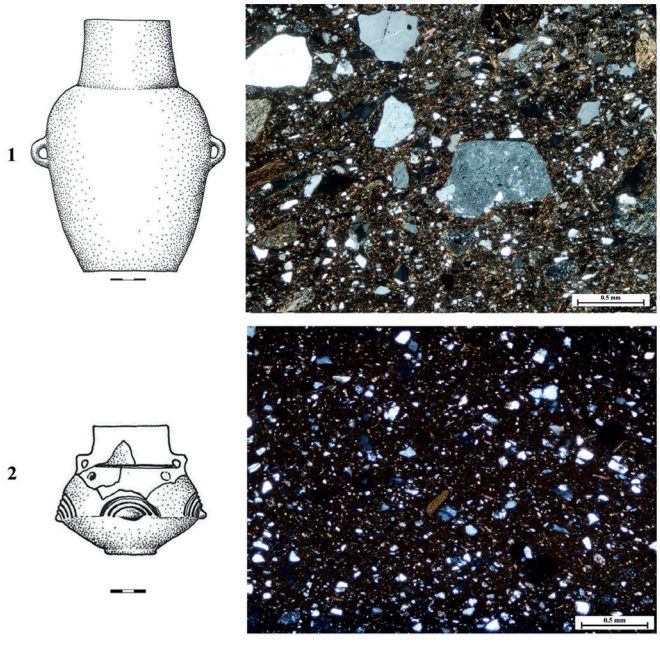
[1] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, mengyanakos@gmail.com, ORCiD: 0000-0002-8946-7023
[2] Institute of Exploration Geosciences, University of Miskolc, Miskolc, Hungary

Keywords: *Bronze Age, Carpathian Basin, Tumulus culture, ceramic analysis, thin section petrography*

This study presents a comparative technological analysis of ceramic assemblages from two contemporaneous Late Bronze Age (1500–1300 BC) cremation cemeteries in the Carpathian Basin: Maklár-Koszpérium (121 burials) and Maklár-Nagyrét II (210 graves). Attributed to the Tumulus period (Reinecke BzB2–C), these sites are situated in close geographic proximity (1.5 km in beeline) in the vicinity of Maklár in northeastern Hungary, raising crucial questions regarding their simultaneous use and the social dynamics of the communities.

To explore the relationship between these burial sites and social groups, this research investigates ceramic manufacturing traditions, specifically focusing on raw material choice and tempering practices. Representative samples of funerary vessels and local sediments were analysed using thin-section petrography and X-ray powder diffraction (XRPD), with the mineralogical data further evaluated via Principal Component Analysis (PCA) to distinguish subtle compositional patterns.

The results reveal pronounced technological discrepancies between the two cemeteries, primarily manifested in distinct tempering recipes and fabric preparation strategies. While both communities utilized similar local geological resources, they maintained discrete, localized technological choices. These variations argue against a single, homogeneous pottery-making tradition and instead indicate differences in the social backgrounds and micro-identities of the individuals, using the two cemeteries. Consequently, these technological divergences could offer a plausible explanation for the maintenance of two separate, but closely situated funerary sites, suggesting that the parallel funerary landscape at Maklár might reflect the deliberate coexistence of two socially differentiated communities. Additionally, phase changes in the clay matrixes indicate that firing temperatures for both assemblages were consistently placed between 600 °C and 850 °C.



Drawings of the analysed vessels and its thin sections
from grave 13 of Maklár-Koszpérium (photomicrographs: 40X, +N)

Notes

Archaeometric investigation of the chaîne opératoire of Mycenaean stirrup jars through the integration of X-ray radiography, XRF analysis and macroscopic observations

Csaba Bodnár[1], Mátyás Horváth[2] and Zoltán May[2]

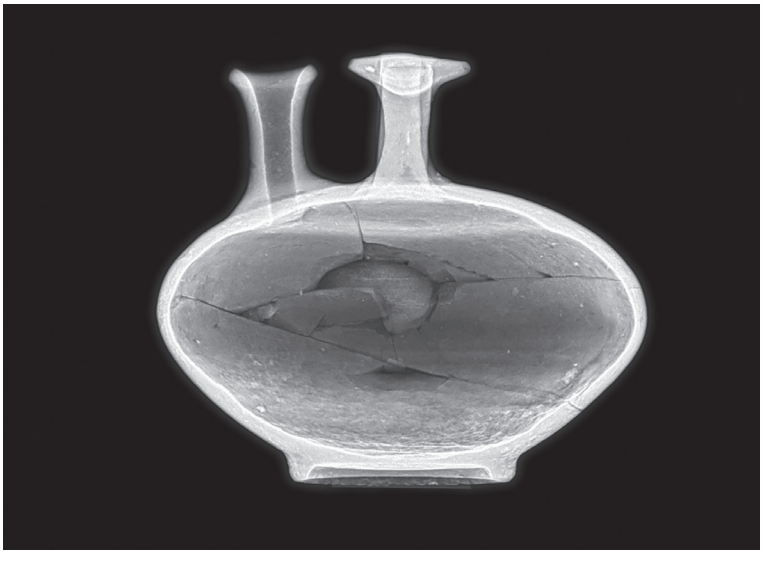
[1] Middle Eastern Collection and Zichy Collection, Ferenc Hopp Museum of Asiatic Arts, Budapest, Hungary, bodnar.cs@gmail.com
[2] Diagnostic Department, Museum of Fine Arts Budapest, Budapest, Hungary

Keywords: *pottery, Mycenaean, chaîne opératoire, X-ray radiography, XRF*

The stirrup jar is a characteristic vessel type of the Late Bronze Age Aegean pottery assemblages. Originating in Crete, it became a key form in Mycenaean ceramic production and was widely distributed across the eastern Mediterranean during the 14th–13th centuries BC. Large numbers of these vessels have been found on Cyprus, in Egypt, and in the Levant, where they were most likely imported for their contents, although evidence for local production is also attested at several sites, indicating complex patterns of manufacture and exchange. Despite their abundance and broad distribution, very few studies have approached this vessel type from a technological perspective and attempted to comprehensively document its entire manufacturing sequence, which could provide important insights into production contexts and places of manufacture.

This paper examines a group of Mycenaean stirrup jars, mostly originating from Cyprus, kept in the collection of the Museum of Fine Arts, Budapest. The study investigates their complete chaîne opératoire from forming techniques through surface treatment to painting methods, in order to assess technological choices at each stage of manufacture. The analysis integrates multiple non-destructive methods, including macroscopic examination, X-ray radiography, photodiagnostic imaging techniques, and portable X-ray fluorescence (XRF) measurements conducted at several points on each vessel.

The datasets obtained through these methods are evaluated comparatively in order to identify similarities and differences in the production practices represented by the vases. The results are used to assess whether the observed morphological, technological, and compositional characteristics reflect a coherent production tradition or point to multiple manufacturing practices. Ultimately, the study aims to determine whether the analyzed vessels can be associated with a specific production region or workshop tradition, thereby contributing to broader discussions on Mycenaean ceramic production, exchange networks, and consumption patterns in the eastern Mediterranean.



Radiographic image of a Mycenaean stirrup jar

Notes

Ceramic technology and craft communities in 1st–2nd century AD: A view from *Noricum*

Barbara Borgers[1], John Gait[2], Katalin Bajnok[3] and Martin Auer[4]

[1] Department of Geosciences, University of Padua,
Padua, Italy, barbara.borgers@unipd.it, ORCiD: 0000-0002-3739-9866
[2] Budapest Neutron Centre, Institute for Energy Security and Environmental Safety,
HUN-REN Centre for Energy Research,
Budapest, Hungary, john.gait@ek.hun-ren.hu, ORCiD: 0000-0002-9566-4090
[3] Budapest Neutron Centre, Institute for Energy Security and Environmental Safety,
HUN-REN Centre for Energy Research,
Budapest, Hungary, bajnok.katalin@ek.hun-ren.hu, ORCiD: 0000-0001-8040-3202
[4] Institut für Archäologien, Universität Innsbruck,
Innsbruck, Austria, Martin.Auer@uibk.ac.at, ORCiD: 0000-0002-6566-9157

Keywords: *Roman pottery, production technology, provenance, practice communities*

Tripod bowls are a distinctive shape in the Late Iron Age in southern central Europe, in the area that would become the Roman province of *Noricum* and *Pannonia* around the turn of the 1st century BC/AD. Their subsequent spread to eastern Europe, which would later become the Roman province of *Dacia*, around the turn of the 2nd century AD, is viewed in light of the detachment of *Norican-Pannonian* soldiers to this part of the Roman Empire [1]. However, little is known about the workshops in Noricum where these bowls were manufactured.

This paper examines 35 tripod bowls from five towns (*municipia*) and roadside settlements (*vici)* in *Noricum*, dating between 50 and 150 AD, with the aim of characterising their technology and origin. To this end, macroscopic observations are combined with thin section petrography [2], stable isotope analysis [3] and small-angle neutron scattering analysis [4]. The compositional data are compared with the local geology to determine whether these bowls were produced locally.

Preliminary results indicate the existence of two main technological traditions: the first includes wheel-thrown tripod bowls with coarse, poorly sorted calcite/marble inclusions, while the second tradition comprises coarse, moderately sorted sedimentary rock/sand inclusions, formed with hand-building techniques followed by secondary wheel-shaping. In combination with the regional geology, these data suggest that the bowls were produced locally or in the vicinity of the investigated sites, although little to no direct evidence of workshops was found.

The findings further indicate that two craft communities were active in this part of *Noricum*; one community practiced hand-building according to pre-Roman traditions in the study area, and the other adopted wheel-throwing. Using a different forming technique, this latter community appears to have settled in *Noricum* in the wake of new opportunities offered by the development of the Roman province.

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Tripod bowl, dating to the 2nd century AD, from Aguntum (modern-day Dölsach), Noricum

Notes

Glazed ceramic products of a Late Roman workshop in Pannonia Valeria

Dorottya Györkös[1], Bernadett Bajnóczi[2], Péter Pekker[3], Máté Szabó[4], Stefan Röhrs[5] and György Szakmány[6]

[1] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, gyorkos.dorottya@hnm.hu, ORCiD: 0000-0003-4011-6342
[2] Institute for Geological and Geochemical Research, HUN-REN Research Center for Astronomy and Earth Sciences, Budapest, Hungary, bajnoczi.bernadett@csfk.org, ORCiD:0000-0003-0006-7611
[3] Research Institute of Biomolecular and Chemical Engineering, University of Pannonia, Veszprém, Hungary, pekkerpeter@gmail.com, ORCiD: 0000-0002-0463-0742
[4] Institute for Geological and Geochemical Research, HUN-REN Research Center for Astronomy and Earth Sciences, Budapest, Hungary, szabo.mate@csfk.org, ORCiD: 0009-0006-7544-3692
[5] Rathgen-Forschungslabor, Stiftung Preußischer Kulturbesitz, Berlin, Germany, s.roehrs@smb.spk-berlin.de, ORCiD: 0000-0002-8713-3572
[6] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, szakmany.gyorgy@ttk.elte.hu, ORCiD: 0000-0002-9557-2030

Keywords: *lead glaze, lead feldspar, waste products, slag, production technology*

Despite the large number of late Roman glazed ceramics excavated throughout Pannonia, relatively few studies have examined their material composition in the Danubian provinces [1, 2]. In this study, Late Roman glazed and unglazed household ceramics, along with associated slags, excavated in the vicinity of Környe in the northern part of the former Pannonia Province, were investigated. The archaeological site lies only six kilometers to the north from the late Roman inner military fortress, most probably referred to as Vincentia in former Pannonia Valeria province [3]. The site comprises two Late Roman pottery kilns containing deformed glazed vessel fragments and vitrified kiln debris, indicating local ceramic production. After macroscopic investigation, a total of 93 samples were analysed using petrography, SEM–EDX, EPMA–EDX, XRD, micro-XRD, and TEM.

The finds can be divided into two main groups based on the characteristics of the ceramic bodies, although the majority of the vessels show similar production technology [4]. Most of the bodies are poorly-sorted, containing sub-angular to sub-rounded very fine to very coarse-grained non-plastic inclusions in the matrix. Comparative analysis of sediments from nearby sand quarries suggests that local raw materials were used for the ceramic bodies. Glazing technology – involving the use of a lead oxide–silica mixture coloured by iron – was consistent throughout the assemblage. Some of the glazed ceramics are characterised by the occurrence of unique, unusually large newly-formed lead feldspar crystals within the glaze (up to 360 μm). TEM studies revealed that these feldspar crystals exhibit twinning and are associated with amorphous phases containing higher lead and lower alumina contents.

In terms of chemical composition, the lead feldspars range from calcium-rich to potassium-rich end-members. The occurrence of newly formed mineral phases (such as diopside, mullite, gehlenite) in both the slags and ceramic bodies further supports high firing temperatures.

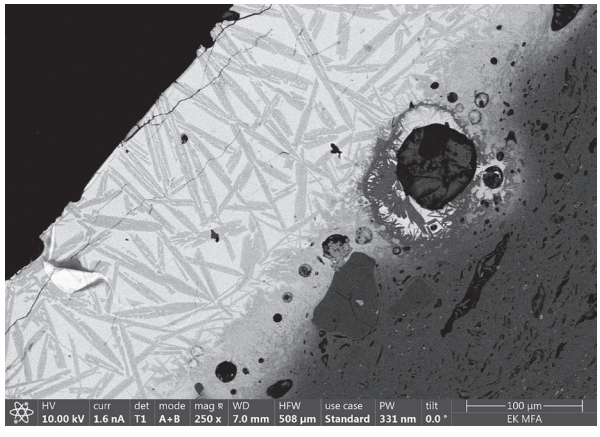
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Characteristic microstructure and newly-formed crystals of Late Roman glazed ceramics, Környe, Hungary

Notes

Bottles at the crossroads: Archaeometric insights into Árpádian Age ceramic vessels at Hajdúböszörmény-Téglagyár

Boglárka Dönczö[1] and Marianna Bálint[2]

[1] HUN-REN Institute for Nuclear Research,
Debrecen, Hungary, donczo.boglarka@atomki.hu, ORCiD: 0000-0002-8915-0923
[2] Hajdúsági Museum,
Hajdúböszörmény, Hungary, regesz@hajdusagimuzeum.hu, ORCiD: 0009-0001-5980-456X

Keywords: *bottles, Árpádian Age, Ismaelithes, petrographic thin section*

The Hajdúböszörmény-Téglagyár site, historically identified through toponymic and archival research as a central settlement of the early medieval Ishmaelite (Muslim) community in northeastern Hungary, remains one of the region's most prominent yet underexplored archaeological locations. Despite its significance, excavations have covered only a small fraction of the extensive Árpádian period village. Nevertheless, even from these limited trenches, a rich and highly diverse ceramic assemblage has been recovered, most notably featuring an unusually high frequency of bottles and water-carrying vessels – which deviates from typical patterns observed in other Árpádian age settlements [1]. These vessels exhibit considerable variation in form, fabric, and manufacturing technique, with some displaying distinctive characteristics that suggest Byzantine influence or provenance [2, 3].

To clarify the function, provenance, and production techniques of these vessels, petrographic thin-section analysis was conducted on ten selected ceramic samples. This archaeometric approach integrates materials science with archaeological context, yielding insights into local ceramic traditions, potential exchange networks, and the material culture of the site's early medieval Ishmaelite inhabitants. The findings contribute to reconstructing the settlement's chronology and spatial organization, while underscoring the value of systematic scientific analysis for understanding medieval Muslim communities in Central Europe.

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Assorted bottles from the Hajdúböszörmény-Téglagyár site

Notes

Medieval whiteware in NE Hungary: Identification of provenance-related and technological features

Veronika Szilágyi[1], Erika Simonyi[2], Gábor Tomka[3], Zoltán Kovács[4], Péter Kónya[5], Katalin Gméling[6], Attila Kreiter[7] and Mária Wolf[8]

[1] Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary, szilagyi.veronika@ek.hun-ren.hu, ORCiD: 0000-0001-8522-676X
[2] Hungarian National Museum, Budapest, Hungary, simonyi.erika@hnm.hu, ORCiD: 0000-0002-2441-4756
[3] Hungarian National Museum, Budapest, Hungary, tomka.gabor@mnm.hu, ORCiD: 0009-0003-1386-342X
[4] HUN-REN Centre for Energy Research, Budapest, Hungary, kovacs.zoltan@ek.hun-ren.hu, ORCiD: 0009-0005-8564-4132
[5] Supervisory Authority of Regulatory Affairs, Budapest, Hungary, peter.konya@sztfh.hu
[6] HUN-REN Centre for Energy Research, Budapest, Hungary, gmeling.katalin@ek.hun-ren.hu, ORCiD: 0000-0003-0253-0745
[7] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, kreiter.attila@mnm.hu, ORCiD: 0000-0002-8339-1021
[8] University of Szeged, Szeged, Hungary, wolfmaria55@gmail.com, ORCiD: 0000-0002-4181-6765

Keywords: *white pottery, production, petrography, microstructure, composition*

White-colored ceramic was a relevant component of assemblages in several European regions in the Middle Ages (e.g. English Surrey whiteware, German stoneware, Northern and Southern French whiteware, medieval whiteware of Poland and Slovakia). Having high aesthetic value, it was a subject of general demand through time and space. However, due to specific manufacturing requirements (e.g. purified from coloring agents, controlled firing, sometimes less workability), its production always was an intentional technological choice. Whiteware was manufactured in specialized, intermediate-to-large-scale production centers [1, 2].

To connect to European whiteware research and to determine the circumstances of production, a detailed study on medieval Hungarian whiteware (HWW), appearing in the 12th/13th c., blooming in the 13th–16th c., and being a pottery type with well described forms, size and decorations, has started [3]. HWW has a specific medieval distribution pattern showing concentration in the mountainous area of NE Hungary. This work focuses on HWW assemblages of 13 NE Hungarian Arpad Era to Late Medieval archaeological sites (Abaújvár, Füzér, Komlóska, Sárospatak, Tiszaeszlár, Tiszalök, Felsőzsolca, Feldebrő, Kács, Sály, Muhi, Ónod, Hejőkeresztúr) to discover the material characteristics identifying the raw material and technology by OM, SEM-EDS, PGAA, NAA and XRD methods. Microfabric investigations revealed that the selected raw material was so appropriate for white pottery production that no elaborate preparation was done. Instrumental mineralogical and chemical investigations proved that multiple sources were applied for the raw material selection. Our study shows that medieval

HWW was a standardized, multi-provenanced pottery type of the Hungarian Kingdom with a simple paste preparation technology. These features emphasize the importance of identifying exact clay sources during our future research.

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Hungarian whiteware — 1: Ónod 122 (15th–16th c.); 2: Muhi 62 (15th–16th c.); 3: Feldebrő 30 (incised-glazed ware, 15th–16th c.); 4: Ónod 124 (13th–14th c.); 5: Sály-Lator 17 (13th–14th c.); 6: Muhi 78 (15th–16th c.). Photo: Erika Simonyi

Notes

Integrating historical clay collections into ceramic provenance studies

Bálint Péterdi[1], Veronika Szilágyi[2], Orsolya Viktorik[3], László Máté[4] and Attila Kreiter[5]

[1] Supervisory Authority for Regulatory Affairs, Budapest, Hungary, peterdi.balint@gmail.com, ORCiD: 0009-0000-8474-9518
[2] Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary, szilagyi.veronika@ek.hun-ren.hu, ORCiD: 0000-0001-8522-676X
[3] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, viktorik.orsolya@hnm.hu, ORCiD: 0000-0003-1628-9403
[4] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, mate.laszlo@hnm.hu, ORCiD: 0000-0003-1832-1286
[5] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, kreiter.attila@hnm.hu, ORCiD: 0000-0002-8339-1021

Keywords: *ceramic archaeometry, clay collection, experimental firing, whiteware, Carpathian Basin*

There is a continuous demand in ceramic archaeometry – mainly in provenance studies – for the systematic processing and use of clay databases. Our work demonstrates the research potential of analysing samples from historical collections such as the so-called Kalecsinszky Clay Collection.

This collection was established at the turn of the 19th and 20th centuries in the former Hungarian Royal Geological Institute, by S. Kalecsinszky and his colleagues. The aim of the collection was to compile the clay resources used in handicraft and industrial production across the Carpathian Basin and to investigate their firing and refractory properties [1]. The collection – raw clay samples and the samples of experimental firings – reached to nearly 1,000 pieces encompassing all the larger and more important clay deposits of the Carpathian Basin, as well as many smaller and less important ones, and a few comparative samples from outside the Carpathian Basin.

Despite the turbulent fate of the collection in the 20th century, a substantial portion of the original assemblage – more than 700 specimens – has been preserved and is accessible for study today in the Supervisory Authority for Regulatory Affairs (SARA, the legal successor of the Geological Institute). This collection offers significant potential for research in ceramic archaeometry.

As a case study, white or light-coloured clays were selected from the collection. After experimental firing, their thin section petrographic characteristics were compared with those of white ceramics ranging from the Middle Ages (12th c.) to the Modern Period (19th c.) in the Kingdom of Hungary. Our aim was to refine the identification of raw material sources and

thereby contribute to discussions of provenance and ceramic technological choices [2].

The authors thank SARA and HNM PCC HNM for the financial support. V. Szilágyi is supported by the Bolyai János Research Fellowship of the HAS.

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A clay sample displayed in a special glass container in the "History of Collections" showcase of the permanent exhibition at SARA

Notes

Glass recycling on the Danube frontier: Preliminary archaeometric results from the Brigetio workshop

Kata Dévai[1], Nadine Schibille[2], Bernadett Bajnóczi[3] and István Fórizs[4]

[1] HUN-REN–ELTE Research Group for Interdisciplinary Archaeology, Hungarian Research Network – ELTE Eötvös Loránd University, Budapest, Hungary, kata.devai@gmail.com, ORCiD: 0000-0002-3624-7246
[2] IRAMAT-Centre Ernest-Babelon, UMR 7065 CNRS, Université d'Orléans, Orléans, France, nadine.schibille@cnrs-orleans.fr, ORCiD: 0000-0001-9242-0392
[3] Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, Budapest, Hungary, bajnoczi.bernadett@csfk.org, ORCiD: 0000-0003-0006-7611
[4] Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, Budapest, Hungary, forizs.istvan@csfk.org, ORCiD: 0000-0003-0813-6079

Keywords: *Roman glass, glass recycling, secondary glassworking, opaque glass, archaeometry*

The secondary glassworking workshop excavated in the civil town of Brigetio (Pannonia), active in the late second to early third century AD, is one of the best documented Roman glassworking contexts on the Danube frontier. Furnaces and refuse deposits yielded raw glass chunks, cullet, production waste, malformed beads, vessel and window-glass fragments, and snake-thread decorated beakers, allowing production and recycling to be investigated within a secure context [1, 2].

The coexistence of vessel and bead production is important. Deformed beads display opaque white, yellow, blue and turquoise decorative glasses comparable to applied trails on locally produced snake-thread vessels, while similarly coloured raw glass and production residues occur in the same assemblage [1, 2]. This permits relationships between raw materials, decorative glasses, finished and failed products, and recycling to be examined within one workshop.

The study combines scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). SEM-EDS characterises glass composition, colourants, opacifiers and microstructural features. LA-ICP-MS analyses at IRAMAT-Centre Ernest-Babelon provide high-resolution elemental data for raw glass, cullet, vessel and window-glass fragments, bead waste and decorative components. Together, the methods distinguish compositional groups and supply streams, assess mixing and recycling, and compare base glasses with coloured and opaque components [3, 4].

The project asks which primary natron glass groups supplied Brigetio, whether one or several supply streams were involved, how extensively cullet was reused or mixed, and wheth-

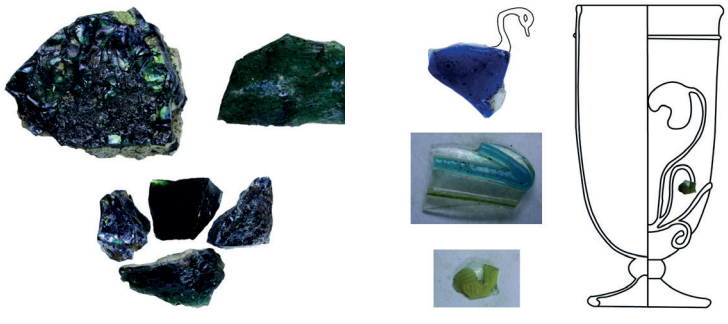
er coloured and opaque glasses were imported pre-coloured, modified locally, or repeatedly recycled. Particular attention is paid to links between coloured raw glass, decorated beads and applied trails on snake-thread vessels.

The project will provide the first integrated workshop-scale archaeometric dataset for Roman glassworking in Pannonia, clarifying material selection, recycling and decorative glassworking on the Danube frontier.

This research was supported by the 2026 Rakow Grant for Glass Research of the Corning Museum of Glass, awarded to Kata Dévai for the project "*From Raw Glass to Snake-Thread Beakers: Workshop Practice and Recycling in a Neglected Frontier Province".*

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Selected materials from the Brigetio secondary glassworking workshop: raw glass chunks and snake-thread decorated vessel fragments with reconstruction

Notes

Exploring Roman and Late Antique glass finds from *Dinogetia*, Romania

Roxana Bugoi[1], Adriana Panaite[2] and Cristina Georgeta Alexandrescu[3]

[1] Horia Hulubei National Institute for Nuclear Physics and Engineering, Măgurele, Romania, bugoi@nipne.ro, ORCiD: 0000-0002-8247-9355
[2] Institutul de Arheologie „Vasile Pârvan", Bucharest, Romania, panaite_adriana92@yahoo.com, ORCiD: 0000-0002-6297-5167
[3] Institutul de Arheologie „Vasile Pârvan", Bucharest, Romania, cgetalexandrescu@gmail.com, ORCiD: 0000-0002-6189-1850

Keywords: *Roman glass, Late Roman glass, Dinogetia, chemical composition, IBA*

The fortification of *Dinogetia* is located 4 km north of Garvăn village, Tulcea County, Romania, on a former small island locally known as "The Little Church". Following the Roman conquest, the castellum, part of the Danube *limes*, hosted several military units and functioned as a fleet station. Most likely, the remains of the Late Roman, Early Byzantine, and Byzantine fortifications we see today overlap the Early Roman fortification.

The communication reports the results of the compositional analysis of 100 Roman glass fragments from Dinogetia excavated during the archaeological campaigns from 1950–1991. The assemblage includes fragments of vessels (bottles, beakers, lamps) and architectural glass remains (window panes), mostly dated to the Late Roman period.

Whenever possible – considering their fragmentary condition or lack of diagnostic features – the items were typologically classified according to the criteria of Isings [1] or Antonaras [2]. The chronology of the archaeological material was established mainly through typological analysis, and supplemented by stratigraphic evidence.

The fragments were analysed for their chemical composition using the external IBA (Ion Beam Analysis) set-up of AGLAE accelerator from the basement of the Louvre Palace, Paris, France [3], in the frame of the EU Horizon 2020 project IPERION-CH.

Several chemical types from the literature were identified: naturally coloured blue-green-yellow Roman glass, typical for the Early Roman period, HIMT (High Iron Manganese Titanium), Foy Série 3.2 and Foy Série 2.1, characteristic of the Late Roman period [4]. The frequency of each chemical type is discussed in relation to the chronology of the finds. Compositional data enabled comments on the raw materials, glass provenance or glass recycling issues.

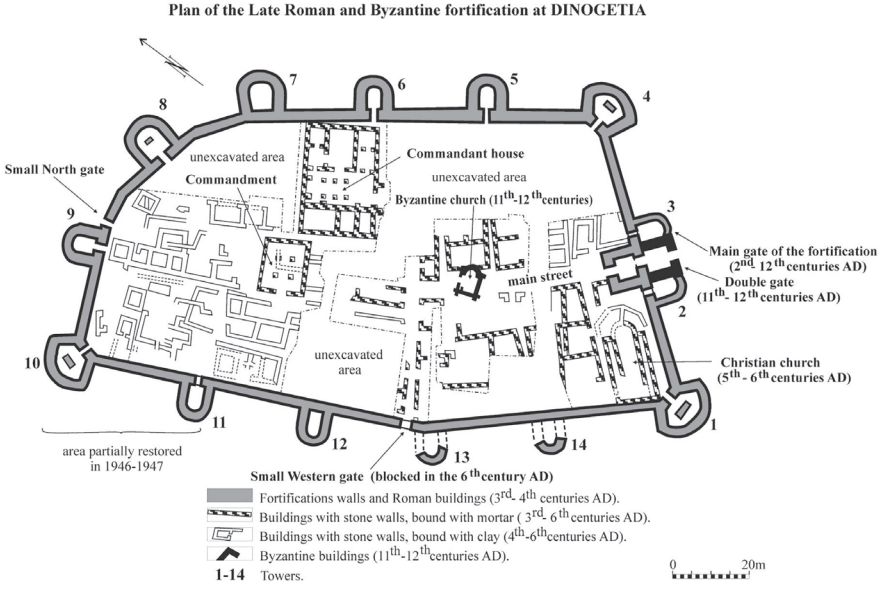
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Plan of the Late Roman and Byzantine fortification at Dinogetia

Notes

Post-antique glass on the territory of Eastern Alps

Žiga Šmit[1,2] and Tina Milavec[3]

[1] Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia, ziga.smit@fmf.uni-lj.si
[2] Jožef Stefan Institute, Ljubljana, Slovenia
[3] Department of Archaeology, Faculty of Arts, University of Ljubljana, Ljubljana, Slovenia, tina.milavec@ff.uni-lj.s

Keywords: *Late Antique glass, glass types, PIXE, PIGE*

In the region of eastern Alps, the period of Late Antiquity is characterized by reduction of population and quality of living places, while the territory served mostly as a transition area for different barbaric nations on their way to Italy. Beside a few cities located at the coast (Koper) and strategic positions by the rivers (Kranj), most of the population retired to remote fortified places, which served as administrative and ecclesiastic centers. In these circumstances the use of glass continued, which is documented in numerous archeological finds. On the other hand, analysis of the glass composition may uncover several patterns of life in these settlements.

Our analysis involved glass from several Late Antique and Early medieval sites, such as Tonovcov grad, Korinjski hrib and Koper [1–3], and of yet unpublished results of glass from Kranj and Gradič near Kobarid. The analytical method was ion-beam analysis based on a 3 MeV in-air proton beam. The method of proton induced X-rays (PIXE) was used for the elements heavier than silicon, while the lighter elements were determined by the method of gamma rays induced by inelastic nuclear scattering.

The results show an interesting time development of glass types. A strong presence of HIMTa glass was observed at Gradič, a religious center with the peak activity in the 4th c. AD. In the nearby Tonovcov grad, with the main population phase in the 6th c. AD, HIMT glass is only shown in a few examples, the most numerous types being Foy 3.2 and Foy 2.1 glasses. However, in comparison with the sites in the Balkans, the frequency of Foy 3.2 in comparison with Foy 2.1 is much weaker. Another specific is almost absence of Levantine I glass, which is not so rare in Northern Italy.

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From Gradič (A) later the population moved to the safer Tonovcov grad (B)

Notes

Provenance of Byzantine glass bracelets from the 11th–12th century Braničevo and Morava (Serbia)

Roman Balvanović[1], Žiga Šmit[2,3], Igor Silachyov[4], Dragana Spasić-Đurić[5], Teodora Branković[5] and Riccardo Avanzinelli[6]

[1] Vinča Institute of Nuclear Sciences, Vinča, Serbia, roman.balvanovic@gmail.com
[2] Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia
[3] Jožef Stefan Institute, Ljubljana, Slovenia
[4] Institute of Nuclear Physics, Almaty, Kazakhstan
[5] National Museum Požarevac, Požarevac, Serbia
[6] Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Firenze, Italy

Keywords: *glass bracelets provenance, isotopes, trace elements, Byzantine, Serbia*

The 11th–12th-century Byzantine towns of Braničevo and Morava (Serbia) yielded large assemblages of glass bracelets, indicating important glass-production centers. Previous major- and minor-element analyses showed that the bracelets were produced using natron, plant ash, and evaporitic mineral soda fluxes. This study applies strontium and neodymium isotope analysis and trace-element data to determine their provenance. Particular attention is given to high-boron glasses produced with evaporitic mineral soda, for which no isotopic data exist to date and whose proposed Anatolian origin has so far been supported only indirectly.

The analysis identified four compositional groups. The first consists of natron glass produced using Late Antique cullet, predominantly of Levantine, and partially Egyptian provenance. The second comprises Islamic plant ash glass, also Levantine but distinct from the first group, likely originating from Beirut and Damascus. The third group includes soda–lime glasses enriched in borates, probably derived from the Bigadiç deposits in western Anatolia. Their trace-element ratios and negative Eu anomaly closely match glass from Ḥiṣn al-Tīnāt, while low εNd values (–8.5) are consistent with marine sediments from the Sea of Crete and the western Levant Basin, supporting a western Anatolian sand source. The fourth group represents recycled mixtures of glasses from the other groups. Two outliers may originate from Raqqa and Sīrāf (Iran). One sample is identified as a furnace or crucible fragment, supporting local glass production. Another is a lead–zinc smelting slag, indicating that secondary glass melting took place near metalworking workshops. Low-zinc blue glasses were colored with N2-type cobalt characteristic of Ptolemaic–Roman Egypt, possibly derived from asbolane-rich deposits in Kashan (Iran). The wide import of glass from across the eastern Mediterranean indicates that Braničevo and Morava functioned as major, versatile industrial centers on the re-established Byzantine Danube frontier during the 11th–12th centuries CE.

Notes

High boron glass beads in Central European Early Iron Age glass networks: New data from Herzegovina

Mudit Trivedi[1], Lucija Grahek[2], Monika Milosavljević[3] and Saša Čaval[4]

[1] Department of Anthropology, Stanford Archaeology Center, Stanford University, mudit1@stanford.edu, ORCiD: 0000-0001-7807-9634
[2] Institute for Archaeology, ZRC SAZU, Ljubljana, Slovenia, lgrahek@zrc-sazu.si, ORCiD: 0000-0002-4055-0627
[3] Department of Archaeology, Faculty of Philosophy, University of Belgrade, Serbia, monika.milosavljevic@gmail.com
[4] Institute for Anthropological and Spatial Studies, ZRC SAZU, Ljubljana, Slovenia / Department for Archaeology and Heritage, University of Primorska, Koper, Slovenia, scaval@zrc-sazu.si, ORCiD: 0000-0001-8449-9299

Keywords: *beads, glass, high boron, Herzegovina, Iron Age*

This paper presents analyses of two glass beads recovered from a distinctive multiperiod site: Baljci in Herzegovina, where our excavations uncovered Iron Age and medieval burials. Glass artefacts and their chemistry from Bosnia and Herzegovina remain understudied, especially for the Iron Age. The two beads from Baljci represent the first documented Balkan examples of a distinctive and understudied glass type which is both "high boron" and which has previously been described as a "low-magnesia, moderate-potash (LMMK)" "glassy faience" [1], about whose origin, distribution and chronology several key questions remain open. This paper presents results of the LA-ICP-MS and micro-CT analysis of these two glass beads. It describes their unusual flux and sand related compositions, characterizes the heterogeneity of the glassy material and comments on its atypical colorant. It compiles and reviews all available evidence for LMMK glass across Europe, comparing these beads to examples published from Poland, Croatia and Italy [1, 2], finds which are delimited to the Early Iron Age or Halstatt C period (c. 800–600 BC). The paper tests relationships between boron, cesium, barium and lithium and of these trace elements with Al_2O_3, MgO, K_2O and TiO_2. On the basis of unusual correlations between these it provides chemical rationale distinguishing this LMMK High Boron glass from extensive newly reported evidence for Iron Age High Boron glass from Georgia [3], and High Boron glass from Turkey, Jordan and Iran [4, 5, 6]. This analysis contributes to the clarification of this important *transitional* Iron Age glass group. It evaluates previously made arguments about the European production and working of this glass in the light of the recent evidence. It also presents hitherto archaeometrically unconsidered potential sources for boron enriched evaporites in the Balkans.

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Notes

Unveiling the Monomachos crown: Archaeometric insights into the materials and medieval glassmaking technology

László Előd Aradi[1], Dorottya Györkös[2], Diego Seguí-Fábián[3] and Etele Kiss[4]

[1] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, aradi.laszlo@hnm.hu, ORCiD: 0000-0003-0276-3119
[2] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, gyorkos.dorottya@hnm.hu, ORCiD: 0000-0003-4011-6342
[3] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary; seguifabian.diego@hnm.hu, ORCiD: 0009-0002-1961-3125
[4] Hungarian National Museum, Budapest, Hungary, kiss.etele@hnm.hu

Keywords: *enamel, Byzantine, cloisonné, XRF, Raman spectroscopy*

In the Middle Ages enamelwork was held in exceptionally high regard and ranked among the most valuable artworks of the Byzantine Empire. For centuries, Byzantium maintained near exclusivity in the creation of cloisonné enamel on gold, a technique associated with the imperial court of Constantinople. Yet only a limited number of these objects have survived to the present. Despite their cultural and historical importance, they remain underrepresented in modern archaeometric research [1]. One of the most peculiar pieces of secular Byzantine enamels is the Monomachos Crown [2]. It consists of seven semi-circular Byzantine gold plaques and two circular gold plates, thought to be associated with the crown.

After assessing the condition of the plaques with UV-VIS photography and FTIR (Fourier-transform infrared spectroscopy), we identified areas affected by glass deterioration and past restorations. Based on subsequent 2D and 3D microscopy, regions of interest were selected for non-destructive analysis, including micro-XRF and Raman spectroscopy. Micro-XRF revealed the distribution of major and trace elements within the enamels, while Raman spectroscopy was performed on the glassy matrix to obtain complementary chemical information on the pigments and opacifiers. The analysis of major and trace elements in the base glass, together with the identification of pigments and opacifiers, provided a basis to reconstruct the glass recipes and assess the possible provenance of the enamels. Calcium antimonate was used as the opacifier in the enamels of the Monomachos Crown. In contrast, tin oxide was also identified as an opacifier in the two gold discs, suggesting a distinct production technology or workshop. The base natron glasses show similarity to Byzantine glasses used in enamelworks in the 9–11th century, confirming either that the Roman glassmaking tradition persisted into the Middle Ages, or that recycling of Roman glasses was prevalent [3].

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Notes

Non-destructive SEM-EDS analysis of the silver and gold hair-rings from the Early Bronze Age from the Lower and Middle course of the Tundzha River, Bulgaria

Todor Valchev[1] and Danail Yovchev[2]

[1] Regional Historical Museum,
Dobrich, Bulgaria, twulchev@gmail.com, ORCiD: 0009-0004-2506-5879
[2] Department of Geology and Exploration of Mineral Resources, University of Mining and Geology "St. Ivan Rilski", Sofia, Bulgaria, d.yovchev@mgu.bg, ORCiD: 0009-0003-3544-6184

Keywords: *Early Bronze Age, Yamnaya culture, silver hair-rings, gold hair-rings, Tundzha River*

The second half of the 4th millennium BC marks one of the most dynamic and interesting periods in Balkan history – the Bronze Age. This is a time of migrations of people, transfer of technological know-how, exchange of ideas and innovations, and cultural influences.

Around 3100 BC, large groups of migrants of the so-called Yamnaya culture appeared on the Balkan Peninsula. These people were nomads who originally lived in the North Black Sea area. The communities of the Yamnaya culture crossed the Stara Planina Mountain and reached the valley of the Tundzha River. The terrain in the Tundzha River watershed is level to rolling. Abundant water and mild climate offered optimal natural conditions for the newcomers. With the bringers of Yamnaya culture also appeared the first silver jewels.

The aim of this report is to present results from the non-destructive SEM-EDS analysis of the 3 golden and 21 silver spiral hair-rings from the Early Bronze Age. The jewels are found in the main and secondary graves of 13 burial mounds in the lower and middle course of the Tundzha River.

Spiral hair-rings were worn on the most visible places in the human body – the face. They are symbols of prestige and represent the social position of their owner in ancient society.



Early Bronze Age golden and silver spiral hair-rings

Notes

Beyond typology and upgrading showcase display: Insights into Late Bronze Age / Early Iron Age craftsmanship for museum valorization

Monica Dinu[1], Luminița Ghervase[2], Corina Borș[3] and Laurențiu-Marian Angheluță[4]

[1] National Institute for Research and Development in Optoelectronics INOE 2000, Măgurele, Romania, monica.dinu@inoe.ro, ORCiD: 0000-0001-7154-2040
[2] National Institute for Research and Development in Optoelectronics INOE 2000, Măgurele, Romania, ghervase@inoe.ro, ORCiD: 0000-0003-3402-8127
[3] National History Museum of Romania, Bucharest, Romania, corina.bors73@gmail.com, ORCiD: 0000-0002-1736-9360
[4] National Institute for Research and Development in Optoelectronics INOE 2000, Măgurele, Romania, laurentiu@inoe.ro, ORCiD: 0000-0001-7895-200X

Keywords: *prehistoric bronze artefacts, XRF, LIBS, X-Ray imaging, 3D documentation, museum valorization*

Our approach is focused on how material characterisation can provide a new basis for presenting prehistoric bronze artefacts by innovative exhibitions. Namely, how to integrate specific data obtained by scientific research into a new way of making exhibitions, both "traditional" and virtual ones to display the artefacts as well as their characterization data. The study case developed by us is based on a series of iconic bronze artefacts, part of the Tărtăria I and II hoards [1], covering a diverse range of relevant objects considering their functionality and typological features.

Beyond using XRF, these objects were investigated also using a discrimination method based on statistical analysis of the elemental composition of artifacts using spectral data obtained through LIBS (laser induced breakdown spectroscopy) technique in order to thoroughly characterize them by a minimally invasive technique [2]. The spectral data obtained from the core of the material are processed through advanced statistical analysis methods and then characterized based on similarities, thus achieving a detailed differentiation ("discrimination") of the objects recovered through archaeological excavation (or through older accidental discoveries) according to the elemental composition of the original material. Further on, X-Ray imaging provided important data regarding the internal structure and compositional consistency of the metal artefacts, being a crucial method for assessing the conservation state of each piece. Using 3D documentation methods, highly detailed 3D models were generated, with particular attention paid to surface morphology, patina coloration, and the challenges posed by reflective surfaces. The resulted models serve as digital replacements for scientific study, documentation and public dissemination [3].

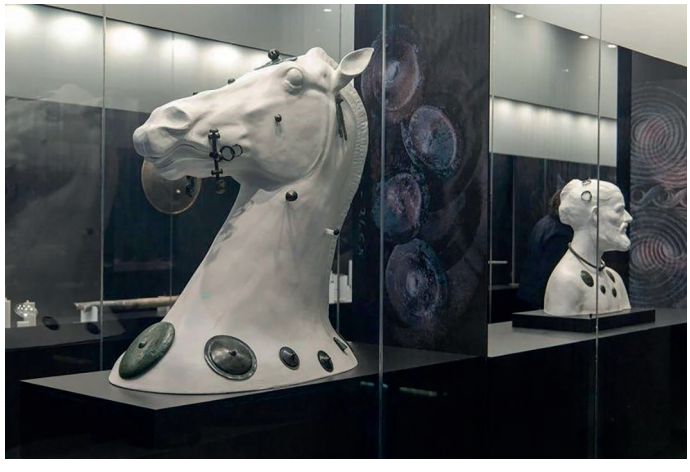
As a result, a complete set of characterization data about the selected artefacts were obtained. The paper will present how such data can be used for the museum valorisation of iconic artefacts while developing exhibitions, both in a “classical” way as well as in virtual ones.

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Notes

"Bommelohrringe" between Balkans and Central Europe

Šárka Krupičková[1], Birgit Bühler[2] and Šimon Ungerman[3]

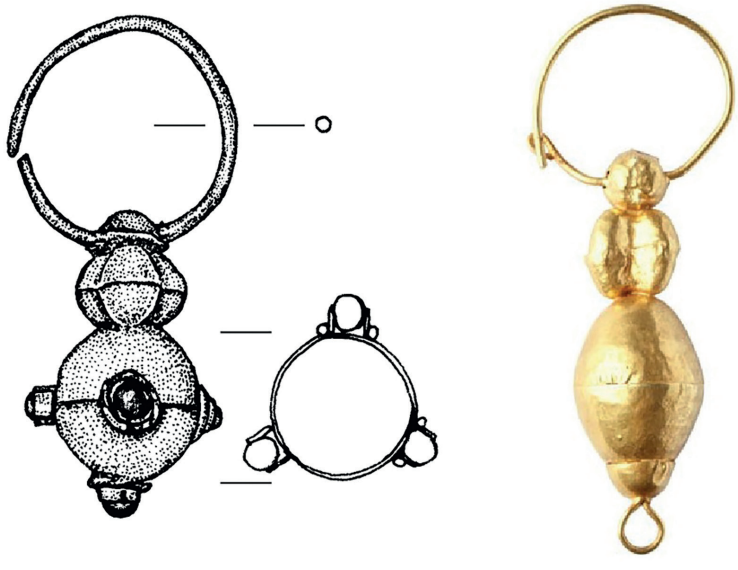
[1] Institute of Archaeology, Czech Academy of Sciences, Brno, Czech Republic, krupickova@arub.cz, ORCiD: 0000-0002-4834-1061
[2] Vienna Institute for Archaeological Science, University of Vienna, Wien, Austria, birgit.buehler@univie.ac.at, ORCiD: 0000-0001-5202-4619
[3] Institute of Archaeology, Czech Academy of Sciences, Brno, Czech Republic, ungerman@arub.cz, ORCiD: 0009-0000-8198-3800

Keywords: *early medieval jewellery, earrings with spherical pendants, production technology, material analyses*

"Bommelohrringe" (earrings with spherical pendants) are a widespread piece of jewellery in the Early Middle Ages. The highest concentration of their occurrence in this period is associated with the Carpathian Basin, or rather the area of Avar burial grounds (including Lower Austria) [1, 2], but they also significantly extend into Central Europe, where these earrings are found in abundance, especially in graves from the territory of today's Bavaria [3]. On a smaller scale, they also appear in other regions – in Rhineland [4], Moravia (Czech Republic) [5], in central Italy [6], etc. Can clearly defined similarities or differences between individual regions be found using modern analytical methods? Is the popularity of earrings with hollow spherical, vertically situated pendants more closely related to the ancient tradition of similar types of earrings? In this contribution, we will try to answer these broadly conceived questions by preliminary comparison of specific "Bommelohrringe" found in the Avar burial ground in Zillingtal with similar types discovered in the territory of neighbouring Moravia. Within our research we used more imaging and analytical methods, including SEM-EDX, LIBS and X-ray.

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"Bommelohrringe" from Zillingtal, Lower Austria (left) and Prušánky, Moravia (right)

Notes

A Byzantine masterpiece in the Avar Khaganate: Archaeometric reassessment of the polychrome buckle from Kunbábony

Eszter Horváth[1,2], László Előd Aradi[3,4], Zsolt Bendő[5], Tamás Váczi[6,7] and Zsófia Rácz[8]

[1] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, horvath.eszter@abtk.hu, ORCiD: 0009-0007-4650-0392
[2] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary
[3] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, aradi.laszlo@hnm.hu, ORCiD: 0000-0003-0276-3119
[4] Lithosphere Fluid Research Lab, Institute of Geography and Earth Sciences, ELTE Eötvös Loránd University, Budapest, Hungary
[5] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, zsolt.bendo@gmail.com, ORCiD: 0009-0000-1195-916X
[6] Institute for Solid State Physics and Optics, HUN-REN Wigner Research Centre for Physics, Budapest, Hungary, ORCiD: 0000-0003-0142-545X
[7] Department of Mineralogy, ELTE Eötvös Loránd University, Budapest, Hungary
[8] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, zsofia_racz@yahoo.de, ORCiD: 0000-0001-5116-2235

Keywords: *Avar elite, early Byzantine metalwork, gem inlay, material characterisation, digital reconstruction*

The 7th-century burial discovered in 1971 at Kunszentmiklós–Kunbábony (central Hungary) is the richest known Avar-period grave [1]. Located in the Danube–Tisza Interfluve, the central territory of the Avar Khaganate, the find represents the highest echelons of the ruling elite. The deceased, a 60–70-year-old man, was a prominent figure in the realm – possibly even the Khagan himself – as evidenced by the exceptional grave goods, anthropological observations and recent archaeogenomic results [2]. Among the personal artefacts, a polychrome gem-inlaid gold buckle stands out as a unique masterpiece of early Byzantine craftsmanship. This study summarises the archaeometric investigation (i.e. OM, SEM-EDX, and μ-Raman analyses) and a comprehensive reassessment of the object [3]. Our findings reveal the buckle's original colour scheme and motif system as they may have appeared in the 7th century AD. Digital reconstruction has proved crucial in reinterpreting the iconographic and stylistic characteristics of the figurative and geometric motifs, compensating for deterioration and incomplete preservation of the inlays. The central ornamental composition on the buckle plate has been identified as miniature stone marquetry, drawing on the late antique tradition of *opus sectile* while also anticipating the Renaissance *commesso (pietra dura)* technique. The innovative decorative technique and early Byzantine parallels clearly associate the buckle with the impe-

rial workshop of Constantinople, meaning it is not merely a status symbol of a barbarian leader, but also a material expression of Byzantine imperial magnificence.

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Digital reconstruction of the Kunbábony buckle
(graphics: Nóra Mészáros, Institute of Archaeology, ELTE Research Centre for the Humanities)

Notes

Archaeometric and technological investigation of a lunula-shaped enamel temple ring from the 10th–11th century burial ground at Hontianska Vrbica (Slovakia)

Zuzana Borzová[1], Ján Štubňa[2] and Kristián Jócsik[3,4]

[1] Department of Archaeology, Faculty of Arts, Constantine the Philosopher University in Nitra, Nitra, Slovakia, zborzova@ukf.sk, ORCiD: 0000-0003-2743-5832
[2] Gemmological Laboratory, Department of Geography, Geoinformatics and Regional Development, Faculty of Natural Sciences and Informatics, Constantine the Philosopher University in Nitra, Nitra, Slovakia, janstubna@gmail.com, ORCID: 0000-0001-9536-0911
[3] Institute of Archaeology, Faculty of Philosophy, University of Lodz, Łódź, Poland, kristian.jocsik2@edu.uni.lodz.pl, ORCiD: 0000-0002-1643-3623
[4] Department of Archaeology, Faculty of Arts, Constantine the Philosopher University in Nitra, Nitra, Slovakia, kristian.jocsik@ukf.sk

Keywords: *alloy, archaeometry, glass, enamel, spectroscopy*

A non-invasive archaeological survey at the site of Hontianska Vrbica (south-western Slovakia) revealed a burial ground dated to the 10th–11th century. Among the recovered finds is a unique lunula-shaped enamel temple earring, representing the first known example of this type from the territory of present-day Slovakia. The objective of this paper is a detailed characterisation of this unique piece of jewellery, aiming to reliably determine the nature of the materials used and subsequently reconstruct period manufacturing techniques. Through archaeometric and technological analyses, we therefore focus on identifying the composition of the metal alloys and analysing the structure of the enamel glass.

To achieve these goals, non-destructive spectroscopic methods were selected, as they do not require specific sample preparation, which is crucial for unique archaeological artefacts. We primarily utilised X-ray fluorescence (XRF) spectrometry (hh-XRF and micro-XRF), a relevant method for characterising metal alloys. Since XRF can also be applied to glass, it allowed for the simultaneous analysis of both the metallic components and the vitreous enamel.

The results were compared with data from electron probe microanalysis (EPMA). While EPMA provides higher accuracy for light element quantification in glass, it requires invasive preparation in the form of polished cross-sections. Indeed, the main limitation of XRF is its low sensitivity for light elements with atomic number $Z < 14$, especially sodium (Na) and magnesium (Mg), which are essential components of medieval glass. Nevertheless, XRF remains a valuable tool for provenance studies and identifying raw material sources. For accurate quantitative analysis, however, calibration using reference materials and combining XRF with complementary approaches such as LA-ICP-MS or SEM-EDS is essential to obtain reliable elemental data.

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Lunula-shaped enamel temple ring from Hontianska Vrbica (Slovakia)

Notes

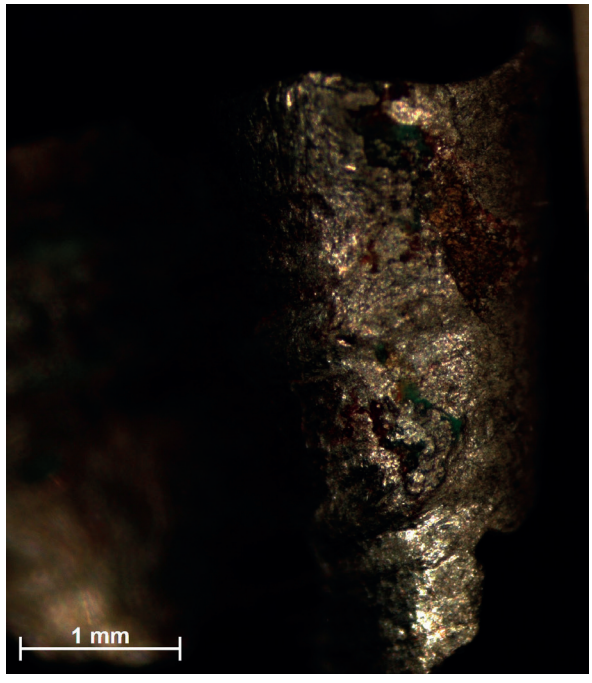
Surface treatments on medieval small finds: A case study

András Török

National Institute of Archaeology, Hungarian National Museum,
Budapest, Hungary, torok.andras@hnm.hu

Keywords: *XRF, Middle Ages, metal, dress accessories*

The research of surface treatments has always been marginal in the field of archaeometallurgy. The popularity of different surface treatments, mostly silvering and tinning, is still highly uncertain within most of the medieval material culture. This case study showcases identified surface treatments – gilding, silvering and tinning – on several artefacts (two silver rings, a copper spur, five S-end lock rings and an iron spur rowel) from the Middle Ages using X-Ray Fluorescence (XRF) spectrometry and optical microscope. The main questions of the topic are the following: what are the best analytical methods for identifying surface treatments?; how popular was gilding, silvering and tinning in medieval times? The results of the research were very interesting and instructive. Firstly, on several artefacts the surface treatments could only be identified with the analytical methods, which also means that they were misinterpreted beforehand. The latter is even more prominent in the case of five S-end lock rings, which were all originally interpreted as silver artefacts; after the measurements all of them could be identified as silvered copper alloy. This result shows that researches like this are not only important from an archaeometallurgical perspective, but also very useful for classical archaeology as well. My case study also offers a practical method for future research into different surface treatments.



Stereomicroscope image of copper and silver surfaces visible on an S-end lock ring

Notes

Tracing the social lives of white stone and serpentinite artefacts in the Balkans and the Carpathian Basin during the 6th and 5th millennia BCE

Kata Furholt[1], Veronika Szilágyi[2], György Szakmány[3], Tamás Sági[4], Edina Pegán[5], Ildiko Medović[6] and Anett Osztás[7]

[1] Institute of Pre- and Protohistoric Archaeology, Kiel University, Kiel, Germany, kata.furholt@ufg.uni-kiel.de, ORCiD: 0000-0002-3944-9951
[2] Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary, szilagyi.veronika@ek.hun-ren.hu, ORCiD: 0000-0001-8522-676X
[3] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, szakmany.gyorgy@ttk.elte.hu, ORCiD: 0000-0002-9557-2030
[4] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, sagi.tamas@ttk.elte.hu, ORCiD: 0000-0003-4664-5472
[5] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, pegan.edina@hnm.hu, ORCiD: 0009-0000-0171-701X
[6] Museum of Vojvodina, Novi Sad, Serbia, ildiko.medovic@muzejvojvodine.org.rs, ORCiD: 0009-0002-3563-4823
[7] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, osztas.anett@htk.elte.hu, ORCiD: 0000-0002-8470-0770

Keywords: *Neolithic, polished stone implement, lithic deposition practice, exchange network, materiality*

This paper examines polished stone artefacts made from serpentinite (a type of greenstone) and white stone (also called light white stone) [1], which occur in relatively large numbers in Late Neolithic burial contexts in southern Transdanubia and the southern Great Pannonian Plain, despite their low overall regional frequency. These implements are mainly associated with Late Neolithic Lengyel communities and, less frequently, with Tisza communities. Larger quantities occur in Vinča contexts, particularly highly standardised white stone tools, suggesting large-scale production.

In Lengyel and Tisza graves, these implements were often deposited around the skull, emphasising their meaningful placement within burial practices. In contrast, serpentinite and white stone tools from Vinča sites were recovered predominantly from domestic contexts and associated with utilitarian practices.

These contrasting deposition patterns suggest that the selection, use and deposition of these materials were strongly embedded in specific cultural contexts and carried social meanings beyond purely economic functions. Their circulation, use, reuse, and deposition likely reflected distinct social values, identities, communicative memories, and ritual practices.

Recently completed archaeometric analyses (MS, PLM, SEM-EDS) [2, 3] indicate raw material procurement from the northern Balkans and the southern Carpathian Basin. The serpen-

tinite and white stone implements most likely originated from the geological formations of the Vardar Ophiolite Zone. Technological analyses suggest that they were circulated as `finished tools` rather than raw material blocks. The stone implements circulated among regions and communities, but the technological knowledge that produced them did not travel with them. This distinction may help explain the varied deposition practices and provide a better understanding of how these objects could have had different social lives and meanings within Late Neolithic communities.

This research is supported by the project NKFIH Advance No. 150223 and the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany´s Excellence Strategy – EXC 2150 – 390870439.

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Serpentinite shaft-hole axes (1–2) and white stone adzes (3–4) from the Late Neolithic sites of Alsónyék-Bátaszék (1, 3; SE Transdanubia, Hungary) and Laka Staza (2, 4; Vojvodina, N Serbia) (photo by K. Furholt)

Notes

Archaeometric analysis of high-pressure meta-ophiolitic pebbles from Oligocene conglomerate outcrops near Carrosio (Italy)

Diego Seguí-Fábián[1,2], György Szakmány[3], Roberto Compagnoni[4], Elisabetta Starnini[5] and Tamás Sági[6]

[1] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, seguifabian.diego@hnm.hu, ORCiD: 0009-0002-1961-3125
[2] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary
[3] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, szakmany.gyorgy@ttk.elte.hu, ORCiD: 0000-0002-9557-2030
[4] Department of Earth Sciences, University of Torino, Torino, Italy, roberto.compagnoni@unito.it
[5] Department of Civilisations and Forms of Knowledge, University of Pisa, Pisa, Italy, elisabetta.starnini@unipi.it, ORCiD: 0000-0002-3933-0854
[6] Department. of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, sagi.tamas@ttk.elte.hu, ORCiD: 0000-0003-4664-5472

Keywords: *eclogite, Na-pyroxenite, Molare conglomerate, Voltri, Neolithic*

Polished stone tools crafted from high-pressure meta-ophiolitic rocks – specifically eclogites and rare Na-pyroxenites – are widely distributed across Europe, spanning thousands of kilometres from Ireland to Bulgaria. In Northern Italy, these geologically rare rocks make up 70% to 90% of Neolithic polished stone tool assemblages. While it has long been known that these rocks originate from the Western Alps, locating exact sourcing areas across thousands of square kilometres remains a major challenge due to the heterogeneity of these rocks. Primary outcrops occur across various Alpine massifs (e.g., Monviso, Voltri), but secondary geological sources, such as the Oligocene conglomerates of the Tertiary Piemonte Basin (Molare Formation), represent an unstudied yet potentially important source of prehistoric raw materials.

This study presents a petrographic and mineral-chemical analysis of sixteen pebbles collected from Molare Formation outcrops near Carrosio (Northern Apennines) to evaluate their archaeometric significance. Analytical methods included thin-section petrography, X-ray diffraction, and scanning electron microscopy. Results identified seven high-pressure meta-ophiolitic pebbles: five eclogites and two omphacite schists. Mineral-chemical trends of pyroxenes indicate a cogenetic evolution of the investigated rocks, originating from a single, localized source, likely the now-eroded palaeo-Voltri massif.

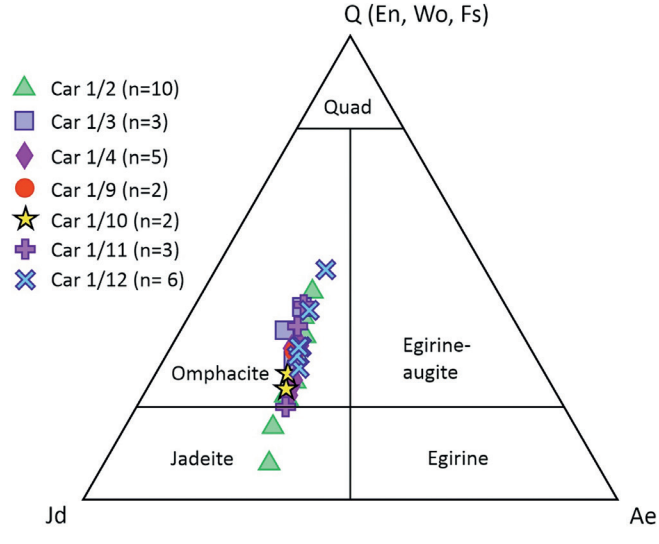
Comparative analysis reveals that a combination of texture, accessory/retrograde minerals, and garnet-pyroxene chemistry is suitable for the definitive differentiation of Carrosio pebbles from Monviso massif rocks. Furthermore, comparisons with Quaternary-Holocene alluvial deposits from the same area indicate modern rivers contain meta-ophiolitic pebbles

from multiple sources, making the Oligocene conglomerates a more reliable source for comparison with primary occurrences.

Notably, the Carrosio pebbles display striking textural and chemical similarities to Neolithic artefacts from Northern Italy, suggesting the Molare Formation was indeed a key source for prehistoric tool manufacturing. Meanwhile, studied Hungarian artefacts show different modal composition and mineral chemistry, pointing toward alternative Alpine sources like the Monviso Massif.

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Pyroxene compositions from high-pressure ophiolite pebbles plotted on the Morimoto (1988) classification diagram

Notes

Complex petrographic and geochemical provenance analysis of Late Neolithic polished stone tools made of alkaline igneous raw materials from Alsónyék-Bátaszék (S-Hungary)

Tamás Sági[1], György Szakmány[2], Veronika Szilágyi[3], Sándor Józsa[4], Zsolt Kasztovszky[5] and Anett Osztás[6]

[1] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, sagi.tamas@ttk.elte.hu, ORCiD: 0000-0003-4664-5472
[2] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, szakmany.gyorgy@ttk.elte.hu, ORCiD: 0000-0002-9557-2030
[3] Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary, szilagyi.veronika@ek.hun-ren.hu, ORCiD: 0000-0001-8522-676X
[4] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, sandor.jozsa@ttk.elte.hu, ORCiD: 0000-0001-8219-0044
[5] Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary, kasztovszky.zsolt@ek.hun-ren.hu, ORCiD: 0000-0002-5745-8616
[6] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, osztas.anett@htk.elte.hu, ORCiD: 0000-0002-8470-0770

Keywords: *Alsónyék-Bátaszék, polished stone tools, alkaline igneous, Mecsek Mountains*

The Alsónyék-Bátaszék site, which was inhabited throughout almost the entire Hungarian Neolithic (ca. 5800–4400 cal BC), is one of the most significant archaeological sites in Hungary. It has been excavated between 2006 and 2009 in the vicinity of Alsónyék and Bátaszék (S-Hungary) during the construction of the M6 motorway. 668 polished stone tools were discovered from the settlement and its burials, predominantly associated with the Late Neolithic Lengyel period (ca. 4800–4400 cal BC at this site). Based on preliminary investigations, the raw material of approximately 60% of the artefacts is of local-regional origin, the largest group among them being the alkaline igneous rocks of Mecsek Mts.

After a detailed geological examination of the artefacts, a field sampling of potential alkaline igneous raw materials was carried out in the Mecsek Mts. During field surveys, efforts were made to collect rocks from locations that would have been easily accessible to Neolithic people. Our goal was to conduct a complex comparative petrographic and geochemical study to determine the provenance of the stone tools as precisely as possible. The applied analytical methods were polarizing microscopy, SEM-EDS (Eötvös University) and PGAA (HUN-REN Centre for Energy Research).

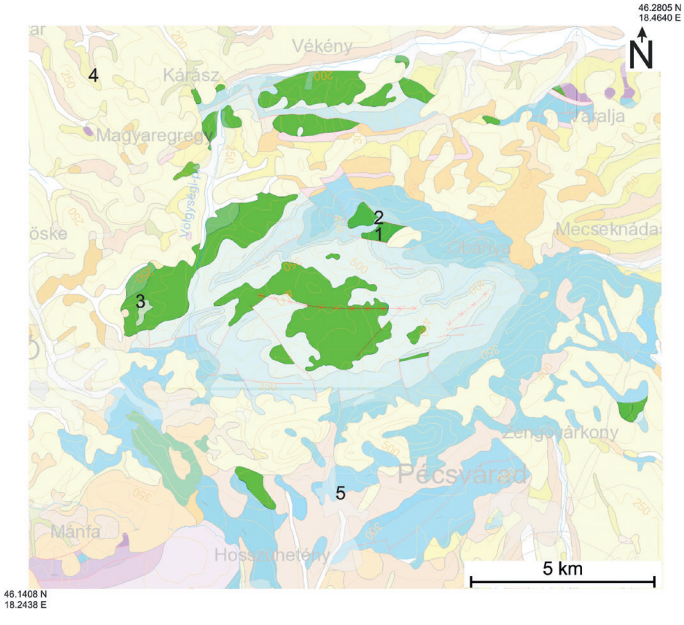
Sources of several types of raw materials have been identified in the Mecsek Mountains, some with a high degree of certainty. 1a, b – predominantly aphanitic or porphyritic alkaline basalt: Mecsekjános area, Hamvas Valley; 2a, b – equigranular gabbro or microgabbro dyke

rocks: Sás Valley, Vágyom Valley, Valley of Ördög-nyereg Stream; 3 – inequigranular (porphyritic) gabbro/microgabbro: Vágyom Valley; 4 – phonolite (Szamár Hill). Moreover, some stone tools made of basalt clearly differ from the typical alkaline rocks of the Mecsek Mts; their most likely source area is the Bakony-Balaton Uplands.

This research was supported by the New National Excellence Program (ÚNKP-22-3; PI: Tamás Sági), and "OTKA" grant K-131814 (PI: Zsolt Kasztovszky).

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The possible alkaline igneous raw material source areas of polished stone tools of Alsónyék-Bátaszék on the geological map of the Mecsek Mts. and surroundings [1]. Key: 1. Szamár Hill (phonolite), 2. Valley of Ördög-nyereg Stream (gabbro, microgabbro), 3. Hamvas Valley (alkaline basalt), 4. Vágyom Valley (alkaline gabbro, microgabbro), 5. Hosszúhetény (alkaline microgabbro).

Notes

Preliminary results of petrographical examinations of polished stone tools from Szeleta Cave, Bükk Mountains, Hungary

Erika Kereskényi[1], Béla Fehér[2] and Zsuzsanna Tóth[3]

[1] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, kereskenyi.erika@hnm.hu, ORCiD: 0000-0002-3805-881X
[2] Department of Mineralogy, Herman Ottó Museum, Miskolc, Hungary, feherbela@t-online.hu
[3] Department of Archaeology, Hungarian National Museum, Budapest, Hungary, toth.zsuzsanna@hnm.hu, ORCiD: 0000-0002-5540-8244

Keywords: *polished stone tools, Szeleta Cave, non-destructive analysis*

A non-destructive mineralogical investigation was carried out on eight polished stone implements from the Szeleta Cave (Bükk Mountains, Northeastern Hungary) using low-vacuum SEM–EDS analysis (JEOL IT510). Due to the limitations of original-surface based analysis, textural features and chemical zoning of the minerals could not be perceived. The artefacts represent diverse protoliths including mafic, ultrabasic, and metamorphic rock types.

Two sholast adzes (52.67.3 and 52.67.12) were classified as basaltic rocks. 52.67.3 is composed of hornblende, augite, labradorite, andesine, and isometric titanomagnetite, which is uniformly distributed throughout the rock. 52.67.12 contains augite, olivine, labradorite with abundant titanomagnetite and accessory Cr-bearing spinel, and apatite. The shafted adze 52.67.9 is coarse-grained and has been classified as diorite. It contains diopside and augite reaching up to 200 µm in size. Plagioclase represented by andesine and oligoclase, ilmenite is an accessory phase in the adze. 52.67.8 flat chisel was observed macroscopically and was determined to be metavolcanite which rock type is very abundant in the surroundings of the Bükk Mountains.

52.67.4 is a shoelast adze and was determined to be amphibolite, composed of magnesiohornblende, andesine, labradorite, clinozoisite, and epidote. 52.67.5 and 52.67.6 are flat chisels classified as amphibolites also. In 52.67.5 magnesiohornblende with variable Al content was recorded, accompanied by labradorite and bytownite, indicating differing metamorphic conditions. In sample 52.67.6 magnesiohornblende and pargasite are the main rock-forming phases with oligoclase; oligoclase is commonly enclosed by amphibole crystals. 52.67.7 flat chisel is classified as a contact metabasite, composed predominantly of cummingtonite and subordinately tschermakite. Mn-bearing ilmenite, phengite, and chlorite were also detected without plagioclase. Amphiboles account for approximately 90 modal% of the rock and occur as large bundled aggregates that show a characteristic fan-shaped habit.

52.67.10 is a broken-in-half shafted shoelast adze and proved to be serpentinite with massive serpentine minerals and magnetite.



Polished stone tools from the Szeleta Cave

Notes

A moment of power? Investigating a Bronze Age composite macehead from Nagycenk (Western Hungary)

Eszter Melis[1], Sophie Bergerbrant[2], Eszter Horváth[3], György Káli[4], Zoltán Kis[5], Viktória Kiss[6], István Major[7], Boglárka Maróti[8], Attila Mrenka[9,10], Ákos Pető[11], Dénes Saláta[12], Bálint Savanyú[13] and Veronika Szilágyi[14]

[1] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, melis.eszter@abtk.hu, ORCiD: 000-0002-5016-5108
[2] Department of Archaeology, Ancient History and Conservation; Archaeology, Uppsala University, Visby, Sweden, sophie.bergerbrant@arkeologi.uu.se, ORCiD: 0000-0002-9614-0264
[3] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, horvath.eszter@abtk.hu, ORCiD: 0009-0007-4650-0392
[4] Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary, kali.gyorgy@ek.hun-ren.hu, ORCiD: 0000-0001-8149-8688
[5] Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary, kis.zoltan@ek.hun-ren.hu, ORCiD: 0000-0002-8365-8507
[6] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, kiss.viktoria@abtk.hu, ORCiD: 0000-0002-6577-9081
[7] International Radiocarbon Competence Centre (INTERACT), HUN-REN Institute for Nuclear Research, Debrecen, Hungary, imajor@atomki.hu, ORCiD: 0000-0003-4675-9875
[8] Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary, maroti.boglarka@ek.hun-ren.hu, ORCiD: 0000-0001-9598-2913
[9] Museum of Sopron, Sopron, Hungary, mrenka.attila@sopronimuzeum.hu
[10] Department of Archaeology, Institute of Historical Sciences, Faculty of Humanities and Social Sciences, University of Pécs, Pécs, Hungary, mrenka.attila@pte.hu, ORCiD: 0009-0009-5589-7517
[11] Department of Nature Conservation and Landscape Management, Institute for Wildlife Management and Nature Conservation, Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary, peto.akos@uni-mate.hu, ORCiD: 0000-0003-3811-1155
[12] Department of Nature Conservation and Landscape Management, Institute for Wildlife Management and Nature Conservation, Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary, salata.denes@uni-mate.hu, ORCiD: 0000-0002-7149-0022
[13] Rómer Flóris Museum of Art and History, Győr, Hungary, savanyu.balint@romer.hu, ORCiD: 0009-0006-7245-3342
[14] Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary, szilagyi.veronika@ek.hun-ren.hu, ORCiD: 0000-0001-8522-676X

Keywords: *Early Bronze Age, neutron-based methods, copper metallurgy, manufacturing technique, organic remains*

In 2018, an extraordinary composite macehead made of metal and stone was discovered during the preventive excavation preceding the construction of the M85 motorway at the site Nagycenk-Farkasverem. The perforated, flattened globular object, measuring 7.2 cm in diameter and weighing 469 g, was found near the left wrist of an inhumation burial of a male aged between 20 and 50 years [1]. Bronze neck rings, arm rings, and ceramic vessels from the

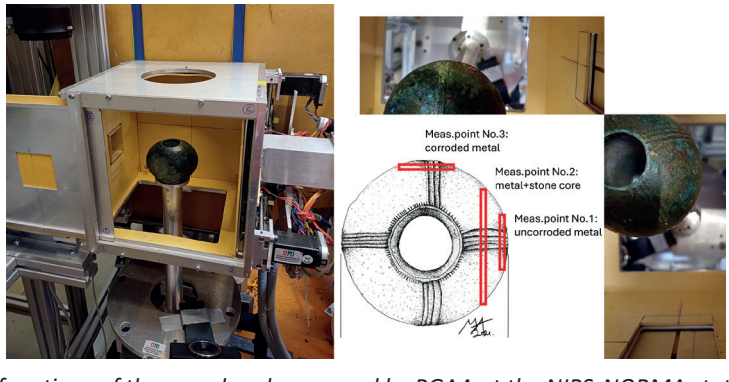
grave associate the burial with the Gáta–Wieselburg culture, while a radiocarbon date obtained from the human remains places the burial between 2022 and 1892 BC (95.4%).

Within the context of the Early Bronze Age in Europe, the bronze coating of the Nagycenk macehead appears to be unique; early parallels are known only from the Near East. Due to the exceptional nature of the object, our investigation primarily relied on non-destructive analytical methods (OM, HH-XRF, PGAA, TOF-ND, NR). Based on the results of this broad interdisciplinary collaboration, our presentation addresses the following questions: 1, how was this composite object manufactured and applying what materials; 2, by what technique was it decorated; and 3, based on the organic remains recovered from the grave, how may the object have been deposited in the burial? Ultimately, the technological and contextual characteristics of the macehead may reveal its significance within Bronze Age society: should the Nagycenk composite object be interpreted as an actual weapon or rather as a symbol of power?

The investigation is supported by the NKKP STARTING Grant (No. 152650) and the MTA–ELTE HTK Lendület "Momentum" BASES Research Group (LP 2023-8). The work of Ákos Pető and Dénes Saláta was supported by the DAAMBA project (National Research, Development and Innovation Office, Grant No.: FK_142894).

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Positions of sections of the macehead measured by PGAA at the NIPS-NORMA station of BNC. The neutron beam was collimated to 3×8 mm

Notes

Function and use-wear of Early Neolithic bone spoons: Evidence from SW Romania

Adina Boroneanț[1] and Monica Mărgărit[2]

[1] Vasile Pârvan Institute of Archaeology, Bucharest, Romania, boro30@gmail.com, ORCiD: 0000-0001-8795-6619
[2] Doctoral School of Economics and Humanities, Valahia University of Târgoviște, Targoviste, Romania, monica.margarit@valahia.ro, ORCiD: 0000-0002-6620-9224

Keywords: *Early Neolithic, bone spoons, microscopy, LIBS, functionality*

Bone artefacts constitute an important, yet still insufficiently explored, component of Early Neolithic material culture in Southeast Europe. Among these, bone spoons are consistently present at sites attributed to the Starčevo–Criș cultural complex, displaying a shared morphological structure alongside notable variability. Typically, these implements consist of a handle of differing lengths and cross-sections, extending into a broadened receptacle characterised by concavities ranging from shallow to deep, with shapes that may be circular, elliptical, or trapezoidal. Despite their widespread occurrence, their precise functions have remained only partially understood, often relying on typological comparison rather than detailed functional analysis.

This study examines a series of bone spoons recovered mainly from two Early Neolithic sites in south-western Romania: Schela Cladovei and Cârcea. Well-preserved specimens were subjected to detailed microscopic analysis using a Keyence VHX-X1 digital microscope, employing a range of lenses and lighting techniques tailored to highlight surface modifications. Coaxial illumination facilitated the identification of micro-wear traces such as surface flattening and fine striations, while the Optical Shadow Effect Mode enabled high-resolution three-dimensional visualisation of surface topography. Observations conducted at magnifications between 20× and 500× allowed for precise characterisation of wear patterns and handling traces, including the reconstruction of use-related surface modifications and their spatial distribution.

In certain cases, the results indicate repetitive contact with relatively soft materials [1–5], while in others the wear patterns are consistent with controlled, gentle movements, suggesting possible use in feeding infants [6]. Additionally, several specimens displayed traces of red and black coloured residues. These were analysed using Laser-Induced Breakdown Spectroscopy (LIBS), integrated within the same instrument. The spectroscopic data identified the red residues as iron oxides, supporting their interpretation as ochre. This evidence points to an additional function involving the mixing or preparation of mineral substances.

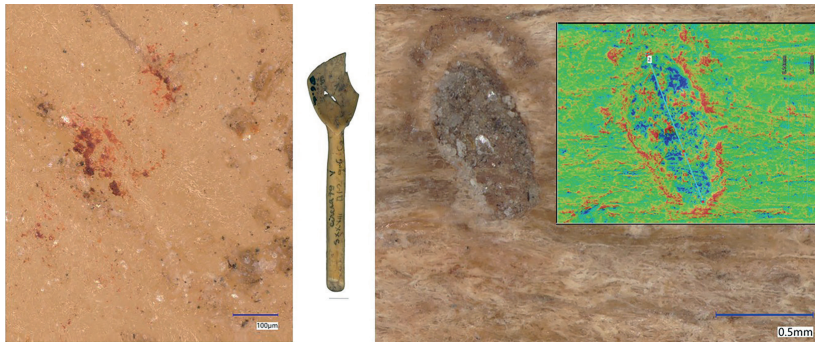
By integrating microscopic use-wear analysis with chemical residue identification, this paper highlights the multifunctionality of bone spoons and contributes to a more nuanced understanding of Early Neolithic practices.

Acknowledgements

This work was supported by a grant of the Ministry of Education and Research, CCCDI – UEFISCDI, project number PN-IV-P6-6.1-CoEx-2024-0042, within PNCDI IV.

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Examples of traces of red residue and tooth marks on Early Neolithic spoons from SW Romania

Notes

Technological continuity *vs.* turnover: A comparative archaeometric study of Neolithic and Chalcolithic ceramic pigments across the Balkan Peninsula and the Carpathian Basin

Angelina Pirovska[1], Boika Zlateva[2,3] and Deyan Lesigyarski[2,4]

[1] Archaeological Museum "Maritza-Iztok", Radnevo, Bulgaria, pirovska.ar@gmail.com
[2] Center of Archaeometry with Laboratory for Conservation and Restoration, Faculty of History, University of Sofia "St. Kl. Ohridski", Sofia, Bulgaria
[3] Faculty of Chemistry and Pharmacy, University of Sofia "St. Kl. Ohridski", Sofia, Bulgaria, ahbz@chem.uni-sofia.bg
[4] National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia, Bulgaria, dlesigyarski@geophys.bas.bg

Keywords: *pigment, Neolithic and Chalcolithic, technological continuity*

The archaeometric investigation of prehistoric ceramic pigments provides deep insights into the technological knowledge of ancient potters, their traditions, and cultural boundaries. While recent large-scale analytical studies across the Carpathian Basin and the Lower Danube reveal highly dynamic, shifting patterns in pigment choices, contemporary data from Bulgaria presents a contrasting narrative of technological stability.

In Hungary, a stark transition from mineral-based white inlays (kaolin and calcite) during the Neolithic to bone-derived hydroxyapatite in the Chalcolithic points to significant socio-technological changes. Similarly, extensive data from Romania underscores a volatile trajectory; within the multi-phase Boian culture, bone powder is introduced alongside calcite in the Giulești phase, becomes dominant in the Vidra phase, and abruptly disappears by the Spantov phase in favor of kaolin-calcite mixtures.

This paper compares these fluctuating regional profiles with the decorative traditions of the Neolithic and Chalcolithic across the Balkan Peninsula. Local archaeometric data highlights a remarkable continuity, primarily defined by the persistent use of calcite-based white decoration. Variations within these assemblages appear to reflect localized geological exploitation rather than the radical technological overhauls seen further north. This paper discusses how these divergent trajectories reflect distinct cultural mechanisms – suggesting deep-seated demographic continuity within the Balkan context, with major technological turnovers potentially delayed until the Early Bronze Age.

Acknowledgements

This study was made available through the kind support of the INFRAMAT Project.

Notes

Remains of an Early Copper Age burnt house from Noşlac (Romania)

Dorottya Láng[1], Ottilia Szigyártó[2], Eszter Horváth[3], Attila Kreiter[4] and András Füzesi[5]

[1] Department of Archaeology, Hungarian National Museum, Budapest, Hungary, lang.dorottya@hnm.hu, ORCiD: 0009-0005-1816-9925
[2] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, szigyarto.ottilia@hnm.hu, ORCiD: 0009-0000-1698-5527
[3] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, horvath.eszter2001@gmail.com
[4] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, kreiter.attila@hnm.hu, ORCiD: 0000-0002-8339-1021
[5] Department of Archaeology, Hungarian National Museum, Budapest, Hungary, fuzesi.andras@hnm.hu, ORCiD: 0000-0002-5039-8593

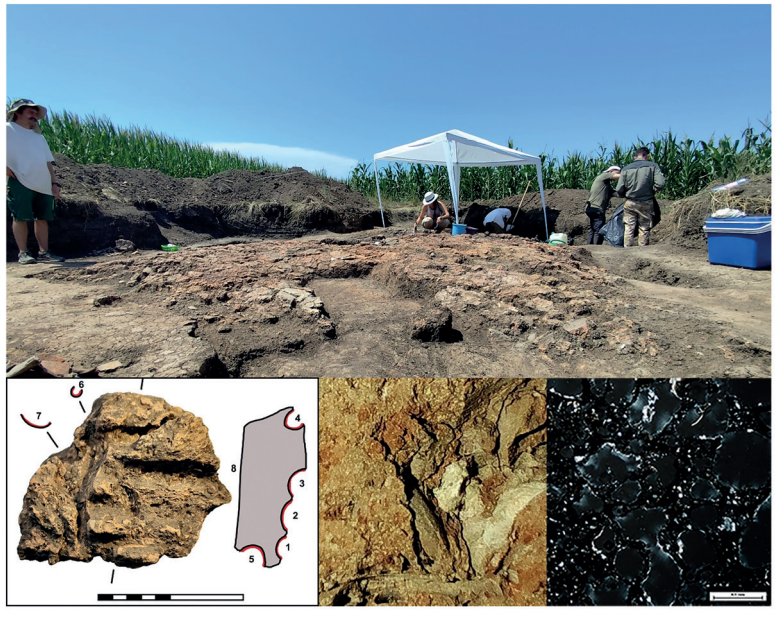
Keywords: *Early Copper Age, burnt house, building structure, daub matrix, archeometric analysis*

In July 2024, a joint excavation conducted by the Hungarian National Museum, Eötvös Loránd University, and Babeş-Bolyai University uncovered two Early Copper Age buildings and a dozen pits in Noşlac (Romania). The site belonged to the late Vinča–Petreşti cultural milieu and has been dated to 4710–4400 BC (2σ). Research concentrated on the remains of a well-preserved burnt house, which was excavated on a one-square-metre grid across an area of 8×5 m. A total of 619 kg of daub (11,713 fragments) was systematically recorded and analysed using archaeological and archaeometric methods.

The analysis examined both the raw materials used for building the house and the imprints preserved within the fragments. Based on variations in composition and degree of burning, a reference collection comprising 20 material types was established and used for the systematic classification of the assemblage. Architectural imprints, including those of pillars, stakes, and planks, were identified on 31.9% of the daub fragments. In total, 8,152 impressions were documented and characterized through detailed graphic recording and metric cross-sectional analysis, yielding an average 2.18 impressions per fragment. These data provided a robust basis for the reconstruction of the building's structural elements and construction techniques.

Furthermore, petrographic analysis was carried out on 33 daub samples selected from four spatial units in order to assess raw material selection, fabric characteristics, and qualitative and quantitative compositional variability. The archaeometric investigation was designed to address three principal research questions:

1. The validity and consistency of the macroscopically defined material types;
2. The variability and spatial distribution of distinct fabric groups within the building;
3. The extent to which raw material selection reflects deliberate choices made by the prehistoric builders.



Remains of an Early Copper Age burnt house from Noşlac

Notes

Fresco fragments from the remains of the 11–13th century church in Senta-Crkveno Brdo, Serbia

Milica Marić Stojanović[1], Perica Špehar[2], Ljiljana Veselinović[3] and Smilja Marković[4]

[1] National Museum of Serbia, Belgrade, Serbia, m.stojanovic@narodnimuzej.rs, ORCiD: 0000-0002-7291-1087
[2] Faculty of Philosophy, University of Belgrade, Belgrade, Serbia, perica.spehar@gmail.com, ORCiD: 0000-0003-1485-3840
[3] Institute of Technical Sciences of SASA, Belgrade, Serbia, ljiljana.veselinovic@itn.sanu.ac.rs, ORCiD: 0000-0002-6100-9178
[4] Institute of Technical Sciences of SASA, Belgrade, Serbia, smilja.markovic@itn.sanu.ac.rs, ORCiD: 0000-0002-9264-4406

Keywords: *fresco, multidisciplinary, 12–13th century, Senta*

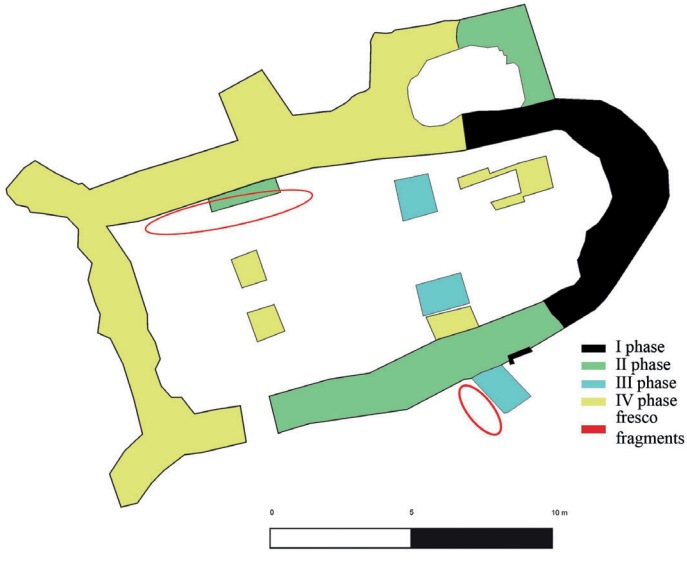
The medieval site of Crkveno Brdo near Senta represents an unfortified settlement from the Arpadian period. The church and its necropolis, built in the 11th or early 12th century, underwent multiple renovation phases. The first reconstructions date back to the mid-12th century (the reign of Géza II), while the final major expansion followed the Mongol invasion (1241–1242) [1].

Fresco fragments with geometric motifs and a limited palette were discovered on the southern wall, while the northern wall features a richer color palette, human motifs, and Latin letters. Some sections display two plaster layers, indicating either painterly corrections or distinct painting phases.

Analyses of ten fresco fragments and one brick piece (using OM, SEM-EDS, FTIR, and XRD) identified the materials and painting techniques, allowing a chronological classification of the samples: Oldest phase: Pigment was applied directly to monolayered plaster in the true fresco technique *(buon fresco)*, with dolomitic lime present; Renovation: White intonaco was applied over semi-dry to dry coarse plaster, indicating the lime painting technique *(secco).* The lime contains dolomitic lime; Latest phase: Executed in the true fresco technique on two-layered plaster (wet-on-wet), without dolomitic lime. The upper plaster is richer in lime compared to the lower one.

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Situation plan of the fresco finds and the phases of the church building

Notes

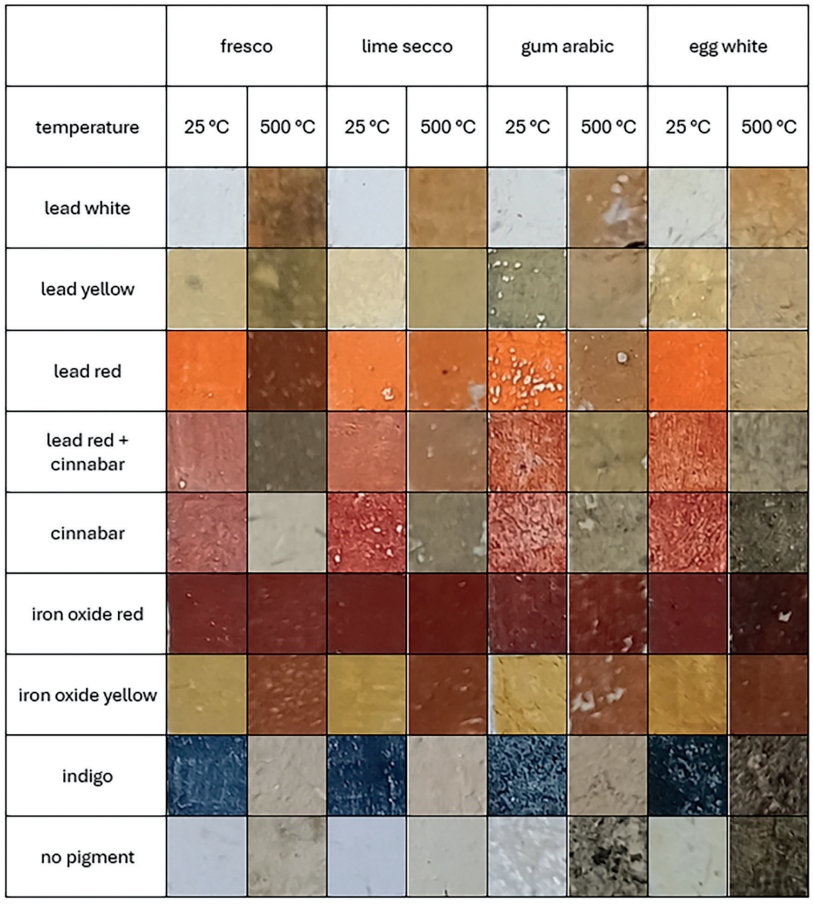
Color change of pigments characteristic in medieval wall paintings

Veronika Nagy[1] and Béla Török[2]

[1] Institute of Chemical Metallurgy and Foundry Engineering, University of Miskolc, Miskolc, Hungary, nagyveronika2000@gmail.com
[2] Institute of Chemical Metallurgy and Foundry Engineering, University of Miskolc, Miskolc, Hungary, bela.torok69@gmail.com, ORCiD: 0000-0002-3394-2753

Keywords: *pigments, heat degradation, CIE L* a* b**

A relatively new, dynamically developing research area in the interdisciplinary research fields of archaeometry, heritage science and materials science is the examination of pigments and painted coatings of different colours. Over time, the pigments in paints can degrade due to environmental influences and undergo partial or complete chemical transformations, changing their colour in the process. Knowledge of the changes of individual pigments under specific conditions provides useful information for historians and restorers. The aim of this work is to characterize the colour change of some common pigments found in medieval wall paintings with increasing temperature. The following seven types of pigments were used for the experiments: lead white, lead yellow, lead red, cinnabar, iron oxide red, iron oxide yellow and indigo. Each pigment was applied to the surface of the sample using four different methods: fresco, lime secco (mezzo secco), gum arabic and egg white (egg tempera) as binders. Then the samples were exposed to temperatures 100, 200, 300, 400 and 500 °C in an electric kiln. Regardless of the pigment of the samples, the first significant changes occurred at 300 °C. Here, a black layer appeared with gum arabic and egg yolk binders, which faded at higher temperatures. In contrast, there were hardly any changes with secco. The most stable pigment was iron oxide red. The least stable was indigo, which disappeared completely at 300 °C, followed by iron oxide yellow, which changed from its original yellowish colour to reddish at the same temperature. These observations were also supported by the measured CIE L* a* b* data, clarifying the extent and direction of the changes.



Effects of 500 °C heat treatment on the colour of mineral pigments commonly used in medieval wall paintings

Notes

Light-coloured inner surface deposits on Copper Age pottery, Eastern Croatia

Marta Mileusnić[1] and Ina Miloglav[2]

[1] Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia, marta.mileusnic@rgn.unizg.hr, ORCiD: 0000-0003-3776-3661
[2] Faculty of Humanities and Social Sciences, University of Zagreb, Zagreb, Croatia, imiloglav@m.ffzg.hr, ORCiD: 0000-0002-9185-9958

Keywords: *archaeometry, pottery, ceramic practices, surface deposits, Copper Age*

This study investigates light-coloured inner surface deposits observed on Copper Age pottery fragments from eastern Croatia (the Slavonia region). The main objective is to determine whether these deposits represent residues related to vessel use or surface modifications associated with ceramic technology. The analytical approach combines optical microscopy (OM), X-ray diffraction (XRD), X-ray fluorescence (XRF), and infrared spectroscopy (IR) to characterise the ceramic assemblage and surface accumulations, thereby yielding complementary data on ceramic microstructure and the mineralogical and chemical composition of the deposits.

Evidence against an intentionally applied coating comes from vessel rims where the deposits do not extend to the lip, indicating they were not applied uniformly across the inner surface. In addition, previous GC-MS analyses have identified beeswax waterproofing treatments on similar vessel forms, suggesting other intentional surface modifications that differ from the deposits examined here. The current evidence instead suggests that the deposits formed during vessel use, probably through the storage of food or other materials rather than cooking. The deposits occur mainly on bowls and cups and are absent on cooking pots. Elevated calcium and phosphorus concentrations in deposits may indicate bone powder or ash; however, preliminary IR analyses do not confirm phosphate-rich mineral phases and instead suggest predominantly carbonate-rich deposits. The absence of phosphate bands may reflect carbonate dominance masking weaker signals or phosphorus present in minor, poorly crystalline, or amorphous forms not detectable by IR.

Ongoing investigations of light-coloured inner surface deposits will refine understanding of their composition and formation pathways. This study contributes to broader discussions on prehistoric ceramic surface deposits and the challenges of distinguishing use-related, technological, and post-depositional modifications in pottery.

Acknowledgement

This research has been fully supported by the Croatian Science Foundation (HRZZ) under the project CULPLUS (IP-2022-10-9489).



Light-coloured deposits observed on the inner surface of a Vučedol culture bowl from Vinkovci (Inv. No. A2357, Vinkovci City Museum, photo: M. Pjevac)

Notes

Firing temperatures of Iron Age ceramics from Bulgaria determined by magnetic susceptibility measurements

Deyan Lesigyarski[1,2], Aneliya Nikolova[1,2], Elena Bozhinova[3], Boika Zlateva[2,4] and Velislav Bonev[2,5]

[1] National Institute of Geophysics, Geodesy, and Geography, Bulgarian Academy of Sciences, Sofia, Bulgaria, dlesigyarski@geophys.bas.bg, samra_2012@abv.bg, ORCiD: 0000-0002-5142-794X (D. Lesigyarski)
[2] Center of Archaeometry with Laboratory for Conservation and Restoration, Sofia University "St. Kl. Ohridski", Sofia, Bulgaria
[3] Regional Archaeological Museum of Plovdiv, Plovdiv, Bulgaria, elena.bozhinova@gmail.com
[4] Faculty of Chemistry and Pharmacy, Sofia University "St. Kl. Ohridski", Sofia, Bulgaria, ahbz@chem.uni-sofia.bg
[5] Faculty of History, Sofia University "St. Kl. Ohridski", Sofia, Bulgaria, velislav.bonev@abv.bg

Keywords: *ceramics, firing temperature, magnetic susceptibility, Iron Age, Bulgaria*

The aim of the present study is to draw conclusions about the firing technology of pottery samples dated to several periods of the Iron Age in Bulgaria. So far, a total of 353 ceramic sherds are analyzed, however, the work is in progress and the number of specimens increases. The analyzed ceramic fragments represent mainly tableware and cooking pots, although tiles and transportation amphorae are also included. The sherds are dated mainly to several periods from the 5th century BCE to the 5th century CE. Besides the rock-magnetic methods, analytical techniques include Raman spectroscopy and X-ray fluorescence (XRF) as well.

Maximum firing temperatures (T_{max}) were determined by stepwise laboratory heating and measuring the mass-specific magnetic susceptibility (χ) of the cooled specimens at each step. T_{max} can be recognised after a significant change in the χ values [1]. Additional laboratory rock-magnetic analyses were performed in order to characterize the complex magnetic mineralogy of the specimens, which reflects conditions during the pottery firing. Portable devices for Raman spectroscopy (Bruker Bravo) and XRF (Bruker Titan S1) were used for the determination of non-magnetic phases and the elemental composition of the analyzed pottery sherds.

The equivalent firing temperature of ceramic sherds from the earlier periods has been determined to be 800 ± 50 °C. Some gradual changes in magnetic susceptibility in the interval of 400–700 °C occur mainly for the darker (gray/black) specimens. These changes could reflect the unstable thermodynamic state of the magnetic oxides formed during the rapid single firing of vessels in antiquity. The average firing temperature for the samples dated to the BCE centuries is equal to 875 ± 25 °C. The T_{max} of the Roman and Late Antique kitchen wares are

generally higher (820 ± 50 °C and up to 920 °C for the tableware) but have more inhomogeneously distributed values compared to those of the earlier Iron Age samples.

Acknowledgements

This study is supported by the Bulgarian National Science Fund under the Contract No. КП-06-H90/4. Laboratory Raman and XRF equipment for this study is supplied with the financial support of the INFRAMAT Project.

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Notes

X-ray analyses of a Roman Age ceramic rattle from Yambol district, Bulgaria

Todor Valchev[1] and Borislava Pavlova[2]

[1] Regional Historical Museum,
Dobrich, Bulgaria, twulchev@gmail.com, ORCiD: 0009-0004-2506-5879
[2] Regional Historical Museum, Yambol, Bulgaria, bobpavlova@gmail.com

Keywords: *X-ray analyses, Roman Age, ceramic rattle*

The 21st century can be seen as the time of great collaboration in the sciences. The development of new technologies has enabled "non-standard" scientific research to occur in different ways, leading to incredible results. One such collaboration has occurred between Physics and Archaeology.

X-rays are a form of electromagnetic radiation inhabiting the region between ultraviolet radiation and gamma rays. They are created by the hits of high velocity electrons within the atoms of the metal target in a special vacuum tube. When the electrons hit the target, the X-rays are created by two different atomic processes: characteristic X-ray emission and Bremsstrahlung (breaking radiation). Using specific X-ray analyses, we can "look" inside the archaeological artifacts without destroying them.

The aim of the poster is to present results from X-ray analyses of one ceramic rattle. It is made from clay which after baking has a brown colour. It has a ball-like shape. The surface is smutted and covered with holes.

During the Roman Age some rattles were filled with rich semantics and had a spiritual influence. The sound of shaking objects was said to protect the owner from bad fortune, illnesses and evil. Sometimes rattles were laid in the graves as personal belongings to keep them safe in the afterlife.

X-rays analyses provide the opportunity to look into the ceramic rattle without breaking it. It is an example of how a non-standard approach can be used for the examination of clay artifacts.



A Roman Age ceramic rattle

Notes

Choosing the best clay? The Athenian mouldmade glazed pottery industry between Hellenistic innovation and Roman imperialism (2nd c. BC – 2nd c. AD)

Florence Liard[1] and Ayed Ben Amara[2]

[1] Université catholique de Louvain – Saint-Louis Bruxelles, CRHiDI, INCAL, CEMA, Brussels, Belgium, florence.liard@uclouvain.be
[2] Archéosciences, Université Bordeaux Montaigne, Maison de l'Archéologie, Pessac, France, ayed.ben-amara@u-bordeaux-montaigne.fr

Keywords: *black glaze, lead glaze, Attica, Skourta Plain, Hellenistic pottery*

This paper presents the results of SEM-EDS and petrographic analyses of glazed mouldmade tablewares that were produced at a turning point in the history of Athenian fine ware industry. The studied material comes from ASCSA excavations at the Athenian Agora. It spans from the invention of the black-glazed «Megarian» bowl in Athens around 225 BC [1] to the inclusion of the local pottery industry in provincial markets of the Roman empire (1st – 2nd c. AD) [2]. This controversial period is marked by an international appeal for these fine wares, with an access to overseas markets inherited from the Classical period; and a by dramatic blow to the pottery industry inflicted by the sack of Athens by Sulla in 86 BC, after what the city would never again be a significant producer of fine pottery [3].

Throughout this period, mouldmade bowls were manufactured by Athenian potters. Archaeometrists highlighted the properties of illitic clays from the Skourta Plain for creating black glazes of exquisite quality in pre-Roman Athens [4], but comparatively little research has been done on clay selection strategies for the pottery fabrics. Also, petrography demonstrated the existence of a local production of lead-glazed pottery in the 1st century BC/AD, in an effort to adapt to Roman tastes [5]. This paper draws on these results to highlight continuity in fabric composition through time, with the concurrential use of two (low-)calcareous clays compatible with the geology of Attica. One of these fabrics, which widely predominates among the mass-produced black-glazed bowls, may derive from clay resources of the Skourta Plain. It becomes increasingly popular among Roman lead-glazed pottery. This technological shift suggests a reorganisation of the pottery industry after Sulla's sack that goes beyond aesthetic considerations, and may involve new skills for adapting the fabric composition to new glazing compounds.

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Notes

Crushed-rock pottery tempering at the villa of Aiano (San Gimignano, Siena, Italy): Between technological practices and cultural history (1st cent. BC – 6th cent. AD)

Florence Liard[1], Marco Cavalieri[2] and Johan Yans[3]

[1] Université catholique de Louvain, CRHiDI, INCAL, CEMA, Brussels, Belgium / Université de Namur, Fontes Antiquitatis, Namur, Belgium, florence.liard@uclouvain.be
[2] Institut des civilisations, arts et lettres, Louvain-la-Neuve, Université catholique de Louvain, Belgium
[3] Département de géologie, Université de Namur, Namur, Belgium

Keywords: *Dolia defossa, ceramica grezza, Etruria, Langobards, crushed-rock temper*

At the wine-producing villa of Aiano in Tuscany (UCLouvain excavations), petrographic and SEM-EDS analyses of 22 locally-made dolia *defossa* (1st century BC/AD) and 13 *ollae* (6th century) revealed two distinctive crushed-rock tempering practices. *Dolia defossa* are tempered with gabbro associated with the Tuscan ophiolitic complex; *ollae* tempered with calcite and marble, the latter recycled from the villa's mosaic *tesserae* [1].

By contrast to alluvial tempering, rock-crushing denotes the intentional choice for one exclusive type of ingredient, in this case for refractory purposes. Beyond functional considerations, we explore the cultural significance of these technological choices by confronting them to the history of the site and region. The wine-producing estate of Aiano was built in the late 3rd / early 4th century AD; earlier dolia were recycled from nearby sites and installed in the cella vinaria; the estate was abandoned toward the 6th century, before various living spaces were refurbished into production activities, spoliating wealthy materials from the villa [2].

The use of gabbroic – and related (augite) – temper is reported in Etruscan *dolia* from the Maremma [3, 4]. Following the installation of Roman colonies in Etruria in the 1st cent. BC, it became commonplace for cookingware [5,6]. The *dolia* from Aiano are suspected to come from regional *figlinae* operating during this period of economic growth.

Tempering pottery with crushed marble *spolia* is documented among northern Italian Late Roman cookingware [7]. It may derive from the earlier use, in Roman Bavaria, of waste materials from marble carving as pottery tempers [8]. In the Balkans, it is found in Langobard-age pottery from Transdanubia [9]. At Aiano, is contemporary with the arrival of the Langobards in the region.

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Notes

Sarmatian pottery in a new light: Provenance analysis of granitoid temper using cathodoluminescence microspectroscopy

Vivien Bozsik[1], Krisztián Fintor[2], Sándor Gulyás[3], Máté Szemerédi[4], Dorottya Walter[5] and Andrea Varga[6]

[1] Department of Geology, University of Szeged, Szeged, Hungary, bozsik.vivien@gmail.com, ORCiD: 0009-0007-3926-335X
[2] Department of Biophysics, University of Pécs, Pécs, Hungary, fintor.krisztian@pte.hu, ORCiD: 0000-0003-4794-9419
[3] Department of Geology, University of Szeged, Szeged, Hungary, gulyas.sandor@szte.hu, ORCiD: 0000-0002-3384-2381
[4] Department of Geology, University of Szeged, Szeged, Hungary, szemeredi.mate@gmail.com, ORCiD: 0000-0002-7432-8418
[5] Department of Archaeology, University of Szeged, Szeged, Hungary, walter.dorottya@szte.hu; ORCiD: 0009-0001-5883-6201
[6] Department of Geology, University of Szeged, Szeged, Hungary, raucsikne.varga.andrea.beata@szte.hu, ORCiD: 0000-0002-8673-1482

Keywords: *cathodoluminescence microspectroscopy, provenance analysis, granitoid temper, feldspar, Late Sarmatian pottery*

Coil-built micaceous–pebbly pottery represents a distinctive component of the Late Sarmatian ceramic tradition of the Great Hungarian Plain. Determining the provenance of granitoid temper remains challenging, as potential source areas are distributed across several granitoid occurrences within the Carpathian Basin and often display similar petrographic characteristics. This study investigates the applicability of cold-cathode cathodoluminescence (CL) microscopy and spectroscopy to the provenance analysis of granitoid-tempered pottery.

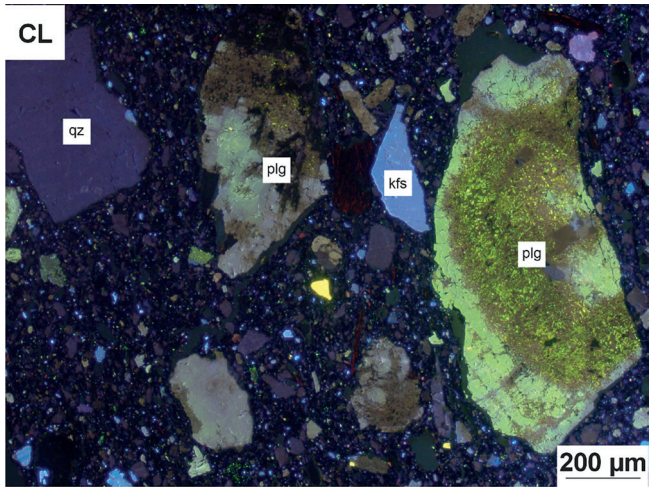
The analysed ceramic material originates from the Late Sarmatian settlement of Tázlár-Templomhegy (Hungary). Feldspar grains from the granitoid temper were compared with feldspars from several granitoid bodies of the Carpathian Basin, including the Velence Granite and Mórágy Metagranite from Hungary, the Codru, Highiş and Munţele Mare granitoids from the Apuseni Mountains (Romania), as well as archaeological rock samples from the Late Sarmatian pottery workshop of the settlement of Nagymágocs-Paptanya (Hungary). Particular attention was paid to the cathodoluminescence properties and emission spectra of K-feldspar and plagioclase grains, which have been shown to be among the most diagnostically useful mineral phases for provenance assessment [1]. Luminescence spectra were processed by peak fitting, and the resulting spectral parameters were evaluated using cluster analysis.

Rock-forming minerals (e.g., plagioclase and K-feldspar varieties) in the studied granitoid rocks exhibit distinct cathodoluminescence characteristics, allowing differentiation among

several potential source regions. Both the spectral characteristics and cluster analysis indicated the closest similarity between the granitoid temper of the pottery and the samples of the Codru granitoid. The results demonstrate that feldspar cathodoluminescence microspectroscopy provides a sensitive tool for characterising granitoid raw materials and offers considerable potential for provenance studies of granitoid-tempered pottery. Beyond its archaeological implications, the method represents a promising approach for archaeometric provenance research based on the luminescence properties of feldspar grains.

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Cathodoluminescence photomicrograph of granitoid temper grains in the analysed pottery sample showing the characteristic luminescence of K-feldspar and plagioclase grains. Mineral abbreviations: kfs: K-feldspar; plg: plagioclase; qz: quartz. Other abbreviation: CL: cathodoluminescence mode

Notes

Clay, craft and provenance: Insights into pottery tradition at the medieval market town of Gutenwerd

Katja Špec[1,2], Nastja Rogan Šmuc[3], Katarina Katja Predovnik[4] and Tomaž Nabergoj[5]

[1] Department of Archaeology, Faculty of Arts, University of Ljubljana, Ljubljana, Slovenia, katja.spec@ff.uni-lj.si, ORCiD: 0009-0007-7185-4619
[2] Department of Geology, Faculty of Natural Sciences and Engineering, University of Ljubljana, Ljubljana, Slovenia, katja.spec@ntf.uni-lj.si
[3] Department of Geology, Faculty of Natural Sciences and Engineering, University of Ljubljana, Ljubljana, Slovenia, nastja.rogan@ntf.uni-lj.si, ORCiD: 0000-0002-5850-3554
[4] Department of Archaeology, Faculty of Arts, University of Ljubljana, Ljubljana, Slovenia, katarinakatja.predovnik@ff.uni-lj.si, ORCiD: 0000-0002-1948-4303
[5] National Museum of Slovenia, Ljubljana, Slovenia, tomaz.nabergoj@nms.si

Keywords: *Medieval Pottery, Early Modern pottery, pottery provenance, pottery tradition, Gutenwerd*

Questions concerning pottery provenance, local production, and craft traditions at the deserted medieval market town of Gutenwerd, situated along the Krka River in present-day south-eastern Slovenia, have so far remained largely unexplored. The site provides insight into broader Central European pottery traditions and technological developments during the High and Late Middle Ages and the Early Modern period.

This study therefore examines selected coarseware and tableware pottery fragments to investigate pottery-making traditions, provenance, and technological variability during the High and Late Middle Ages and the Early Modern period. It also explores the continuity and transformation of ceramic production practices that may reflect differences in potters' knowledge, skills, and manufacturing traditions. The pottery was first analysed macroscopically, then subjected to archaeometric analyses using thin-section petrography, X-ray fluorescence (XRF), X-ray diffraction (XRD), and inductively coupled plasma mass spectrometry (ICP-MS). These analyses identified several distinct technological and petrographic groups, indicating variability in raw material selection and pottery production practices over time. High Medieval pottery is characterised by coarse fabrics rich in carbonates and vessels produced on hand-operated wheels, while Late Medieval and Early Modern pottery displays increasingly refined clay preparation, greater use of quartz temper, wheel-throwing on foot-powered wheels, and a higher proportion of oxidising firing conditions. Mineralogical and chemical analyses also revealed strong correspondence between pottery fragments and locally sampled clays, supporting the hypothesis of local pottery production.

Although no direct archaeological evidence of pottery workshops has yet been identified, the results of the analyses support the hypothesis of local pottery production and provide

important insights into raw material procurement, technological practices, and changes in pottery production over time. The results contribute to broader discussions of ceramic provenance, technological traditions, and local production in the medieval and early modern Central European region, while also representing the first comprehensive archaeometric study of pottery from this period within Slovenian archaeology.



View of the site of the deserted medieval market town of Gutenwerd (photo: A. Gaspari, 2021)

Notes

Interdisciplinary studies of selected glass beads and metal jewellery pieces from the Iron Age site at Derecske (NE-Hungary)

Dániel Bence Bartha[1], Anikó Angyal[2], Orsolya Cserpák-Laczi[3], János Dani[4], Enikő Furu[5] and Zsófia Sz. Osváth[6]

[1] University of Szeged, Szeged, Hungary, danielbartha120@gmail.com
[2] HUN-REN Institute for Nuclear Research, Debrecen, Hungary, angyal@atomki.hu, ORCiD: 0000-0003-4444-7333
[3] Déri Museum, Debrecen, Hungary, orsolya.laczi@gmail.com
[4] Déri Museum, Debrecen, Hungary / University of Szeged, Szeged, Hungary, drdanij@gmail.com, ORCID: 0000-0003-4327-0038
[5] HUN-REN Institute for Nuclear Research, Debrecen, Hungary, furu.eniko@atomki.hu, ORCiD: 0009-0000-4688-0814
[6] Móra Ferenc Museum, Szeged, Hungary, zsofia.osvath@gmail.com, ORCiD: 0000-0001-7295-993X

Keywords: *glassy beads, micro-XRF, Middle Iron Age, metal jewellery*

More than 190 glass beads, five hair rings, and a rare punched electrum plate (i.e., clothing appliqué) were recovered from a cemetery with 19 graves near Derecske (E-Hungary) dating back to the Middle Iron Age Vekerzug culture [1]. Micro-XRF analysis was conducted in order to determine the chemical composition of the selected glass beads and the alloy types of the precious metal artefacts.

The parts of the hair rings were produced from various metal alloys: the bases of the artefacts were made of copper, tin bronze or recycled tin bronze. The precious metal sheets covering the base metals, the conical ends of the hair rings and the punched plate made of electrum alloys in varying proportions. The higher silver content of the conical ends could be the result of intentional alloying, just as the copper content in other jewellery parts may have served to enhance the golden shade, creating an optical/visual contrast and thereby achieving an aesthetic effect [2].

The majority of the glassy artefacts were made of mineral natron glass [3]. Colorants were cobalt and copper together in blue [4, 5], copper in turquoise [6] and calcium antimonate in white glasses [6, 7]. Some of the glasses contain antimony most probably as decolourant or opacifier [6, 7]. One of the beads was produced of plant ash glass [3], which has black body due to its higher iron content [8] and pale yellow dots due to their lead antimonate and lead stannate contents [4]. The presence of plant ash glass and lead stannate in glasses had not yet been documented from the Middle Iron Age of Hungary [5].

These studies are the first of their kind, as no interdisciplinary analyses of Vekerzug culture metal jewellery have been conducted to date. They can provide significant insights into the

(trade)networks of Middle Iron Age communities of the Carpathian Basin based on the possible provenance and raw materials.

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The black glass bead, the punched electrum plate and a hair ring

Notes

Connecting to the long-distance trade: Compositional analysis and provenance of glass beads from the Iron Age cemetery of Pilismarót-Basaharc, Hungary

Károly Tankó[1], Bernadett Bajnóczi[2], Erzsébet Jerem[3] and Kata Dévai[4]

[1] HUN-REN – ELTE Research Group for Interdisciplinary Archaeology, ELTE Eötvös Loránd University, Budapest, Hungary, tanko.karoly@btk.elte.hu, ORCiD: 0000-0003-0293-7959
[2] Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, Budapest, Hungary, bajnoczi.bernadett@csfk.org, ORCiD: 0000-0003-0006-7611
[3] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, jerem@archaeolingua.hu, ORCiD: 0009-0001-7563-8987
[4] HUN-REN – ELTE Research Group for Interdisciplinary Archaeology, ELTE Eötvös Loránd University, Budapest, Hungary, kata.devai@gmail.com, ORCiD: 0000-0002-3624-7246

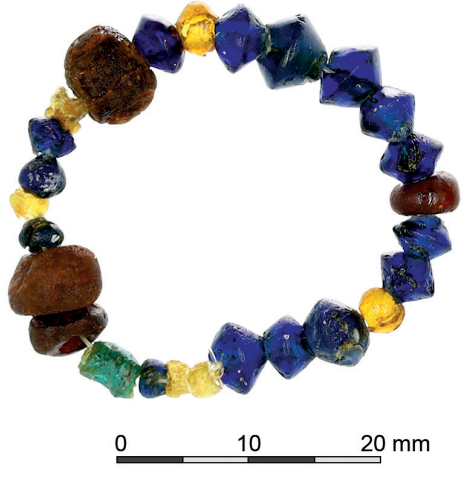
Keywords: *Iron Age, glass beads, SEM-EDS, Carpathian Basin, La Tène*

This study presents the findings of a compositional and provenance study of glass beads from the cemetery of Pilismarót-Basaharc, a pivotal site for understanding the transition between the Early and Late Iron Ages and the early Celtic presence in the Carpathian Basin [1]. The material culture of this community reflects a complex interplay of local traditions and far-reaching connectivity, integrating Transdanubian Early Iron Age traditions, Eastern Alpine-Balkan influences, and 'Scythian-type' features from the Great Hungarian Plain. The cemetery's high frequency of female and child burials adorned with glass, amber, and coral highlights a profound engagement with high-prestige ornaments. The glass beads, notable for their diversity in opacity, colour, and morphology, serve as primary indicators of long-distance trade.

Fifty-nine glass beads, representing all colours and forms, were selected from seven graves. Handheld XRF and SEM-EDS were used to determine their chemical composition and colorants, in order to identify specific glass types and their potential origins. Beyond mere classification, the results offer a novel perspective on the dynamics of regional and international exchange during the Early Celtic period. By contextualising glass alongside other prestige goods like amber and graphite, the research underscores the symbiotic relationship between emerging political centres and their peripheries, revealing how glass functioned as a catalyst for social connectivity in the Danube Bend.

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Iron Age glass beads from Pilismarót-Basaharc, Grave 105

Notes

Archaeometric analyses on champlévé enamelled fittings from the collection of the King Saint Stephen Museum (Hungary)

Bernadett Bajnóczi[1], Veronika Bereková[2], László Előd Aradi[3] and Diego Seguí-Fábián[4]

[1] Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, Budapest, Hungary, bajnoczi.bernadett@csfk.org, ORCiD: 0000-0003-0006-7611
[2] King Saint Stephen Museum, Székesfehérvár, Hungary, berek.veronika@szikm.hu
[3] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, aradi.laszlo@hnm.hu, ORCiD: 0000-0003-0276-3119
[4] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, seguifabian.diego@hnm.hu, ORCiD: 0009-0002-1961-3125

Keywords: *Limoges, champlévé enamel, medieval*

During the 12th and 13th centuries, numerous churches across Europe used altar and processional crosses produced in the renowned workshops of Limoges and southern France. These inexpensive yet magnificent objects, distinguished by their champlevé enamel decoration, were widely distributed and even reached as far as the Kingdom of Hungary [1]. The collection of the King Saint Stephen Museum in Székesfehérvár preserves several enamelled fittings imported from Limoges. These gilded copper fittings are decorated with dark and light blue, turquoise and red enamels. Based on their form, these fittings were most likely originally mounted on a cross, although their use as decorative elements on a reliquary cannot be excluded.

Six fittings – two corpuses (the body of Christ), two saint figurines, a rhomb-shaped fitting, and a medallion depicting Christ in Glory (Maiestas Domini) – have been subjected to archaeometric analysis in order to provide a more detailed understanding of the material composition and manufacturing techniques of the enamels. The chemical composition, colorants and opacifiers of the enamels were determined using handheld XRF, SEM-EDX, Raman microspectroscopy, and micro-XRF analyses.

The turquoise and blue enamels on four fittings are ‘late type’ enamels made of vegetal soda ash glass and opacified with tin oxide. These enamels were applied to Limoges objects from the beginning of the 13th century to the middle of the 14th century [2, 3]. However, two of the fittings (a corpus and a medallion) were decorated with turquoise and blue enamels made from a different type of glass and opacifiers: one of the enamels was made from mineral soda glass and was opacified with calcium antimonate, while the other was made from vegetal soda ash glass and was opacified with tin oxide. The presence of both ‘early type’ and ‘late type’ enamels on the same object indicates that these two fittings likely originat-

ed from a brief transitional period between the end of the 12th century and the beginning of the 13th century [2].

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Fittings decorated with 'early type' and 'late type' enamels: a medallion depicting Christ in Glory and a corpus

Notes

The life history of an extraordinary object: Examination of the burial and a bronze sheet belt of an elite woman from the beginning of the Late Bronze Age

Kristóf Fülöp[1], Eszter Bódai[2], Eszter Horváth[3], Bernadett Bajnóczi[4], Anett Gémes[5], István Major[6], Wayne Powell[7] and Viktória Kiss[8]

[1] MTA–ELTE HTK Lendület "Momentum" BASES Research Group, Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, fulop.kristof@htk.elte.hu, ORCiD: 0009-0005-9763-672X
[2] Katona József Museum, Kecskemét, Hungary, bodaieszter97@gmail.com, ORCiD: 0009-0000-9657-0574
[3] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, horvath.eszter@htk.elte.hu, ORCiD: 0009-0007-4650-0392
[4] Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, Budapest, Hungary, bajnoczi.bernadett@csfk.org, ORCiD: 0000-0003-0006-7611
[5] Department of Biological Anthropology, Institute of Biology, Faculty of Science, ELTE Eötvös Loránd University, Budapest, Hungary / Salisbury Ltd., Budapest, Hungary, anett.gemes@ttk.elte.hu, ORCiD: 0000-0002-5107-8364
[6] International Radiocarbon AMS Competence and Training Center, HUN-REN Institute for Nuclear Research, Debrecen, Hungary, major.istvan@atomki.hu, ORCiD: 0000-0003-4675-9875
[7] Department of Earth and Environmental Sciences, CU NY Brooklyn College, New York, USA, wpowell@brooklyn.cuny.edu, ORCiD: 0000-0003-3387-2430
[8] MTA–ELTE HTK Lendület "Momentum" BASES Research Group, Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, kiss.viktoria@htk.elte.hu, ORCiD: 0000-0002-6577-9081

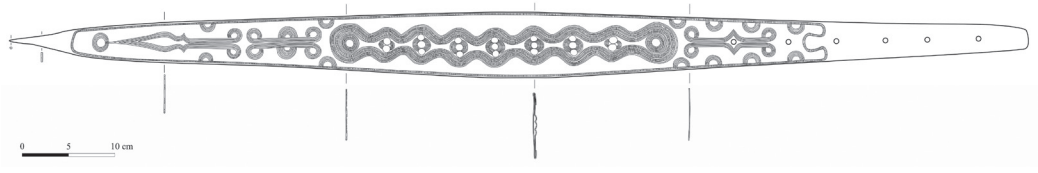
Keywords: *bronze sheet belt, mid-2nd millennium BC, lead isotope analysis, FTIR and microscopic analysis, bioarchaeological studies*

The recently uncovered burial at Hajós-Méhes-dűlői-csatorna, located in the southern Danube–Tisza Interfluve, belongs to the group of richly furnished female burials dating to the beginning of the Tumulus Culture in the middle of the 2nd millennium BC. Despite the poor preservation of the grave, the 2024 excavation allows for a detailed reconstruction of the rich funerary attire of the deceased woman. Among the components of the costume, the most remarkable find is an in situ preserved bronze sheet belt of the Sieding-Szeged type.

To investigate raw material procurement and exchange networks, we analysed the elemental composition and lead isotope ratios of the bronze artefacts. FTIR analysis is used to determine the origin of the associated amber bead, specifically whether it was made of Baltic amber, while micro-XRF spectrometry is used to identify the chemical composition of the glass bead. In addition, bioarchaeological (physical anthropology, ^{14}C, C and N stable isotope) anal-

yses have established the absolute date of the burial, the sex and age of the deceased, and provided information on her diet, such as evidence for millet consumption.

Finally, stereo-microscopic analyses of the unique belt shed light on the moment of its "birth". Various traces of use, later modifications, and damage indicate a long and intensive "life" of the object, while the archaeological context allows us to reconstruct the final stage of its biography as the central element of the funerary attire of an adult woman.



The reconstructed bronze sheet belt from Hajós
(drawing: Zsóka Varga, Institute of Archaeology ELTE RCH)

Notes

Looking into the situla. Elementary composition and the manufacturing process of the Early Iron Age bronze situla from Kurd

Bence Soós[1], Mihály Braun[2] and Balázs Lukács[3]

[1] Department of Prehistory and Early History, Department of Archaeology, Hungarian National Museum, Budapest, Hungary, soos.bence@mnm.hu, ORCiD: 0000-0002-2056-5549
[2] HUN-REN Institute for Nuclear Research, Debrecen, Hungary, mbraun@atomki.hu, ORCiD: 0000-0003-1726-9455
[3] Works of Art Conservation and Restoration Department, Hungarian National Museum, Budapest, Hungary, lukacs.balazs@hnm.hu, ORCiD: 0000-0003-3909-5660

Keywords: *Hallstatt period, metal vessel, LA-ICP-MS*

The Early Iron Age hoard found near Kurd (Tolna County, Hungary) comprising 14 ribbed bronze buckets and a large situla is an outstanding assemblage in the eastern Hallstatt zone both in terms of the number of bronze vessels and its context. While outstanding in the region, the hoard, the specific combination of the vessels in the hoard, is characteristic of elite drinking services developed in the Picenum and Verucchio regions of Italy and adopted by transalpine elites by the 6th century BCE [1, 2, 3].

Although the significance of the hoard has been acknowledged for more than a century, analysis into the production technology and elementary composition of the vessels have never been carried out [4]. The proposed poster outlines the first step of the re-evaluation of the hoard, namely an in-depth investigation of the large composite situla of the assemblage. This includes micro and macro observations of use-wear traces on the item as a means of outlining the biography of the vessel and, more importantly, its elementary composition analysis. The bronze situla was probed at eight different locations and the samples were subjected to LA-ICP-MS.

Results of the analysis provide insight into the production technology of this outstanding item and helps outlining how its manufacturing is embedded in the traditions of Early Iron Age toreutics in Central Europe.

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Notes

p-XRF analysis of Thracian type fibulae from Bulgaria

Velislav Bonev[1], Boika Zlateva[1,2],
Deyan Lesigyarski[3] and Kalin Madzarov[4]

[1] Center of Archaeometry with Laboratory of Conservation and Restoration, Faculty of History, University of Sofia, Sofia, Bulgaria, velislav.bonev@abv.bg
[2] Faculty of Chemistry and Pharmacy, University of Sofia "St. Kl. Ohridski", Sofia, Bulgaria, ahbz@chem.uni-sofia.bg
[3] National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Science, Sofia, Bulgaria
[4] National Archaeological Institute with Museum, Bulgarian Academy of Science, Sofia, Bulgaria

Keywords: *fibulae, Thracian type, p-XRF, Bulgaria*

Fibulae, as elements of attire, fulfilled both utilitarian and decorative functions, serving not only as garment fasteners but also as markers of aesthetic expression. This dual functionality contributed to their broad geographical distribution and long chronological use. Moreover, on one hand, they show the mode and the personal choice of their owner and on the other, the fibulae can be used to reveal the cultural contrasts between different regions and/or ethnicities. Finally, by determining their production technology one can make assumptions about the level of technological development of the region and also the level of knowledge of ancient metallurgist. The present study applies portable X-ray fluorescence spectroscopy (p-XRF, Titan S1, Bruker, Germany) for 29 Thracian type fibulae and the bronze ingot and the two semi-finished products for Thracian-type fibulae were also analyzed from NE Bulgaria (village Obretenik). The results show that artefacts are produced on the tin-based bronzes, (tin and copper are macro-components (%) with traces of iron, gold, bismuth, chromium, nickel, arsenic, zinc, lead. Statistical treatment – CA, FA, PCA allowed contextualization of the analytical results and permitted to obtain a better knowledge of the used metal alloys and manufacturing procedure of the investigated bronze artefacts, mainly fibulae.

Acknowledgements

This study is supported by the BG05M2OP001-1.001-0001 "Creation and development for Heritage BG" Centre of Excellence and the INFRAMAT

Notes

Crossroads of cultures and craft traditions: A comparative material characterisation of Gepidic and Langobardic period fine metalwork in the 6th-century AD Carpathian Basin

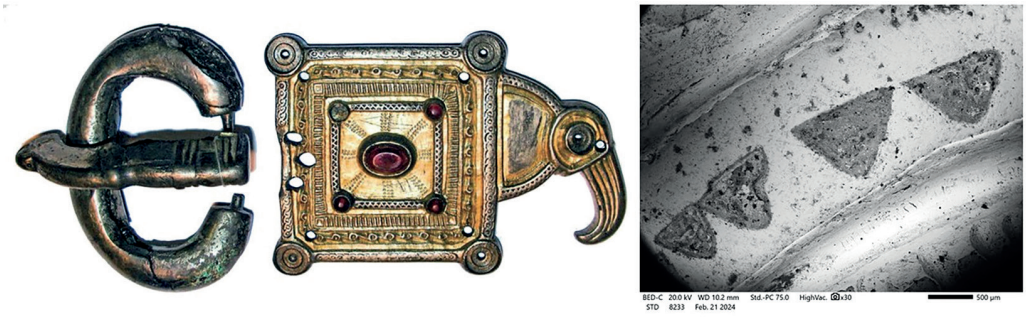
Viktória Mozgai[1], Eszter Horváth[2] and Bernadett Bajnóczi[3]

[1] Institute for Geological and Geochemical Research,
HUN-REN Research Centre for Astronomy and Earth Sciences,
Budapest, Hungary, mozgai.viktoria@csfk.org, ORCiD: 0000-0001-9712-2773
[2] Institute of Archaeology, ELTE Research Centre for the Humanities,
Budapest, Hungary, horvath.eszter@abtk.hu, ORCiD: 0009-0007-4650-0392
[3] Institute for Geological and Geochemical Research,
HUN-REN Research Centre for Astronomy and Earth Sciences,
Budapest, Hungary, bajnoczi.bernadett@csfk.org, ORCiD: 0000-0003-0006-7611

Keywords: *polychrome fine metalwork, niello inlays, comparative analysis, Carpathian Basin, Gepidic and Langobardic period*

Since prehistoric times, the Danube has served as a significant cultural and civilisational boundary. In the Carpathian Basin, the two banks of the river often developed at different rates, as reflected in their distinct material cultures. During the first two-thirds of the 6th century AD, this area was ruled by two Germanic tribes: the Gepids in the Tisza region, and the Langobards in Transdanubia. Despite their different origins and histories, the two peoples were bound together by a shared history of conflicts and alliances. This study focuses on non-ferrous fine metalwork pieces from these two regions, exploring the chronological and regional differences and similarities in raw material preferences, alloying practices, and decorative techniques. Nearly 150 objects from Hungarian museum collections were investigated using various non-destructive analytical methods (optical microscopy, SEM-EDX, handheld XRF and μ-XRD) to determine the chemical composition of metal alloys, inlaid or applied ornaments and coatings, and the microtexture and mineralogical composition of niello inlays. This bluish-black solid mineral material was widely used in Roman and early medieval times to decorate silver, gold, and copper-based alloy objects. Alongside garnet inlays, gilding, and chip carving, niello was a key element of the so-called 'Danubian polychrome animal style', which dates from the mid-5th century AD. However, there are several questions and uncertainties regarding its composition, preparation, and application during different periods. Our systematic analysis revealed significant regional differences in the metal alloys used, implying two distinct metalworking traditions in the 6th century. Silver content was strongly 'diluted' with copper or copper-based alloy, which practically dominates in the composition: brass in the Tisza region, while bronze and gunmetal in Transdanubia. In contrast, the composition of niello inlays proved to be highly heterogeneous, ranging from pure sil-

ver sulphide, reflecting Roman traditions, to various silver-copper sulphides and pure copper sulphides.



The gilded silver belt buckle from Szolnok-Szanda and the BSE image of its niello inlays

Notes

Technology and alloy composition of an early medieval disc brooch from Nitra-Mikov dvor (Slovakia)

Kristián Jócsik[1,2]

[1] Institute of Archaeology, Faculty of Philosophy and History, University of Lodz, Łódź, Poland, kristian.jocsik2@edu.uni.lodz.pl, ORCiD: 0000-0002-1643-3623
[2] Institute of Archaeology, Constantine the Philosopher University in Nitra, Nitra, Slovakia, kristian.jocsik@ukf.sk

Keywords: *archaeometry, leaded brass, artifact technology, Early Middle Ages, disc brooch*

The cemetery of Nitra-Mikov dvor represents a newly investigated early medieval burial ground dated to the 10th–11th century and excavated during rescue archaeological research conducted between 2019 and 2021. An exceptional find from grave 4/2019 is a disc brooch whose closest analogies originate from the Carolingian-Ottonian cultural sphere of western and north-western Europe. The contribution presents the results of material and technological analyses aimed at interpreting the manufacturing technology of the brooch. The artefact was analysed using handheld X-ray fluorescence spectrometry (hh-XRF), laser-induced breakdown spectroscopy (LIBS), and scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS). The analyses revealed that the brooch was manufactured from a lead-rich copper alloy with a stable presence of zinc, corresponding to leaded brass with a low zinc content. XRF measurements identified elevated concentrations of lead (up to 21.75%) and consistent zinc values ranging between 4.41–5.34%. Laser-Induced Breakdown Spectroscopy (LIBS) depth profiling indicated compositional variability between surface and deeper layers, particularly an increase in lead concentration interpreted as segregated lead-rich phases within the metallic matrix. The elevated lead content likely improved the fluidity of the melt and facilitated the casting of the small and plastically complex object. Macroscopic and microscopic observations identified several perforations in the central decorative motif interpreted as casting defects rather than intentional openwork decoration. The results correspond well with archaeometric data from Carolingian and Ottonian disc brooches from the Netherlands and northern Germany, where leaded brass alloys appear to have been commonly employed in the production of such objects.



Disc brooch from Nitra-Mikov dvor

Notes

Provenance analysis of serpentinite polished stone tools from the Late Neolithic Alsónyék-Bátaszék site

Edina Pegán[1], György Szakmány[2], Kata Furholt[3], Anett Osztás[4] and Tamás Sági[5]

[1] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, pegan.edina@hnm.hu, ORCiD: 0009-0000-0171-701X
[2] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, szakmany.gyorgy@ttk.elte.hu, ORCiD: 0000-0002-9557-2030
[3] Institute of Pre- and Protohistoric Archaeology, Kiel University, Kiel, Germany, kata.furholt@ufg.uni-kiel.de, ORCiD: 0000-0002-3944-9951
[4] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, osztas.anett@htk.elte.hu, ORCiD: 0000-0002-8470-0770
[5] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, sagi.tamas@ttk.elte.hu, ORCiD: 0000-0003-4664-5472

Keywords: *Transdanubia (S-Hungary), polished stone tools, serpentinite, 5th millennium BCE*

Serpentinite was a rarely used raw material during the Neolithic period in the Carpathian Basin, but its usage expanded significantly in the subsequent Copper Age due to its aesthetic appeal and ease of workability. Consequently, it was frequently deposited in Neolithic-Eneolithic burials as grave goods, suggesting the particular importance of mortuary practices in these prehistoric communities across Central Europe as well. In Hungary, serpentinite stone axes were discovered – among others – at the Alsónyék-Bátaszék archaeological site (S-Hungary) between 2006 and 2009 during the construction of the M6 motorway. Since serpentinite suitable for making stone tools does not occur in the vicinity, only distant raw material sources can be considered.

A complex comparative petrographic and geochemical study of selected polished stone tools and geological samples has been conducted in order to determine the provenance of the stone tools. During this project 17 serpentinite stone axes from Alsónyék-Bátaszék and 18 field samples gathered from eight distinct geological sites across the Carpathian Basin (Bernstein, Steinbach, Rumpersdorf, Fruška Gora, Korlaće, Stragari, the Ibar Valley, and Dobšiná) were studied. The analytical methods included macroscopic description, polarizing microscopy, and SEM-EDS analyses at the Department of Petrology and Geochemistry, Eötvös Loránd University. The non-destructive methods were strongly prioritised because archaeological objects are protected under strict cultural heritage legislation.



The potential source areas identified for some polished serpentinite tools among the analysed assemblage (https://online.mapcreator.io/ [2025.05.17.])

Notes

Petrological and geochemical analysis of metabasites and contact metabasites from the Little Carpathians as possible source materials for Middle Neolithic polished stone tools

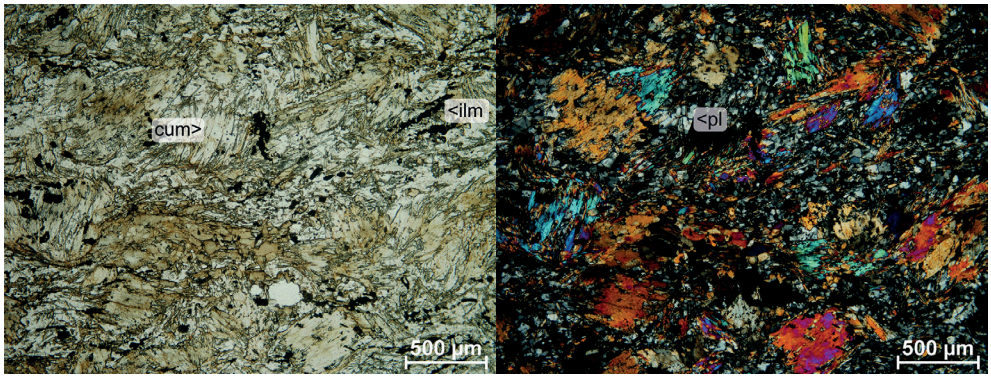
Zsófia Farkas[1], Szilvia Guba[2], György Szakmány[3], Veronika Szilágyi[4], Zsolt Kasztovszky[5] and Tamás Sági[6]

[1] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, farkas.zsofia@ttk.elte.hu
[2] Hungarian National Museum, Forgách-Lipthay Castle Museum, Szécsény, Hungary, guba.szilvia@hnm.hu, ORCiD: 0000-0003-2769-6813
[3] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, szakmany.gyorgy@ttk.elte.hu, 0000-0002-9557-2030
[4] Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary, szilagyi.veronika@ek.hun-ren.hu, ORCiD: 0000-0001-8522-676X
[5] Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary, kasztovszky.zsolt@ek.hun-ren.hu, ORCiD: 0000-0002-5745-8616
[6] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, sagi.tamas@ttk.elte.hu, ORCiD: 0000-0003-4664-5472

Keywords: *Little Carpathians, (contact) metabasite, polished stone tools*

Various metabasites, contact metabasites, and metasediments in the Pernek-Pezinok Units of the Little Carpathians have long been of interest to researchers as potential raw materials, however no substantive detailed petrographic studies have been conducted on the subject. Our aim is to create a primary comparative petrological collection that can be expanded in the future for comparative archaeometric purposes. Firstly, the geological samples were compared to Middle Neolithic (Zselíz culture) polished stone tools from the archaeological sites of Szécsény-Ültetés, Öcsöd-Kováshalom, Gödöllő Hills. Altogether 33 artefacts and 30 field samples have been analysed. To reach the goal, several analytical methods were combined (polarizing microscopy, SEM-EDX, PGAA, magnetic susceptibility and density determination). Based on the results the low- to medium grade metabasites and contact metabasites of the Little Carpathians were classified into five petrogenetic groups: T1 (cordierite hornfels, metapsammites), T2 (metapyroclastic rocks, metatuffs/metapsammites), T3 (contact metabasites, metagabbros), T4 (greenschists, amphibolites), and T5 (other rocks). From the comparative archaeological finds, 3 petrogenetic groups were created based on their petrological properties: K1 (contact metabasites/metaultrabasites), K2 (greenschists, amphibolites), K3 (other rocks).

Conclusions have been drawn mainly based on amphibole mineral chemistry and PGAA results, magnetic susceptibility and density are not strong differentiating factors. In the case of contact metabasites, Mg-Fe-Mn-Li amphiboles (cummingtonite, gedrite), while in the case of greenschists and amphibolites, Ca-amphiboles (mostly actinolite and/or magnesiohornblende, edenite, pargasite) were the critical minerals for comparison. Based on PGAA analyses, the investigated rock types of the Little Carpathians form significantly different groups. Compared to the field samples some archaeological finds are very similar to the contact metabasites, amphibole main elements compositions show almost a complete match; however, differences can be found in texture and modal composition.



Microphotographs of a typical contact metabasite/metaultrabasite from the Little Carpathians (left: PPL, right: XPL). The rock has an unoriented texture (nematoblastic/blastohypidiomorphic) and contains more than 80% amphibole (cummingtonite). Abbreviations: cum - cummingtonite, ilm - ilmenite, pl - plagioclase

Notes

Archaeometric research on prehistoric ground stone assemblages in Vojvodina (North Serbia)

Kata Furholt[1], Ildiko Medović[2], Dóra Georgina Miklós[3], Ivan Dulić[4], Violeta Gajić[5], Tamás Sági[6] and Zsolt Kasztovszky[7]

[1] Institute of Pre- and Protohistoric Archaeology, Kiel University, Kiel, Germany, kata.furholt@ufg.uni-kiel.de, ORCiD: 0000-0002-3944-9951
[2] Museum of Vojvodina, Novi Sad, Serbia, ildiko.medovic@muzejvojvodine.org.rs, ORCiD: 0009-0002-3563-4823
[3] Hungarian National Museum, Budapest, Hungary, miklos.dora@hnm.hu, ORCiD: 0009-0009-1774-8510
[4] Independent researcher, Novi Sad, Serbia, dulici58@gmail.com
[5] Faculty of Mining and Geology, University of Belgrade, Belgrade, Serbia, violeta.gajic@rgf.bg.ac.rs, ORCiD: 0000-0002-3389-8721
[6] Department of Petrology and Geochemistry, ELTE Eötvös Loránd University, Budapest, Hungary, sagi.tamas@ttk.elte.hu, ORCiD: 0000-0003-4664-5472
[7] Budapest Neutron Centre, HUN-REN Centre for Energy Research, Budapest, Hungary, kasztovszky.zsolt@ek.hun-ren.hu, ORCiD: 0000-0002-5745-8616

Keywords: *Neolithic and Eneolithic, Vojvodina, polished, grinding, percussive and abrasive stone tools, provenance analysis, exchange network*

This poster presents ongoing archaeometric research on polished, grinding and abrasive stone tools from eleven prehistoric – mostly Late Neolithic – sites in the Vojvodina region in North Serbia. The project aims to investigate tool production and the raw material characterisation and procurement through an integrated study of archaeological artefacts and geological reference samples.

Our approach combines morphometric, technological, petrographic, and archaeometric analyses. We prefer to use non-destructive analytical methods (magnetic susceptibility measurement (MS), prompt-gamma activation analysis (PGAA), scanning electron microscopy with energy-dispersive spectroscopy (SEM-EDS) on original artefact surfaces, and micro-X-ray diffraction (μXRD). At this stage of the research, nearly 200 artefacts have been studied macroscopically (including MS measurements), and all data have been recorded in a specific relational database. The more detailed archaeometric analyses on selected samples have only recently started, which have been combining thin-section petrography with a range of non-destructive techniques.

The preliminary results indicate that the large number of polished stone items reflects multiple phases of use and modification during their "lives". For instance, renewed cutting edges and grinding surfaces and the secondary use of the polished tools as percussive or abrasive tools. Rather than functioning as simultaneously multifunctional tools, these artefacts appear to have undergone successive phases of reuse and transformation. In several cases,

evidence of intentional fragmentation was identified, followed by the production and use of new polished stone tools. These observations highlight the complex biographies of lithic artefacts and provide new insights into how prehistoric communities created, used, reused, and valued their everyday lithic implements.

The preliminary identification of raw material types suggests that prehistoric communities in Vojvodina maintained connections along major river corridors in multiple directions. The lithic raw materials may have originated from sources associated with the Danube, Tisza, Tamiš, and Morava–Vardar river valleys. Altogether, these waterways appear to have played a significant role in patterns of mobility, communication, and resource procurement.

This research is supported by the project NKFIH Advance No. 150223 and Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany´s Excellence Strategy – EXC 2150 – 390870439.



Silicified limestone adze before polishing, from the Zabalj–Nove Zemlje site (Vojvodina, northern Serbia) (made by K. Furholt)

Notes

Reconstructing a city's marble biography through the provenance of artefacts from Roman Marcianopolis

Vasiliki Anevlavi[1,2], Petya Andreeva[3], Dimitra Kourtidou[4] and Walter Prochaska[5]

[1] National Hellenic Research Foundation, Athens, Greece
[2] Austrian Archaeological Institute, Austrian Academy of Sciences, Vienna, Austria, vasiliki.anevlavi@oeaw.ac.at, ORCiD: 0000-0001-7332-1129
[3] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, petya_letters@abv.bg, ORCiD: 0000-0001-6749-3880
[4] Austrian Archaeological Institute, Austrian Academy of Sciences, Vienna, Austria, dimitra.kourtidou@oeaw.ac.at, ORCiD: 0000-0002-9511-6801
[5] Austrian Archaeological Institute, Austrian Academy of Sciences, Vienna, Austria, walter.prochaska@oeaw.ac.at, ORCiD: 0000-0003-3047-2976

Keywords: *marble provenance, stable isotope analysis, trace element geochemistry, petrography*

Roman cities were shaped not only by monumental architecture but also by the materials that connected them to wider economic and cultural networks. White marble, often transported over considerable distances, represents one of the most informative indicators of these connections. While provenance studies frequently focus on large assemblages, individual artefacts can also provide valuable insights into patterns of supply, consumption, and connectivity [1].

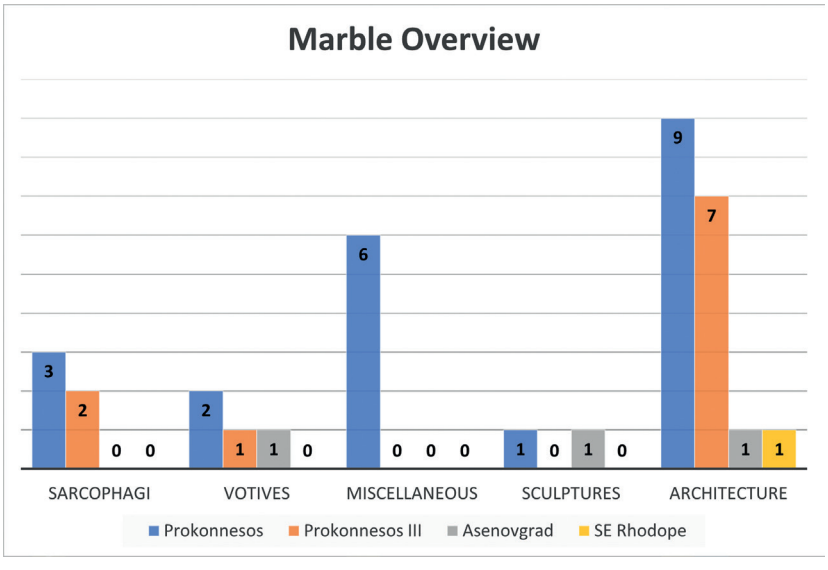
This study presents new provenance data from a selection of white marble artefacts from Roman Marcianopolis (modern Devnya, Bulgaria), one of the principal urban centres of the Lower Danube region. The material studied includes architectural elements, sculptural fragments, statuary, and decorative objects. A multi-analytical approach combining stable isotope analysis ($\delta^{13}C$ and $\delta^{18}O$), trace element characterisation by ICP–MS, petrographic examination, and X-ray diffraction (XRD) was employed to determine the origin of the marbles [2].

Rather than treating the artefacts as an isolated corpus, the study examines how provenance information resulting from individual objects contributes to the reconstruction of the city's broader marble biography. The results demonstrate the coexistence of multiple marble sources and reveal connections extending beyond the immediate hinterland (Asenovgrad and SE Rhodope) to major quarrying regions of the eastern Mediterranean (Prokonnesos). At the same time, differences in material selection between object categories provide insights into patterns of acquisition, use, and consumption within the urban environment.

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Overview of the identified marble provenances from Marcianopolis according to artefact category, illustrating the predominance of Prokonnesian marble and the more limited contribution of regional marble sources

Notes

New archaeometric investigations of marble portrait sculpture from the collections of the Museum Carnuntinum

Julianna Burucs[1], Bernadett Bajnóczi[2] and Attila Demény[3]

[1] Department of Classical and Roman Provincial Archaeology, Institute of Archaeological Sciences, Faculty of Humanities, ELTE Eötvös Loránd University, Budapest, Hungary, bbjulianna@student.elte.hu, burucsjuli@gmail.com, ORCiD: 0009-0008-1538-7988
[2] Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, Budapest, Hungary, bajnoczi.bernadett@csfk.org, ORCiD: 0000-0003-0006-7611
[3] Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, Budapest, Hungary, demeny.attila@csfk.org, ORCiD: 0000-0003-0522-9018

Keywords: *marble provenance, multi-analytical approach, Roman provincial portraiture, Pannonia Superior, Carnuntum*

Carnuntum, the capital of *Pannonia Superior*, has yielded an exceptionally rich corpus of Roman stone monuments, including one of the most significant assemblages of sculptural material from the Middle Danube region. *Carnuntum*'s central political, military, and economic role within the province makes its sculptural material particularly relevant for the study of marble supply and consumption.

Complementing previous archaeometric research on marble monuments from *Carnuntum* [1, 2, 3], this contribution investigates four marble portraits [4] preserved in the collections of the Museum Carnuntinum using a multiple analytical approach combining X-ray diffraction (XRD), stable isotope analysis, chemical composition (ICP-OES and ICP-MS), cathodoluminescence microscopy (CL), and maximum grain size measurements (MGS).

Roman portrait sculpture in the round is comparatively rare in Pannonia, making the investigated assemblage particularly valuable for the study of material selection and marble procurement. The group comprises two headless portrait busts excavated in the military amphitheatre area of *Carnuntum*, a portrait head of uncertain provenance dated to the Antonine period, and a portrait bust of the empress Iulia Domna acquired for the museum collections in the 20th century. The representative archaeological context of the presumed private portraits and the distinct material character of the imperial portrait provide an opportunity to investigate potential links between social status, visual representation, and material selection, particularly in a province lacking local marble resources.

Preliminary mineralogical analyses indicate the presence of at least three distinct marble groups within the investigated assemblage. These are represented by the coarse-grained yellowish-white marble of the excavated amphitheatre busts, the medium-grained yellowish

marble of the portrait head dated to the Antonine period, and the red-veined white marble of the Iulia Domna bust. The results contribute to the evaluation of raw material provenance, material selection, and marble procurement, offering new insights into workshop practices and marble use in Roman Pannonia.

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Marble portraits from the collection of the Museum Carnuntinum, Kulturfabrik Hainburg, Landessammlungen Niederösterreich, inv. nos. CAR-S-1324, CAR-S-1313 and CAR-S-1314. Photos and collage: Julianna Burucs

Notes

Prehistoric amber exchange networks in the Carpathian Basin: An archaeometric study of the Žabalj Pendant

Kata Furholt[1], Hendrik Groß[2], Stefan Schröder[3] and Max Schröder[4]

[1] Department of Prehistoric and Protohistoric Archaeology, Kiel University, Kiel, Germany, kata.furholt@ufg.uni-kiel.de, ORCiD: 0000-0002-3944-9951
[2] Department of Materials Science, Kiel University, Kiel, Germany, hegr@tf.uni-kiel.de, ORCiD: 0000-0003-1804-6878
[3] Department of Materials Science, Kiel University, Kiel, Germany, ssch@tf.uni-kiel.de, ORCiD: 0000-0001-9996-2637
[4] Department of Materials Science, Kiel University, Kiel, Germany, stu236815@mail.uni-kiel.de

Keywords: *amber, FTIR spectroscopy, SEM-EDX, provenance study, Carpathian Basin*

This paper presents archaeometric analyses on a prehistoric amber pendant from the multi-periodic site of Žabalj-Nove Zemlje (Vojvodina, northern Serbia) [1], and discusses its significance within the broader context of prehistoric amber use and exchange in the Carpathian Basin [2]. The pendant was recovered from the disturbed upper daub layer of a burnt Late Neolithic house associated with the Tisza and Vinča communities (5060–4830 cal BCE).

The object is a small triangular ornament made of a translucent orange-brown material, carefully polished and heavily worn through use. To identify the raw material, the pendant was analysed using Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy (SEM-EDX) and Fourier-Transform Infrared Spectroscopy (FTIR). The analyses excluded a mineral origin, confirming that the object is made of amber [1]. Regarding the origin of this amber pendant, we compared the Žabalj pendant with reference amber samples from several geological regions: Baltic amber (Succinite), Bitterfeld amber (Germany), Romanian amber (Rumanite), Sicilian amber (Simetite) and Ukrainian amber [3]. The combined provenance analyses revealed that the pendant has an unusually high oxygen content and detectable amounts of aluminium, silicon, calcium, and phosphorus, which might interfere with several depositional and taphonomic factors, for instance, direct burning or high-temperature context, secondary mineral contamination, and surface alteration. Altogether, the Žabalj pendant is most probably related to the succinite-like amber type (Baltic).

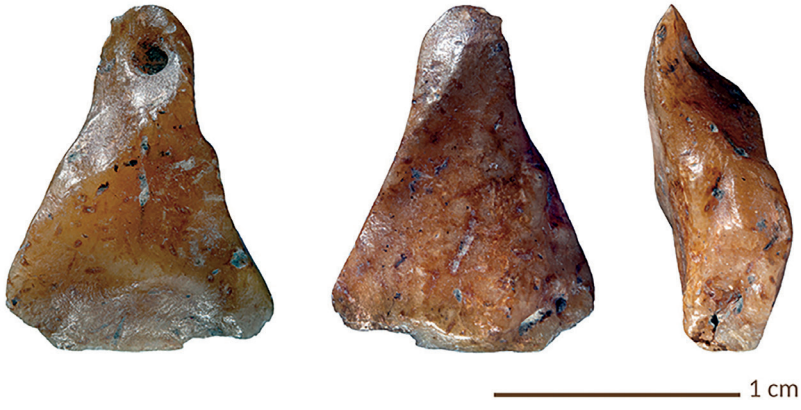
The vast majority of amber finds in the region date to the Bronze Age and consist mainly of standardised beads from graves and hoards, often linked to Baltic amber exchange networks. The Žabalj pendant differs markedly from these finds in both morphology and preparation. Its irregular triangular shape and off-centre perforation have no close parallels among currently known Bronze Age amber finds. Consequently, the pendant may represent a rare example of Neolithic amber use in the southern Carpathian Basin.

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The perforated pendant from the front, back and side views (made by Anna Sara Jagiolla)

Notes

Identification of the organic content from ceramic vessels by GG-MS, HPLC, FTIR, NMR and Raman spectroscopy: examples from Bulgaria

Boika Zlateva[1,2], Anelia Nikolova[3], Deyan Lesigyarski[3], Veronika Mihaylova[1] and Alentina Lyubomirova[1]

[1] Faculty of Chemistry and Pharmacy, University of Sofia "St. Kl. Ochridski", Sofia, Bulgaria, ahbz@chem.uni-sofia.bg
[2] Center for Archaeometry with Laboratory for Conservation and Restoration, Faculty of History, University of Sofia "St. Kl. Ochridski, Sofia, Bulgaria
[3] National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia, Bulgaria

Keywords: *organic content, bitumen, tars, Bulgaria*

Residue analysis, as used in archaeometry, is a generic term used to describe the characterization of traces of organic products from the past. Organic remains usually cannot be identified using traditional techniques of archaeological investigation because they are either amorphous, invisible or present at trace concentrations. Using modern instrumental techniques for analysis it is possible to identify nature and origins of them. In this investigation we used several instrumental methods of analysis (by GG-MS, HPLC, FTIR, NMR and Raman spectroscopy) to characterize the archaeological organic residues, mainly bitumen and tars from Bulgarian lands. Bitumen and tars were used for multiple purposes from the Paleolithic through historical times: as glues and adhesives in construction works; in toolmaking or repairing; for other restorations; to waterproof containers, baskets, boats; for sealing; in medicine and magic, for disinfection, as shewing gum; for painting and decorations; for sculpting, etc. They can provide useful information for the practices in the past, especially when the textual and the archaeological evidences are combined with the analytical and the organic chemistry and the molecular biology`s methods and instruments.

The results are preliminary. The goal is to place regional cultures between East and West in short and middle-term trends and long duration perspectives in history.

Acknowledgements

This study is supported by the BG05M2OP001-1.001-0001 "Creation and development for Heritage BG" Centre of Excellence and the INFRAMAT

Notes

Tracing the origin of garnets in Migration Period polychrome jewellery through multivariate Raman data analysis

László Előd Aradi[1], Eszter Horváth[2,3], Viktória Mozgai[4] and Bernadett Bajnóczi[5]

[1] Archaeometry Laboratory, Hungarian National Museum, Budapest, Hungary, aradi.laszlo@hnm.hu, ORCiD: 0000-0003-0276-3119
[2] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, horvath.eszter@abtk.hu, ORCiD: 0009-0007-4650-0392
[3] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary
[4] Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, Budapest, Hungary, mozgai.viktoria@csfk.org, ORCiD: 0000-0001-9712-2773
[5] Institute for Geological and Geochemical Research, HUN-REN Research Centre for Astronomy and Earth Sciences, Budapest, Hungary, bajnoczi.bernadett@csfk.org, ORCiD: 0000-0003-0006-7611

Keywords: *polychrome, jewellery, garnet, Migration Period, Raman spectroscopy*

Garnet jewellery was widespread in the Carpathian Basin during the Migration Period, starting from the late 4th to the 7th century AD, through the Hunnic, Gepidic, Langobardic, and Avar periods. These red gemstones were mainly used to ornament prestigious objects associated with the aristocracy and social elite. Determining the provenance of garnet gemstones can provide insights into trade, production, and workshop connections during the Migration Period. However, garnet sources changed significantly over time, thus tracking these spatial and temporal variations requires a large dataset. Due to the value of these objects, only non-destructive and non-invasive methods can be used, and Raman spectroscopy is among the most suitable techniques for analysing garnet inlays. Despite the lack of direct chemical information in Raman spectra of garnets, it remains the only feasible method to study jewellery with large numbers of inlays, especially when analysis time is limited.

Our current database contains more than 2500 Raman spectra of garnets, originating both from archaeological and geological contexts [1, 2]. Reference garnets are available for most known garnet sources (i.e. clusters; [3]) relevant during the Antiquity and in the early medieval times, which provides us a chance to reveal the possible source of garnet inlays based on their Raman spectra. PCA applied to the Raman spectra yields better discrimination than the corresponding major and minor element datasets obtained from SEM-EDS analyses. Clear separation along the first principal components allows the discrimination of most known almandine and pyrope garnet sources. This method is sufficiently robust to build classification models based on Raman data, supplemented by the optical observations of their inclusions.

These results enhance the accuracy of rapid and precise garnet provenance determination, allowing to reveal the changing trade connections during the Migration Period.

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Notes

X-ray radiography and p-XRF analysis of the modern art painting

Boika Zlateva[1,2], Deyan Lesigyarski[3] and Ilya Borisov[4]

[1] Faculty of Chemistry and Pharmacy, University of Sofia "St. Kl. Ochridski", Sofia, Bulgaria, ahbz@chem.uni-sofia.bg
[2] Center for Archaeometry with Laboratory for Conservation and Restoration, Faculty of History, University of Sofia "St. Kl. Ochridski", Sofia, Bulgaria
[3] National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia, Bulgaria
[4] Institute of Ethnology and Folklore Studies with Ethnographic Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria

Keywords: *X-ray radiography, p-XRF, painting, N. Karaneshev*

X-ray radiography is one of the oldest and most widely employed scientific methods for the investigation of works of art. In the case of paintings, for example, the radiographic examination provides a reading of the work in its entirety, returning important indications both on the support and on the pictorial layers, useful for the interpretation of the stratigraphic succession of the original or restored portions.

In this case, we made X-ray image (Eresko MF4, General Electric, USA) and elemental analysis (p-XRF, Bruker, Germany) of painting of N. Karaneshev (1876–1964), named "Monastery doors" in aimed to reconstruct original form and to help restoration work.

N. Karaneshev is one of the famous Bulgarian painters in the period of 1910–1925, studied in Sofia (Bulgaria) and in Florence (Italy) and his works are well-characterized of detailed architecture and interior details. The precise naturalistic description of the picture is priceless evidence for ethnographic surveys.

For this reason, the works of N. Karaneshev are subject of interest, especially for the reconstruction of the natural culture and folklore of the beginning of 20th century in Bulgaria.

The results show two different periods of restoration, using different types of pigments and obligation of the original author annotation of the picture.

Acknowledgements

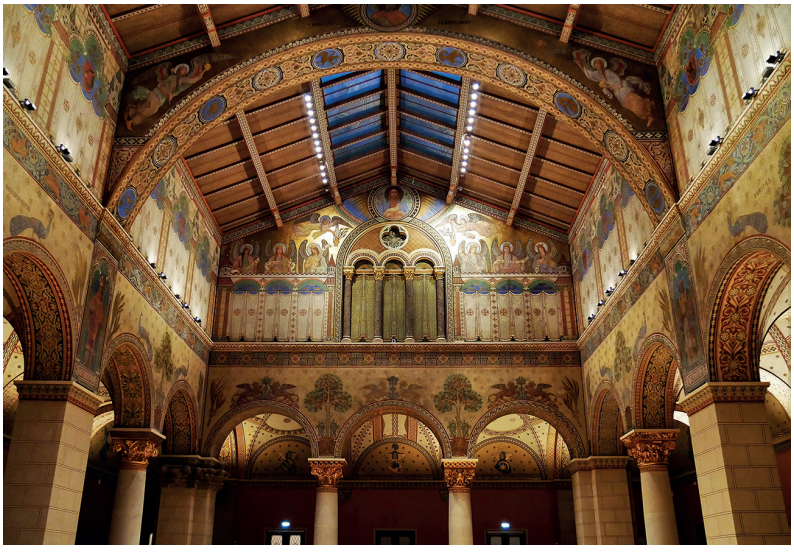
This study is supported by the BG05M2OP001-1.001-0001 "Creation and development for Heritage BG" Centre of Excellence and the INFRAMAT.

Notes

Session 3

ENDURING LEGACIES

Science-led conservation of tangible heritage



Moments in Budapest
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The conservation process of a Gepidic-period spatha with silver mountings and wooden scabbard remains

Szulamit Emma Horváth[1] and Zsófia Masek[2]

[1] Budapest History Museum,
Budapest, Hungary, horvath.sz.emma@gmail.com, ORCiD: 0009-004-2960-8340
[2] Institute of Archaeology, ELTE Research Centre for the Humanities,
Budapest, Hungary, masek.zsofia@abtk.hu, ORCiD: 0000-0002-9006-5806

Keywords: *conservation process; early Merovingian period; militaria; wooden, leather, and silk remains*

The presentation introduces the manufacturing technology, conservation, and material analysis results of a double-edged longsword *(spatha)* recovered from an early 6th-century Gepidic-period cemetery (site: Tiszapüspöki-Fehér-tó-part, Hungary). The uniqueness of the find is largely due to the preservation of the wooden and leather remnants of the scabbard, the remains of the wooden crossguard and grip, as well as the remnants of the suspension straps. These provided a rare opportunity to examine the structural composition of the weapon and the method of fastening the scabbard. During the conservation process, a ey priority was the preservation of archaeological trace evidence and ensuring their interpretability. Decisions were therefore supported by X-ray radiography, μ-XRF, and FTIR analyses. Furthermore, investigations into the corrosion mechanisms of the iron, copper, and silver components based on the halide ion load of the soil also provided important data for a better understanding of the processes affecting archaeological metals buried in the ground, highlighting the correlation between modern agricultural impacts and metal degradation. With the aid of these analyses, we can gain a new, detailed insight into the organic components of the Gepidic-period weaponry, raising new perspectives for archaeological evaluation, which can be further studied by expanding sampling procedures; moreover, the conservation process also serves as a case study for preserving the object in accordance with modern heritage protection standards.



The condition of the sword following restoration and X-ray images taken before restoration, showing top and side views

Notes

Manufacturing process revealed through archaeometry and conservation – A case study of a bronze artefacts from the site of "Gerena"

Violeta Karailieva[1] and Veselina Chakarova[2]

[1] Department of Restoration, National Academy of Art, Sofia, Bulgaria, v.karailieva@nha.bg
[2] Laboratory of X-ray Diffraction Methods and Computed Tomography, Institute of Physical Chemistry, Bulgarian Academy of Sciences, Sofia, Bulgaria, veselinachakarova@abv.bg

Keywords: *environment pollution, restoration, XRF, medieval bronze*

The archaeological site known as "Gerena", located on the outskirts of Radnevo in south-eastern Bulgaria, contains structural remains and cultural layers dating from the Neolithic, Chalcolithic, Bronze, Iron Ages and Medieval period. The artefacts recovered from the graves are broadly dated to the period between the second half of the 12th century and the second half of the 13th century AD.

The grave inventory comprises objects made from a variety of materials. Among these are glass and bronze bracelets, glass beads, bronze and silver-plated earrings, and bronze rings. This study focuses on some of the bronze artefacts discovered during the 2022–2023 excavations.

A bronze amulet, one of the most peculiar finds, was also examined, especially regarding its manufacturing technology. This particular type of amulet appears to be unique to this necropolis, prompting specific analytical interest.

The alloy composition has been determined by X-ray fluorescence (XRF) and XRD, while manufacturing features have been examined with tomographic imaging. The conservation and restoration program was significantly refined and adapted in accordance with the analytical results.

An in-depth examination of the technological aspects of artefact production provides further insight into past cultural and technological developments, illuminating aspects of medieval society that remain insufficiently understood in the absence of analytical data. Through a combination of archaeometric analysis and conservation treatment, the study aims to elucidate the artefacts' history and contribute to a better understanding of their production technology.

Acknowledgements

Specialist Martin Tzvetkov from the Institute of Information and Communication Technologies (IICT), BAS – Department of Scientific Computations with Laboratory on 3D Digitisation and Microstructure Analysis – for the tomographic analysis regarding the manufacturing details.

Assoc. prof. Georgi Avdeev, PhD, from the Institute of Physical Chemistry, BAS – Laboratory of X-ray Diffraction Methods and Computed Tomography – for the fluorescent analysis (XRF) regarding the corrosion products.

Plamen Karailiev, team leader of the excavations and director of the Archaeological Museum ”Mines Maritsa-East” – for the opportunity to work with the artefacts.

Notes

Material characterisation using non-destructive techniques: The case of the Ephesiou summer house

Xanthippi Foulidi[1], Theodore Ganetsos[2,3], Evangelos Papakitsos[4], Konstantinos Brachos[5] Nikolaos Laskaris[6] and Dimitrios Christou[7]

[1] Department of History, Archaeology and Cultural Resources Management, University of the Peloponnese, Kalamata, Greece, foulidi@go.uop.gr, ORCiD: 0000-0002-6014-6015
[2] University of West Attica, Athens, Greece, ganetsos@uniwa.gr, ORCiD: 0000-0003-2081-4960
[3] Laboratory for Materials and Cultural Heritage, Faculty of Technology, University of Novi Sad, Serbia
[4] University of the Witwatersrand, School of Physics, Johannesburg, South Africa, papakitsev@uniwa.gr, ORCiD: 0000-0002-0218-489X
[5] University of West Attica, Athens, Greece, kbrachos@uniwa.gr
[6] University of West Attica, Athens, Greece, n.laskaris@uniwa.gr
[7] Department of History, Archaeology and Cultural Resources Management, University of the Peloponnese, Kalamata, Greece, ham22053@go.uop.gr, ORCiD: 0009-0006-6308-9286

Keywords: *material, ndt, XRF, characterisation*

The Efesiou summer house, a highly regarded eclectic building on Navarinou, Byronos and Santaroza streets on the Kalamata beach, was rebuilt in 1899 according to the sign posted on the outside of the building, based on designs by Ernest Ziller. The most characteristic elements of the building are the arches of the two balconies facing Navarinou Street, the decorative arches of the openings of the facades that end in unusual ornaments, the art nouveau ironwork of the balconies and the main entrance door, as well as its carved wood ornaments.

It belonged to the Efesiou family, who originated from Asia Minor and already from the pre-revolutionary period formed a commercial network with Malta and Tunis. In 1861, a company of the Ephesians operated in Tunis under Const. Konstantopoulos and Spyros Elias Ephesios, who exported silk and oil. At the same time, with a partner, Ioannis Alamagas, they imported salted cod and dried octopus from Malta to Kalamata. At the same time, the profession of "banker" was practiced by Spyridon Ephesios, Nikolaos Ephesios, and Stamatios Ephesios.

They also owned the "Ephesian" house at 4 Mavromichalaion Street and Grigoriou Episkopou Street, near Mavromichalis Square, a work of the Italian architect, erected in the last decade of the 19th century, as well as the single-aisled church of Agios Nikolaos of Ephesian, with a gable roof and a three-sided niche and neoclassical features, named after the first Ephesian in Kalamata, Nikoletos Ephesian. During World War II, the family suffered financial disaster from bank stocks and bonds and sold their houses.

Using non-destructive portable Raman and XRF spectroscopy we analysed the pigments in frescoes and made a comparison with well-known identified pigments of the same period. This is very important related to the reconstruction of this building with respect for its historical value and the authenticity of the materials.

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The Ephesiou summer house on Navarino Street

Notes

Thin films from liquid-phase exfoliated h-BN as protective coatings for mural paintings preservation

Bojana Savić[1], Radmila Panajotović[2], Ivana R. Milošević[3], Lena Schwarz[4], Jovan Ciganović[5], Jasna Vujin[6], Thomas Griesser[7], Markus Kratzer[8], Christian Teichert[9], Irena Živković[10] and Tijana Tomašević-Ilić[11]

[1] Faculty of Applied Arts, University of Arts Belgrade, Belgrade, Serbia, bojana.savic@fpu.bg.ac.rs, ORCiD: 0009-0000-2873-6106
[2] Institute of Physics Belgrade, University of Belgrade, Belgrade, Serbia, radmila@ipb.ac.rs, ORCiD: 0000-0002-2174-0062
[3] Institute of Physics Belgrade, University of Belgrade, Belgrade, Serbia, ivana.milosevic@ipb.ac.rs, ORCiD: 0000-0002-4463-5986
[4] Department of Physics, Mechanics and Electrical Engineering, Montanuniversität Leoben, Leoben, Austria, lena.schwarz@stud.unileoben.ac.at
[5] Vinca Institute of Nuclear Sciences-National Institute of the Republic of Serbia, University of Belgrade, Belgrade, Serbia, jovanc@vin.bg.ac.rs, ORCiD: 0000-0002-3860-4374
[6] Institute of Physics Belgrade, University of Belgrade, Belgrade, Serbia, jasnam@ipb.ac.rs, ORCiD: 0000-0002-7081-8364
[7] Institute of Chemistry of Polymeric Materials, Technical University of Leoben, Leoben, Austria, thomas.griesser@unileoben.ac.at, ORCiD: 0000-0002-9493-3770
[8] Department of Physics, Mechanics and Electrical Engineering, Montanuniversität Leoben, Leoben, Austria, markus.kratzer@unileoben.ac.at, ORCiD: 0000-0001-5181-6796
[9] Department of Physics, Mechanics and Electrical Engineering, Montanuniversität Leoben, Leoben, Austria, teichert@unileoben.ac.at, ORCiD: 0000-0002-0796-2355
[10] Faculty of Applied Arts, University of Arts Belgrade, Belgrade, Serbia, irena.zivkovic@fpu.bg.ac.rs, ORCiD: 0000-0001-7399-3945
[11] Institute of Physics Belgrade, University of Belgrade, Belgrade, Serbia, ttijana@ipb.ac.rs, ORCID: 0000-0003-2870-0765

Keywords: *conservation, wall paintings, 2D materials, Langmuir–Blodgett deposition*

St. George's Church in New Belgrade represents an example of the conservation challenges affecting cultural heritage exposed to persistent moisture in urban environments. The original wall paintings, created in the 1930s, were severely damaged by humidity and have been replaced in the early 2000s with new acrylic-based decorations painted on dry plaster. However, the new decorations also rapidly deteriorated under the same environmental conditions, emphasizing the urgent need for advanced protective materials suitable for sensitive painted surfaces. Recent studies have demonstrated the high protective efficacy of 2D materials, although their application has mainly been limited to consolidation products or coatings for artefacts with similar coloration [1, 2]. Our research focused on transparent nanostructured coatings based on 2D materials that address the limitations of traditional and contemporary protective coatings, preserve the aesthetics and original composition of the heritage materi-

al, and can be applied to artifacts with a wider color range. Ultrathin hexagonal boron nitride (h-BN) films were fabricated from liquid-phase exfoliated nanosheets using the Langmuir–Blodgett (LB) deposition method onto replicas of wall-painting samples prepared as test substrates. Compatibility between the coatings and painted surfaces was evaluated using X-ray Photoelectron Spectroscopy (XPS), profilometry, and Photo-induced Force Microscopy (PiFM) combined with hyperspectral photo-induced infrared imaging (hyPIR). The results demonstrate that the LB method enables the formation of continuous h-BN coatings without altering the original micro-scale topography of the replicas. Furthermore, structural analyses confirmed the absence of undesirable chemical interactions between the coating and substrate. Wettability measurements additionally showed a significant shift toward hydrophobicity after film deposition, indicating that these transparent, and nanometer thin h-BN coatings could be an adequate material for cultural heritage protection even in highly humid environments.

This research was supported by the Science Fund of the Republic of Serbia, Grant No. 7456, 2D Material-based Tiled Network Films for Heritage Protection-2DHeriPro.

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Thin films from liquid-phase exfoliated h-BN as protective coatings for mural paintings preservation

Notes

Session 4

THE FIRE OF INVENTION

Ancient metallurgy from ore to artefact



Moments in Budapest
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From ore to ornament: The life history of Late Neolithic copper jewellery from Alsónyék-Bátaszék (southern Hungary)

Anett Osztás[1], Krisztina Szabó[2], Eszter Horváth[3] and Zsuzsanna Siklósi[4]

[1] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, osztas.anett@htk.elte.hu, ORCiD: 0000-0002-8470-0770
[2] National Institute of Archaeology, Hungarian National Museum, Budapest, Hungary, Szabo.Krisztina@hnm.hu
[3] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, horvath.eszter@htk.elte.hu, ORCiD: 0009-0007-4650-0392
[4] MTA–ELTE Lendület "Momentum" Innovation Research Group, Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, siklosi.zsuzsanna@btk.elte.hu, ORCiD: 0000-0002-6451-5578

Keywords: *Late Neolithic, copper jewellery, provenance, plant materials, manufacturing process*

During the second half of the Late Neolithic period in present-day Hungary (c. 4700–4500 cal BCE), there is an increase in the number of copper items in Southeastern Transdanubia. These artefacts are found exclusively in burials associated with the sites of the Lengyel complex and occur only as jewellery (e.g., beads, rings and bracelets). They can clearly be regarded as prestige items. While these finds are well known from previous research, they have not yet been subjected to any archaeometric analysis.

In order to understand why there are large quantities of copper artefacts in this region, despite the near absence of copper at Lengyel sites further north, it is important to study their provenance. A recent research project investigated the origin of the copper ore by combining the analysis of the chemical composition and lead isotopes of archaeological samples from southeastern Transdanubian Lengyel sites and potential ore deposits. The results clearly exclude the exploitation of local sources, pointing instead to a long-distance prestige exchange network [1].

This presentation focuses on the provenance results obtained from Late Neolithic contexts of the prominent prehistoric site of Alsónyék-Bátaszék (five samples). To reconstruct the manufacturing processes, the study is extended to include a technological analysis of artefacts employing optical microscopy (approximately 10 pieces). We also examine the plant materials used for stringing copper beads (two samples) and the possible textile imprint on a bracelet using polarising and scanning electron microscopy. These analyses contribute to a better understanding the social network of the communities, early metalworking traditions as well as some aspects of funerary practices and everyday life.

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A spiral copper bracelet from Alsónyék-Bátaszék (subsite 5603/1, grave 2222) (created by Zs. Varga, P. Hámori and Zs. Réti, Institute of Archaeology ELTE RCH)

Notes

The provenience of the Early Copper Age Szeged-Szillér hoard

Zsuzsanna Siklósi[1], Ernst Pernicka[2,3] and Jaroslav Peška[4]

[1] MTA–ELTE Lendület "Momentum" Innovation Research Group, Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, siklosi.zsuzsanna@btk.elte.hu, ORCiD: 0000-0002-6451-5578
[2] Curt-Engelhorn-Zentrum Archäometrie gGmbH, Mannheim, Germany, ernst.pernicka@ceza.de, ORCiD: 0000-0003-4746-9239
[3] Institut für Geowissenschaften, Universität Heidelberg, Heidelberg, Germany
[4] Archaeological Centre Olomouc, Olomouc, Czech Republic, peska@ac-olomouc.cz, ORCiD: 0000-0002-0827-4255

Keywords: *provenience, lead isotope analysis, Early Copper Age, copper, hoard*

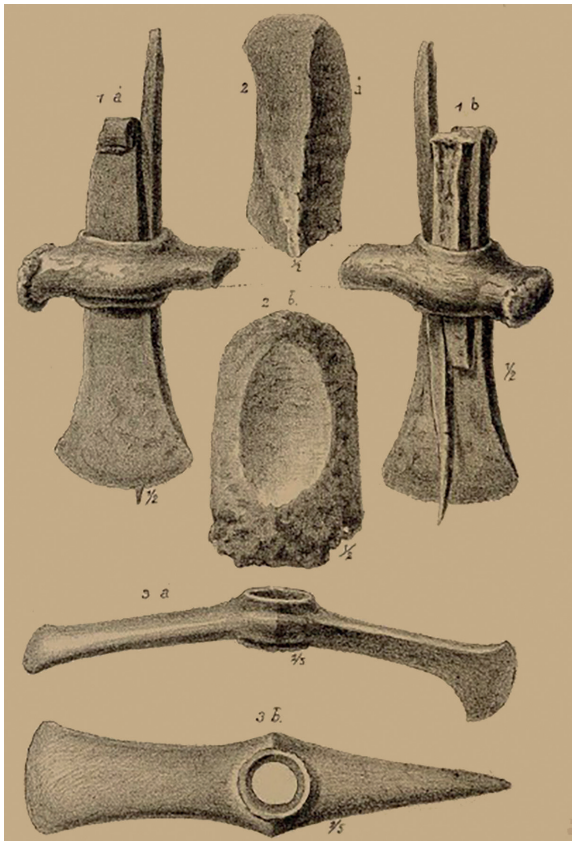
Since its discovery in the 19th century, the Szeged-Szillér copper hoard has been of paramount importance in European Copper Age research. It was one of the find assemblages on which Ferenc Pulszky based his definition of the Copper Age as a distinct period [1]. Although the find circumstances of the hoard are unknown, based on its composition (ingot, a Jászladány-type axe and two fragments, a flat axe, an awl and a chisel), it may have been a workshop hoard containing not only finished and in-use objects but also heavily worn and fragmentary items – likely intended for remelting [2]. A similar find assemblage was found at Nedakonice in southeastern Moravia, which contains two flat Stollhof-type axes, a chisel, and a cast cake [3].

In our presentation, we present the results of lead isotope analyses of the copper artefacts, which allow us to infer the origin of the artefacts' raw material. These results are consistent with previously published provenance studies of Early Copper Age artefacts from the Great Hungarian Plain [4], which point to interactions with copper ore sources in southeastern Europe, particularly in present-day Bulgaria.

The project is funded by the International Visegrad Fund (no. 22430152, Mysterium Magnum – Origins of Metallurgy in Central Europe).

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The Szeged-Szillér hoard (Pulszky 1884, fig. 1)

Notes

Compositional analysis of the Middle Copper Age hoard of Bagota

János Dani[1,2], Marianna Bálint[3], István Bacskai[4], Anikó Angyal[5], Anikó Horváth[6] and Mihály Braun[7]

[1] Archaeological Department, University of Szeged, Szeged, Hungary, drdanij@gmail.com, ORCiD: 0000-0003-4327-0038
[2] Déri Museum, Debrecen, Hungary
[3] Hajdúsági Museum, Hajdúböszörmény, Hungary, mbbalatonszelet12@gmail.com, ORCiD: 0009-0001-5980-456X
[4] Pelta Bt, Hajdúnánás, Hungary, peltabt@gmail.com
[5] HUN-REN Institute for Nuclear Research, Debrecen, Hungary, angyal@atomki.hu, ORCiD: 0000-0003-4444-7333
[6] HUN-REN Institute for Nuclear Research, Debrecen, Hungary, horvatha@atomki.hu, ORCiD: 0000-0002-9241-9516
[7] HUN-REN Institute for Nuclear Research, Debrecen, Hungary, mbraun@atomki.hu, ORCiD: 0000-0003-1726-9455

Keywords: *Copper Age metallurgy, Carpathian Basin*

In 2025, a composite hoard, among other items, containing copper and silver objects was discovered in Hajdúböszörmény-Bagota, Eastern Hungary. The fact that the hoard was hidden inside a pot belonging to the Middle Copper Age Hunyadihalom culture provides a solid basis for its relative chronological position (roughly the first half of the 4th Millennium BC).

Micro-XRF and ICP-MS analysis made in the HUN-REN Institute for Nuclear Research (Debrecen) of the artefacts (the flat axes, dagger, and silver beads) found in the hoard sheds fundamentally new light on the development of metalworking technology of the Middle Copper Age in the Carpathian Basin.

Analysis of copper objects suggests that these may have been the first copper-base alloys in the prehistory of the Carpathian Basin, predating the local Early Bronze Age by at least 1,000 years. On the other hand, it turned out that the beads were made of high-purity silver, which can only be produced through cupellation.

Both metallurgical processes require a very high level of technical expertise and a significant network of interregional connections (to ensure the dissemination of the metallurgical 'know-how' and the procurement of raw materials).



The unearthing of the hoard at the site

Notes

The use of mineral resources of Maramureș in prehistoric metal deposits from Northwestern Romania. XRF analyses

Gabriela Ilieș[1], Gheorghina Olariu[2], Marin Ilieș[3] and Liviu Marta[4]

[1] Faculty of Geography, Babeș-Bolyai University, Cluj-Napoca, Romania, gabriela.ilies@ubbcluj.ro
[2] Satu Mare County Museum, Satu Mare, Romania, ginaolariu@gmail.com
[3] Faculty of Geography, Babeș-Bolyai University,
Cluj-Napoca, Romania, marin.ilies.gf@gmail.com, ORCiD: 0000-0002-3443-3918
[4] Satu Mare County Museum,
Satu Mare, Romania, liviumarta@yahoo.com, liviu.marta@muzeusm.ro

Keywords: *metal mining areas, non-ferrous metal, Northeastern Carpathian Basin, bronze deposits*

This study investigates the dynamics of the exploitation of the ore deposits in Maramureș, characterized by a complex metal composition including copper, iron, lead, silver, and gold. To this end, a significant number of samples were collected from locations where metal-rich rocks have been identified. These locations were cross-checked against medieval written sources that mention the exploitation of ore veins reaching the surface. Sources situated along a stretch of more than 120 km, between the Oaș Mountains and the Rodna Mountains, were investigated. These sources are located in areas where metal extraction activities are historically documented. Field surveys revealed evidence of intensive anthropogenic activity at several sites. In addition, areas associated with the extraction of ore-bearing rocks were identified.

In order to obtain data regarding the utilization of metals extracted from the Maramureș region, assemblages of bronze artefacts from several regions were analysed: the Maramureș, Baia Mare, and Oaș depressions, the Satu Mare Plain, and the Carei Plain. Preliminary analyses highlight significant results concerning the use, in the lowland areas, of ores originating from the Oaș and Gutâi mountain regions.



Notes

Copper ingots and axes: Rethinking copper forms in the prehistoric Aegean

Athina Nikolopoulou[1] and Eleni Filippaki[2]

[1] Laboratory of Palaeoenvironment and Ancient Metals Studies, Institute of Nanoscience and Nanotechnology (INN), NCSR "Demokritos", Athens, Greece, a.nikolopoulou@inn.demokritos.gr, ORCiD: 0009-0007-3345-6249
[2] Laboratory of Palaeoenvironment and Ancient Metals Studies, Institute of Nanoscience and Nanotechnology (INN), NCSR "Demokritos", Athens, Greece, e.filippaki@inn.demokritos.gr, ORCiD: 0000-0003-0881-3674

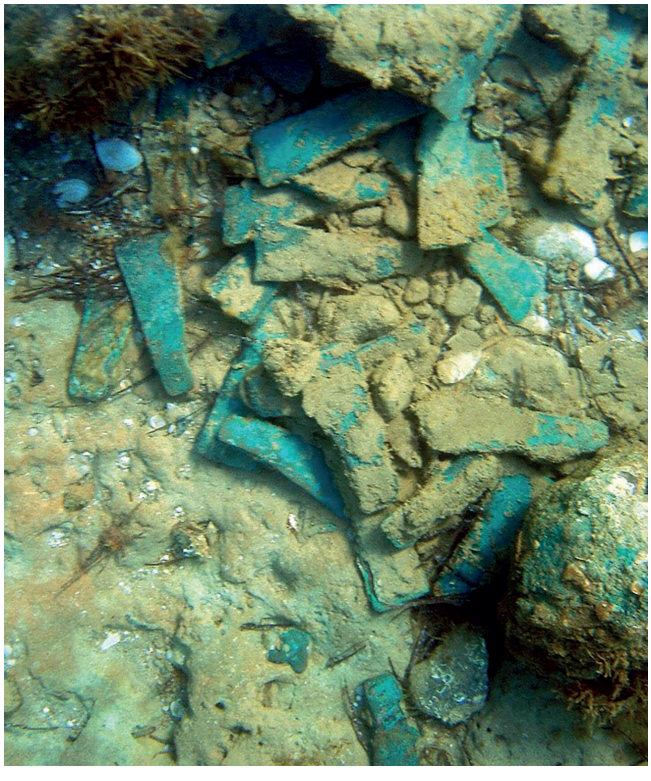
Keywords: *copper, ingots, axes, Bronze Age, Aegean*

Copper ingots and axes are among the most characteristic metal forms of the prehistoric Aegean and are commonly assigned different roles within metallurgical systems. Ingots are generally associated with the storage and movement of metal, whereas axes are typically interpreted as finished tools. Despite these distinctions, the relationship between the two categories remains insufficiently explored.

This study investigates a group of copper ingots and axes from a prehistoric hoard in northern Greece through elemental analyses (SEM-EDS), lead isotope analyses, metallographic examination, and the study of manufacturing technology. The analysed material consists predominantly of copper containing varying amounts of arsenic, lead, antimony, and zinc. Metallographic observations indicate that the examined specimens were cast in moulds and display limited evidence of subsequent mechanical processing, while lead isotope analyses provide information concerning the provenance of the metal.

In several cases, the analysed axes exhibit compositional and technological characteristics comparable to those observed in the ingots despite their different morphology. This correspondence suggests that typological distinctions do not necessarily reflect clearly differentiated technological histories and raises questions concerning the extent to which form alone can be used to define the role of copper in prehistoric metallurgy.

The study offers a new perspective on the relationship between copper form and metallurgical practice and contributes to broader discussions concerning the interpretation of prehistoric metal assemblages in the prehistoric Aegean.



Copper axes and ingots from the prehistoric hoard in northern Greece, photographed in situ

Notes

Roman iron semi-products in circulation: Standardisation and variability in production practices — evidence from the Hrvatska Dubica iron-bar assemblage, Croatia

Tena Karavidović[1], Béla Török[2], Péter Barkóczy[3] and Mónika Mende-Tokár[4]

[1] Institute of Archaeology, Zagreb, Croatia, tkaravidovic@iarh.hr, ORCiD: 0000-0003-3046-786X
[2] Institute of Chemical Metallurgy and Foundry Engineering, University of Miskolc, Miskolc, Hungary, bela.torok69@gmail.com, ORCiD: 0000-0002-3394-2753
[3] Institute of Physical Metallurgy, Metalforming and Nanotechnology, University of Miskolc, Miskolc, Hungary, peter.barkoczy@gmail.com, ORCiD: 0000-0003-1868-3463
[4] Institute of Physical Metallurgy, Metalforming and Nanotechnology, University of Miskolc, Miskolc, Hungary, monika.tokar@uni-miskolc.hu, ORCiD: 0000-0003-4314-6598

Keywords: *iron bar, Roman period, metallography, iron production, smithing*

The study presents a comprehensive morphometric and metallographic analysis of Roman iron semi-products from the Hrvatska Dubica iron-bar assemblage (Croatia). The assemblage originally comprised 97 bars recovered from the riverbed of the Una River, approximately 4 km downstream of Hrvatska Dubica (Croatia), of which 27 preserved examples were available for analysis. The bars can broadly be dated to the Roman period, between the 2nd and 4th centuries CE. The findspot lies near a major iron-producing region associated with Roman mining and smelting activities in the provinces of Dalmatia and Pannonia, encompassing present-day north-western Bosnia and Herzegovina and the border areas of southern continental Croatia.

The study combines detailed morphometric characterisation of all 27 bars with metallographic investigation of cross-sections from 12 selected examples. Cross-sectional samples taken from ends of each bar were prepared and analysed using optical microscopy and SEM–EDS. Entire cross-sectional surfaces were examined by optical microscopy to assess characteristic microstructural features, while SEM–EDS was employed for the detailed characterisation of carbon-bearing phases and slag inclusions.

The results reveal a notable degree of standardisation in the production of iron semi-products. Most bars belong to a relatively narrow range of quadrangular forms weighing between 2.65 and 5.32 kg, corresponding approximately to 8–16 Roman *librae*, with the majority clustering within the 12–15 *librae* range. At the same time, differences in shaping and microstructural composition indicate variability in manufacturing processes and smithing practices. These observations suggest that the assemblage incorporates products originating from multiple workshops and/or craftspeople while conforming to broadly shared morphological

and metrological standards. Considered alongside comparable finds from sites across Pannonian provinces, the Hrvatska Dubica assemblage provides evidence for the circulation of iron semi-products through organised riverine and overland transport networks. The assemblage therefore offers insights into the standardisation, production organisation and distribution of iron within the provincial economy of the Roman Empire.

Notes

Silver sources in the "long eighth century" of East-Central-Europe

Gergely Szenthe[1], Viktória Mozgai[2], Mihály Braun[3] and Bernadett Bajnóczi[4]

[1] Department of Archaeology, Hungarian National Museum, Budapest, Hungary, szenthe.gergely@hnm.hu, ORCiD: 0000-0002-8481-2203
[2] Institute for Geological and Geochemical Research, HUN-REN Research Center for Astronomy and Earth Sciences, Budapest, Hungary, mozgai.viktoria@csfk.org, ORCiD: 0000-0001-9712-2773
[3] HUN-REN Institute for Nuclear Research, Debrecen, Hungary, braun.mihaly@atomki.hu, ORCiD: 0000-0003-1726-9455
[4] Institute for Geological and Geochemical Research, HUN-REN Research Center for Astronomy and Earth Sciences, Budapest, Hungary, bajnoczi.bernadett@csfk.org, ORCiD: 0000-0003-0006-7611

Keywords: *early medieval archaeology, metal resources, lead isotope analysis, silver*

From the second half and late 7th century onward, silver served as the primary driver of the early medieval European economy. Recent research has reshaped our understanding of raw material consumption during the 7th to 10th centuries. According to these findings, the European silver-based coinages emerging in the 670s were initially supported by Byzantine silver, whereas from the 9th century onward, silver originating from the Arabic Caliphate played an increasingly significant role. Within this matrix, locally extracted silver resources also gained growing importance from the 7th century.

This presentation aims to investigate the silver sources of the early medieval Carpathian Basin – focusing primarily on the so-called "long 8th century", a crucial period for early medieval development – based on a series of lead isotope and chemical composition analyses. Although peripheral from the perspective of dominant economic routes, this region is expected to provide vital data on how emerging early medieval socio-political centres extended their spheres of influence during this period, and how these spheres potentially converged on the eve of the 9th-century Frankish–Bulgarian and Frankish–Byzantine confrontations, which are already documented in written sources.

The chronological phase under investigation precedes the period when substantial amounts of Eastern silver entered European economies via Arabic silver coins. Consequently, it offers key data regarding the local silver sources that underpinned the transition toward the European Middle Ages.

Project funded by the Hungarian NRDI Fund (TKP2021-NKTA-24).

Notes

The metallurgical examination of the iron blooms from Pécs, Jakab-hegy site

Ádám Thiele[1], Mira Majdán[2] and Tena Karavidović[3]

[1] Department of Materials Science and Engineering, Faculty of Mechanical Engineering, Budapest University of Technology and Economics, Budapest, Hungary, thiele.adam@gmail.com
[2] Janus Pannonius Museum,
Pécs, Hungary, majdan.mira@jpm.hu, ORCiD: 0009-0004-8682-3661
[3] Institute of Archaeology, Zagreb, Croatia, tkaravidovic@iarh.hr, ORCiD: 0000-0003-3046-786X

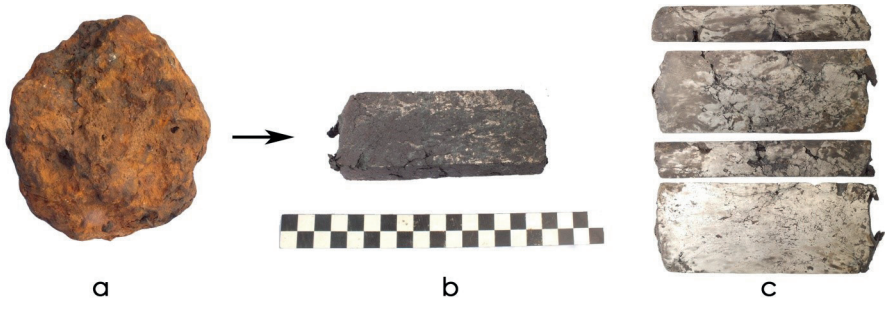
Keywords: *Iron Age, fortified settlement, depot, iron bloom, metallurgical examination, iron production, iron semi-products*

In October 2023, archaeologists from the Janus Pannonius Museum discovered a depot containing 29 iron blooms, each weighing 1.7–4 kilograms, on the Jakab-hegy near Pécs. The depot might be linked to the Iron Age settlement horizons on the hill, either the Early Iron Age Hallstatt culture associated with the remains of tumuli and earthworks, or to the Late Iron Age La Tène culture.

Bulk mass and density measurements, metallographic examinations (optical microscopy), and compositional analyses (p-XRF) were performed on samples cut from five blooms from the depot. In addition, experimental forging was carried out on one of the blooms, producing an iron bar purified to a density of 7.65 g/cm³.

It was established that the iron blooms could have been produced in small smelting furnaces with an inner hearth diameter of 25–35 cm, that they may have undergone only compaction immediately after removal from the furnace, and that they still contain a significant amount of slag, approximately one third by weight. Their material is high-quality, pure carbon steel, free of elements that could affect its mechanical properties (P, As, Cu), with a low to medium carbon content (on average approximately 0–0.4%). They must therefore have been regarded as a valuable raw material at the time, which may explain why they were concealed in a depot.

The provenance of the ores used and the location of smelting remain uncertain; however, some ore sources can potentially be excluded, such as phosphorus-rich bog iron ore, which occurs in large quantities in nearby Somogy.



Forging the 394/16 iron bloom into an iron block. a) The iron bloom. b) The forged iron block still with a rough surface. c) The etched iron block, on whose surface the heterogeneous carbon distribution is clearly visible

Notes

Session 5

MARKING TIME

Advanced dating methods in archaeological science



Moments in Budapest
© Attila Mitcsenkov

Sample preparation and AMS ^{14}C analyses of wood from Târgșoru Vechi-Holcim

Mirela Mihon[1], Oana Gâza[2], Cristian Mănăilescu[3], Maria Ilie[4], Doru Păcești lă[5], Paul Mereuță[6], Bogdan Ciupercă[7], Tudor-Vilgir Hila[8] and Cătălin Dîscă[9]

[1] Horia Hulubei-National Institute for R&D in Physics and Nuclear Engineering, Măgurele, Ilfov, Romania, mirela.mihon@nipne.ro, ORCiD: 0000-0002-9165-2690
[2] Horia Hulubei-National Institute for R&D in Physics and Nuclear Engineering, Măgurele, Ilfov, Romania, oana.gaza@nipne.ro, ORCiD: 0009-0008-0461-2582
[3] Horia Hulubei-National Institute for R&D in Physics and Nuclear Engineering, Măgurele, Ilfov, Romania, cristian.manailescu@nipne.ro, ORCiD: 0000-0003-1120-3180
[4] Horia Hulubei-National Institute for R&D in Physics and Nuclear Engineering, Măgurele, Ilfov, Romania, maria.ilie@nipne.ro, ORCiD: 0000-0003-3290-0890
[5] Horia Hulubei-National Institute for R&D in Physics and Nuclear Engineering, Măgurele, Ilfov, Romania, doru.pacesila@nipne.ro, ORCiD: 0000-0001-8024-6120
[6] Horia Hulubei-National Institute for R&D in Physics and Nuclear Engineering, Măgurele, Ilfov, Romania, paul.mereuta@nipne.ro, ORCiD: 0000-0002-9911-4766
[7] Prahova County Museum of History and Archaeology, Ploiești, Romania, bogdanciuperca@yahoo.com, ORCiD: 0000-0003-1323-9160
[8] Prahova County Museum of History and Archaeology, Ploiești, Romania, hilatudorvirgil@yahoo.com, ORCiD: 0009-0003-4411-5766
[9] Prahova County Museum of History and Archaeology, Ploiești, Romania, catalindisca@yahoo.com, ORCiD: 0000-0002-6901-3825

Keywords: *radiocarbon dating, AMS, pretreatment, wood, SEM-EDS*

The village of Târgșoru Vechi, located in the southwestern part of Prahova County, is well known in the field literature due to the numerous discoveries made in the area of the former medieval princely court. The most significant discoveries date from the 8th–10th centuries AD [1], but several features from the Early and Late Iron Age have also been identified. Sampling for radiocarbon dating was done from Holcim 80, a pit with a diameter of 1.60 meters, which extended downward 0.40 meters below its outlining level. Inside the feature were identified fragments of potsherds and several pieces of carbonised wood. A range of pretreatment methods were applied to wood samples from the Holcim site, to investigate the most suitable methods for removing contamination. We used scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM–EDS) to characterise the sample. Radiocarbon dating of carbonised wood can be problematic due to contamination from exogenous carbon**.** The cleaned samples were graphitized using the Automated Graphitization Equipment (AGE3) and the isotopic ratios $^{14}C/^{12}C$, $^{13}C/^{12}C$ were measured with the 1MV Tandetron Accelerator Mass Spectrometry [2]. After obtaining the calendar ages, using the IntCal20 calibration curve the placement of the studied archeological site in time was confirmed, which paves the way for an extensive “Holcim gravel pit” site investigation.

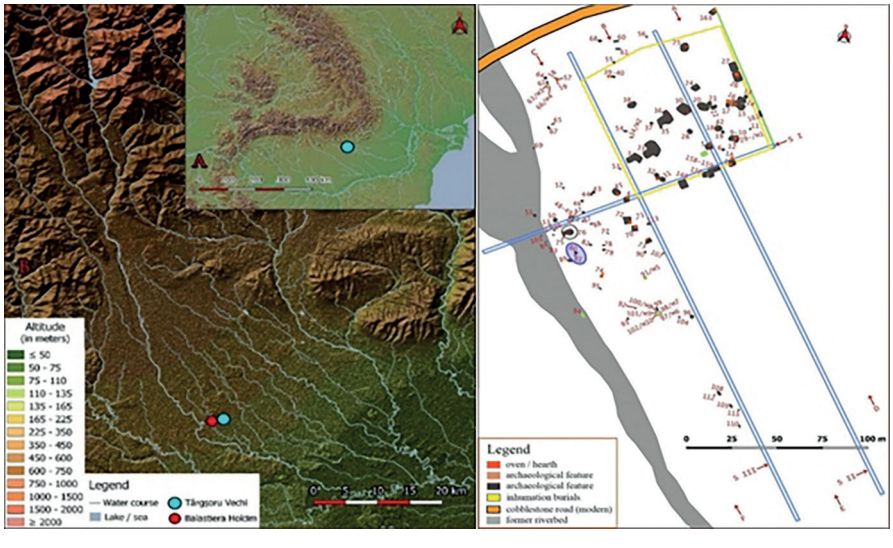
Acknowledgements

This work was supported by a grant of the Ministry of Education and Research, CCCDI-UEFISCDI, project number PN-IV-P6-6.1-CoEx-2024-0042, within PNCDI IV. Experiments were carried out at 1 MV Tandetron™ accelerator from "Horia Hulubei" National Institute for Physics and Nuclear Engineering (IFIN-HH) and were supported by the Romanian Government Programme through the National Programme for Infrastructure of National Interest (IOSIN) and Research Programme Partnership in Priority Areas PNII MEN-UEFISCDI, contract PN 23210201.

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Location of the archaeological site from Târgșoru Vechi-Holcim

Notes

A case study of direct radiocarbon dating on pottery from the Great Hungarian Plain

Anna Szigeti[1,2,3], István Major[4], György Sipos[5], Dávid Filyó[6], János Dani[7,8], Mihály Molnár[9] and Botond Buró[10]

[1] Archaeological Department, University of Szeged, Szeged, Hungary
[2] Radiocarbon Competence Centre, HUN-REN Institute for Nuclear Research, Debrecen, Hungary, szigeti.anna@atomki.hu, ORCiD: 0009-0001-8794-1318
[3] Isotoptech Zrt., Debrecen, Hungary
[4] Radiocarbon Competence Centre, HUN-REN Institute for Nuclear Research, Debrecen, Hungary, imajor@atomki.hu, ORCiD: 0000-0003-4675-9875
[5] Department of Geoinformatics, Physical and Environmental Geography, University of Szeged, Szeged, Hungary, gysipos@geo.u-szeged.hu, ORCiD: 0000-0001-6224-2361
[6] Department of Geoinformatics, Physical and Environmental Geography, University of Szeged, Szeged, Hungary, filyodavid852@gmail.com, ORCiD: 0009-0005-1203-6101
[7] Archaeological Department, University of Szeged, Szeged, Hungary, drdanij@gmail.com, ORCiD: 0000-0003-4327-0038
[8] Déri Museum, Debrecen, Hungary
[9] Radiocarbon Competence Centre, HUN-REN Institute for Nuclear Research, Debrecen, Hungary, mmol@atomki.hu, ORCiD: 0000-0003-4382-9508
[10] Radiocarbon Competence Centre, HUN-REN Institute for Nuclear Research, Debrecen, Hungary; buro.botond@atomki.hu, ORCiD: 0000-0002-2173-1537

Keywords: *radiocarbon dating, pottery dating, ^{14}C, TL*

The aim of the present study was to investigate the reliability of radiocarbon dating for pottery samples. Seven samples of known archaeological age (one Neolithic: Körös/Criş culture, and six Bronze Age: Hajdúbagos–Cehăluţ culture) were selected from three sampling sites on the eastern Great Hungarian Plain. Their ages were compared using thermoluminescence (TL) dating of the same potsherds, and radiocarbon dating of associated bones from the same features. Based on previous experiments and the literature [1], the acid–base–acid (ABA) chemical pre-treatment was used to remove contaminants from the pulverised samples. To test the method's reliability, triplicate subsamples were treated, then combusted in 2-steps: at 400 °C (low temperature fraction, LTF) and 800 °C (high temperature fraction, HTF). Thus, 42 radiocarbon dates were obtained from the pottery samples, which were then compared with the TL ages and the ^{14}C ages of the bone samples. All bone ^{14}C results align with the expected archaeological ages, but the TL and ^{14}C pottery ages are more nuanced.

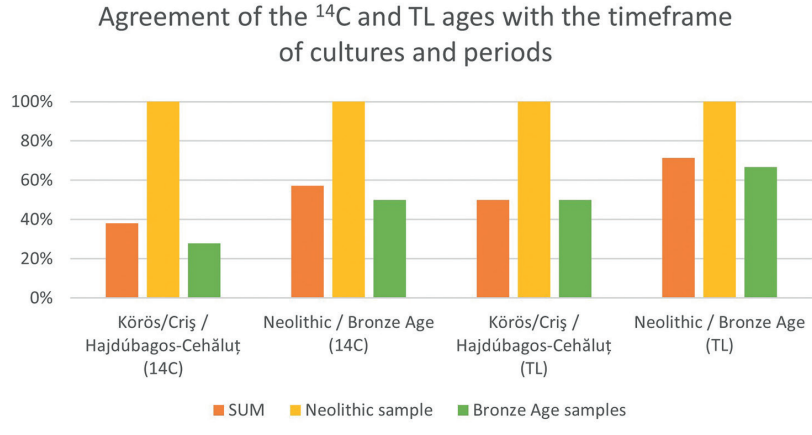
According to the literature [1], the ages of all the HTF carbon in the pottery are older than the LTF ages. The triplicate LTF ^{14}C ages of the Neolithic pottery align well with the Körös/Criş culture. However, only 27.8% of LTF ages align with the Hajdúbagos–Cehăluţ timeframe and 50% with the entire Bronze Age period. In the case of TL ages, 57% align with the examined cultures and 71% with the archaeological periods.

The reason why certain LTF and TL dating results yield younger dates may be contamination from soil carbon, the use of grog as a temper, or the secondary burning of samples. The excellent correlation between the ^{14}C ages of the Neolithic sample and the archaeological age might be due to the organic temper of the clay. This encourages further research into this archaeological period or pottery with organic tempering.

Project No. KDP-2023-C2321722 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the 2023-2.1.2-KDP-2023-00002 funding scheme.

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Agreement of the LTF ^{14}C and TL ages of the pottery samples with the chronological position of the examined archaeological cultures and periods (created by the authors)

Notes

Dendrochronological analysis of the Árpád-Era wells at Külsővat (Hungary)

Mátyás Árvai[1], Melinda Koller[2] and Eszter Piroska[3]

[1] HUN-REN Institute for Soil Sciences,
Budapest, Hungary, arvai.matyas@atk.hun-ren.hu, ORCiD: 0000-0002-2405-3858
[2] National Institute of Archaeology, Hungarian National Museum,
Budapest, Hungary, koller.melinda@hnm.hu
[3] National Institute of Archaeology, Hungarian National Museum,
Budapest, Hungary, piroska.eszter@hnm.hu

Keywords: *dendrochronology, Middle Ages, well, wooden structure*

In 2024 and the spring of 2025 we conducted an archaeological excavation in the southern part of the village of Külsővat (Hungary), located on the eastern side of the Marcal Valley, in the Kisalföld region. The excavated area, covering nearly 2 hectares and rising 1 to 10 meters above the former floodplain, provided particularly favorable geographical conditions for settlement during periods. Among the settlement remains, which date from prehistoric times – specifically the Middle Copper Age, the Early Bronze Age, and the Celtic period – traces of an Árpád-Era village were also discovered in the northern and southwestern parts of the excavation site.

Economic features on the outskirts of the Árpád-Era settlement were primarily concentrated in the lower-lying western part, while the residential area expanded toward the northeast and likely continues beyond the excavation site. In addition to the ovens and the smaller and larger storage pits, the number of wells was particularly noteworthy. Of the excavated ten wells, the wooden structure has been preserved in six. We collected 46 wooden samples from these in order to date the settlement as accurately as possible. The archaeological features, also the wells, contained a rich collection of pottery from the specific period.

21 samples were selected for tree species identification and 25 for tree-ring analysis. Most of the identified tree species were the most characteristic and common hardwoods of the once-extensive floodplains. Based on the cross-correlations, it was determined that the site belongs to a single period. Although there was some overlap between the dating of the ceramic material and the dendrochronological results, the wood from the wells proved to be younger than the archaeological finds from these. These anomalies raise exciting methodological questions, which are attempted to be answered.



The wooden structure of Well SNR 42

Notes

Session 6

HISTORY IN MOTION

Reconstructing the past through experimental science



Moments in Budapest
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From sea to summit: Marine shell beads in the Late Bronze Age hoards of Somló Hill

Dorottya Láng[1,2]

[1] Department of Archaeology, Hungarian National Museum, Budapest, Hungary, lang.dorottya@hnm.hu, ORCiD: 0009-0005-1816-9925
[2] Doctoral School of History, ELTE Eötvös Loránd University, Budapest, Hungary

Keywords: *Late Bronze Age, Carpathian Basin, experimental archaeology, use-wear analysis, personal adornment*

Among the Late Bronze Age hoards discovered on Somló Hill, small, flat, disc-shaped white beads frequently occur alongside amber and blue glass beads. These white beads were most likely manufactured from marine shells, as suggested by the characteristic wavy patterns visible on certain specimens, which are typical features of saltwater shell species. Furthermore, many beads display distinctive ribs on their convex surfaces, a characteristic commonly associated with cockles and scallops.

These shell species may have been particularly suitable for bead production because, unlike many other shell types, their material is relatively soft and can be more easily worked and perforated. Since these species are not native to the region surrounding Somló Hill, the raw material, or more likely the finished beads themselves must have reached the site through long-distance exchange networks.

To investigate the manufacturing process of these ornaments, an experimental archaeological approach can be employed. The production sequence likely involved shell fragmentation, abrasive shaping and grinding, perforation of preforms, and final polishing. Each stage generates distinctive use-wear traces that may be preserved on archaeological specimens. Comparison of experimentally produced beads with the archaeological material offers the potential to identify specific manufacturing stages and techniques, thereby providing a more detailed understanding of shell bead production and the technological practices associated with Late Bronze Age personal adornment.

The research was financed by the NKFI STARTING_25 Grant No. 152369 research programme.

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Late Bronze Age shell beads from the Carpathian Basin

Notes

Casting Bronze Age ingots

János Gábor Tarbay[1]

[1] Department of Archaeology, Hungarian National Museum,
Budapest, Hungary, tarbay.gabor@hnm.hu, ORCiD: 0000-0002-2363-7034

Keywords: *Bronze Age, Central Europe, metal casting, ingots, experimental archaeology*

The poster presents the results of experimental casting undertaken to reproduce ingot types known from the Central European Bronze Age, with a focus on forms that have not previously been subjected to experimental study. These include bar ingots, cuboid ingots, loaf-shaped ingots, and small plano-convex ingots, which are typically found in hoard contexts [1–4]. During the experiments, replica ingots made of both unalloyed copper and copper alloys were cast in open and closed moulds. Technological traces and casting defects observed on the replicas were compared with use-wear and production traces identified on archaeological specimens.

The research was financed by the NKFI STARTING_25 Grant No. 152369 research programme.

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Experiment Phase II: Open sandstone casting moulds for ingots and the tools used to produce them (Photo: J. G. Tarbay)

Notes

Session 7

WRITTEN IN BONE

Biological archives of health, diet, and mobility



Moments in Budapest
© Attila Mitcsenkov

Isotopic dietary and palaeoenvironmental reconstruction of a Mesolithic hunter-gatherer from the Hódmezővásárhely-Gorzsa sand mine No. 5 site, SE-Hungary

István Major[1], Zsuzsa Lisztes-Szabó[2], Anikó Horváth[2], István Futó[2], Katalin Tóth[3], Tamás Szeniczey[4], Tamás Hajdu[4,5], Dániel Gerber[6], Anna Szécsényi-Nagy[6], Barna Kenteley[7], János Angyal[8], Kristóf István Szegedi[3], Tibor Marton[9] and János Dani[10,11]

[1] International Radiocarbon AMS Competence and Training Center (INTERACT), HUN-REN Institute for Nuclear Research, Debrecen, Hungary, imajor@atomki.hu
[2] Isotope Climatology and Environmental Research Centre (ICER), HUN-REN Institute for Nuclear Research, Debrecen, Hungary
[3] Hungarian National Museum, Budapest, Hungary
[4] Department of Biological Anthropology, Institute of Biology, ELTE Eötvös Loránd University, Budapest, Hungary
[5] Centre for Applied Bioanthropology, Institute for Anthropological Research, Zagreb, Croatia
[6] Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary
[7] Non-independent Department of Biomaterials and Prosthetic Dentistry, Faculty of Dentistry, University of Debrecen, Debrecen, Hungary
[8] Non-independent Department of Periodontology, Faculty of Dentistry, University of Debrecen, Debrecen, Hungary
[9] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest Hungary
[10] Department of Archaeology, University of Szeged, Szeged, Hungary
[11] Archaeological Department, Déri Museum, Debrecen, Hungary

Keywords: *Mesolithic, Hungary, stable isotopes, bioarchaeology, palaeoenvironment*

A Mesolithic burial was unearthed during the 2009 excavation campaign of the Gorzsa sand mine No. 5, located on the south-eastern outskirts of Hódmezővásárhely in Southern Hungary. The burial was situated at the summit of a hill rising from the marshy floodplain of the Tisza River. Based on anthropological analysis, the skeleton belonged to a tall and robust male with an estimated age of approximately 50–60 years, whose death is dated to the period between 7900 and 7700 BCE. The burial is regarded as unique within the broader region and yielded archaeological materials lacking close parallels. To reconstruct the lifeway and environment of this individual, we conducted multiple stable isotope analyses, complemented by detailed dental examinations. Stable strontium and oxygen isotope results indicate that the hunter-gatherer might probably have lived in the immediate vicinity of the burial or in an environment with closely comparable isotopic signals; and no evidence of long-distance mobility could be revealed. The carbon isotope ratio results unambiguously indicate a diet dominated by C_3 plants, but the high $\delta^{15}N$ and extremely low $\delta^{34}S$ values are somewhat

contradictory. This suggests a reasonably specialised hunter-gatherer diet, ranging from fish consumption to possible intake of nuts, mushrooms, roots or even insects. These assumptions may be refined and clarified in the future by analysing dental calculus microremains.



The skull of the Mesolithic hunter-gatherer from Gorzsa (Photo: Déri Museum)

Notes

Diet and settlement patterns during the Neolithic in the Southern Carpathian Basin

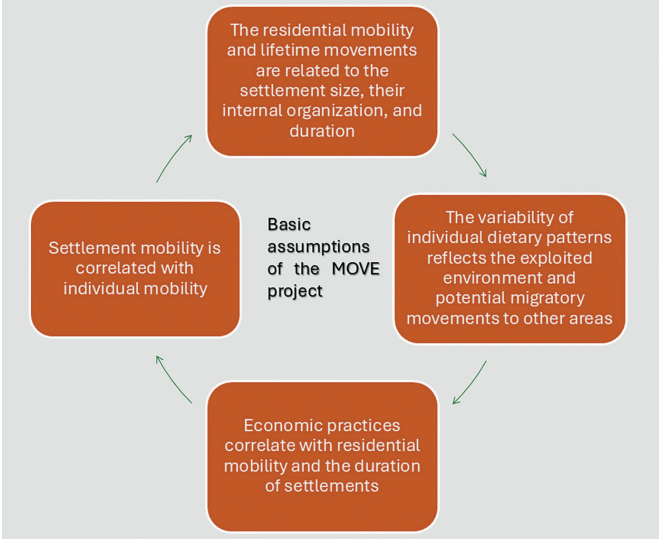
Jelena Jovanović[1], Tamara Blagojević[2], Maja Kokanović[3], Mario Novak[4,5], Maja Krznarić-Škrivanko[6], Dragana Rajković[7], Anđelka Putica[8], Andrej Starović[9], Lidija Balj[10], Darko Radmanović[11], Branislav Vasov[12], Camille de Becdelièvre[13,14], Guy Andre[15], Sara Bernardini [16,17], Federico Lugli[18,19] and Gwenaëlle Goude[20]

[1] BioSense Institute, University of Novi Sad, Novi Sad, Serbia, jelena.jovanovic@biosense.rs, ORCiD: 0000-0001-6134-8180
[2] BioSense Institute, University of Novi Sad, Novi Sad, Serbia, tamara.blagojevic@biosense.rs, ORCiD: 0000-0002-1993-4714
[3] BioSense Institute, University of Novi Sad, Novi Sad, Serbia, maja.kokanovic@biosense.rs, ORCiD: 0000-0002-1509-6186
[4] Center for Applied Bioanthropology, Institute for Anthropological Research, Zagreb, Croatia, mario.novak@inantro.hr, ORCiD: 0000-0002-4567-8742
[5] Faculty of Humanities, University of Primorska, Koper, Slovenia
[6] Vinkovci Municipal Museum, Vinkovci, Croatia, maja@muzejvk.hr, ORCiD: 0000-0002-6409-8663
[7] Archaeological Museum Osijek, Osijek, Croatia, dragana.rajkovic@amo.hr, ORCiD: 0000-0002-8653-2651
[8] Sombor City Museum, Sombor, Serbia, anputica@gmail.com
[9] National Museum of Serbia, Belgrade, Serbia, a.starovic@narodnimuzej.rs, ORCiD: 0009-0002-0256-0223
[10] Museum of Vojvodina, Novi Sad, Serbia, lidija.balj@muzejvojvodine.org.rs
[11] Museum of Vojvodina, Novi Sad, Serbia, rad.darko@gmail.com
[12] Museum Unit in Odžaci, Odžaci, Serbia, branislavvasov@yahoo.com
[13] LAB – Laboratory for Archaeobioanthropology, Hebrew University in Jerusalem, Jerusalem, Israel, c.debecdelievre@gmail.com
[14] CNRS, Ministry of Culture, LAMPEA, UMR 7269, Aix-en-Provence, France
[15] CNRS, Ministry of Culture, LAMPEA, UMR 7269, Aix-en-Provence, France, guy.andre@univ-amu.fr
[16] Department of Cultural Heritage, University of Bologna, Bologna, Italy, ORCiD: 0000-0001-7283-6323
[17] Department of Chemical and Geological Sciences, University of Modena and Reggio Emilia, Modena, Italy, sara.bernardini@unimore.it
[18] Department of Chemical and Geological Sciences, University of Modena and Reggio Emilia, Modena, Italy, ORCiD: 0000-0002-5642-2216
[19] Institut für Geowissenschaften, Goethe-Universität Frankfurt, Frankfurt, Germany
[20] CNRS, Ministry of Culture, LAMPEA, UMR 7269, Aix-en-Provence, France, gwenaelle.goude@univ-amu.fr, ORCiD: 0000-0002-3008-3607

Keywords: *first farmers, dietary behaviors, mobility, stable isotopes, settlement patterns, Neolithic, southern Carpathian Basin*

The Southern Carpathian Basin represents one of the key areas for studying nature and dynamics of the expansion of agro-pastoral communities, as well as the adaptation of various elements of the "Neolithic package" to new natural environments. The MOVE project aims to examine the origins of a sedentary lifestyle through the study of mobility and settlement patterns of the Neolithic (~6250–4500 cal. BCE) communities in this area by integrating various archaeological and bioarchaeological data. Through analysis of the ratio of stable isotopes of carbon, nitrogen, and sulfur ($\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$) and strontium radiogenic signal ($^{87}Sr/^{86}Sr$) as well as archaeozoological and contextual analysis, we obtained the following: 1. insight into the size, duration, and organization of settlements; 2. degree of mobility, patterns of nutrition, and exploitation of the environment during the Neolithic; 3. economic strategies of Neolithic communities. The results indicate that people did not move much outside the locally accessible areas, that they exploited local environments, that there were certain differences between the Early and Late Neolithic, especially in the organization and duration of settlements, as well as a high degree of adaptation to the natural environment. They had a mixed diet of plant and animal origin, with a noticeable trend towards greater consumption of domestic animals during the Late Neolithic, which is probably related to the intensification of agricultural practices and increased sedentism in this period. Differences observed within sites may reflect the adaptation of communities to local conditions and available food sources. The study contributes to a deeper understanding of the process of Neolithization and the development of early agro-pastoral communities in the Southern Carpathian Basin.

This research was supported by the Science Fund of the Republic of Serbia, GRANT No. 7498, *Moving across the plain: reconstructing the lifetime movements of farming pioneers and their successors during the Neolithic in the Southern Carpathian Basin-MOVE.*



Basic assumptions of the MOVE project

Why studying Neolithic mobility in the Eastern Balkans requires crossing modern borders

Aurelien Tafani[1], Christophe Snoeck[2], Hanna James[2], Robert H. Tykot[3], Kevin Salesse[4], Valentin Radu[5] and Cătălin Lazăr[6]

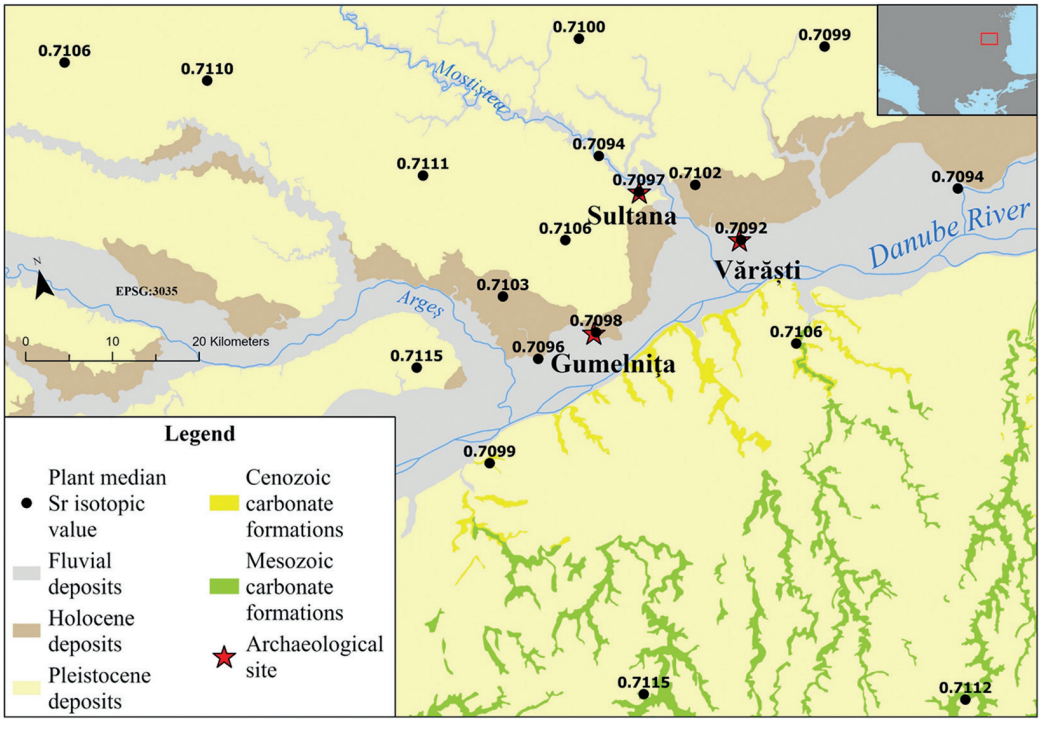
[1] Institute Research of the University of Bucharest, University of Bucharest, Bucharest, Romania, aurelien.newyork@gmail.com, ORCiD: 0000-0003-2480-6255
[2] Archaeology, Environmental Changes & Geo-Chemistry Research Group, Vrije Universiteit Brussel, Brussels, Belgium
[3] Applied Anthropology, University of South Florida, Tampa, United States
[4] Department of Anthropology, Faculty of Science, Masaryk University, Brno, Czech Republic
[5] Centrul Național de Cercetări Pluridisciplinare „Alexandra Bolomey", Muzeul Național de Istorie a României, Bucharest, Romania
[6] Institute Research of the University of Bucharest, University of Bucharest, Bucharest, Romania, catalin.lazar@icub.unibuc.ro

Keywords: *strontium, isotopes, mobility, Neolithic*

The study of individual mobility is a cornerstone for understanding the social dynamics of ancient communities, offering critical insights into human identity. Among the methods used by archaeologists, strontium isotope analysis has emerged as the gold standard due to its reliability, robustness, and increasing accessibility—ushering in a "Golden Age" for the technique. However, its application in the Eastern Balkans remains limited, with few studies addressing the establishment of a biologically available strontium (BASr) baseline for the region.

This presentation reviews the current state of research and presents new results from the Eneolithic necropolises of Gumelnița, Vărăști, and Sultana, alongside our efforts to develop a BASr baseline for the Lower Danube Valley. We emphasize the necessity of interpreting these findings within a regional, transnational framework, as ancient cultural entities often transcended the boundaries of modern nation-states.

This work was supported by a grant of the Romanian Ministry of Education and Research, CNCS UEFISCDI, project number PN-IV-P1-PCE-2023-1899 (BioArhSteppe).



Bioavailable strontium (BASr) in southern Romania

Notes

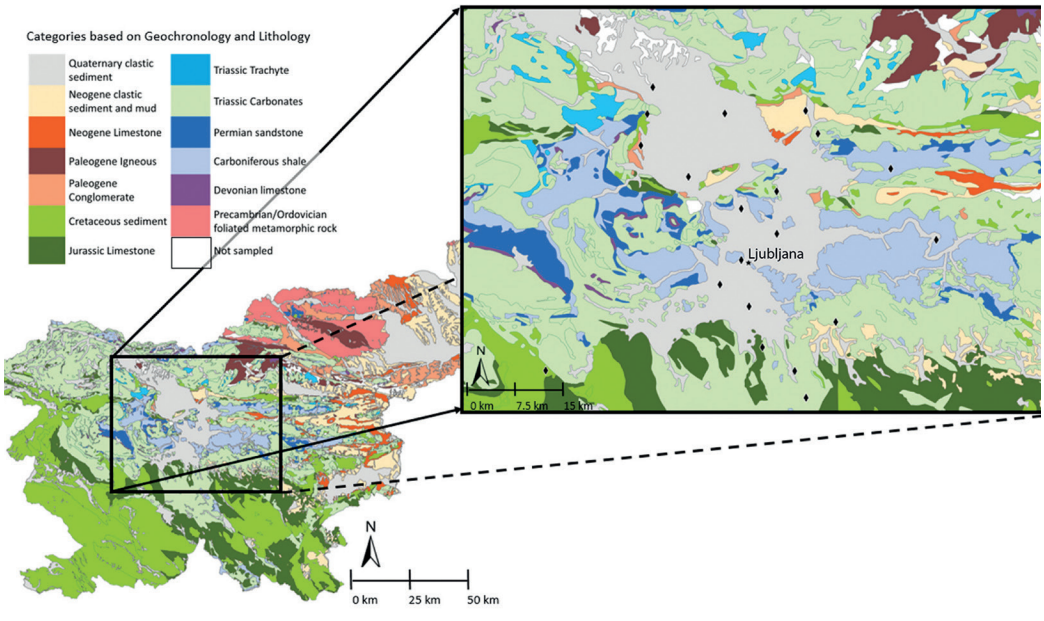
Exploring the potential of isotope analyses in Slovenian archaeology

Christophe Snoeck[1], Tamara Leskovar[2], Carina T. Gerritzen[3], Tom Boonants[4], Doris Potočnik[5], Nives Ogrinc[6], Steven Goderis[7] and Matija Črešnar[8]

[1] Archaeology, Environmental Changes and Geo-Chemistry, Vrije Universiteit Brussel, Brussels, Belgium, christophe.snoeck@vub.be, ORCiD: 0000-0003-3770-4055
[2] Department of Archaeology, Center for Interdisciplinary Research in Archaeology, Faculty of Arts, University of Ljubljana, Ljubljana, Slovenia, tamara.leskovar@ff.uni-lj.si, ORCiD: 0000-0002-4585-4726
[3] Archaeology, Environmental Changes and Geo-Chemistry, Vrije Universiteit Brussel, Brussels, Belgium, carina.gerritzen@vub.be, ORCiD: 0000-0002-1494-2643
[4] Archaeology, Environmental Changes and Geo-Chemistry, Vrije Universiteit Brussel, Brussels, Belgium, tom.boonants@vub.be, ORCiD: 0000-0003-1112-2516
[5] Jožef Stefan Institute, Ljubljana, Slovenia, doris.potocnik@ijs.si, ORCiD: 0000-0002-4636-5916
[6] Jožef Stefan Institute, Ljubljana, Slovenia, nives.ogrinc@ijs.si, ORCiD: 0000-0002-5709-1594
[7] Archaeology, Environmental Changes and Geo-Chemistry, Vrije Universiteit Brussel, Brussels, Belgium, steven.goderis@vub.be, ORCiD: 0000-0002-6666-7153
[8] Department of Archaeology, Center for Interdisciplinary Research in Archaeology, Faculty of Arts, University of Ljubljana / GreenHer Centre of Excellence, University of Ljubljana, Ljubljana, Slovenia, matija.cresnar@ff.uni-lj.si, ORCiD: 0000-0002-7856-6384

Keywords: *bioarchaeology, isotope studies, strontium baseline, Slovenia*

Isotope analysis has become an increasingly important tool in archaeological research, providing new insights into past human lifeways, mobility, diet, and population dynamics. Recent studies have applied multi-isotopic approaches in Slovenia, including carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$), oxygen ($\delta^{18}O$), and strontium ($^{87}Sr/^{86}Sr$) isotope analyses, to a wide range of archaeological contexts spanning prehistory, the Roman period, all the way to the recent archaeological periods. These investigations, initiated by the Vrije Universiteit Brussels, University of Ljubljana and Jožef Stefan Institute, have enabled the reconstruction of dietary practices, opened the debate about the possibilities of identification of local and non-local individuals, and a more in-depth exploration of social and biological aspects of past populations. Particular attention has been given to the development of robust bioavailable strontium baselines for the whole country of Slovenia. Together, these studies illustrate the growing contribution of isotope analysis to Slovenian archaeology, combining methodological innovation with bioarchaeological applications. By integrating isotopic data with archaeological, osteological, and environmental evidence, researchers are developing increasingly nuanced reconstructions of mobility patterns, dietary behaviour, and human-environment interactions across diverse chronological and cultural settings.



Geological map of Slovenia with zoomed in area of Ljubljana (star) and its surroundings with marked locations of strontium plant samples sites (diamonds)

Notes

Epigenetics of ancient Pannonia populations

Chen Kozulin[1]

[1] Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary, Chen.Kozulin@abtk.hu, ORCiD: 0000-0001-5103-2545

Keywords: *ancient epigenetics, DNA methylation reconstruction, Roman Pannonia, environmental adaptation*

Ancient epigenetics is an emerging branch of ancient DNA research that has gained increasing attention with advances in modeling DNA degradation patterns. Reconstruction of methylation profiles in ancient samples offers a potential bridge between genotype and phenotype, providing insights into rapid, environmentally driven adaptations that are not readily captured by genetics, anthropology, or archaeology alone [1]. By establishing differential methylation profiles of human remains from the Roman period in Pannonia (1st–4th centuries CE), this study expands population genetic analyses to include aspects of lived conditions and environmental variability. Such an approach enables a more nuanced interpretation of past human biology beyond genetic ancestry alone. Several computational tools for ancient methylation reconstruction have been developed in recent years, with varying degrees of success [2, 3]. These methods exploit differences in deamination patterns between methylated and unmethylated cytosines to infer methylation states and identify differentially methylated regions (DMRs). Depending on their genomic context, DMRs can reveal regulatory variation and contribute to the inference of environmental adaptations [1]. Initial applications of the Reconstruction of Ancient Methylation tool (RoAM; [4]) indicate potential differences between populations from distinct Roman-period settlements in Pannonia. However, given the heterogeneous genetic backgrounds of these populations, it remains unclear whether the observed variation reflects differences in local environmental conditions or the diverse origins of the individuals. Future work will therefore incorporate populations of well-characterized and distinct origins, alongside further refinement of the analytical pipeline. While epigenetic analyses of ancient human remains have previously been limited to a small number of samples, often with a focus on evolutionary questions, this project represents – to our knowledge – one of the first applications of such approaches within a historical, rather than strictly paleogenomic, framework.

References

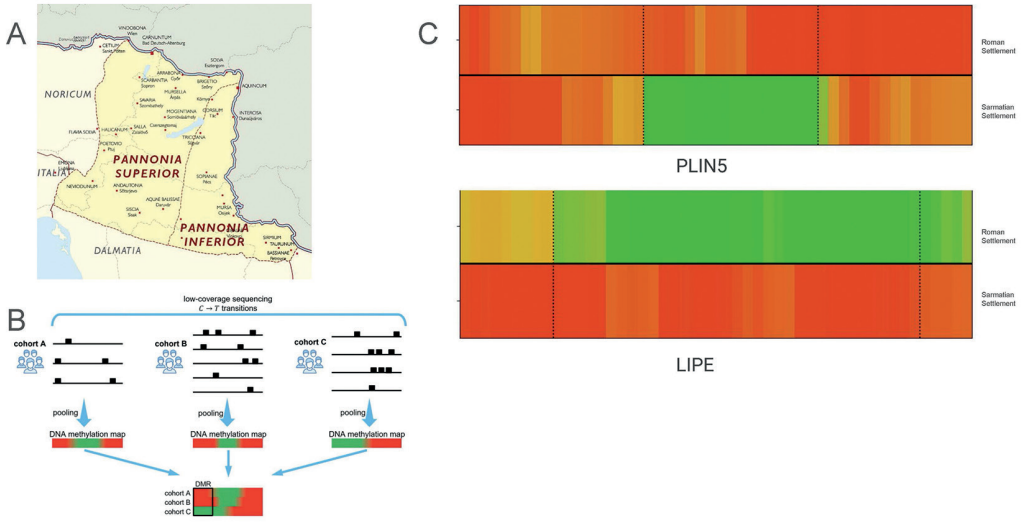
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Biological Memory: Epigenetics of Ancient Pannonia Populations. ***A.*** *Located at the border of the Roman Empire, Pannonia presents an intriguing case for studying rapid, environmentally driven adaptations that are not readily captured by genetics.* ***B.*** *Computational methods for ancient methylation reconstruction exploit differences in deamination patterns to infer methylation states and identify Differentially Methylated Regions (DMRs).* ***C.*** *DMRs detected between populations from Roman and Sarmatian settlements in Pannonia*

Notes

At an isotopic crossroads: An intersectional study of a 'mass grave' from Romano-Byzantine Ibida (Romania) applying archaeothanatology, bioarchaeology, and isotopic proxies

Mackenzie Masters[1,2], Andrei Dorian Soficaru[3], Jasmine Volkaert[4], Malin Holst[5], Jane Evans[6] and Michelle Alexander[7]

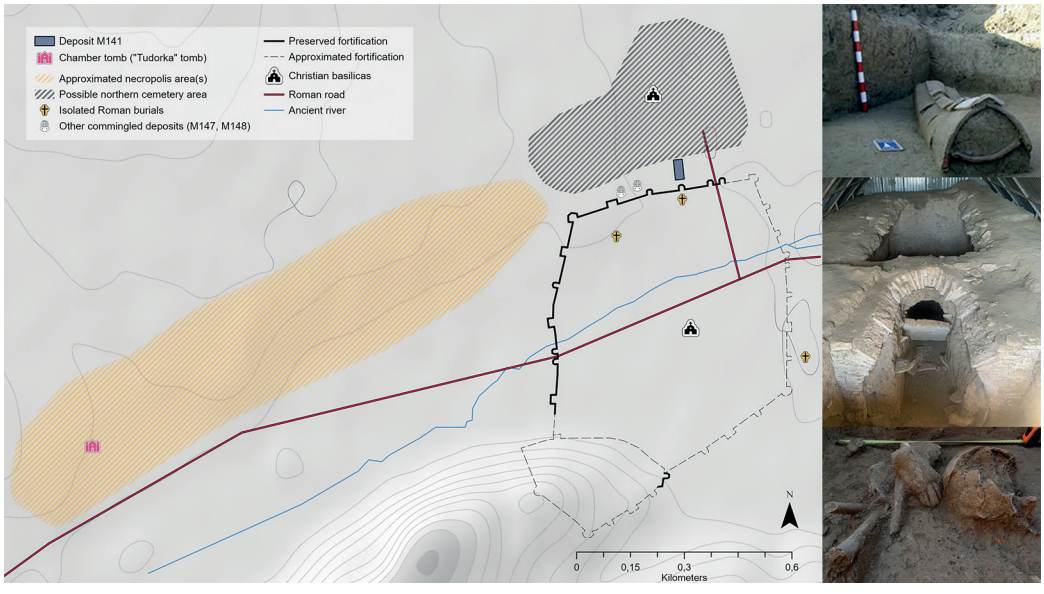
[1] University of York, York, UK
[2] Vrije Universiteit Brussel, Brussels, Belgium, Mackenzie.Masters@vub.be, ORCiD: 0000-0002-8940-5906
[3] Academia Română, Bucharest, Romania, anthropodorian@gmail.com, ORCiD: 0000-0001-8658-6695
[4] University of York, York, UK
[5] University of York, York, UK / York Osteoarchaeology Ltd., York, UK, malin.holst@york.ac.uk, ORCiD: 0000-0002-4183-7574
[6] British Geological Survey, Keyworth, Nottingham, UK, je@bgs.ac.uk
[7] University of York, Heslington, York, UK, michelle.alexander@york.ac.uk, ORCiD: 0000-0001-8000-3639

Keywords: *multi-isotopic analysis, commingled remains, frontier studies*

The extensive mortuary landscape at the fortress Ibida (Romania), comprising a high-status tomb (MNI=39), a general necropolis (n=161), and M141, a commingled secondary multiple burial pit representing a suspected 'massacre of outsiders' (MNI=37), offers the unique opportunity to investigate coalescing populations along the lower Danube Limes frontier. This study presents the largest (n=119) multi-isotopic analysis (C, N, S, Sr, O, Pb) of any Roman period (1st–7th c. CE) site from the region and a novel approach to integrating multi-method assessment (archaeothanatology, osteology, proteomics) to re-examine the M141 deposit as commingled assemblages of human remains are often neglected in biomolecular research.

Analysis reveals M141 contains both sexes and multiple age cohorts (infant to elderly) with minimal perimortem trauma, challenging the massacre narrative. Isotopic analysis identifies distinct dietary histories, suggesting distinguishable subsistence strategies and/or cultural identities, with the majority of M141 individuals consuming C_4 foods (millet), contrasting the C_3-dominant diet of individuals in the high-status tomb and necropolis. While sulphur, strontium and oxygen isotopes identify potential non-locals across all contexts, lead isotope concentrations present a possible cultural divide with the high-status group presenting elevated anthropogenic values (ppm>0.5), suggesting long-term Roman cultural influence.

The assessment of the M141 group exposes a unique range of dietary and mobility practices exhibited at Ibida, otherwise masked if commingled remains are excluded from analysis, underscoring the underappreciated role of commingled deposits in reconstructing the complex, fluid human experiences of the Roman frontier.



Site plan and exemplary mortuary discoveries from Ibida

Notes

Genetic contrast and dietary differences between neighbouring elite and low-status burial groups in the Middle–Late Avar period

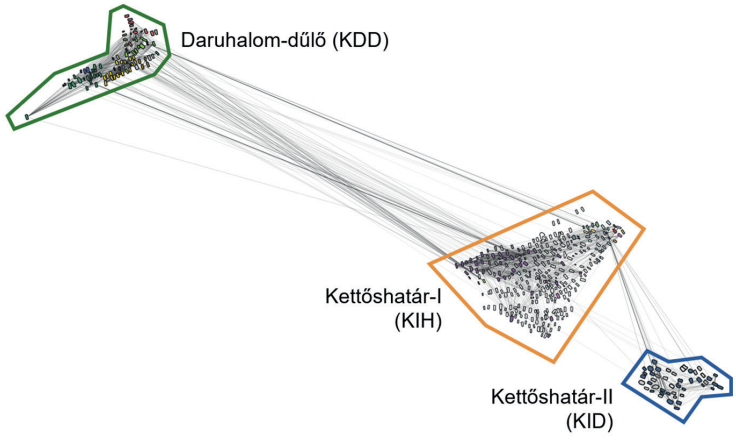
Yusuf Can Özdemir[1,2], Zsófia Rácz[3], Levente Samu[4,5], Norbert Faragó[6], Kristóf Jakab[7,8], Csaba Szalontai[9], Olga Spekker[10,11], Ágota Madai[12], Tivadar Vida[13,14], Johannes Krause[15], Balázs G. Mende[16] and Anna Szécsényi-Nagy[17]

[1] Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary, yusuf.can.ozdemir@htk.elte.hu, ORCiD: 0000-0002-3597-3713
[2] Doctoral School of Biology, Institute of Biology, ELTE Eötvös Loránd University, Budapest, Hungary
[3] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, racz.zsofia@btk.elte.hu, ORCiD: 0000-0001-5116-2235
[4] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, samu.levente@btk.elte.hu, ORCiD: 0000-0002-9967-9468
[5] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary
[6] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, farago.norbert@btk.elte.hu, ORCiD: 0000-0002-0351-1223
[7] Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary, jakab.kristof@htk.elte.hu, ORCiD: 0009-0002-4503-9614
[8] Doctoral School of Biology, Institute of Biology, ELTE Eötvös Loránd University, Budapest, Hungary
[9] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, csaba.szalontai@gmail.com
[10] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, olga.spekker@gmail.com, ORCiD: 0000-0002-0350-1906
[11] Department of Biological Anthropology, University of Szeged, Szeged, Hungary,
[12] Department of Biological Anthropology, University of Szeged, Szeged, Hungary, madaiagota97@gmail.com
[13] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, vida.tivadar@btk.elte.hu, ORCiD: 0000-0002-0588-1906
[14] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary
[15] Department of Archaeogenetics, Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany, krause@eva.mpg.de, ORCiD: 0000-0001-9144-3920
[16] Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary, mende.balazs@htk.elte.hu, ORCiD: 0000-0001-7667-8633
[17] Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary, szecsenyi-nagy.anna@htk.elte.hu, ORCiD: 0000-0003-2095-738X

Keywords: *avar, population genetics, ancient DNA, stable isotope*

Founded by an East Asian elite group coming from the steppe region, the Avar Khaganate ruled for more than two centuries in the Carpathian Basin after the mid-6th century. Here, we present 221 ancient human individuals from three Avar period burial sites (7th–8th centuries CE), located in Hungary. Two larger sites were used by lower-status communities,

while the smallest site was used by a group belonging to the „highest" strata of the Avar period. We captured genomic information of the individuals, followed by enrichment and DNA sequencing. Then, we used kinship and ancestry estimation programs to analyse the dataset. The low-status communities have predominantly European ancestries and are connected to a larger, realm-wide kinship web. Meanwhile, the elite group has East Asian genetic origins similar to other Avar elites, and is part of a separate, tightly-connected elite network. We constructed pedigrees that shed light on social patterns. The elite site is reserved only for a single pedigree descending from a founder male, and their reproductive partners, as well as other females who likely also were exogamous partners. There are no kinship links between different strata despite their close proximity (50–200 m) and their coexistence for around five generations, demonstrating a reproductive barrier between the ruling and the ruled. The low-status pedigrees on the other hand, show several interconnections with each other, while we observe some differences in their treatment of deceased exogamous individuals. Through strontium data, we show individual and community-level mobility patterns, while dietary stable isotopes indicate differences in the consumption of crops between the elites and commoners of the area. Notably, nitrogen levels do not differ between the two groups. These findings provide a framework for understanding the long-term coexistence, interaction, and reproductive separation of steppe(-derived) elites and surrounding populations in early medieval societies.



Identity-by descent links between the individuals buried in the Avar-period Kiskundorozsma burial sites

Notes

Genes, bones and isotopes in the Northern Balkans: Mostiștea–Lower Danube Corridor (c. 5300–4000 cal BCE)

Alexandra Gabriela Gheorghe[1,2], Mircea Iliescu[2,3], Ana García-Vázquez[4], Aurélien Tafani[5] and Cătălin Lazăr[6]

[1] Faculty of Biology, University of Bucharest, Bucharest, Romania
[2] ArchaeoSciences Platform (ASp), Research Institute of the University of Bucharest (ICUB), University of Bucharest, Bucharest, Romania
[3] University of Cambridge, Cambridge, UK, fmi20@cam.ac.uk, ORCiD: 0000-0002-8071-2790
[4] ArchaeoSciences Platform (ASp), Research Institute of the University of Bucharest (ICUB), University of Bucharest, Bucharest, Romania, ana.garcia-vazquez@icub.unibuc.ro, ORCiD: 0000-0002-9041-4148
[5] ArchaeoSciences Platform (ASp), Research Institute of the University of Bucharest (ICUB), University of Bucharest, Bucharest, Romania, aurelian-georges.tafani@icub.unibuc.ro, ORCiD: 0000-0003-2480-6255
[6] ArchaeoSciences Platform (ASp), Research Institute of the University of Bucharest (ICUB), University of Bucharest, Bucharest, Romania, catalin.lazar@icub.unibuc.ro, ORCiD: 0000-0001-7559-1843

Keywords: *ancient DNA, stable isotopes, strontium, Boian–Gumelnița, Lower Danube Basin, Balkans*

The Mostiștea Basin and the Lower Danube valley form a key micro-region for reassessing the biological history of later Neolithic and Eneolithic communities in southeastern Europe. This paper outlines an integrated research framework for Sultana-Malu Roșu and Sultana-Valea Orbului, Curătești, Vărăști and Gumelnița, combining existing ancient DNA, radiocarbon, stable-isotope, strontium-isotope, osteological and archaeological evidence. Rather than treating Boian and Gumelnița (KGK VI) archaeological signals as material culture (how archaeologists often do), we integrate them as direct proxies for population identity. The review paper asks how genetic background, mobility, diet, funerary practice and health intersect within a long-lived riverine landscape.

Published mtDNA data from Vărăști, Curătești, Gumelnița, Sultana-Malu Roșu and Sultana-Valea Orbului cemeteries place these communities within the Middle/Late Neolithic and Eneolithic genetic horizon of Romania, while genome-wide regional datasets indicate a major Neolithic population turnover around the Danube, followed by variable farmer-hunter-gatherer admixture [1, 2]. At Gumelnița, $\delta^{13}C$ and $\delta^{15}N$ results from humans, animals, plants, fish and freshwater molluscs reveal a mixed subsistence economy based on crops, terrestrial animal products and freshwater resources, requiring freshwater-reservoir correction of radiocarbon dates [3]. Strontium and amelogenin proteomic evidence further identifies four non-local individuals among seventeen tested persons, consistent with childhood origins south of

the Danube and suggesting that mobility intensified during the final centuries of the KGK VI sequence [4]. At Sultana, new crop-isotope and radiocarbon evidence points to flexible plant management under hydroclimatic instability before the 5.9 ka event [5].

By bringing these datasets into a single biocultural model, the proposed study frames the Mostiștea-Lower Danube population pool as a dynamic archive of ancestry, mobility, diet, resilience and vulnerability. It also defines the rationale for future osteological and palaeogenomic work on human remains from this region, including pathology and life-history reconstruction.

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Notes

New osteological data on tuberculosis in the Early Copper Age Carpathian Basin

Piroska Rácz[1], Zsuzsanna M. Virág[2] and Zsuzsanna Siklósi[3]

[1] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, racz.piroska@htk.elte.hu, ORCiD: 0009-0006-1291-3837
[2] Department of Prehistory and the Migration Period, Budapest History Museum, Aquincum Museum and Archaeological Park, Budapest, Hungary, zsuzsanna.m.virag@gmail.com
[3] MTA–ELTE Lendület "Momentum" Innovation Research Group, Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, siklosi.zsuzsanna@btk.elte.hu, ORCiD: 0000-0002-6451-5578

Keywords: *early-stage tuberculosis, atypical tuberculosis, foot tuberculosis, Early Copper Age*

Recently, alongside the classical lesions, there has been increasing attention to atypical or early-stage tuberculosis (TB) alterations in the palaeopathological practice [1, 2]. Although TB infection has been detected in human remains from many archaeological periods and geographical locations worldwide, no TB cases had been reported from the Copper Age of the Carpathian Basin until 2023. The absence of evidence of TB infection in the Copper Age was hypothesised to be due to a more mobile lifestyle and lower population density during this period than in the preceding Neolithic [3]. The first case was reported from the Sármellék-Száraz eleje site (Late Copper Age, Baden culture) [4]. Newly analysed Early Copper Age grave groups from the Budapest-Rákoscsaba-Major-hegy site [5] also yielded three probable TB cases, based on visual inspection. TB-related symptoms occurred in two cases together with hypervascularisation, bone remodelling and lytic lesions in tarsal bones. In both cases, joint surfaces were intact or revealed minimal erosion. In the paleopathological literature joint involvement is emphasised in connection with TB of the foot and ankle region. However, joint involvement indicates a more advanced stage of the disease, as in most cases the process begins with an osseous focus [6]. New data reveal that TB may have been much more widespread in the Copper Age Carpathian Basin than was previously assumed. The absence of osteological evidence of TB-infection in the past reflects that the formerly examined materials were not representative enough and/or subtle or atypical bony alterations were earlier not associated with TB or escaped attention. The results also highlight possible early-stage osteological symptoms of TB in the foot region.

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Hypervascularisation, bone remodelling and lytic lesions in tarsal bones.
Budapest-Rákoscsaba-Major-hegy site, Grave 158 (35–39-year-old female (Photo by Piroska Rácz)

Notes

Beyond grave goods: New perspectives on a Late Bronze Age cemetery at Mány-Méhes-dűlő East

Polett Kósa[1], Csilla Líbor[2], Nóra Szabó[3], Kristóf Fülöp[4], Anett Gémes[5], László Gucsi[6], Kristóf Jakab[7], István Major[8], Anna Szécsényi-Nagy[9] and Viktória Kiss[10]

[1] Department of Archaeology, Hungarian National Museum, Budapest, Hungary, kosa.polett@hnm.hu, ORCiD: 0000-0001-7245-6734
[2] Department of Archaeology, Hungarian National Museum, Budapest, Hungary, libor.csilla@hnm.hu, ORCiD: 0009-0001-2700-2917
[3] MTA–ELTE HTK Lendület "Momentum" BASES Research Group, Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, szabo.nora@htk.elte.hu, ORCiD: 0000-0002-4981-6567
[4] MTA–ELTE HTK Lendület "Momentum" BASES Research Group, Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, fulop.kristof@htk.elte.hu, ORCiD: 0009-0005-9763-672X
[5] Department of Biological Anthropology, ELTE Eötvös Loránd University, Budapest, Hungary, gemesanett@gmail.com, ORCiD: 0000-0002-5107-8364
[6] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, gucsi.laszlo@htk.elte.hu, ORCiD: 0000-0003-0964-6900
[7] Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary, jakab.kristof@htk.elte.hu, ORCiD: 0009-0002-4503-9614
[8] Radiocarbon Competence Centre, HUN-REN Institute for Nuclear Research, Debrecen, Hungary, imajor@atomki.hu, ORCiD: 0000-0003-4675-9875
[9] Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary, szecsenyi-nagy.anna@htk.elte.hu, ORCiD: 0000-0003-2095-738X
[10] MTA–ELTE HTK Lendület "Momentum" BASES Research Group, Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, kiss.viktoria@htk.elte.hu, ORCiD: 0000-0002-6577-9081

Keywords: *Late Bronze Age, Tumulus culture, Carpathian Basin, archaeogenetic research*

In 2021, preventive excavations preceding the construction of the M100 motorway in Fejér County, Hungary, uncovered a small Late Bronze Age burial ground. Despite the limited number of graves, the cemetery provides valuable insights into the social and biological composition of local communities during the Tumulus culture period.

Among the burials, a richly furnished grave of a young woman stands out due to the exceptional quantity and quality of its grave goods, including bronze ornaments and gold hair rings.

Alongside typological, anthropological and radiocarbon analyses, selected human remains from the cemetery have recently been sampled for archaeogenetic investigation. The integration of archaeological and bioarchaeological approaches offers new opportunities to explore questions of biological relatedness, mobility and population connections within the

community. The results of these analyses are expected to further refine our understanding of the individuals buried at the site and their broader cultural context.

The rich female burial discovered at Mány raises important questions regarding social status, identity and the mechanisms through which prestige was expressed during the Late Bronze Age. By placing the cemetery within a wider regional framework and combining artefactual, chronological, anthropological and emerging genetic evidence, this study aims to contribute to ongoing discussions concerning interregional contacts and the role of socially prominent individuals in Bronze Age communities. Despite the limited number of graves, the cemetery provides a valuable case study demonstrating the interpretative potential of small burial assemblages.



The richly furnished female burial from Grave 83 at Mány-Méhes-dűlő East (photo: Balázs Némethi)

Notes

Archaeogenetic characterisation of Migration Period communities in Transylvania

Noémi Borbély[1], Alpár Dobos[2], Szilárd Sándor Gál[3], Zsófia Rácz[4], Gergely Szenthe[5], Erwin Gáll[6], Szabolcs Nagy[7], Melinda Megyes[8], Botond Heltai[9], Kristóf Jakab[10], Balázs Gusztáv Mende[11], Tivadar Vida[12] and Anna Szécsényi-Nagy[13]

[1] Institute of Archaeogenomics, ELTE Research Centre for the Humanities / Doctoral School of Biology, Institute of Biology, ELTE Eötvös Loránd University, Budapest, Hungary, borbely.noemi@abtk.hu, ORCiD: 0000-0002-1488-5298
[2] National Museum of Transylvanian History, Cluj-Napoca, Romania, alpardobos@yahoo.com, ORCiD: 0009-0005-2180-0255
[3] Mureș County Museum; Târgu Mureș, Romania, szilardsandor.gal@gmail.com, ORCiD: 0000-0002-2274-0216
[4] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, zsofia_racz@yahoo.de, ORCiD: 0000-0001-5116-2235
[5] Hungarian National Museum, Budapest, Hungary, szenthe.gergely@mnm.hu, ORCiD: 0000-0002-8481-2203
[6] Vasile Pârvan Archaeological Institute of Bucharest, Romanian Academy, Bucharest, Romania, erwin.gall@iavb.ro, ORCiD: 0000-0002-5923-3461
[7] National Museum of Transylvanian History, Cluj-Napoca, Romania, kollek2001@yahoo.com
[8] Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary, megyes.melinda@abtk.hu, ORCiD: 0000-0002-7178-5883
[9] Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary, heltai.botond@abtk.hu, ORCiD: 0009-0006-8843-0428
[10] Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary, jakab.kristof@abtk.hu, ORCiD: 0009-0002-4503-9614
[11] Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary, mende.balazs@abtk.hu, ORCiD: 0000-0001-7667-8633
[12] Institute of Archaeological Sciences, ELTE Eötvös Loránd University / Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary; vida.tivadar@abtk.hu, ORCiD: 0000-0002-0588-1906
[13] Institute of Archaeogenomics, ELTE Research Centre for the Humanities, Budapest, Hungary, szecsenyi-nagy.anna@abtk.hu, ORCiD: 0000-0003-2095-738X

Keywords: *archaeogenetics, biomolecular archaeology, Migration Period, Carpathian Basin, next-generation sequencing*

The application of advanced biomolecular methods to Migration Period populations in the Carpathian Basin has recently provided novel perspectives on the region's dynamic history. As part of the ERC HistoGenes project, which investigates the population history of Eastern Central Europe through the multidisciplinary integration of genomics, archaeology, history, and anthropology, this study focuses on the genomic landscape of early medieval Transylvania. We analysed high-throughput whole-genome sequencing data utilising a 1240k SNP cap-

ture panel (average coverage of 498,000 SNPs/sample) from 116 individuals dating from the 4th to the 8th centuries AD. The samples originate from seven distinct Transylvanian sites, including Gepid and Avar period cemeteries, as well as burials associated with the Chernyakhov-Sântana de Mureș culture. Sites of prominent interest include Florești (n=75) – featuring a Germanic elite female burial with rich gold grave goods and instances of artificial cranial deformation – and Turda (n=1), representing a high-status Gepid female burial.

PCA and fastNGSadmix analyses reveal that while a Central European genetic component dominates, Northern European, Southern European, Near Eastern, and minor East Asian elements are also present, displaying high intra-site heterogeneity. Furthermore, archaeogenetic kinship analyses revealed complex local social structures, identifying 22 first-degree and 26 second-degree relationships connecting 39 individuals, forming pedigrees within Florești.

Our findings demonstrate that Early Medieval Transylvania represents a genetic crossroads, characterised by highly interconnected yet diverse communities. While this comprehensive genomic dataset provides a robust baseline for regional comparisons, the upcoming integration of further archaeometric analyses – including radiocarbon dating, stable isotope analyses, and fine-scale IBD-sharing analyses – will further refine our understanding of mobility, kinship structures, and demographic processes in the Carpathian Basin.



Geographic location and chronological distribution of the analysed Migration Period Transylvanian sites (n=116). Numbers in parentheses following site names indicate the number of sampled individuals per site. The red bounding box in the inset map marks the study area within the European continent.

Notes

Session 8

MORE THAN MEAT

Multidisciplinary approaches to zooarchaeology



Moments in Budapest
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Stratigraphical and spatio-temporal analysis of the animal bone finds of the Late Neolithic tell-like settlement of Öcsöd-Kováshalom, Hungary

Péter Csippán[1,2]

[1] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, csippan.peter@btk.elte.hu, ORCiD: 0000-0001-6237-9077
[2] Department of Archaeology, Hungarian National Museum, Budapest, Hungary, csippan.peter@hnm.hu

Keywords: *Late Neolithic, tell-like settlement, archaeozoology, spatio-temporal analysis, utility analysis*

More than 20,000 animal bone fragments were uncovered at the Late Neolithic tell-like settlement of Öcsöd-Kováshalom, Hungary, which is one of the most important settlements of the Late Neolithic Tisza Culture on the Great Hungarian Plain. The site was excavated by Pál Raczky between 1980 and 1985.

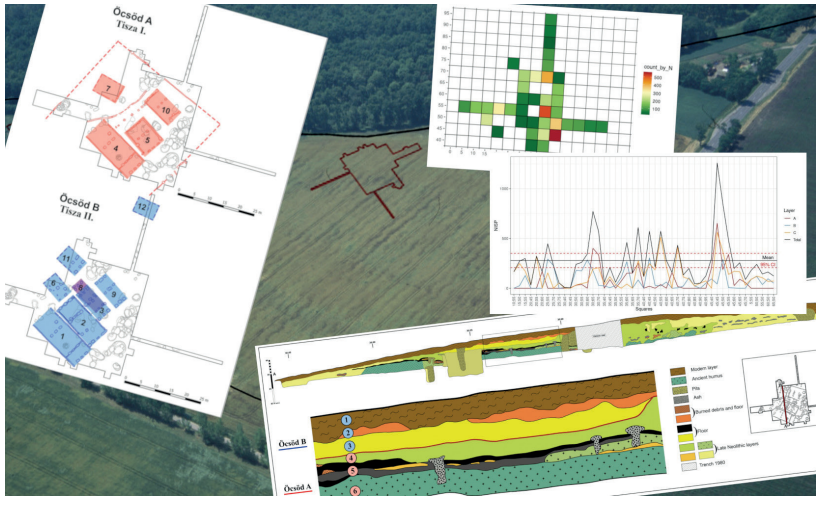
In the last few decades, a lot of important papers have been published about the role of the settlement and the spatial distribution of social activities [1–4]. Based on previous analyses of this huge amount of bone material by Sándor Bökönyi, Erika Gál, and Zsófia Eszter Kovács [5], a lot of new information was obtained about meat consumption practices and the everyday life of the Neolithic inhabitants.

To gain a deeper understanding of these everyday activities, the author re-analyzed the bone assemblage from both qualitative and quantitative perspectives, including statistical correlations, the energetics of consumption, and the spatial and temporal distribution of the bone finds.

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The complexity of the Öcsöd-Kováshalom site

Notes

A multi-method dental approach to herd management and paleodietary reconstruction in Copper Age cattle from Hungary

Linoy Namdar[1] and Zsuzsana Siklósi[2]

[1] MTA–ELTE Lendület "Momentum" Innovation Research Group, Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, namdar.linoy@btk.elte.hu, ORCiD: 0000-0001-6522-7503
[2] MTA–ELTE Lendület "Momentum" Innovation Research Group, Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, siklosi.zsuzsanna@btk.elte.hu, ORCiD: 0000-0002-6451-5578

Keywords: *microwear, mesowear, Copper Age, animal diet, zooarchaeology*

Reconstructing the diet and management of ancient cattle provides important insights into early husbandry practices and the organisation of agrarian economies. This study presents a multi-disciplinary investigation of cattle diet and herd management across multiple Early and Middle Copper Age (4500–3650 cal BCE) sites in the Carpathian Basin [1–5]. By integrating dental mesowear, dental microwear, and geometric morphometrics, we aim to reconstruct cattle's dietary practices during their lives and in the period preceding death.

Two classic Mesowear score analyses were compared and applied, to assess long-term dietary signals preserved in the occlusal relief of maxillary and mandibular tooth cusps [6–8]. 2D geometric morphometrics was applied to quantify the second maxillary molar cusp shape, to improve dietary classification accuracy from 56% using traditional mesowear scoring to 67–76%, by capturing aspects of cusp shape [8]. Dental microwear analysis provided short-term dietary information by capturing fine surface textures on the maxillary enamel facets, indicative of the last few weeks before death [9–10].

By applying this integrated methodological framework to assemblages from multiple Copper Age sites, this study investigates whether shared cattle management strategies, including grazing regimes and seasonal herding practices, were operating at a regional scale. The results contribute to a broader understanding of how Copper Age communities organised animal husbandry, and whether common economic and cultural networks shaped livestock management across the region during this period.

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Notes

What went down the well: Animal husbandry and ritual consumption at Emporion Pistiros

Stella Nikolova[1], Suzanne Pilaar-Birch[2], Emil Nankov[3] and Eli Filipova[4]

[1] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, stella.nikolova97@gmail.com, ORCiD: 0009-0008-9032-7248
[2] University of Georgia, Geography-Geology 103, Athens, Georgia, USA, sepbirch@uga.edu, ORCiD: 0000-0003-1544-5881
[3] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, ORCiD: 0000-0002-1970-0125
[4] Institute for Balkan Studies and Centre for Thracology, Bulgarian Academy of Sciences, Sofia, Bulgaria, eli.filipova@balkanstudies.bg, ORCiD: 0009-0006-9414-8568

Keywords: *animal husbandry, Classical Greece, stable isotope analysis, zooarchaeology, ancient diet*

This study investigates animal husbandry practices at the trade settlement of Emporion Pistiros (near the town of present day Vetren, Bulgaria). The site was founded by Greek merchants in the late 5th century BC within the territory of the Odrysian Kingdom of Thrace [1]. Ongoing annual excavations have uncovered an exceptionally large faunal assemblage (over 50,000 bones), dating from the late 5th to the early 3rd century BC. Domestic livestock form approximately 92% of all remains, indicating extensive husbandry.

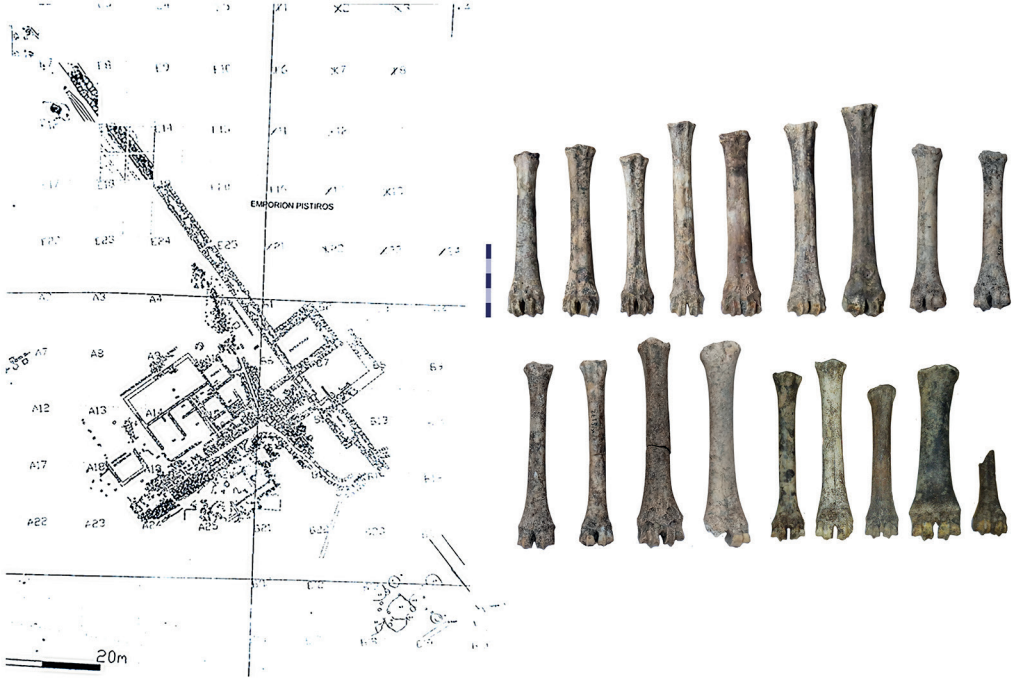
Animal diet was assessed through stable isotope analysis ($\delta^{13}C$ and $\delta^{15}N$), conducted on 54 samples from domestic mammals carried out at the University of Georgia, US. The bulk of the samples were taken from the fill of a well excavated in 2010 and 2011. This deposit contained 1,315 animal remains, with a high predominance of complete cattle *metapodia*. Its formation has been interpreted as the result of a single event (large celebration / ritual feast) [2–3], and that is why it was chosen as a case study.

The isotope results reveal a highly differentiated dietary pattern between all species. The highest difference is observed within the diet of cattle, forming two distinct groups: one consuming C_4 plants, likely millet used as fodder, and another characterized by a predominantly C_3-based diet. Within the well, we find larger cattle, which are fed on C_4 and a single small individual with a C_3 diet. In this deposit, sheep and goat also exhibit correlation between their morphometric size and isotopic composition, forming distinct groups.

These findings provide new insights into animal husbandry practices during the Classical period, as similar studies are still rarely conducted, e.g. Argilos [4]. They also open a debate on why differently kept animals are discovered together within a ritual deposit and address the possibility that they reflect populations of animals kept by different groups of people. This demonstrates the use of animal diet as a proxy in the study of past culture, religion, and identity.

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Plan of the excavated area of Emporion Pistiros, after V. Colarova (left), sheep and goat metapodia from the site chosen for stable isotope analysis (right)

Notes

Animal bone remains from the Csókakő Castle: Cultural and environmental imprints

Erika Gál[1] and Gyöngyi Kovács[2]

[1] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, gal.erika@htk.elte.hu, ORCiD: 0000-0002-4226-3218
[2] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, kovacs.gyongyi@htk.elte.hu, ORCiD 0000-0002-4694-8011

Keywords: *animal bone remains and objects, Csókakő Castle, Hungary, medieval aristocratic residence, Turkish border fortress*

Our lecture presents the results and highlights of the medieval (13th–15th century) and Ottoman Period (mid-16th–17th century) archaeozoological assemblages from the recently excavated Csókakő Castle (Lower Castle/Alsóvár) [1]. The identification of animal bones has not been restricted to the analysis of butchery and food remains, which usually form the main part of animal bone materials. Palaeopathological examinations and the documentation of bone, antler, and ivory tools have also been carried out during the National Research, Development and Innovation Office (NKFIH) Project K-143099 'Castles, settlement network, material culture, 1300–1700 – Complex microregional historical, landscape historical and archaeological research in Transdanubia' (2022–2026) [2].

As main results, we highlight the shift in the exploitation of pigs and caprines, the second most frequently consumed animals after cattle, following the conversion of a medieval aristocratic residence into a Turkish border fortress in the 1540s. The presence of a few simple bone objects such as handles and gaming pieces suggests that some skilled persons likely practised bone manufacturing in the Castle of Csókakő during the Ottoman Period. However, more sophisticated artefacts carved from the hard tissues of animals, such as a bone belt stiffener, knives, and a decorative bone inlay from a gun, arrived at the castle with their owners. The top products found in the fortification are the bone rosette and a double-sided ivory comb, which represent rare finds outside the Buda Castle area in Hungary.

Not only cultural impacts, but the environmental conditions are also reflected in the animal bone assemblages of this site, located in a forested area in the Vértes Hills. Both the medieval and post-medieval layers yielded one of the highest frequencies of wild mammalian and avian remains concerning the medieval noble residences and Turkish fortifications in Hungary, respectively. The rate of game remains, in addition to the notable frequency of pig remains, seems to support the written evidence regarding the presence of a few Christian soldiers, as hunting involves the killing of animals without ritually bleeding the carcass. However, Hungarian peasants assigned to castle construction may also have contributed to the consumption of pork.

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https://doi.org/10.55023/issn.1786-271X.2026-013



Bone rosette found in the Ottoman Period assemblage of Csókakő Castle (site Lower Castle/Alsóvár)

Notes

Bone applications of fishing nets

Kata Szathmári[1,2]

[1] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, szathmari.kata@htk.elte.hu, ORCiD: 0009-0005-3714-3229
[2] Doctoral School of History, Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, bo1z6s@student.elte.hu

Keywords: *seine nets, fishing, fish bones, Middle Ages*

Seine nets are composed of a variety of materials that come together to form a single tool. Unfortunately, most of these materials are highly perishable, making them difficult to study from an archaeological perspective. The durable components of seine nets are primarily the weights, which can be made of stone, ceramic, or even bone. However, another component of seine nets, the so-called “cibék” (which is usually carved from wood and is a toggle used on the hauling harness of a seine net), can also be made of fish-bone. This type of object is known from ethnographic literature and analogies [1]. The main question of the research to be presented is whether objects of identical form appearing in medieval archaeological finds could have been used in the manner known from ethnography. To determine this, use-wear analyses were conducted on objects from Hungarian medieval contexts and known ethnographic analogies. The function of these objects was previously unknown; the analyses aims to determine this by presenting a possible way of use.

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“Tanyavetés”, the use of seine net in Komárom (Herman 1887, 449, Table III)

Notes

Session 9

FOOD FOR THOUGHT

Tracing ancient consumption through organic residues



Moments in Budapest
© Attila Mitcsenkov

Finds of flax/linseed at prehistoric sites in Serbia and Romania and the issue of flax seed size

Dragana Filipović[1,2], Djurdja Obradović[3] and Mihaela Golea[4]

[1] Interdisciplinary Centre for Archaeology and the Evolution of Human Behaviour, University of Algarve, Faro, Portugal, dfilipovic@ualg.pt, ORCiD 0000-0003-4389-2945
[2] ArchaeoSciences Platform, Research Institute of the University of Bucharest, Bucharest, Romania
[3] Institute of Archaeology, Belgrade, Serbia, djurdja.obradovic@gmail.com, ORCiD: 0000-0002-5528-2688
[4] "Vasile Pârvan" Institute of Archaeology, the Romanian Academy, Bucharest, Romania, mihaelas.golea@yahoo.com, ORCID: 0009-0008-4264-9779

Keywords: *prehistory, SE Europe, flax, morphometrics*

Flax (*Linum usitatissimum*) is one of the oldest crops in Europe, including in the Balkans. Many of the prehistoric sites in Serbia and Romania contain remains of flax/linseed, mainly in the form of charred seeds. There is also clear evidence of textile production in these regions: fragments of linen textile and rope were discovered at one of the Neolithic sites; impressions of linen fabric were documented on a number of ceramic vessels; finds of loom weights and spindle whorls are frequent. Was flax here cultivated in prehistory only for fibre or also for oil? In the Alpine region, the size of waterlogged flax seeds from prehistoric lakeshore and wetland settlements has been used to distinguish between the flax variety cultivated for the extraction of oil and that cultivated for the extraction of fibres. Based on the abundance of "small" and "large" seeds, and the occurrence of textile-making tools, scholars have identified periods of greater importance of one or the other variety of flax in the 4th and 3rd millennium BCE in this region. Although charred seeds are not quite suitable for this approach, because their 'original' morphology changed due to the exposure to heat (e.g. reduction of the width has been observed in a study of the Alpine sites), we took measurements of well-preserved charred seeds from several sites that yielded solid quantities. We examine the patterns in seed sizes in relation to the archaeological context, chronology and potential growing conditions of flax. We observe different seed sizes within sites and periods, perhaps a reflection of varied charring conditions but possibly also of different flax variants – for oil and for fibre, where for the latter we cannot exclude the use of wild flax.



Charred flax seeds from Svinjarička Čuka, Serbia

Notes

Combining morphometry and organic residue analyses to understand Copper Age pottery use in the Carpathian Basin

Rebeka Solti[1], Isabel Wiltshire[2], Izzy Davis[3], Lilly Olet[4], Melanie Roffet-Salque[5], Lucy Cramp[6] and Zsuzsanna Siklósi[7]

[1] MTA–ELTE Lendület "Momentum" Innovation Research Group, Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, ementesch@student.elte.hu
[2] School of Chemistry, University of Bristol, Bristol, United Kingdom, isabel.wiltshire@bristol.ac.uk, ORCiD: 0009-0002-1681-9769
[3] School of Chemistry, University of Bristol, Bristol, United Kingdom, xa21927@bristol.ac.uk, ORCiD: 0000-0003-0754-1275
[4] School of Chemistry, University of Bristol, Bristol, United Kingdom, lilly.olet@gmail.com, ORCiD: 0000-0002-2887-0775
[5] School of Chemistry, University of Bristol, Bristol, United Kingdom, Melanie.Salque@bristol.ac.uk, ORCiD: 0000-0001-9508-788X
[6] Department of Anthropology and Archaeology, University of Bristol, Bristol, United Kingdom, Lucy.Cramp@bristol.ac.uk, ORCiD: 0000-0003-2012-2753
[7] MTA–ELTE Lendület "Momentum" Innovation Research Group, Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, siklosi.zsuzsanna@btk.elte.hu, ORCiD: 0000-0002-6451-5578

Keywords: *Copper Age, Carpathian Basin, pottery, organic residue analysis, morphometry*

This study presents the results of combined morphometric and organic residue analyses of Early and Middle Copper Age (4500–3650 BCE) pottery assemblages from the area of present-day Hungary, including 13 settlements, as well as burial contexts including 2 formal cemeteries, multiple grave groups and lone settlement burials. Morphometric analysis assesses frequencies of individual and communal vessels for preparation and consumption, as well as the size and frequency of storage vessels. This can lead to insights about food preparation and dining practices, including processing methods, the size of served groups and storage capacity [1]. Organic residue analysis identifies the presence of various adipose and dairy fats on selected potsherds. This can provide direct evidence of the significance of animal-derived products in diet and confirm the increase in dairy consumption. By correlating these results with regional and temporal variables, patterns of change in foodways of local communities can be determined.

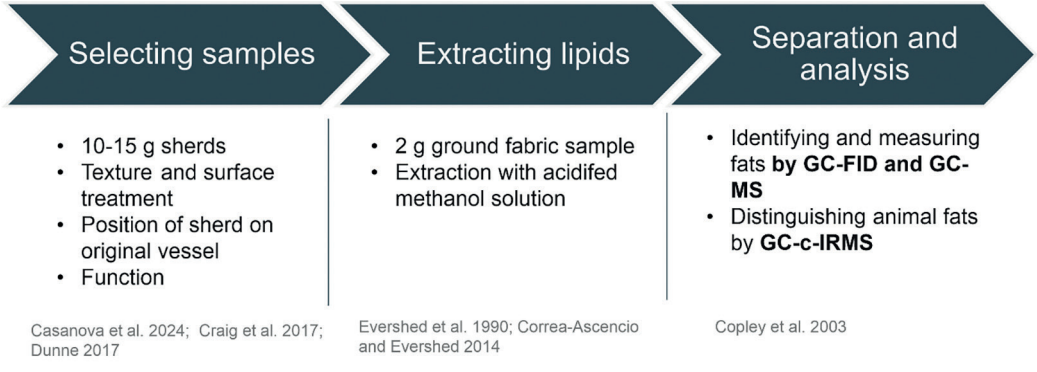
Results of morphometry-based functional analysis indicated the overall importance of communality in both food preparation and consumption, the frequency of small drinking vessels suggested the emergence of individual drinking culture toward the end of the Middle Copper Age. Grave goods did not mirror everyday pottery use, as individual vessels and small storage vessels were greatly overrepresented in burials, suggesting intentional selection from a

range of domestic vessels [2]. Results from organic residue analysis did not show a clear correlation between vessel form and the content type. However, it was confirmed that pottery was frequently used for processing animal carcass products throughout the period under investigation, while dairy processing became common only at the end of the Middle Copper Age.

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Overview of the methodology used for organic residue analysis

Notes

Molecular traces of Copper Age life: Lipid analysis of Lasinja culture pottery from Poljana Križevačka 2, Croatia

Mateja Hulina[1], Andrijana Meščić Macan[2] and Lana Pađen[3]

[1] Institute of Archaeology, Zagreb, Croatia, mhulina@iarh.hr, ORCiD: 0009-0007-6026-6707
[2] Institute for Anthropological Research, Zagreb, Croatia, andrijana.mescic.macan@inantro.hr, ORCiD: 0000-0002-0537-0292
[3] Department of Physiology and Radiobiology, Faculty of Veterinary Medicine, University of Zagreb, Zagreb, Croatia, lpaden@vef.unizg.hr, ORCiD: 0000-0003-2841-7433

Keywords: *pottery, organic residue analysis, Copper Age, Lasinja culture, diet*

Poljana Križevačka 2 is a Copper Age settlement located in northern Croatia belonging to the Middle Copper Age Lasinja culture (late 5th millennium BC/beginning of 4th millennium). Excavations revealed several large dugout type structures, alongside smaller pits and postholes that may represent the remains of above-ground buildings or houses. The larger dugout type structures were most likely used as dwellings and/or working areas. They are often grouped together and with smaller pits, potentially reflecting kinship-based or familial organization within the settlement.

A lot of pottery sherds were recovered, together with lithic and polished stone artefacts. However, the absence of preserved faunal remains has limited attempts to reconstruct subsistence strategies and dietary practices of the settlement's inhabitants.

This paper presents preliminary results of the organic residue analysis conducted on ceramic vessels, including bowls, jars, jugs, and spoons, recovered from the larger dugout structures at Poljana Križevačka 2. Lipids were extracted following established protocols [1], and analysed using gas chromatography (GC-FID) and gas chromatography–mass spectrometry (GC-MS) on an Agilent 7250 GC/QTOF high-resolution mass spectrometer. The aim of the study is to provide a clearer understanding of subsistence strategies, dietary practices, and potential vessel use at the settlement.

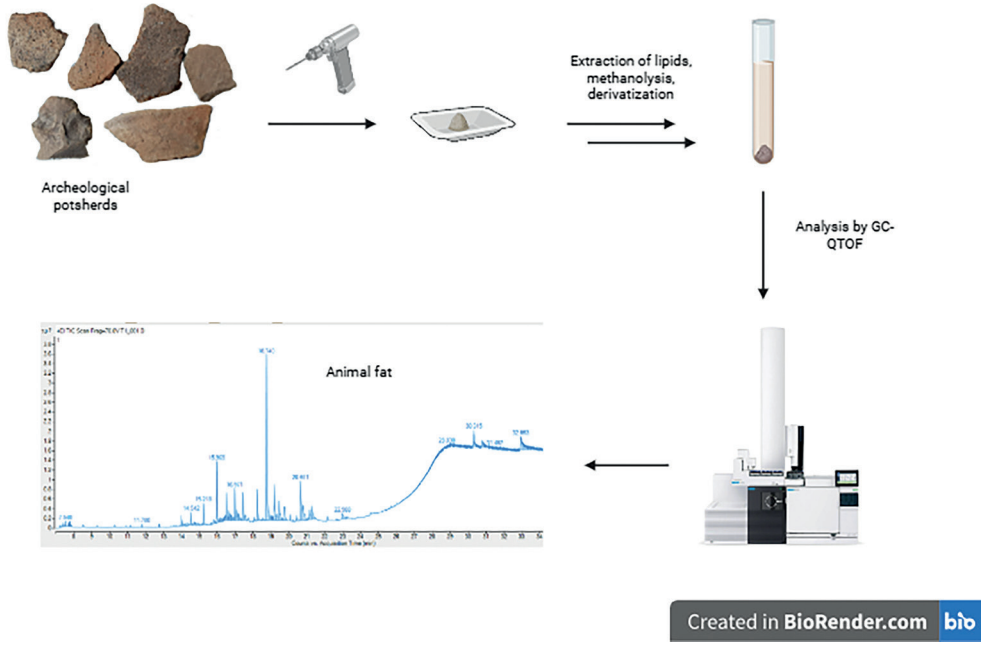
Preliminary analyses indicate the presence of residues consistent with animal fats, but further analyses (compound specific ^{13}C isotope analysis – GC-C-IRMS) will be necessary for closer interpretation.

Organic residue studies of Lasinja culture pottery from Croatia remain very limited, with only a single published study to date [2]. Therefore, this research represents an important contribution to the growing understanding of foodways, and pottery use within the Lasinja cultural horizon in Croatia and beyond.

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Organic residue analysis workflow

Notes

Lunch at the lake: Organic residue analysis from the pile-dwelling site of Stare gmajne (late 4th millennium BC, Ljubljansko barje, Slovenia)

Ines Nabernik Bošnjak[1], Elena Leghissa[2], Oliver Edward Craig[3], Alexandre Lucquin[4] and Lara González Carretero[5]

[1] BioArCh, University of York,
York, United Kingdom, ines.nabernik@york.ac.uk, ORCiD: 0009-0007-1023-1848
[2] ZRC SAZU, Institute of Archaeology,
Ljubljana, Slovenia, elena.leghissa@zrc-sazu.si, ORCiD: 0009-0001-8078-5914
[3] BioArCh, University of York,
York, United Kingdom, oliver.craig@york.ac.uk, ORCiD: 0000-0002-4296-8402
[4] BioArCh, University of York,
York, United Kingdom, alexandre.lucquin@york.ac.uk, ORCiD: 0000-0003-4892-6323
[5] BioArCh, University of York,
York, United Kingdom, lara.gonzalezcarretero@york.ac.uk, ORCiD: 0000-0001-8013-5252

Keywords: *Ljubljansko barje, Copper Age, pile-dwelling settlement, organic residue analysis, prehistoric diet*

During the late 4th millennium BC, the Stare gmajne site functioned as a well-established metallurgical and agrarian settlement within a broader regional and cultural context [1]. This study, part of ongoing doctoral research, employs a comprehensive multi-proxy analytical approach to selected potsherds containing absorbed organic residues and adhering food-crusts. To reconstruct vessel use and culinary practices among the Copper Age lakeshore community, high-resolution digital microscopy, scanning electron microscopy (SEM), lipid residue analysis, and bulk stable isotope analysis were utilised. The results indicate that vessels were primarily used to process freshwater and vegetal resources, particularly cultivated cereals and wild, starch-rich underground storage organs. Although domestic animals capable of providing dairy products were already integrated into the broader economic system, only one vessel exhibited possible evidence of dairy processing, whilst ruminant adipose fats were identified in a small number of vessels. This first extensive study of food remains from a southeastern Alpine lakeshore settlement underscores the importance of integrating interdisciplinary analytical approaches to reconstruct a more in-depth understanding of distinct ancient foodways.

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Food remains on a potsherd (Stare gmajne, c. 34th BC)

Notes

Microstructural analysis of carbonized porridge from a Dacian settlement in north-western Romania

Beatrice Ciuta[1]

[1] "1 Decembrie 1918" University from Alba Iulia,
Alba Iulia, Romania, beatrice.ciuta@uab.ro, ORCiD: 0000-0003-1241-6399

Keywords: *Dacian period, carbonized porridge, microstructure, food residues, cereal consumption*

This paper aims to investigate carbonized cereal-based food remains through microstructural analysis in order to reconstruct food preparation practices in a Dacian settlement from north-western Romania. The analysed material was recovered from the site of Șimleu Silvaniei-Cetate (Sălaj County) and derives from two distinct archaeological contexts: a metallurgical workshop and dwelling L1 located on Terrace T1.

The investigated fragments consist of compact charred aggregates composed of tightly agglutinated cereal components. Microscopic examination revealed a dense and homogeneous internal matrix lacking pores, vesicles, or differentiated crust structures commonly associated with baked products. Instead, the observed microstructural characteristics indicate a preparation obtained through boiling, supporting the interpretation of the fragments as carbonized porridge or gruel-like remains.

Although the plant material is poorly preserved and does not allow precise taxonomic identification, the visible inclusions suggest the use of small-grained cereals. The occurrence of similar remains in two separate contexts may indicate that boiled cereal preparations formed part of everyday dietary practices within the settlement.

The study contributes to current research on archaeological food residues by demonstrating the interpretative potential of charred amorphous food remains from Dacian contexts. The results provide direct evidence for cereal processing, cooking techniques, and food consumption practices in Late Iron Age communities from the north-western Carpathian Basin.

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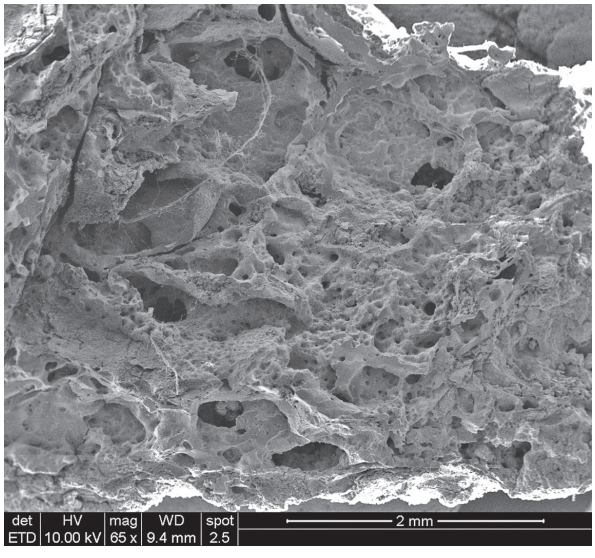
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Interior view of a charred porridge fragment from Șimleu Silvaniei-Cetate, Romania

Notes

Pottery forms, function and content: Complex interpretation of the Late Copper Age potteries based on organic residue analysis by Py-GC/MS

Zsuzsanna Czégény[1], Gergő Szabó[2], István Sándor Czirok[3], Tibor Marton[4], Péter Csippán[5,6] and Szilvia Fábián[7]

[1] Institute of Materials and Environmental Sciences, HUN-REN Research Centre for Natural Sciences, Budapest, Hungary, czegeny.zsuzsanna@ttk.hu, ORCiD: 0000-0001-9636-9547
[2] Institute of Materials and Environmental Sciences, HUN-REN Research Centre for Natural Sciences, Budapest, Hungary, szabo.gergo@ttk.hu, ORCiD: 0009-0006-7755-2729
[3] Institute of Materials and Environmental Sciences, HUN-REN Research Centre for Natural Sciences, Budapest, Hungary, czirok.istvan.sandor@ttk.hu, ORCiD: 0000-0002-8960-0605
[4] Institute of Archaeology ELTE Research Centre for the Humanities, Budapest, Hungary, marton.tibor@abtk.hu, ORCiD: 0000-0002-3770-2001
[5] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, csippan.peter@btk.elte.hu, ORCiD: 0000-0001-6237-9077
[6] Department of Archaeology, Hungarian National Museum, Budapest, Hungary, csippan.peter@hnm.hu
[7] Division of International Relations, Hungarian National Museum, Budapest, Hungary, fabian.szilvia@hnm.hu, ORCiD; 0009-0005-6728-8824

Keywords: *organic residue analysis, Py(THM)-GC/MS, vessel function, consumption practises, Late Copper Age*

Organic residues preserved in porous ceramics carry information about human activities at the site through time. Conventional analytical approaches typically use solvent extraction, derivatisation, and subsequent GC/MS analysis. In contrast, Py(THM)-GC/MS offers a solvent-free, powerful tool for the direct screening of traces of organic compounds adsorbed on solid surfaces, requiring only a few mg of sample and no prior sample preparation. Thermally assisted hydrolysis and methylation (THM) enables the analysis of high molecular weight and low volatility compounds, including long fatty acids and polyphenols, which are the main organic residue components of most of the archaeological samples. Lipid molecules are the most well-preserved and widespread components, especially in pottery. Although degradation processes may alter their distribution over time, fatty acid residues of different chain lengths are degraded roughly at the same rates, preserving characteristic abundance ratios that can be used to determine the general category of the lipid origin. Furthermore, biomarker molecules can provide evidence for certain substances.

One aim of the research project was to delineate vessel function and use-contexts, and — through their spatial distribution — to infer the locations of specific activities by integrating archaeological and interdisciplinary approaches. The functional analysis of the ceramic assemblage was further strengthened by identifying organic residues cooked, consumed, or

stored within the vessels, providing key evidence for addressing these questions.Organic residue analysis of 52 ceramic samples from the Late Copper Age Protoboleráz and Baden periods was performed using the Py(THM)-GC/MS method. The extensive and heterogeneous dataset, integrated with the morphological attributes of the ceramic vessels, was subjected to multivariate statistical analysis employing principal component analysis (PCA) and factor analysis of mixed data (FAMD). Although the analyses conducted do not allow for complete food reconstructions, they do reveal patterns regarding the relationship between organic materials and vessel types, as well as their use, for both periods.



Montage by Zoltán Henrik Tóth, National Institute of Archaeology, Hungarian National Museum

Notes

Session 10

MAPPING THE INVISIBLE

Geophysical and remote sensing applications



Moments in Budapest
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In search of the past: Integrated remote sensing and geophysical approaches in archaeological research on the Ludogorsko Plateau, Northeastern Bulgaria

Denitsa Sandeva-Minkova[1], Hristo Popov[2], Tanya Hristova[3], Plamen Georgiev[4], Zheni Vasileva[5], Petar Minkov[6], Yana Dimitrova[7], Nikola Tonkov[8] and Anton Atanasov[9]

[1] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, denitsa.sandeva@abv.bg, ORCiD: 0009-0007-1520-5825
[2] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, director@naim.bg, ORCiD: 0000-0002-1727-6666
[3] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, thristova1975@gmail.com, ORCiD: 0009-0008-5481-3097
[4] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, plamen_georgiev@naim.bg, ORCiD: 0000-0002-1337-4226
[5] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, vassileva.jeni@gmail.com, ORCiD: 0000-0003-1028-2462
[6] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, petraki_orlovski@abv.bg, ORCiD: 0000-0003-2708-6548
[7] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, yanadimitr@yahoo.com, ORCiD: 0000-0003-1411-9937
[8] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, tonkov_n@hotmail.com, ORCiD: 0000-0002-5045-070X
[9] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, anton.atanasov@naim.bg, ORCiD: 0009-0001-8936-3566

Keywords: *non-invasive investigations, field surveys, geophysical surveys, remote sensing, satellite imagery*

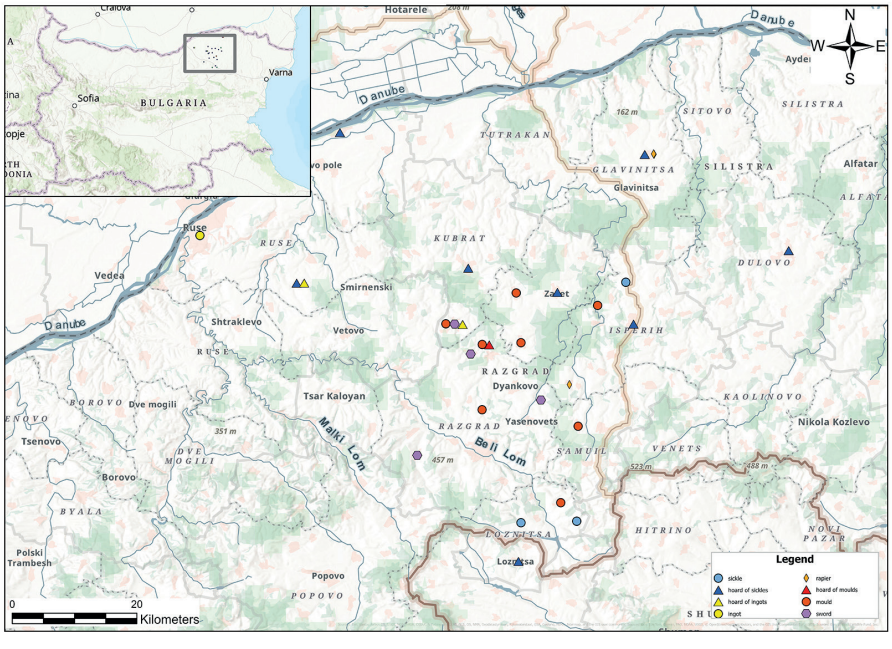
Over the past several years, systematic interdisciplinary investigations have been conducted on the Ludogorsko Plateau in present-day northeastern Bulgaria as part of a project funded by the Bulgarian National Science Fund ("Non-destructive archaeology: an interdisciplinary study of the settlement pattern of the Ludogorsko Plateau in the Bronze and Early Iron Age", Contract No. KP-06-N80/12). The main objectives of the project are the identification, analysis, and interpretation of evidence of human occupation in the region across different chronological periods, with a particular focus on the Bronze and Iron Ages. This period is represented by a large number of hoards and individual finds, including the eponymous hoard of stone moulds from Pobit Kamak.

A multidisciplinary approach combining various non-destructive methods has been applied, including the analysis of satellite imagery, LiDAR data, field surveys, and geophysical investigations of newly identified sites. Among the main tools used for selecting sites to be visited is the survey of the selected area based on soil and vegetation anomalies.

The results of investigations conducted between 2021 and 2025 indicate intensive occupation of the region during the Late Bronze Age and the Iron Age. Numerous sites were identified as clearly distinguishable dark anomalies in multi-temporal Google Earth Pro imagery and were subsequently confirmed through field verification. These surveys frequently revealed high densities of archaeological material representing multiple chronological periods.

Following further site selection, extensive geophysical surveys were carried out using two main methods: magnetometry and electrical resistivity survey.

This integrated approach has resulted in high efficiency in site identification and field registration. Analysis of the acquired data enables the identification of patterns in settlement density and habitation characteristics across different historical periods and facilitates the study of the internal organization and spatial structure of previously unidentified settlements and potential production areas.



Map of hoards and individual finds discovered in the Ludogorie Plateau

Notes

AI ArchaeoTopia: AI-assisted georeferencing and mound-symbol extraction from archival topographic maps of Bulgaria

Nadezhda Kecheva[1], Angel Bogdanov Grigorov[2], Lyubomir Angelov[3], Ivo D. Cholakov[4], Julia Tzvetkova[5], Ivet Kirilova[6], Veronika Gencheva[7], Kalin Dimitrov[8], Lyubomir Nedyalkov[9], Adela Sobotkova[10] and Iban Berganzo-Besga[11]

[1] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, nadezhda.kecheva@naim.bg, ORCiD: 0000-0002-0128-1129
[2] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, angelbogdanovgrigorov@gmail.com, ORCiD: 0009-0007-4625-3555
[3] Burgas Free University, Burgas, Bulgaria, lubomir.angelov.an@gmail.com
[4] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, ivocholakov@gmail.com, ORCiD: 0009-0002-9139-8394
[5] Sofia University "St. Kl. Ohridski", Sofia, Bulgaria, julia.tzvetkova@uni-sofia.bg, ORCiD: 0000-0002-0211-885X
[6] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, ivetkkirilova@gmail.com, ORCiD: 0009-0002-4863-5585
[7] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, VMgencheva@gmail.com
[8] National Archaeological Institute with Museum, Bulgarian Academy of Sciences, Sofia, Bulgaria, kalin.d@abv.bg
[9] Freelancer, software engineer, lnedialkov@abv.bg
[10] Aarhus University, Aarhus, Denmark, adela@cas.au.dk, ORCiD: 0000-0002-4541-3963
[11] Barcelona Supercomputing Center, Barcelona, Spain, iban.berganzo@bsc.es, ORCiD: 0000-0002-6161-2452

Keywords: *archival topographic maps, artificial intelligence, mound-symbol extraction, Archaeological Map of Bulgaria*

Mounds are among the most emblematic and most endangered archaeological sites in Bulgaria. Traditional surface surveys cannot keep pace with their ongoing destruction through agriculture, urbanization, and looting. Mid-20th-century topographic maps produced at scales of 1:25,000 and 1:5,000 represent one of the last systematic records of mound locations across Bulgarian territory, yet the spatial information they contain remains largely inaccessible for modern GIS-based analysis.

The AI ArchaeoTopia project, funded by the Bulgarian National Science Fund (contract no. КП-06-Н100/5, 2025), addresses this gap through the development of an AI-assisted pipeline for the georeferencing and automated feature extraction of archival topographic maps. As a foundational step, an initial automated georeferencing procedure was applied to nearly 1,300 topographic sheets at 1:25,000 scale covering the territory of Bulgaria. However, due

to geometric distortions and cartographic variability across the series, the results did not meet the level of positional accuracy required for feature extraction and were therefore systematically checked and corrected manually. This experience also informs ongoing work on the 1:5,000 series (nearly 16,000 sheets), where greater cartographic consistency may offer better conditions for testing and refining automated georeferencing approaches.

Building on this georeferenced dataset, the project is developing and testing methods for the automatic detection and digitization of mound symbols on the maps, with the aim of integrating identified locations into the GIS-based Archaeological Map of Bulgaria (GIS AKB) – the national archaeological information system for site recording. Preliminary experiments applying visual foundation models, particularly the Segment Anything Model (SAM) and its domain-adapted variants to automatic feature detection on topographic maps [1] are in progress.

This contribution presents the georeferencing workflow, the challenges encountered, and the current state of the automated feature detection pipeline, with discussion of implications for large-scale archaeological heritage documentation in Bulgaria and the wider Balkan region.

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Notes

Seeing the unseen: The archaeological site of Tărtăria-Podu Tărtăriei vest after more than a decade since its discovery

Corina Borș[1], Andrei Asăndulesei[2], Mihai Florea[3] and Călin Șuteu[4]

[1] National History Museum of Romania, Bucharest, Romania, corina.bors73@gmail.com, ORCiD: 0000-0002-1736-9360
[2] Universitatea „Alexandru Ioan Cuza", Iași, Romania, andrei.asandulesei@yahoo.com, ORCiD: 0000-0001-8781-0468
[3] National History Museum of Romania, Bucharest, Romania, mihaimfs@yahoo.com
[4] Gigapixel Art SRL, Cugir, Alba, Romania, suteu.calin@gmail.com

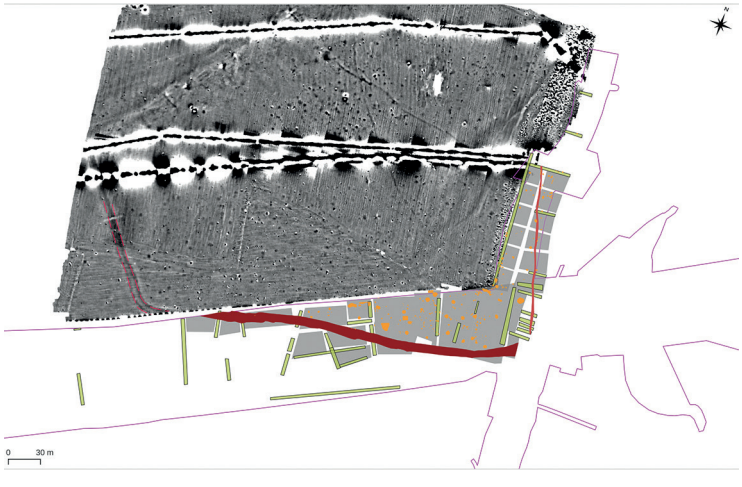
Keywords: *geophysic prospections, DStrech algorithm, magnetic susceptibility of soil, Middle Hallstatt period, site delimitation*

This prehistoric site was discovered in 2012 by large-scale archaeological excavations occasioned by the construction of the A1 motorway [1, 2]. Throughout an open area archaeological excavation was completely investigated in an area of about 2 hectares (on the southern and eastern limits of the site), significant archaeological features and vestiges being discovered, providing major new data and finds from 9th–8th c. BC [7]. At that time non-invasive field investigations were still – to a certain degree – a pioneering matter for Romanian archaeology. Since 2016, a multi-annual archaeological research program was initiated, aiming field excavations and geophysics surveys for documenting the setting of the prehistoric habitation [3]. From 2021 onward, a new complex range of non-intrusive investigations were undertaken. Commencing 2024 by using the DStretch algorithm (4, 5, 6, 8] for processing different vertical images of the area of interest we were able to identify accurately the outline of a particular structure. During the last two campaigns the DStretch algorithm to precisely identify the horizontal limits of the delineation ditch, as identified by magnetometry in the past years. Using the LDK colorspace, sufficient chromatic contrast was generated, and the layout was marked by GPS points. Further geophysical prospections were tested on the site, like MS – magnetic susceptibility of soil (volume κ), in various configurations. The MS method provides high potential in defining the limits as well as the presence / absence of archaeological horizons (features / vestiges) in broader landscapes, if a correct survey strategy is applied. The presentation will focus on how this approach is useful in preparing a full dossier for requesting the protection of the archaeological site according to the provision of the national legislation.

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Notes

The possibilities and limitations of using various non-destructive investigations on multiperiod settlements in the Vál Valley

Rebeka Mesterházy-Gergácz[1,2], Gábor Mesterházy[3], Veronika Berek[4], Mihály Pethe[5], László Rupnik[6] and Zoltán Czajlik[7]

[1] National Institute of Archaeology, Hungarian National Museum, Budapest, Hungary, gergacz.rebeka@hnm.hu, ORCiD: 0000-0003-1035-4024
[2] Doctoral School of History, Institute of Archaeological Sciences ELTE Eötvös Loránd University, Budapest, Hungary,
[3] National Institute of Archaeology, Hungarian National Museum, Budapest, Hungary, mesterhazy.gabor@hnm.hu, ORCiD: 0000-0002-3575-6874
[4] Szent István Király Museum, Székesfehérvár, Hungary, berek.veronika@szikm.hu
[5] National Institute of Archaeology, Hungarian National Museum, Budapest, Hungary, pethe.mihaly@hnm.hu, ORCiD: 0000-0002-1080-2977
[6] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, rupnik.laci@gmail.com, ORCiD: 0000-0003-0502-9331
[7] Institute of Archaeological Sciences, ELTE Eötvös Loránd University Budapest, Hungary, czajlik.zoltan@btk.elte.hu, ORCiD: 0000-0003-0340-2841

Keywords: *magnetometer survey, aerial reconnaissance, systematic artefact collection, metal detector survey, settlements*

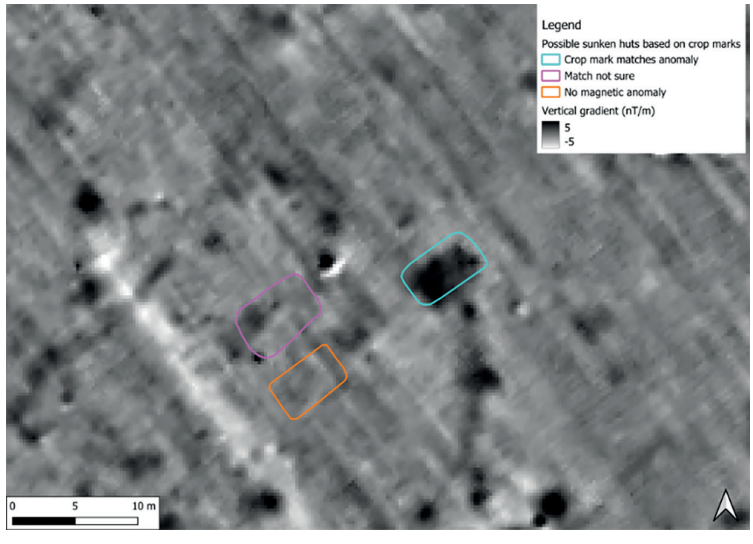
The topographical survey of the Vál Valley started in the autumn of 2023 as a collaboration between the Hungarian National Museum, Eötvös Loránd University and Szent István Király Museum. The investigation aims to explore the archaeological sites throughout the valley, with a particular focus on the Late Iron Age, and to gather comprehensive information about the settlements. We were particularly interested in the location, extent, and internal structure of specific sites within the valley, as well as the possibilities and limitations of surveying them using only non- and semi-destructive methods.

The backbone of the research is the systematic artefact collection, which we use to examine the entire research area. This helps to localise the sites, define their extents and the spatial distribution and intensity of different periods within each site, while also providing chronological data. To improve the accuracy of the latter, it is further supported by the metal detector surveys. In addition, we employ aerial and geophysical surveys to examine the internal structures of the sites, localise their features and attempt to interpret them as pits, ditches or sunken huts. To analyse and evaluate the data from the different sources, we use GIS tools.

Based on the results of the first few studied settlements, the combined use of various research methods proved to be significantly more effective. This approach provided data that would have otherwise remained inaccessible, especially in the case of multiperiod sites. By comparing the crop marks visible on the aerial images with the magnetic anomalies, we were

able to more accurately determine the probable age of certain features. Alongside this, the distribution and density of surface artefacts also contributed to our understanding of the features and utilisation of the sites across different periods.

Using and comparing all four survey methods allowed us to achieve a far more comprehensive interpretation of multiperiod sites than could be achieved with fewer methods.



Comparison between crop marks suggesting sunken huts and the results of the magnetometer survey

Notes

Peak under the canopy. Exploring Osogovo Mountains using LiDAR, remote sensing and ground control

Barbora Weissová[1], Katrin Dorfner[2], Damjan Donev[3] and Radomir Ivanovikj[4]

[1] Institute of Classical Archaeology, Faculty of Arts, Charles University, Prague, Czech Republic, barbora.weissova@ff.cuni.cz, ORCiD: 0000-0002-3297-6855
[2] Institute of Classical Archaeology, Faculty of Arts, Charles University, Prague, Czech Republic, katrin.dorfner@ff.cuni.cz, ORCiD: 0009-0008-1581-3430
[3] Institute of National History, Skopje, North Macedonia, damjaned@gmail.com, ORCiD: 0009-0007-4698-5908
[4] Archaeological Museum of the Republic of North Macedonia, Skopje, North Macedonia, ivanovicradomir@gmail.com, ORCiD 0000-0003-4416-8991

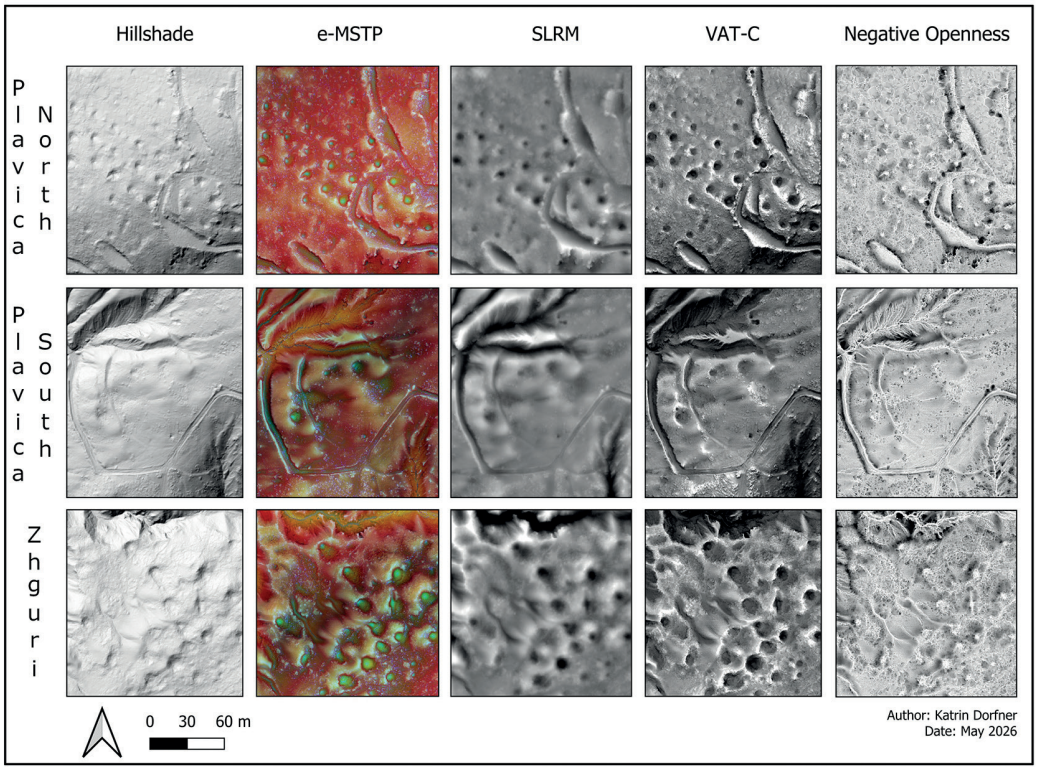
Keywords: *LiDAR, remote sensing, Osogovo Mountains, mining, Republic of North Macedonia*

This paper presents results of the first field campaign of the four-year project *Peek under the Canopy: Mining Landscapes in the West Osogovo Mountains* (PRIMUS 25/SSH/007). The project investigates the largely unexplored mining landscape of the western slopes of the Osogovo Mountains in the northeastern part of the Republic of North Macedonia through an integrated non-invasive methodology combining airborne LiDAR data analysis with systematic ground verification.

The principal objective of the project is to elucidate the role of the region's rich polymetallic ore deposits and associated extractive activities within the economic systems of the Roman and Ottoman Empires. To date, the significance of this mining district has been inferred primarily from written sources, a limited archaeological record, and preliminary field reconnaissance undertaken in 2022. The project seeks to provide the first comprehensive archaeological assessment of the area and to establish a robust empirical basis for evaluating long-term mining exploitation and its socio-economic impact.

The primary analytical dataset consists of high-resolution LiDAR imagery acquired by the Agency for Real Estate Cadastre of the Republic of North Macedonia between 2019 and 2021. The data were processed using a range of visualization techniques designed to enhance the detection of archaeological features, with particular emphasis on mining-related remains obscured by dense forest cover. Remote-sensing analysis resulted in the identification of 7,984 potential anthropogenic features, of which 1,616 were subjected to field verification during the ground-control campaign conducted in March–April 2026.

The paper presents the preliminary results of this integrated remote-sensing and field-based investigation, with particular focus on assessing the effectiveness and limitations of the available LiDAR dataset for large-scale archaeological prospection in heavily forested mining landscapes. The study also discusses the implications of the identified mining features for future research into the chronology, organization, and economic significance of ore extraction in the Osogovo Mountains.



Visualisation methods used to study exploitation sites in the Osogovo Mountains

Notes

Session 11

CONTEXT IS EVERYTHING

Geoarchaeological and environmental perspectives



Moments in Budapest
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Large rivers, small rivers and rising seas: Long-term settlement strategies in the Lower Danube and Western Black Sea region

Alfred Vespremeanu-Stroe[1], Cătălin Lazăr[2], Daniel Garvăn[3], Marta Andriiovych[4], Vladimir Slavchev[5], Laurențiu Țuțuianu[6], George Grosu[7], Adrian Cîrjan[8] and Luminița Preoteasa[9]

[1] GEODAR Research Center for Geomorphology, Geoarchaeology, and Paleo-Environments, ICUB Research Institute of the University of Bucharest, Bucharest, Romania, fredi@geo.unibuc.ro, ORCiD: 0000-0001-6559-3490
[2] ArchaeoSciences Platform, ICUB Research Institute of the University of Bucharest, Bucharest, Romania, catalin.lazar@icub.unibuc.ro, ORCiD: 0000-0001-7559-1843
[3] Buzău County Museum, Buzău, Romania, daniel.garvan@gmail.com, ORCiD: 0000-0002-9732-1796
[4] Laboratory of Prehistoric Archaeology and Anthropology (LAP), University of Geneva, Geneva, Switzerland, Marta.Andriiovych@unige.ch, ORCiD: 0000-0001-8950-4130
[5] Varna Regional Museum of Archaeology, Varna, Bulgaria, v.slavchev@gmail.com, ORCiD: 0000-0002-6369-4527
[6] GEODAR Research Center for Geomorphology, Geoarchaeology, and Paleo-Environments, ICUB Research Institute of the University of Bucharest, Bucharest, Romania, laurentiu.tutuianu@drd.unibuc.ro, ORCiD: 0000-0002-0110-6195
[7] GEODAR Research Center for Geomorphology, Geoarchaeology, and Paleo-Environments, ICUB Research Institute of the University of Bucharest, Bucharest, Romania, george-cristian.grosu@s.unibuc.ro, ORCiD: 0009-0002-0571-5948
[8] GEODAR Research Center for Geomorphology, Geoarchaeology, and Paleo-Environments, ICUB Research Institute of the University of Bucharest, Bucharest, Romania, cirjanmihaiadrian@gmail.com, ORCiD: 0009-0006-5045-3739
[9] GEODAR Research Center for Geomorphology, Geoarchaeology, and Paleo-Environments, ICUB Research Institute of the University of Bucharest, Bucharest, Romania, luminita.preoteasa@geo.unibuc.ro, ORCiD: 0000-0001-9249-2089

Keywords: *Chalcolithic, flood memory, floodplain dynamics, sea-level change*

Recent geoarchaeological investigations from the East Lower Danube Plain have demonstrated that Chalcolithic communities displayed a marked preference for settlement along small river valleys (e.g., Călmățui, Mostiștea, Teleorman), which were largely protected from hazardous flooding while avoiding major Carpathian rivers (e.g., Buzău, Ialomița, Argeș); palaeogeographic evidence integrating chronostratigraphic data, floodplain aggradation records and macrocharcoal sequences indicates deliberate landscape selection for lower flood hazard and geomorphic stability. Building on these findings [1], this study expands the analysis along two complementary directions.

The first objective tests whether this small-river preference also characterized the Cucuteni–Trypillia cultural complex, which occupied contrasting environmental settings across the for-

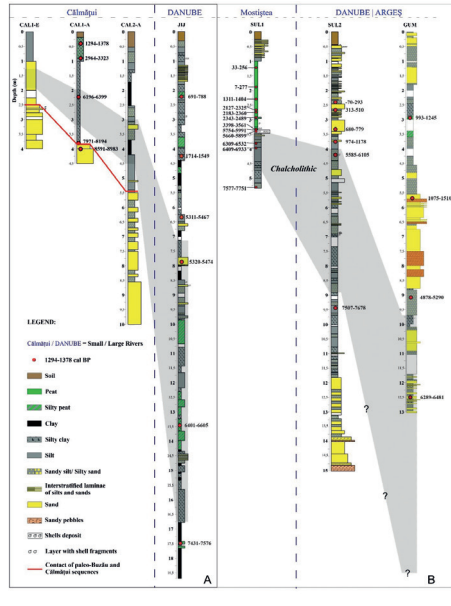
est-steppe zone of Eastern Europe. Using GIS-based analyses of settlement distribution, river hierarchy and floodplain morphology, we evaluate whether flood-averse positioning was a widespread Chalcolithic adaptation or a phenomenon restricted to the Lower Danube region.

The second objective examines the relationship between settlement altitude and relative sea level along the western Black Sea coast. Incorporating sites from the Hamangia and Gumelnița–Varna (KGK VI) cultural groups, together with Bronze Age, Iron Age, Greek, Roman and Medieval settlements, we compare site elevations against reconstructed palaeoshorelines and sea-level curves. We evaluate whether coastal communities systematically occupied elevations minimizing exposure to shoreline migration and marine transgression, and whether this risk awareness persisted into historical periods.

Preliminary results suggest that Chalcolithic communities developed long-term settlement strategies shaped by accumulated environmental knowledge. In the Lower Danube, settlement clustering along small rivers reflects flood-memory operating over multiple generations. Along the Black Sea coast, early evidence points to recurrent occupation of elevated, stable positions. These patterns highlight the role of environmental memory in shaping Chalcolithic settlement decisions, and this study evaluates how such risk awareness (both fluvial and coastal hazards) was transformed across the transition to Bronze Age, Iron Age and historical communities.

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Chrono-stratigraphic transects based on sediment cores extracted along small rivers (Călmățui and Mostiștea) and large rivers (Danube and Argeș). The grey bands indicate the thickness of sedimentary sequences deposited during the Chalcolithic. Radiocarbon dates are indicated by red circles and expressed as calibrated age ranges (2σ, cal BP)

Reconstructing the Late Bronze Age–Iron Age metallurgical society of Colchis through palynological evidence

Nino Sulava[1], Rusudan Chagelishvili[2], Nana Rezesidze[3], Magda Batiashvili[4] and Eliso Kvavadze[5]

[1] Georgian National Museum, Tbilisi, Georgia, nino_sulava@yahoo.com, ORCiD: 0009-0009-2684-2111
[2] Georgian National Museum, Tbilisi, Georgia, rchagelishvili@gmail.com, ORCiD: 0000-0001-9567-8735
[3] Georgian National Museum, Tbilisi, Georgia, rezesidzenana@gmail.com, ORCiD: 0009-0003-2690-4067
[4] Georgian National Museum, Tbilisi, Georgia, magdabatiashvili@gmail.com, ORCiD: 0000-0003-1319-8127
[5] Georgian National Museum, Tbilisi, Georgia, e.kvavadze001@gmail.com, ORCiD: 0000-0002-6059-0861

Keywords: *Late Bronze–Iron Age, palynology, copper metallurgy, South Caucasus, Georgia*

The Colchian bronze culture of western Georgia is renowned for its rich metallurgical tradition during the Late Bronze Age–Iron Age [1]. Recent archaeological and geological investigations in the mountainous region of Lechkhumi (ancient Colchis), have identified approximately 30 previously unknown copper–smelting sites dating to the 13th–8th centuries BC, highlighting the scale and importance of metallurgical production in the region [2–4]. While archaeological research has provided substantial evidence for and metalworking activities, much less is known about the landscapes in which these activities took place and the communities that supported them. This study explores how palynological evidence can contribute to a better understanding of the environmental and social context of metallurgy in ancient Colchis.

More than 50 pollen and non–pollen palynomorph taxa were identified from slag fragments in metallurgical contexts, providing insight into the surrounding environment. Bracken fern (Pteridium aquilinum) and disturbance–related fungal spores indicate local forest clearance, likely for charcoal production. Palynological and charcoal evidence shows nearby forests were the main fuel source for copper smelting, underlining the strong link between metallurgy and woodland resources [3, 5].

At the same time, the presence of herbaceous and agricultural taxa suggests that farming activities were practiced alongside metallurgy. These findings reveal a landscape shaped by the interaction of woodland management, metal production, and subsistence practices. Rather than functioning as an isolated craft, metallurgy appears to have been embedded within a

broader economic system that relied on the coordinated exploitation of natural resources. The study therefore offers new insights into how Colchian communities organized and sustained metallurgical production, highlighting the close connections between technology, environment, and everyday life in the LBA–IA South Caucasus.

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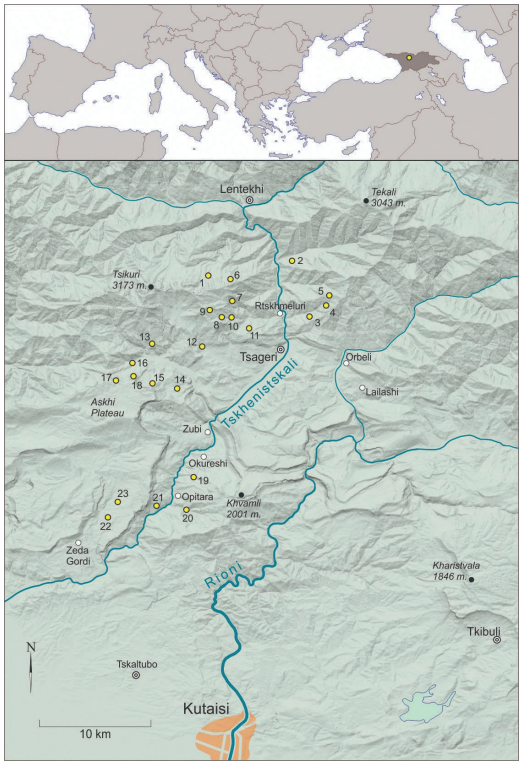
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Map of Lechkhumi with the location of the copper production sites

Destructive earthquakes in ancient Tomis (Constanța, Romania) – Archaeoseismological and historical data

Miklós Kázmér[1], Krzysztof Gaidzik[2], Cristina-Georgeta Alexandrescu[3] and Irina Sodoleanu[4]

[1] ELTE Eötvös Loránd University,
Budapest, Hungary, mkazmer@gmail.com, ORCiD: 0000-0003-1092-1316
[2] University of Silesia at Katowice,
Sosnowiec, Poland, k.gaidzik@gmail.com, ORCiD: 0000-0003-3286-0833
[3] "Vasile Pârvan" Institute of Archaeology,
Bucharest, Romania, cgetalexandrescu@gmail.com, ORCiD: 0000-0002-6189-1850
[4] Museum of National History and Archaeology,
Constanța, Romania, ORCiD: 0009-0003-9131-2914

Keywords: *rchaeoseismology, earthquake, Black Sea, Dobruja, tsunami, Tomis*

Archaeoseismology is a method that enables the identification and assessment of the intensity of destructive earthquakes in the past. Instead of focusing solely on stratigraphic levels with collapsed walls, our approach involved seeking evidence of lateral loading on structures, including in-plane and out-of-plane deformations, as well as deformed floors. The historical and archaeological context further constrain the chronology of destruction phases. A terraced building complex in ancient Tomis (modern Constanța, Romania), located on the western shore of the Black Sea and a major urban center of the Roman and Late Roman provinces of Moesia Inferior (later Scythia), is examined. Excavated sectors of the complex, developed across multiple terraces overlooking the ancient harbor, display a wide range of earthquake-induced features: extrusion, axial fractures, faults, funnels, troughs, folds, and lateral spreading within a massive mosaic pavement. Interestingly, several meter-sized wall fragments suffered shearing, dropping, tilting, and forced compaction due to a 6-meter free fall into the underlying storerooms. The combined evidence from structural collapse (walls, vaults, and floors) and deformation of the mosaic pavement indicate that the shaking intensity reached at least level IX or higher, leading to significant destruction in the affected settlements. Archaeological analyses, numismatic data, as well as written sources constrain the main seismic events that severely affected Tomis to the 4th and late 5th century AD. This interval closely precedes a documented tsunami along the western Black Sea coast around 544/545 AD, suggesting a period of heightened geohazard activity. These results contribute to the reconstruction of the seismic history of the region and have important implications for seismic hazard assessment along the western Black Sea coast.



Mosaic-covered floor on top of a collapsed vault (in the foreground) and displaced wall (background) in the Roman storerooms of Tomis. Archaeological Database photo #DSC00394.

Notes

Workspaces and areas of exploitation – Geoarchaeological record of the iron production environments in altered lowland landscapes

Tena Karavidović[1], Tomislav Brenko[2], Sibila Borojević-Šoštarić[3] and Tajana Sekelj Ivančan[4]

[1] Institute of Archaeology, Zagreb, Croatia, tkaravidovic@iarh.hr, ORCiD: 0000-0003-3046-786X
[2] Geology and Petroleum Engineering, Faculty of Mining, University of Zagreb, Zagreb, Croatia, tomislav.brenko@rgn.unizg.hr, ORCiD: 0000-0002-8935-1813
[3] Geology and Petroleum Engineering, Faculty of Mining, University of Zagreb, Zagreb, Croatia, sibila.borojevic-sostaric@rgn.unizg.hr, ORCiD: 0000-0003-1861-2470
[4] Institute of Archaeology, Zagreb, Croatia, tsivancan@iarh.hr, ORCiD: 0000-0001-5992-8434

Keywords: *bog iron ore, geoarchaeology, iron production*

Bog iron ores were exploited for iron extraction across Europe from prehistoric times to the early modern period. In the southern Carpathian Basin, specifically in the upper alluvial plain of the Drava in northern Croatia, more than 150 archaeological sites display surface evidence of iron production activities. Provenance analyses of slag and ore from excavated sites indicate that regionally occurring bog iron ores were used for iron extraction during Late Antiquity and the Early Middle Ages.

Bog iron ores are renewable, sedimentary deposits that form as continuous layers or lenses in lowland and wetland environments. Their formation is favoured by alluvial sandy, loamy, or clayey soils characterised by variable redox potentials and a continuous flow of shallow, iron-rich groundwater (Fe^{2+}). Investigating these ore deposits and their properties enhances our understanding of the natural conditions that influenced past production strategies and resource management. However, in-depth study of historical bog iron ore deposits is challenging due to potential exhaustion in the past or degradation. Regeneration or development of ore deposits is further hindered by land reclamation efforts and associated environmental impacts. As a result, reconstructing the environmental settings of past iron production – including workspaces and exploited ore deposits – remains a complex task.

This study provides an overview of geoarchaeological approaches undertaken to reconstruct potential areas of development and exploitation of bog iron ores in the past in the area of the alluvial plain of the Drava River, Croatia. Initial methodologies included systematic field surveys, investigation into the formation mechanisms of bog iron ores within the region, including comprehensive analysis of soil and ore developmental phases (mineralogical (XRD) and geochemical (XRF, LA-ICP-MS/AES), and remote sensing techniques (LiDAR and predictive modelling). These approaches are combined with the contextual analysis of archaeological iron production workspaces and their spatial localisation, to understand the mutu-

al dependency between the potential for bog iron ore deposit formation and archaeological workspace placement, and the overall distribution of primary iron production sites along the alluvial plain of the Drava river. The results show that although the landscape is significantly altered, the potential for the development of bog iron deposits can be spatially delineated and these areas correlate to distribution of iron production sites, implicating resource availability as primary natural driving factor for workspace location selection and long-term iron production on a regional scale.

Notes

Landscape history of the Jurišina humka kurgan in Žabalj, Serbia

Ádám Bede[1], József Dózsai[2], Kristóf Süveges[3], András István Csathó[4], Attila Molnár V.[5], Orsolya Valkó[6] and Balázs Deák[7]

[1] 'Lendület' Seed Ecology Research Group, HUN-REN Centre for Ecological Research, Vácrátót, Hungary, bedeadam@gmail.com, ORCID: 0000-0001-7768-439X
[2] Association for the Protection of Great Bustard, Mokrin, Serbia, dojozzy@gmail.com
[3] 'Lendület' Seed Ecology Research Group, HUN-REN Centre for Ecological Research, Vácrátót, Hungary, eska1994@gmail.com
[4] Independent researcher, Battonya, Hungary, csatho@mezsgyevedelem.hu, ORCID: 0000-0002-6379-5459
[5] Department of Botany, University of Debrecen, Debrecen, Hungary, mva@science.unideb.hu, ORCID: 0000-0001-7096-9579
[6] 'Lendület' Seed Ecology Research Group, HUN-REN Centre for Ecological Research, Vácrátót, Hungary, valkoorsi@gmail.com, ORCID: 0000-0001-7919-6293
[7] 'Lendület' Seed Ecology Research Group, HUN-REN Centre for Ecological Research, Vácrátót, Hungary, debalazs@gmail.com, ORCID: 0000-0001-6938-1997

Keywords: *Yamnaya Culture, burial mound, cultural heritage, dry grasslands, conservation*

The kurgan, built by the Yamnaya Culture [1], is situated on an elevated ground near the ancient bank of river Tisza, and was. During the 'Árpád Age' (AD 11–14th centuries) the local community built a stone church and established a cemetery on the mound. The temple was abandoned in later centuries, but its ruins (pieces of stone and brick) are still present on the surface, and many human remains can still be found on the agriculturally disturbed ground. Besides the two modern geodetic markers on the top, there is also an old carved stone point from the 19th century. The mound has several Serbian and Hungarian names. The names *Kamenita humka* and *Kő-halom* ('Stony Mound') refer to the ruins of the former church, while the names *Jurišina kosa* ('Yuri's Hair') and *Jurišina humk*a ('Yuri's Mound') are connected to an old Serbian family name. The kurgan was surrounded by vast grasslands at the end of the 18th century. Due to the intensifying land use (indicated by the increasing number of farms) the area of grasslands considerably decreased by the middle of the 19th century; former grasslands were ploughed and the kurgan became isolated. This landscape configuration has remained, and largely unchanged until present day [2]. Despite being unmanaged, the entire mound is still covered by a species-rich loess grassland holding a very high richness and cover of typical dry grassland species such as *Centaurea scabiosa*, *Euphorbia glareosa*, *E. cyparissias*, *F. rupicola*, *Salvia nemorosa*, *Stipa capillata* and *Thalictrum minus*. The mound also harboured the populations of protected and red listed grassland species such as *Agropyron pectinatum*, *Adonis vernalis*, *Allium paniculatum*; and *Sternbergia colchiciflora* has archive data. Among the weed species, several regionally rare species were recorded such as

Calepina irregularis, *Camelina microcarpa*, *Erodium ciconium* and *Nigella arvensis*. Owing to its high conservation value, the kurgan was designated as a locally protected area [3].

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The Jurišina humka kurgan in Žabalj, Serbia (photo by Á. Bede)

Notes

A statistical approach to distinguishing anthropogenic and natural sediments via routine soil chemical properties: A pilot study from Perkáta-Forrás-dűlő Bronze Age tell site, Hungary

Gabriella Kovács[1] and Ákos Pető[2]

[1] Department of Nature Conservation and Environmental Management, Institute of Wildlife Management and Nature Conservation, Hungarian University of Agriculture and Life Sciences, Doctoral School of Natural Sciences, Gödöllő, Hungary, mikromorfologus@gmail.com, ORCiD: 0000-0002-8193-9903
[2] Department of Nature Conservation and Environmental Management, Institute of Wildlife Management and Nature Conservation, Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary, Peto.Akos@uni-mate.hu, ORCiD: 0000-0003-3811-1155

Keywords: *soil geochemistry, Bronze Age tell, minimally invasive core drilling, statistical analysis, cultural heritage protection*

Distinguishing archaeological deposits from natural soil horizons in tell sediments remains a major challenge in geoarchaeological research. Bronze Age tells are highly complex, vertically stratified monuments, whose investigation is often constrained by the practical, financial, and heritage-related limitations of large-scale excavations. Core drilling provides a valuable, minimally invasive alternative, allowing buried sequences to be investigated while preserving archaeological deposits *in situ*.

This study explores the potential of routine soil geochemical properties for identifying and characterizing buried archaeological deposits. Two sediment cores (PK5 and PK7) were analyzed independently to account for local stratigraphic variability. Selected parameters – including pH (KCl), calcium carbonate ($CaCO_3$), total organic carbon (TOC), and total phosphorus (P_{total}) – were evaluated in relation to depth. Statistical analyses were employed to examine depth-dependent patterns and identify variations that may reflect differences between natural soil development and human activity. The observed geochemical trends were subsequently compared with the distribution of archaeological macro-remains to provide an independent basis for interpretation.

Both profiles exhibited distinct vertical variability and clear indications of human influence, although the extent and intensity of these signatures differed between the cores. The results demonstrate that statistical evaluation of routine soil chemical data can provide useful evidence for recognizing and interpreting buried archaeological horizons. Therefore, integrating core-based sampling, geochemistry, and statistical analysis offers a promising approach for the investigation of protected tell sites, supporting archaeological interpretation while reducing the need for extensive excavations.



The inner fort of Perkáta-Forrás-dűlő Bronze Age tell site

Notes

Session 12

CODE OF THE PAST

Computational tools for a data-driven archaeology



Moments in Budapest
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Project WEAR: A methodological framework for experimental and computational analysis of stone tool uses

Laura Dietrich[1,2], Christoph von Tycowicz[3], Julius Mayer[4], Lohengrin Baunack[5], Iris Schmidt[6] and Michael Brandl[7]

[1] Martin-Luther University Halle-Wietenberg (MLU), Halle (Saale), Germany, Laura.Dietrich@oeaw.ac.at, ORCiD: 0000-0002-7570-0576
[2] Austrian Archaeological Institute, Austrian Academy of Sciences (OEAI), Vienna, Austria
[3] Zuse Institute Berlin (ZIB), Berlin, Germany, ORCiD: 0000-0002-1447-4069
[4] Zuse Institute Berlin (ZIB), Berlin, Germany, ORCiD: 0000-0002-7076-1118
[5] Martin-Luther University Halle-Wietenberg (MLU), Halle (Saale), Germany, ORCiD: 0009-0009-2676-8679
[6] Austrian Archaeological Institute, Austrian Academy of Sciences (OEAI), Vienna, Austria
[7] Austrian Archaeological Institute, Austrian Academy of Sciences (OEAI), Vienna, Austria, ORCiD: 0000-0002-0214-8231

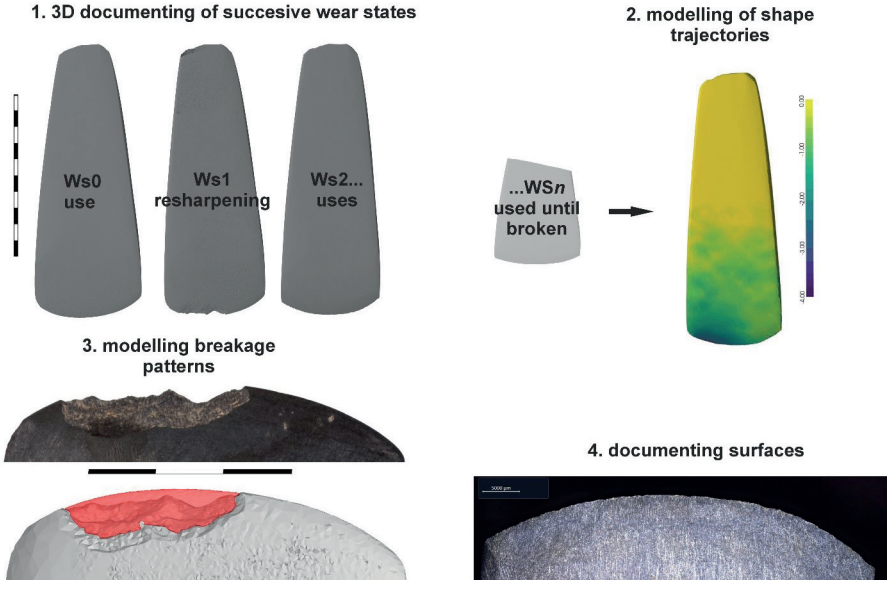
Keywords: *experimental archaeology, geometric morphometrics, computational analyses, stone tools, Neolithic, Central Europe, Linearbandkeramik (LBK)*

Project WEAR develops an integrative methodological framework for the experimental and computational analysis of Neolithic bifacial stone tools from Central Europe, with a particular focus on axes, adzes, and chisels associated with the *Linearbandkeramik* (LBK) culture. Traditional typological approaches to these tools have largely relied on static classifications based on dimensional ratios, despite the fact that such artefacts undergo continuous morphological transformation throughout their use-life. Existing studies often depend on subjective assessments and small datasets, limiting reproducibility and quantitative evaluation.

To address these limitations, the WEAR project combines experimental archaeology, geometric morphometrics, material sciences, and computational modelling in order to reconstruct the functional and morphological life histories of stone tools. The methodological workflow integrates raw material characterization, controlled replication experiments, long-term use simulations, and sequential three-dimensional documentation of wear states. Mechanical devices are employed to standardize variables such as motion, pressure, and duration of work, while human participants serve as comparative controls. Analytical methods include X-ray diffraction (XRD), electron probe microanalysis (EPMA), X-ray fluorescence (XRF), Fourier-transform infrared spectroscopy (FTIR), and advanced statistical modelling of shape trajectories in size-and-shape space.

The project further generates open-access synthetic datasets that model wear progression, breakage patterns, and task-specific deformation processes. Preliminary results demon-

strate that tool dimensions and wear parameters change simultaneously, though at varying rates, during repeated use and resharpening episodes. Consequently, metric ratios commonly used in archaeological typologies cannot be considered stable or invariant. Analyses of LBK flat adzes indicate that morphological variability is more likely related to intensity of use and maintenance histories than to stylistic or technological differences. By integrating experimental replication with computational analysis, Project WEAR provides a reproducible framework for identifying original tool functions and understanding long-term processes of technological transformation in Neolithic societies.



Notes

Settlement pattern analysis and predictive modelling with a probabilistic approach in the Tiszazug microregion, Eastern Hungary

Gábor Mesterházy[1], András Füzesi[2] and Norbert Faragó[3]

[1] National Institute of Archaeology, Hungarian National Museum, Budapest, Hungary, mesterhazy.gabor@hnm.hu, ORCiD: 0000-0002-3575-6874
[2] Department of Archaeology, Hungarian National Museum, Budapest, Hungary, fuzesi.andras@hnm.hu, ORCiD: 0000-0002-5039-8593
[3] Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, norbert.farago@gmail.com, ORCiD: 0000-0002-0351-1223

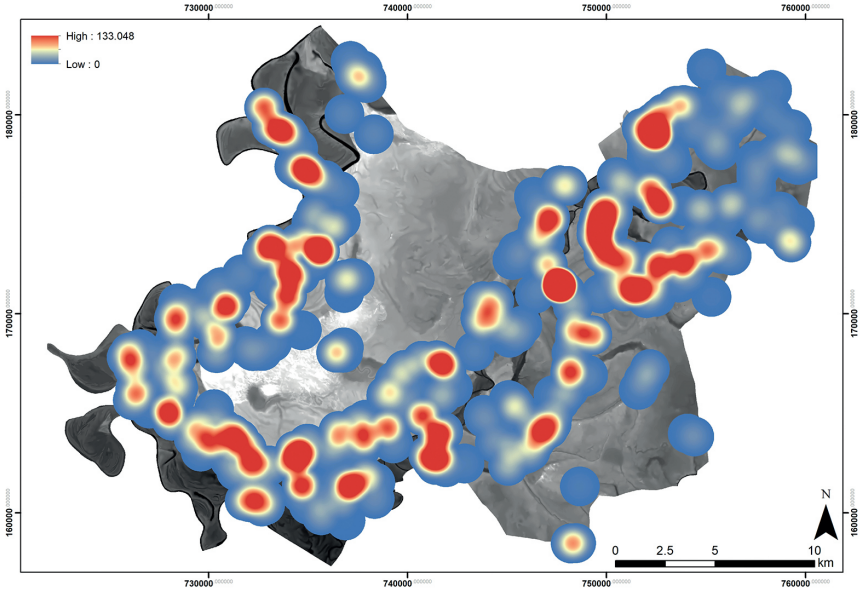
Keywords: *predictive modelling, settlement pattern analysis, probability modelling, GIS, Neolithic*

The advantages of concurrently examining long-term archaeological settlement patterns and integrating temporal aspects into the modelling process have proven highly beneficial over the past few decades in microregional studies. These spatiotemporal investigations have provided a clearer understanding of how human activities occurred within the landscape, as well as how shifting environmental, social, and ecological conditions have necessitated and constrained human adaptation. This study aims to explore changes in the Early (EN), Middle (MN), and Late Neolithic (LN) (6000–4300 BC) settlement patterns of the Tiszazug microregion in Eastern Hungary by integrating a microregional settlement database, chronological probability modelling, a radiocarbon-dated temporal framework and predictive modelling.

The Archaeological Topography of Hungary in the 1980s and 1990s identified 758 archaeological sites within the 546 km² Tiszazug microregion through extensive field surveys. During a recent complete chronological review of the collected artefacts, Bevan's and Crema's probabilistic method was applied to gain artifact-based chronological uncertainty of approximately 17,500 Neolithic finds. A site-based summary of the individual assessments aimed to balance the low count of highly diagnostic ceramics with the high count of moderately diagnostic ceramics to calculate the overall occupation probability of the sites during the Neolithic periods. The absolute chronological framework for the Körös culture (EN), Alföld Linear Pottery culture (MN), Szakálhát group (MN) and Tisza culture (LN) in the microregion was established using more than 60 collected and newly measured radiocarbon dates, highlighting asynchronous and overlapping cultural phases.

KDE-based probabilistic settlement pattern analysis and maximum entropy predictive modelling were conducted to visualise and analyse culture-dependent occupation strategies throughout the Neolithic. The models indicate significant changes from the Early to the Late

Neolithic in habitation areas and intensity, highlighting short- or long-lived local and microregional centres and their changing environmental conditions.



Kernel density of the overall Neolithic settlement network based on probability modelling

Notes

Mapping technological knowledge and social connections: Network analysis of Copper Age pottery forming in the Carpathian Basin

Eszter Solnay[1,2], Zoltán Kovács[3,4] and Zsuzsanna Siklósi[5]

[1] MTA–ELTE Lendület "Momentum" Innovation Research Group, Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, solnay.eszter@btk.elte.hu, ORCiD: 0000-0002-1647-9699
[2] UMR 8215 Trajectoires, CNRS, Paris, France
[3] MTA–ELTE Lendület "Momentum" Innovation Research Group, Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, kovzoltan@student.elte.hu, ORCiD: 0000-0001-6472-0558
[4] Department of Biological Physics, ELTE Eötvös Loránd University, Budapest, Hungary
[5] MTA–ELTE Lendület "Momentum" Innovation Research Group, Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary, siklosi.zsuzsanna@btk.elte.hu, ORCiD: 0000-0002-6451-5578

Keywords: *Copper Age, Carpathian Basin, network analysis, pottery forming techniques, social connections*

To reconstruct the social networks of Early and Middle Copper Age (4500–3650 BCE) communities in the Carpathian Basin, this study investigates pottery forming techniques. Because these techniques require intensive, direct interaction to learn, they serve as reliable indicators of distinct communities of practice. This research aims to move beyond broad regional correlations by utilising network analysis to uncover fine-grained spatial and temporal connections between individual sites and to trace the diffusion patterns of minor technological variations. To achieve this, macroscopic traces on 1605 ceramic vessels from 24 sites across Transdanubia, the Budapest Region, and the Great Hungarian Plain were systematically examined to reconstruct specific forming methods and coiling processes [1, 2, 3]. After validating site sample coverage with the iNEXT package, these categorical data were transformed and projected into a network using Uniform Manifold Approximation and Projection (UMAP) and clustered via the Leiden algorithm, with cluster robustness validated through Jackknife and downsampling methods.

The network analysis successfully revealed the hidden microstructures of knowledge transmission, overcoming the limitations of less robust statistical approaches. The results demonstrate that the diffusion of minor technological variations was not random but followed distinct spatial and temporal trajectories. Rather than indicating direct long-distance interactions, the patterns suggest a progressive, step-by-step diffusion of technical knowledge primarily between neighbouring communities. Furthermore, a clear temporal shift was identified: earlier communities typically displayed peripheral, strictly localised networks, whereas later settlements occupied highly connected, central positions that bridged distinct mac-

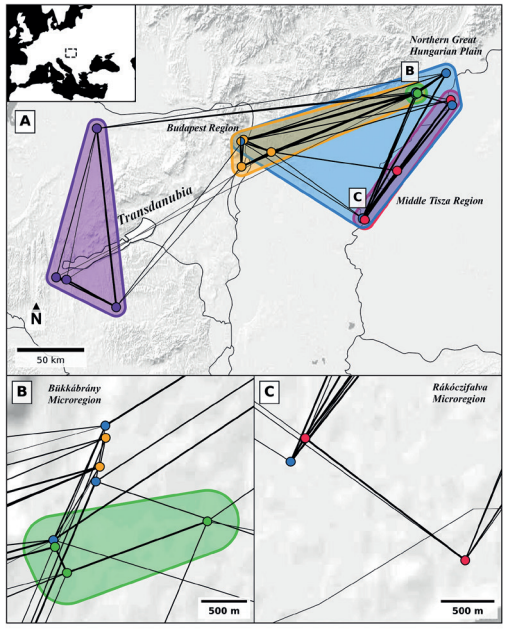
ro-regions and integrated broader technical repertoires. Ultimately, this study establishes the network analysis of forming techniques as a crucial methodological tool for modelling the gradual transformation of prehistoric technical traditions. By moving beyond mere artefacts, it successfully identifies social relationships and knowledge-transfer networks.

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Network of the analysed Early and Middle Copper Age sites in the Carpathian Basin. The different colours represent the distinct clusters in the network, thereby revealing previously unknown microstructures within the potters' knowledge-transfer network

Notes

Protocol for interdisciplinary data harvesting aimed at continuous bioarcheological and geological research improvement with machine learning computing techniques

Ioan Gabriel Mircea[1], Ágnes Gál[2], Cristina Mircea[3] and Sorin Nemeti[4]

[1] Department of Computer Science, Faculty of Mathematics and Informatics, Babeş-Bolyai University, Cluj-Napoca, Romania, ioan.mircea@ubbcluj.ro, ORCiD: 0000-0003-1769-2990
[2] Department of Geology, Faculty of Biology and Geology, Babeş-Bolyai University, Cluj-Napoca, Romania, agnes.gal@ubbcluj.ro, ORCiD: 0000-0001-5366-3340
[3] Department of Molecular Biology and Biotechnology, Faculty of Biology and Geology, Babeş-Bolyai University, Cluj-Napoca, Romania, cristina.mircea@ubbcluj.ro, ORCiD: 0000-0001-8527-3814
[4] Department of History and Archaeology, Faculty of History and Philosophy, Babeş-Bolyai University, Cluj-Napoca, Romania, sorin.nemeti@ubbcluj.ro, ORCiD: 0000-0001-9330-5812

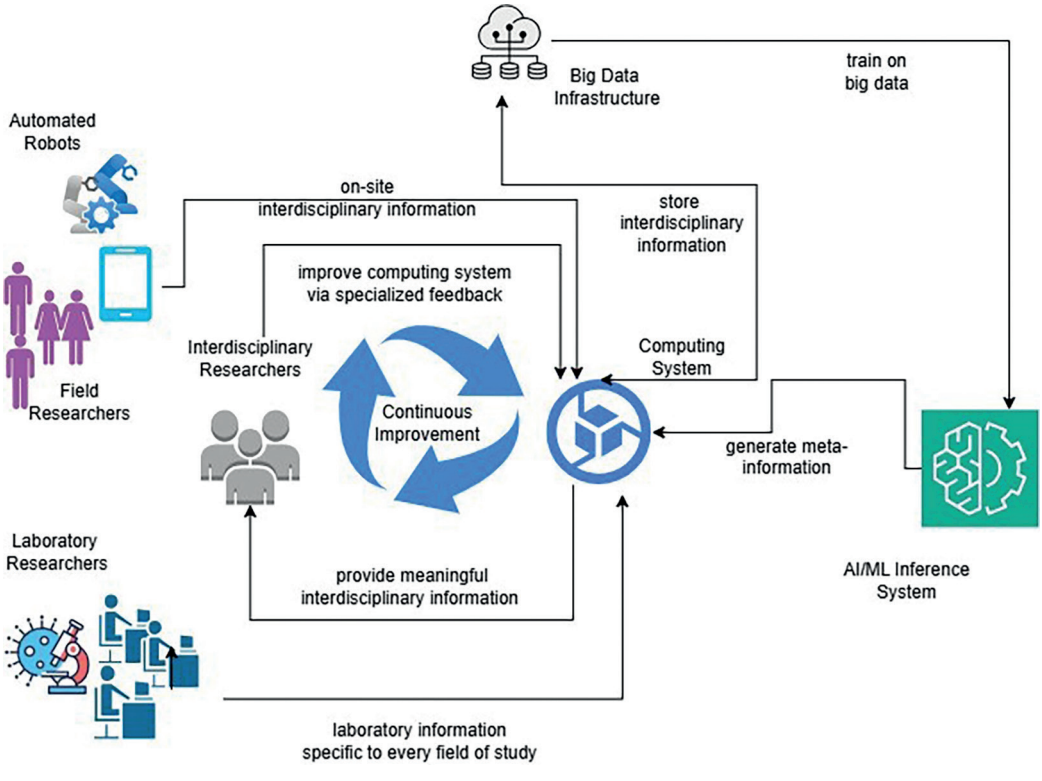
Keywords: *interdisciplinary research, big data harvesting protocol, bioarchaeology, geology, machine learning*

Achieving performant interdisciplinary research by actual standards relies heavily on building a big-data infrastructure as the basis for subsequent AI/machine learning-driven inference over a plethora of multimodal interdisciplinary data.

With this in mind, the authors propose a novel interdisciplinary methodology that covers all aspects of proper bioarchaeological and geological research, starting with on-site data-harvesting procedures tailored to modern interdisciplinary needs (e.g., systematic excavation of artefacts using stratigraphic recording, mapping artefacts' locations with GPS, total stations, or 3D photogrammetry, collection of sediment cores, rock and mineral sampling from specific stratigraphic layers, etc.), followed by customized laboratory protocols (e.g., cleaning and conservation of the extracted artefacts, physiscal anthropological analysis, ancient DNA extraction, stable isotope analysis, preparation of thin sections for petrographic microscopy, sediment sieving and grain-size analysis, mineralogical analysis, etc.) for data processing (e.g., digitizing field records and artefacts, statistical analysis of identified patterns, processing DNA sequence data and interpreting isotopic values, creating 3D models of the artefacts, analyzing sediment composition datasets, constructing stratigraphic profiles and geological timelines, modeling past environmental or landscape changes, etc.), and culminating in a perpetual feedback loop (e.g. return to the field to collect additional samples, modify excavation strategies, refine research questions, reanalyze previously collected material with new techniques, etc.).

The proposed methodology will be validated during an interdisciplinary summer camp centered around an archaeological excavation at the Roman castrum of Potaissa, Turda, Roma-

nia, that would provide enough archaeological, biological, and geological data to fuel an informatics system enhanced with novel AI capabilities, which in turn will provide a generation of young interdisciplinary researchers with meaningful metadata.



Overview of the proposed continuously improving ML-enhanced computing system for interdisciplinary bioarchaeological and geological research

Notes

A digital workflow for the documentation and analysis of carved building stones

Ákos Ekrik[1,2]

[1] Institute of Archaeology, ELTE Research Centre for the Humanities, Budapest, Hungary, ekrik.akos@htk.elte.hu, ORCiD: 0009-0002-4167-5760
[2] Doctoral School of History, Institute of Archaeological Sciences, ELTE Eötvös Loránd University, Budapest, Hungary

Keywords: *photogrammetry, cultural heritage, artificial intelligence, CNN, medieval architecture*

Carved building stones are important sources for the study of historic architecture, but their documentation and comparison can be a slow and demanding process. This paper presents a digital workflow designed to make the recording and analysis of such material more efficient, consistent, and easier to reuse in further research. The case study is based on the carved stones of the Inner City Parish Church of Pest, documented through photogrammetric 3D surveys. These detailed 3D models make it possible to record the stones accurately and to extract profiles, sections, and other formal features from them. In this workflow, photogrammetry is not only used for visual documentation, but also as a starting point for digital analysis. The extracted data are further processed with Python-based methods and used in connection with convolutional neural networks. The aim is to explore how machine learning can help recognize recurring shapes and profile types among the carved stones. By creating clear and comparable profile data, and by defining idealized profile forms, the workflow can provide better training material for the model.

The paper argues that these digital methods can support the work of researchers by reducing repetitive manual tasks and speeding up the comparison of stone elements. The proposed workflow does not replace expert interpretation, but offers a practical tool for organizing, analysing, and identifying carved building stones more effectively. In this way, it contributes to the modern documentation of cultural heritage and to the development of new research methods in architectural, art historical and archaeological studies.



Generated image based on DKA-047510, illustrating AI robots assisting in the reconstruction of the Inner City Parish Church of Pest

Notes





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