



INSTITUTE OF ARCHEOLOGY  
AND ART HISTORY OF ROMANIAN  
ACADEMY CLUJ-NAPOCA



UNIVERSITATEA TEHNICĂ  
DIN CLUJ-NAPOCA

JAHA  
JOURNAL OF ANCIENT HISTORY  
AND ARCHAEOLOGY

editura  
MEGA

---

# Journal of Ancient History and Archaeology

DOI: <http://dx.doi.org/10.14795/j.v12i4>

ISSN 2360 266x

ISSN-L 2360 266x



Scopus®



Clarivate  
Analytics



Central and Eastern European Online Library

EBSCO



DOAJ  
DIRECTORY OF  
OPEN ACCESS  
JOURNALS

No. 12.4/2025



# CONTENTS

## STUDIES

### ANCIENT HISTORY

#### Ian PLANT

THE EVIDENCE FOR WOMEN'S LITERACY IN ARCHAIC AND CLASSICAL ATHENS ..... 5

#### Osman EMİR, İsmail KÖSE, Yasin TOPALOĞLU

AN EVALUATION OF THE ANCIENT TRAPEZOUS-SATALA ROAD: KARAKABAN ROAD AND ALTERNATIVE ROUTES ..... 26

#### Ovidiu ȚENȚEA, Ioan Carol OPRIȘ

REDISCOVERING SUCIDAVA MOESICA: INSIGHTS FROM RECENT LANDSCAPE ARCHAEOLOGY ..... 42

### ARCHAEOLOGY

#### Marius-Mihai CIUTĂ, Anamaria TUDORIE

BEGINNINGS OF THE NEOLITHIC IN TRANSYLVANIA: A FRAGMENTARY FIGURINE FROM LIMBA-OARDA DE JOS-BORDANE (ALBA COUNTY) ..... 61

#### Zerrin AYDIN TAVUKÇU, Sinem COŞKUN

TRACES OF THE GOD DIONYSUS IN THE SOUTH NECROPOLIS OF TRALLEIS: A TERRACOTTA MASK ..... 76

#### Cristinel PLANTOS

OLD FINDS, NEW INTERPRETATIONS. ABOUT A POSSIBLE HELLENISTIC TYPE BED IN THE LA TÈNE DATE SETTLEMENT AT CRAIVA - PIATRA CRAIVII (ALBA COUNTY) ..... 84

#### Cristina-Georgeta ALEXANDRESCU

INSIDE THE GOVERNOR'S PALACE AT APULUM: A PRELIMINARY STUDY OF SPACE, FUNCTION, AND DECORATIVE EXPRESSION WITH AN EMPHASIS ON MARBLE USE ..... 93

### ARCHAEOLOGICAL MATERIAL

#### Cristian Ioan POPA

THE EPONYMOUS SITE OF THE PETREȘTI CULTURE (I). BALKAN CONNECTIONS OF SOME CERAMIC VESSELS ..... 110

#### Denis TOPAL, Lavinia GRUMEZA

THE MEDUSA-GORGON OF MERENI (REPUBLIC OF MOLDOVA) AND HER MYTH ..... 126

#### Rada VARGA, Claudiu TĂNĂSELIA,

#### Erika Andrea LEVEI

MATERIAL ANALYSIS OF 'BATAVIAN' POTTERY FROM ROMAN DACIA: X-RAY FLUORESCENCE AND GRAPH CLUSTERING ..... 142

#### Abdullah Kasım SONKAYA

NEW INSIGHTS INTO EASTERN LYDIAN SCULPTURE: AN ANALYSIS OF A RECENTLY DISCOVERED MARBLE HECATE STATUETTE FROM THE BLAUNDOS EXCAVATIONS ..... 154

#### Vitalie BÂRCĂ, Cristinel PLANTOS

AN ENAMELLED ZOOMORPHIC BROOCH RECENTLY DISCOVERED IN THE NORTHERN CEMETERY OF APULUM (ALBA IULIA) ..... 164

#### Irina ACHIM, Cătălin PAVEL

VICTORIA-FORTUNA INTAGLIO INSCRIBED "ZOH" FROM CAPIDAVA (SCYTHIA) IN ITS ARCHAEOLOGICAL CONTEXT ..... 177

### ARCHAEOLOGICAL MAPPING

#### Astrid VICAS

MAPPING THE EARLY SPREAD OF COPPER METALLURGY IN EUROPE: PICKING UP GENETIC TRAILS ..... 195

#### Florin-Gheorghe FODOREAN

MAPS OF ROMAN DACIA. VII. ADRIEN-HUBERT BRUÉ (1786-1832) AND 'CARTE DE LA DACIE ANCIENNE DE LA PANNONIE DE L'ILLYRIE ET MOESIE' (1875) ..... 223

### ARCHAEOLOGICAL TOPOGRAPHY

#### Edmond NOGYI

FROM MÁGURA CĂLANULUI TO THE ORĂȘTIE MOUNTAINS: PREDICTING LIMESTONE TRANSPORTATION ROUTES WITH LEAST-COST PATH ANALYSIS ..... 227

### EPIGRAPHY AND PAPHYROLOGY

#### Imre Áron ILLÉS

EPIKLESIS (OGIS 458): RENUNTIATIO OR APPELLATIO? ..... 242

#### Emine HAJDARI, Slavche ATANASOVSKI,

#### Arben HAJDARI

THE SODALES OF THE COLLEGIUM OF MINERVA AND HERCULES IN A RECENT DISCOVERED FUNERARY MONUMENT FROM SCUPI ..... 250

### NUMISMATICS

#### Adela BÂLTĂC, Mihai DIMA

A HOARD FROM THE EARLY 3RD CENTURY AD DISCOVERED IN THE MAIN GATE - MAIN TOWER SECTOR IN HISTRIA (CONSTANȚA COUNTY, ROMANIA) ..... 256

## CULTURAL HERITAGE PROTECTION

## REVIEWS

### **Claudiu PURDEA, Cătălin BORANGIC**

LOST ARTEFACTS: THE CASE OF THE DACIAN SICA WEAPONS  
FROM THE ORĂȘTIE MOUNTAINS ..... 267

### **Sergiu MUSTEAȚĂ**

WORLD HERITAGE SERIAL PROPERTIES: FROM CONCEPTUAL  
FOUNDATIONS TO EFFECTIVE MANAGEMENT. A CRITICAL  
STUDY WITH APPLICATIONS TO ROMANIA ..... 289

### **Victor COJOCARU**

John Ma, *Polis: A New History of the Ancient Greek City-State from  
the Early Iron Age to the End of Antiquity*. Princeton: Princeton  
University Press, 2024. XVIII + 713 pages, 71 illustrations, 1 table,  
and 16 maps integrated into the text ..... 299

Design & layout: Petru Ureche



EDITURA MEGA | [www.edituramega.ro](http://www.edituramega.ro)  
e-mail: [mega@edituramega.ro](mailto:mega@edituramega.ro)

## ARCHAEOLOGICAL MAPPING

---

### MAPPING THE EARLY SPREAD OF COPPER METALLURGY IN EUROPE: PICKING UP GENETIC TRAILS

**Abstract:** This article addresses the diffusion of the early stages of European metallurgy. It suggests a community instrumental to its spread by mapping information from two sets of data: 1) identical by descent (IBD) autosomal chromosome segment sharing among ancient individuals from between around 4300–2000 BCE with individuals from the Chalcolithic buried in the Urziceni, Romania necropolis, a community known to be metallurgically competent, and 2) the location of copper metallurgical activity, copper mines, and selected gold artifacts, mainly in Europe but also in parts of Southwest Asia, in the same time frame. The information collected is consistent with identifying genetic descendants of individuals buried in the Urziceni necropolis as agents of metallurgical activity. The Urziceni necropolis is attributed to the Bodrogkeresztúr archaeological-cultural construct but belongs to the intra-Carpathian range of that culture. The results support formulating further questions concerning traces of metallurgical activity in Europe and parts of Southwest Asia.

**Keywords:** *Maps relating copper metallurgical activity and chromosomal segment sharing among ancient individuals, Agents of early copper metallurgy diffusion in Europe, Intra-Carpathian Bodrogkeresztúr, Cultural implications of ancient DNA information.*

**Astrid VICAS**

Saint Leo University, Florida, USA  
astrid.vicas@saintleo.edu

---

#### INTRODUCTION

The earliest local European development of metallurgy, understood to include knowledge of smelting, occurred in Serbia by the beginning of the fifth millennium BCE.<sup>1</sup> Early metallurgical networks in Europe have received the label of Carpatho-Balkan. The area they cover is variable and expansive. Their most influential formulation in CHERNYKH 1992 as the Carpatho-Balkan Metallurgical Province (CBMP) was framed in terms of archaeological-cultural constructs. CHERNYKH associated the following cultures with the CBMP: Vinča-Pločnik, Butmir, Karanovo VI-Gumelnița, Tiszapolgár-Bodrogkeresztúr, Cucuteni-Trypillia, and, tentatively, Serednii Stih and Khvalynsk,<sup>2</sup> to which he added Sălcuța, Petrești, and Lengyel.<sup>3</sup> The CBMP grew to include yet more Late Neolithic cultural groups of Central and Southeast Europe, such as Sopot, Tisza, and Herpály-Czósshalom.<sup>4</sup> While cultural community and metallurgical province are distinct concepts, CHERNYKH nevertheless believed that the latter could not be isolated from

<sup>1</sup> RADIVOJEVIĆ/ROBERTS 2021b, 603, 605.

<sup>2</sup> CHERNYKH 1992, Fig. 5.

<sup>3</sup> CHERNYKH 1992, 49–50.

<sup>4</sup> CHERNYKH/ORLOVSKA 2015.

the processes of change that affected archaeological cultures and historico-cultural communities.<sup>5</sup>

Previous approaches to charting the spread of the earliest stages of metallurgy in Europe concur that, after the last third of the fifth millennium BCE, its direction of diffusion was westward.<sup>6</sup> A variety of candidate cultures have been proposed to host the westward spread of metallurgy, of which the following is a partial listing: the Moravany-Brodzany, Ludanice, Bajč-Retz/Furtenstrich groups in Slovakia;<sup>7</sup> the Brześć Kujawski culture stemming from Lengyel influence in Poland;<sup>8</sup> the Münchshöfen horizon in Austria and northern Italy and the Mondsee culture in Austria;<sup>9</sup> the Oberpullendorf/Bisamberg culture in Austria;<sup>10</sup> the Schernau-Goldberg culture in Germany;<sup>11</sup> the Münchshöfen/Wallerfing/Epi-Lengyel horizon in Germany;<sup>12</sup> and the Baalberge and Jordanów cultures in Germany.<sup>13</sup> The presence of early metal finds in Late Neolithic France is attributed to the westward transfer of metallurgical knowledge via the Square-Mouthed Pottery culture of northern Italy from Epi-Lengyel communities encompassing Münchshöfen, Lasinja, and Jordanów cultures.<sup>14</sup>

Assessments about whether some copper finds provide evidence of local metallurgical capability, including smelting, vary. It was opined that Münchshöfen-related metallurgy in Keutschacher See and Mondsee culture-related metallurgy, both in Austria, and Baalberge-related Makotřasy metallurgy in Czechia were local and indigenous.<sup>15</sup> Funnel Beaker culture-related finds of crucibles and possible tuyères in Lønt, Denmark, are considered evidence of indigenous production.<sup>16</sup> While it has been suggested that the spread of metallurgy to Poland and northern Europe was due to Baden culture bearers,<sup>17</sup> even though Baden culture is too late by several centuries to explain the spread of metallurgy northward into Denmark, now dated to around 3800–3500 BCE,<sup>18</sup> a more established view is that the CBMP had a northern Polish-Slovak-Czech zone that had developed local metallurgy.<sup>19</sup> More recently, finds from Poland ranging from the Brześć Kujawski to the Funnel Beaker cultures are attributed to Lengyel and Tisza sources.<sup>20</sup>

This survey of the proposed agents of metallurgical activity in North and West Europe gives a sense of the diversity claimed for local and indigenous metallurgical

activity in Europe in the fifth to fourth millennia BCE. The cultures with which the spread of metallurgy to Western Europe is associated belong, for the most part, to the Lengyel and Epi-Lengyel horizon, the Funnel Beaker culture and its variants, and occasionally the Michelsberg culture, but also the Tisza culture.

Assessments of indigeneity undergo continuous revision as it has been suggested that the Mondsee copper is not local to the eastern Alps but comes from an as yet unidentified source in Southeast Europe, most likely Serbia.<sup>21</sup> Moreover, as copper objects, especially from North Central Europe and South Scandinavia, are analyzed anew, further suggestions for a temporal progression of the spread of metallurgy arise. BROZIO *et alii* 2023 have proposed the following temporal stages based on lead isotope analyses: approximately 4000–3500 BCE, a period in which the most likely sources of copper are still in southeastern Europe, most notably Serbia; approximately 3500–3000/2800 BCE, a period in which the Slovak Ore Mountains and the eastern Alpine region join Serbia as sources; approximately 2800–2300/2000 BCE, a period in which the sources are the Slovak Ore Mountains and the western Alps of northern Italy; and post-2000 BCE, a period in which the Alps of northern Italy and the Great Orme mine in Wales are probable sources of copper, but which does not exclude an Iberian source.<sup>22</sup> The period between 3300–2800 BCE of low to little metallurgical activity is attributed to the disintegration of the copper supply network in Southeast Europe, dated to 3700–3200 BCE and offset by sourcing from Slovakia and the eastern Alps in Austria and northern Italy.<sup>23</sup>

Southeast European ores are represented preponderantly by Serbian<sup>24</sup> or Bulgarian sources.<sup>25</sup> The availability of sampled ores and artifacts for analysis affects the assessment of provenience.<sup>26</sup> For instance, early metallurgy in Brixlegg, Austria, is attributed to the Epi-Lengyel Münchshöfen culture, but the provenience of the copper is attributed to a Serbian source.<sup>27</sup> This solution combines local cultural production with non-local sourcing, which also appears to be operative in the proposed temporal progression of metallurgy in Western Europe. There are few studies of the metallurgically-rich areas of the intra-Carpathian zone, although there are some compositional analyses.<sup>28</sup> As more information could be acquired in the future, assessments of provenience may be further refined since they are impacted by the location of sampled ores.

Finally, it has been recognized that Bell Beaker culture bearers have no particular relation to the spread of metallurgy,<sup>29</sup> although metallurgical activity in the fourth

<sup>5</sup> CHERNYKH 1992, 12.

<sup>6</sup> MATUSCHIK 1998; MERKL/STEINIGER/STRAHM 2013; STRAHM 2005; STRAHM 2007; ROUSSOT-LARROQUE 2008; PÉTREQUIN/KLASSEN/CASSEN 2012; DOLFINI 2013; ROSENSTOCK/SCHARL/SCHIER 2016; HEYD/WALKER 2015.

<sup>7</sup> SCHREINER/HEYD/PERNICKA 2012, 357.

<sup>8</sup> WILK, 2018, 486.

<sup>9</sup> TURCK 2010, 20, 23, 37ff.

<sup>10</sup> TURCK 2010, 27, 29.

<sup>11</sup> TURCK 2010, 22.

<sup>12</sup> TURCK 2010, 27.

<sup>13</sup> TURCK 2010, 53ff.

<sup>14</sup> ROUSSOT-LARROQUE 2008, 120.

<sup>15</sup> TURCK 2010, 33–36, 41.

<sup>16</sup> GEBAUER *et alii* 2021.

<sup>17</sup> KOWALSKI *et alii* 2019.

<sup>18</sup> GEBAUER *et alii* 2021.

<sup>19</sup> MATUSCHIK 1998, 245.

<sup>20</sup> ZURKIEWICZ *et alii* 2023, 9.

<sup>21</sup> FRANK/PERNICKA 2012, 132, following HÖPPNER *et alii* 2005.

<sup>22</sup> BROZIO *et alii* 2023, 6/30–13/30.

<sup>23</sup> BROZIO *et alii* 2023, 19/30.

<sup>24</sup> PERNICKA *et alii* 1993; RADIVOJEVIĆ/GRUJIĆ 2017, Supplement; RADIVOJEVIĆ/ROBERTS 2021b.

<sup>25</sup> STOS-GALE/GALE 2009.

<sup>26</sup> A newer database, GlobaLID, could remedy the issue in the future. See WESTNER *et alii* 2021.

<sup>27</sup> HÖPPNER *et alii* 2005.

<sup>28</sup> LAZAROVICI/LAZAROVICI/CONSTANTINESCU 2015; MAREŞ/URSU 2002.

<sup>29</sup> MERKL 2010.

period identified in BROZIO *et alii* 2023 is associated with Bell Beaker culture, and it is generally believed that there was no metallurgy in the British Isles before the arrival of Bell Beaker culture bearers.<sup>30</sup>

Overall, there is agreement that metallurgy in Western Europe spread from Southeast Europe or the Carpatho-Balkan Metallurgical Province. Generally, the trend noted is a shift westward as metallurgy in the Balkans and the Carpathians receded.<sup>31</sup> Several locations in Central and Northwest Europe are thought to give evidence of native metallurgy. Bodrogkeresztúr culture, when noted, is mentioned as one amongst several metallurgically capable communities, as it is in CHERNYKH 1992. In some cases, it is restricted to Serbia.<sup>32</sup> Otherwise, it is identified as diffusing from East Hungary westward.<sup>33</sup>

Overlapping with the expansive attribution of source cultures involved in the transmission of metallurgy is the problem of conceptualizing the transmission of metallurgical know-how. ROGERS 1983 (1962) is cited in this regard,<sup>34</sup> notwithstanding that Rogers's model was developed to conceptualize phases in the consumer adoption of innovation in post-industrial societies. One of the issues with drawing on Rogers's model is that, in its early stage, before know-how is sufficiently widespread for reverse engineering, metallurgy requires face-to-face coordinated interaction, as experimental archaeology has brought to light.<sup>35</sup>

Barring other evidence, the implicit baseline assumption that one can infer from the literature is that early metallurgy is associated with the historical-cultural entities identified as occupying the territory in which its traces were found. Another assumption is that the spread occurred by contiguity, where neighboring communities/cultures learned metallurgy by social contact. Sometimes, what that contact might have been is construed in light of the consumer adoption of innovation.

Some have posed the question of whether there could have been specific factors tied to unique historical events explaining the westward movement of metallurgy.<sup>36</sup> That is a large question, the answer to which requires building up pieces of evidence.

Useful evidence can include identical by descent (IBD) tracts of DNA shared among ancient individuals described as belonging to cultural archaeological communities. This article provides visual representations exemplifying IBD segment-sharing information and information concerning mostly evidence of copper metallurgy. The initial purpose was to address whether the agents of the early westward diffusion of metallurgical capability in Europe could be identified with greater accuracy. The findings raise additional results and possible future questions to address.

<sup>30</sup> CASE 1966; BUDD *et alii* 1992; TIMBERLAKE 2009.

<sup>31</sup> ROSENSTOCK/SCHARL/SCHIER 2016, 93; BROZIO *et alii* 2023.

<sup>32</sup> RADIVOJEVIĆ/ROBERTS 2021a; RADIVOJEVIĆ/GRUJIĆ 2017, Supplement.

<sup>33</sup> PÉTREQUIN/KLASSEN/CASSEN 2012, 1302–1303.

<sup>34</sup> ROSENSTOCK/SCHARL/SCHIER 2016; SCHARL 2016; KLIMSCHA 2017.

<sup>35</sup> HEEB 2014, 107.

<sup>36</sup> HEYD/WALKER 2015, 379.

## OBJECTIVE OF THE ARTICLE

The goal of the project is to provide visual representations combining evidence of copper activity—such as slags, crucibles, and tuyères—and mines, mostly in Europe, and selected gold artifact finds between around 4300–2000 BCE and ancient individuals from which DNA has been collected. The individuals retained have two properties in common: they are dated to the same time frame, that is, around 4300–2000 BCE, and share IBD tracts with individuals from a community that was known to be metallurgically capable, buried in the necropolis at Urziceni, in Northwest Romania. Individuals who share chromosomal IBD tracts are genetically related.

The Chalcolithic Urziceni individuals are classified with the Bodrogkeresztúr cultural-archaeological label. The Urziceni necropolis is dated to around 4300–4000 BCE.<sup>37</sup> Grave goods such as obsidian sourced from Southeast Slovakia show that the individuals buried in this necropolis were familiar with resource-rich sites in Slovakia.<sup>38</sup> Moreover, the activity of Bodrogkeresztúr and the temporally overlapping Tiszapolgár culture bearers extended broadly in an area covering all of Northwest and Central Romania, including the intra-Carpathian bent.<sup>39</sup> Northwest Serbia was the southwesternmost tip of the range over which Bodrogkeresztúr culture bearers were known to be active.

Methods of identifying shared segments of autosomal DNA between ancient individuals descended from common ancestors have been applied to several thousand ancient Eurasian genomes.<sup>40</sup> These methods are presented as suitable for identifying shared segments to a cut-off point of 2 centiMorgans (cM) in ARIANO *et alii* 2022, 8 cM in RINGBAUER *et alii* 2023, and 12 cM in RINGBAUER *et alii* 2024, reflecting differences in methodology and reporting choices. Samples sharing IBD segments with Urziceni individuals reported in those sources down to the cut-off date of 2000 BCE are used here. Two hundred six samples sharing IBD segments with 31 individuals from the Urziceni necropolis and dated to between 4300–2000 BCE in the supplements to ARIANO *et alii* 2022, RINGBAUER *et alii* 2023, and RINGBAUER *et alii* 2024 are included in this project.<sup>41</sup>

The approximately 4300–2000 BCE time frame reflects the availability of geolocation information for both of copper metallurgical activity and individuals who share IBD segments with Urziceni necropolis samples from the Chalcolithic. The beginning anchor date, approximately 4300 BCE, represents the time frame at which the Bodrogkeresztúr archaeological label is meaningful. It is not applied after around 3800–3700 BCE.<sup>42</sup>

<sup>37</sup> ZSÜCS-CSILLIK/VIRAG 2016.

<sup>38</sup> BORONEANȚ *et alii* 2018.

<sup>39</sup> DIACONESCU 2009; DIACONESCU 2014; LUCA 1999; LUCA 2000; MAREȘ/URSU 2002; ROMAN 1971.

<sup>40</sup> 258 samples in ARIANO *et alii* 2022, Supplementary Data; 4,274 samples in RINGBAUER *et alii* 2023, B\_Results.IBD\_Published; and 4,248 in RINGBAUER *et alii* 2024, Table2\_Results.IBD\_Published.

<sup>41</sup> Low-coverage sample Urziceni I18117\_d from RINGBAUER *et alii* 2024 is excluded.

<sup>42</sup> ROTEA *et alii* 2023, 15.

Since the number of individuals associated with metallurgy is small, one would not expect them to have left a substantial genetic footprint. Nevertheless, detecting traces of genetic presence can yield possible new directions to explore, one of the most significant uses of ancient DNA information. The identification of IBD tracts is more reliable in samples with higher coverage. Nevertheless, information about both higher and lower coverage samples is illustrated. The 31 Urziceni samples retained have high coverage. However, 15% of the samples that share IBD tracts with Urziceni individuals in ARIANO *et alii* 2022 and 33% of samples in RINGBAUER *et alii* 2023 have lower coverage. Lower coverage samples are retained for mapping, although they are distinguished in Figs. 1a and 1b. The data is mapped by time transects suggested in BROZIO *et alii* 2023, that is, 4000 BCE or before—but not antedating the Urziceni samples—to 3500 BCE, 3500 BCE to 2800 BCE, and 2800 BCE to 2000 BCE (Figs. 1b, 2b, 3, 4, and 5). Because the dating of evidence of metallurgical activity and mines can be very broad, they may straddle more than one transect. Hence, a map showing all data (Figs. 2a and 2b) provides an overview of the distribution of ancient DNA samples with respect to evidence of metallurgical activity and mines. Sample information is collected in the Supplement to this article.

For the sake of mapping, ancient DNA samples that share identical geographical coordinates are represented by a single point on a map. The purpose of the maps is to chart the spatial spread of the samples, not their frequency. The latter can be misleading since some locations, such as northern Europe, have been more intensively studied, and others have been more heavily sampled for forensic reasons. Moreover, where a higher and lower coverage sample share identical geographical coordinates, the higher coverage sample is foregrounded.

The collection of over 10000 ancient Eurasian individuals whose DNA has been published to date does not, on the whole, reflect a program of archaeological research, although a significant part is owed to an interest in the genetic impact of populations of the Eurasian steppes. The British Isles have also been well sampled. Thus, the availability of information varies by location. Among the 206 samples in the collection retained for IBD links to Urziceni individuals, some sample locations, especially in Croatia, are strongly represented because of an interest in mass graves with evidence of violent death. Others, as in Ireland, are owed to an interest in monumental graves. However, no ancient DNA sampling has focused on the issue of the transmission of metallurgy. Finding information that may be relevant to the early spread of metallurgy in Europe from this collection is noteworthy.

Information not presented in the maps because it pertains to individuals ancestral to the Urziceni samples concerns the filiation through which metallurgical competency could have been transmitted to the intra-Carpathian Tiszapolgár-Bodrogheresztúr group. Both the ARIANO *et alii* 2022 and RINGBAUER *et alii* 2023 datasets show that there is IBD-segment sharing with individuals from Chalcolithic Bulgaria.<sup>43</sup>

<sup>43</sup> Samples I2424 from Smyadovo, I2509 from Veliko Tarnovo, I2427 from Sushina, and I2431 from Ivanovo (MATHIESON *et alii* 2018).

They belong to the Kodjadermen-Gumelnița-Karanovo VI complex, a likely source of metallurgical know-how that made its way northwestward into the intra-Carpathian zone. As of this writing, there are no ancient DNA samples from Sălcuța culture bearers of the Tiszapolgár/Bodrogheresztúr contact period. IBD tract-sharing with individuals of the Kodjadermen-Gumelnița-Karanovo VI complex implies that the latter are perhaps not mere proxies for the more geographically and temporally closer and archaeologically relevant Sălcuța culture bearers.<sup>44</sup>

## THE ANCIENT DNA SAMPLES BY LOCATION AND EVIDENCE OF METALLURGY

The locations of IBD samples suggest that Urziceni-related presence extended beyond areas usually discussed in the spread of early metallurgy, that is, Central Europe, the Alps, and northern Europe, although the Pontic-Caspian steppes seem to have been bypassed (Fig. 1). The following subsections provide a summary of the locations of the human samples and, where available, information about burials. They also add information related to copper metallurgy and mines, as well as select instances of gold or other artifacts that could be diagnostic of Urziceni-related presence.

### Central and Southeast Europe

For the time period in consideration and as of this writing, there are few samples other than Urziceni from Romania. Nevertheless, a mid-fourth-millennium BCE individual from Gura Baciului (Fig. 2b, #1) in northwestern Romania with exceptionally high hunter-gatherer admixture shares an IBD segment with a Urziceni sample. She has no apparent relation to metallurgy.<sup>45</sup> Furthermore, IBD sharing information has picked up links with contemporaries or near-contemporaries of Urziceni individuals in Croatia, Serbia, and Hungary.

Contemporaries include victims of mass violence in Potočani, Croatia (Fig. 3, #2).<sup>46</sup> The individuals are ascribed to Lasinja culture, generally thought to be Lengyel-descended, although similarities with Bodrogheresztúr culture are also noted. Lasinja culture is also contemporaneous with the following neighboring cultures and groups: Ludanice, Bisamberg-Oberpullendorf, Münchshöffen, and Bubanj-Hum-Sălcuța.<sup>47</sup> There is no local metallurgy, although there are some metal finds.<sup>48</sup> The site has been extensively researched, and DNA has been extracted from 38 of the 41 victims. Of the 38, 20 share IBD segments with Urziceni

<sup>44</sup> Sălcuța culture bearers would have, in part, descended from Gumelnițans (PĂTROI 2010). Gumelnița admixture in some Bodrogheresztúr individuals is also supported in VICAS 2021a, Appendix, Table 1; VICAS 2021b, Appendix, Table 1; CHINTALAPATI *et alii* 2022, Supplementary File 2, Table E; and SZECSENYI-NAGY *et alii* 2025, Supplementary data 5, Tables 5Ec and 5Ed. This point does not weaken the expectation raised by ROMAN 1971, given stratigraphic evidence and evidence from pottery and burial sites, that a close relationship would have been established between Sălcuța and Bodrogheresztúr culture bearers. Urziceni graves containing Sălcuța-type pottery are identified in SZECSENYI-NAGY *et alii* 2025, Fig. 6.

<sup>45</sup> GONZÁLES-FORTES *et alii* 2017, e4.

<sup>46</sup> NOVAK *et alii* 2021.

<sup>47</sup> ČATAJ 2018, 25, 27.

<sup>48</sup> ČATAJ 2018, 40.

individuals. This suggests geographical proximity without the transfer of technology. A later sample from near Beli Manastir, Croatia (Fig. 4, #3), is from approximately the same area. The description of its burial does not mention metals.<sup>49</sup>

Two samples from Serbia fall within the selected time frame. They both belong to the Tiszapolgár-Bodrogkeresztúr culture from Podlokanj, near the border with Romania and Hungary (Fig. 3, #4). They may be seen as representatives of the southwestern range of Bodrogkeresztúr culture.

Of the samples from Hungary, an individual identified as belonging to the Late Chalcolithic Hunyadialom culture (Fig. 3, #5) has shared IBD links with four Urziceni individuals. This is expected, as Hunyadialom was considered in the older literature a successor culture to Bodrogkeresztúr.<sup>50</sup> A few more samples from Hungary belong to Balaton-Lasinja, Protoboleráz, and Late Chalcolithic Baden cultures, the first being contemporaneous with Bodrogkeresztúr. The Balaton-Lasinja individuals were buried with typical pots for the culture (Fig. 3, #6, #7).<sup>51</sup> The description of the Protoboleráz burials (Fig. 3, #8) makes no mention of copper objects or evidence of metallurgy.<sup>52</sup> There are several Baden culture individuals from cemeteries in which copper grave artifacts have been recovered, and one of them is buried with a copper chisel (Fig. 4, #9, #10, #11, #13).<sup>53</sup> A Late Baden individual was buried in a tumulus and belonged to the Viss group (Fig. 4, #12). There were no copper objects reported on the mound burial site.<sup>54</sup> The Great Hungarian Plain, not known to harbor significant copper ore resources, might have been a transit area for individuals with Urziceni IBD links (Fig. 2a).

### Southwest Ukraine

The individuals from the Cututeni-Trypillia culture, whose remains were found in the Vertebe Cave in southwestern Ukraine, represent the easternmost incidence of Chalcolithic Urziceni relatedness in the fourth millennium BCE. No information specific to the samples, which are of low coverage (Fig. 3, #14), is recorded.<sup>55</sup>

### South Russia

In the retained time frame, there is a Urziceni-related individual in South Russia. He belongs to the Kalmykia Yamnaya culture of the Early Bronze Age. The sample, for which there is otherwise no description, has low coverage (Fig. 5, #107).<sup>56</sup> Despite the attention given to sampling the Pontic-Caspian steppes, the paucity of evidence for a northeastward dispersion of Urziceni descendants is notable (Fig. 1a).

<sup>49</sup> MATHIESON *et alii* 2018, Supplementary information, 18–19.

<sup>50</sup> BOGNÁR-KUTZIAN 1972. Nevertheless, according to the calibrated radiocarbon date of the Hunyadialom sample, it is contemporary with Bodrogkeresztúr.

<sup>51</sup> LIPSON *et alii* 2017, Supplementary information, 9.

<sup>52</sup> LIPSON *et alii* 2017, Supplementary information, 15, 30–32.

<sup>53</sup> LIPSON *et alii* 2017, Supplementary information, 31–33; BONDÁR 2019, Table 1, 32, Balatonlelle-Felső-Gamász; GAMBA *et alii* 2014; MATHIESON *et alii* 2015.

<sup>54</sup> OLALDE *et alii* 2018, Supplementary information, 137–138.

<sup>55</sup> GELABERT *et alii* 2022.

<sup>56</sup> ALLENTOFT *et alii* 2015.

### North Central Europe

North-Central Europe would be the core area of diffusion, as this area contains a greater number of sites proposed for indigenous metallurgy. It is also an area in which metal finds have been assiduously documented.<sup>57</sup>

There is no ancient DNA sample from Slovakia from the relevant time frame. The same can be said for Austria. A sampling program aimed at understanding the early spread of metallurgy would have included these areas.

Samples from Poland and Czechia constitute about 14% of the individuals sharing IBD tracts with Urziceni. Of the 13 samples from Poland, 46% are characterized as being from the Brześć Kujawski Group of the Lengyel culture in Konary and Osłonki (Fig. 3, #15, #16), the rest being from the Funnel Beaker culture in Pikutkowo (Fig. 3, #17), and the Globular Amphora culture in Koszyce and Wilczyce (Fig. 4, #18, #19). The burials of the Brześć Kujawski and the Funnel Beaker individuals with Urziceni IBD segment sharing have no distinguishing characteristics.<sup>58</sup> Interest in massacres prompted a relatively large collection of samples from a mass grave in Koszyce dating to the Globular Amphora culture. Four of the 15 victims share IBD tracts with Urziceni individuals. They are described as being part of an extended family group. The Globular Amphora individual buried as part of a group in Wilczyce shared the same type of burial goods, Złota group type ceramic vessels, as the other individuals.<sup>59</sup> Finally, an individual described as belonging to Bell Beaker culture in Kornice (Fig. 5, #20) is related to other individuals from the site, and no distinguishing characteristics are noted.<sup>60</sup>

Recent studies have brought to light a variety of locations that give evidence of metallurgical activity. The Brześć Kujawski finds are the earliest. The Lublin-Volhynia finds at Złota-Grodzisko (Fig. 2b, #113) are dated to 4300/4200–3800 BCE, the same time frame as for a tuyère found at Kotowo (Fig. 2b, #114). The Funnel Beaker Culture finds at Gródek Nadbużny (Fig. 2b, #127) are dated to 3513–3372 cal BCE, those at Ćmielów (Fig. 2b, #116) are dated to 3600–3400 BCE, while the finds from Janówek (Fig. 2b, #128) are dated to 3400–2700 BCE.<sup>61</sup> Given the presence of Urziceni-related individuals in the 4300–3500 BCE and 3500–2800 BCE transects (Figs. 3 and 4), Urziceni-related descendants may be plausibly inferred to have been agents of change in the adoption of metallurgy in this area.

The same might be said of Czechia. Of the 16 samples from Czechia, the largest pre-Corded Ware subset is described as belonging to the Baalberge group of the Funnel Beaker culture, including samples from Makotřasy (Fig. 3, #21), the latter sharing IBD tracts with five Urziceni individuals, Bílina (Fig. 3, #24), Březno u Loun (Fig. 3, #26), and Kolín-Štářalka (Fig. 3, #25). The rest of the IBD samples are attributed to Jordanów culture in Tuchoměřice and Neratovice (Fig. 3, #22, #23) and Globular Amphora culture in Blšany and Předměřice (Fig. 4, #28, #29). Late samples near the cut-off

<sup>57</sup> SCHAUER *et alii* 2021.

<sup>58</sup> FERNANDES *et alii* 2018, Supplementary information, 6–7.

<sup>59</sup> SCHROEDER *et alii* 2019, Supplementary information, 5–6/25.

<sup>60</sup> OLALDE *et alii* 2018, Supplementary data.

<sup>61</sup> ZURKIEWICZ *et alii* 2023.

date are described as belonging to Corded Ware, Bell Beaker, or Únetiče cultures (Fig. 5, #30–#34). Of the three Funnel Beaker-affiliated burials in Makotřasy, one was found in an enclosure interpreted as a cult feature, and the second in a ditch at the entrance of the enclosure containing several individuals described as resting in mostly non-reverential positions. The third was the skull of an infant and is without further description.<sup>62</sup> The other samples show no distinctive characteristics.<sup>63</sup> An individual in Louny (Fig. 4, #27), initially described as being from Late Hallstatt but redated to the Baalberge period, is buried without grave goods and is without otherwise distinctive characteristics.<sup>64</sup>

Makotřasy is a location that shows metallurgical activity in the earliest time transect, and it is also plausible to infer Urziceni-related agency in metallurgical activity in the area.

In Germany, only samples near the cut-off point for dates in shared IBD segments with Urziceni individuals are available. One sample, from Southwest Germany, is described as belonging to the Early Bronze Age Singen culture (Fig. 5, #35).<sup>65</sup> It is the only one among eleven Singen burials to show Urziceni relatedness. The other sample is from Alburg-Lerchenhaid, Bavaria, and is buried with Bell Beaker artifacts (Fig. 5, #36).<sup>66</sup> Southern Germany may have been a transit area for individuals bearing Urziceni-related ancestry.

### Scandinavia

An individual from Kyndeløse, Denmark, belongs to the relevant time frame, although he has low coverage and is from the most recent time transect (Fig. 5, #37).<sup>67</sup> He was buried in a passage grave.<sup>68</sup> An interest in megalithic structures has also uncovered remains from a collective passage grave in Gökhem, Sweden, belonging to the Funnel Beaker culture in the second transect (Fig. 4, #38), which brings to light the northern extension of European Farmer cultures.<sup>69</sup> Interest in megalithic burials has, moreover, directed attention to a dolmen burial at Ansarve, Sweden; two samples tested showed evidence of a farmer lifestyle (Fig. 4, #39), and the third, of a mixed diet incorporating marine sources (Fig. 5, #39). The location, the island of Gotland in the Baltic Sea, presents the northeasternmost extension of the Funnel Beaker culture.<sup>70</sup>

A crucible in Lønt, Denmark, with Funnel Beaker pottery dated to around 3800–3500 BCE (Fig. 2b, #119), provides evidence that metallurgically capable individuals were active in Denmark.<sup>71</sup> While the source of the copper used in Scandinavia has not been found, it is believed to be likely central European, Czechia, South Poland, and Central

Germany being candidate sources.<sup>72</sup> It is also believed that metallurgy in the region was part of a cultural network tying Denmark to Baalberge and Michelsberg cultures.<sup>73</sup> Given the presence of Urziceni-descended individuals in Poland and Czechia, it is possible that the areas represented by the latter two countries are the strongest candidate sources for the spread of metallurgical activity in the Funnel Beaker period in Denmark (Fig. 2a).

### Italy

Seven percent of the ancient DNA samples with IBD links to Urziceni are from Italy. IBD sharing identifies a low-coverage individual from Remedello, Brescia, belonging to the Remedello Copper Age culture in Lombardy (Fig. 4, #43), who shares IBD segments with three Urziceni individuals. IBD sharing also includes the Iceman (Fig. 3, #44). Although the sample is contaminated, its discovery uncovered the best-preserved copper chisel to date.<sup>74</sup> A majority of IBD-sharing samples are from Sardinia from the fourth to second millennia BCE. They are from Carbonia in Southwest Sardinia (Fig. 4, #41) and Serra Crabiles (Fig. 5, #45, #47), Su Crussifiso Manu (Fig. 5, #46), and Anghelu Ruju (Figs. 3 and 5, #40) in Northwest Sardinia. The Su Crussifiso Manu and Serra Crabiles samples are ascribed to Monte Claro culture.<sup>75</sup> The concentration of Sardinian samples might reflect better sampling, with Sardinia representing 69% of the samples from Italy. Nevertheless, Grotta Continenza in Central Italy is also represented (Figs. 2b and 4, #42).<sup>76</sup>

Local metal use occurred in the late/final Neolithic, dated to around 4500–3600 cal BCE, mostly concentrated in northern Italy at sites such as Botteghino (Fig. 2b, #124). Copper slags were found at Orti Bottagone (Fig. 2b, #126). It has been argued that the dating is comparable to the copper finds at Brixlegg (Fig. 2b, #123), in the northeastern Alps, which suggests a simultaneous diffusion both north and south of the Alps as early as the last quarter of the fifth millennium BCE from a North Central Balkan or Carpathian source, extending further into Central Italy and Sardinia.<sup>77</sup> Advances in metallurgical techniques are thought to be owed to Alpine smiths of the Copper Age, defined as approximately 3600–3000 cal BCE. Tuscan metalworkers are believed to have been instrumental in transmitting metallurgy further west.<sup>78</sup> While Neolithic traces of metallurgy are viewed as being of external provenience, metallurgy in Italy between 3600–2200 BCE is analyzed into three exchange networks: the first included the northeastern Alps, East-Central Europe, and the Balkans; the second, the middle and upper Tyrrhenian region, the western Alps, and the French Midi; and the third, the southeastern Alps and northeastern Italy.<sup>79</sup> The

<sup>62</sup> PAPANICOLAOU *et alii* 2021, Supplementary materials, 28/100, 30/100.

<sup>63</sup> PAPANICOLAOU *et alii* 2021, Supplementary materials; PATTERSON *et alii* 2022, Supplementary information. NARASIMHAN *et alii* 2019, Supplementary material.

<sup>64</sup> PATTERSON *et alii* 2022, Supplementary information, 21.

<sup>65</sup> FURTWÄNGLER *et alii* 2020.

<sup>66</sup> OLALDE *et alii* 2018, Supplementary information, 37–38.

<sup>67</sup> ALLENTOFT *et alii* 2015.

<sup>68</sup> MALMSTRÖM *et alii* 2019.

<sup>69</sup> SKOGLUND *et alii* 2014, Supplementary material, 18.

<sup>70</sup> SÁNCHEZ-QUINTO *et alii* 2019, Supplement, 15–17.

<sup>71</sup> GEBAUER *et alii* 2021, 2/21.

<sup>72</sup> GEBAUER *et alii* 2021, 13–14/21.

<sup>73</sup> GEBAUER *et alii* 2021, 15/21.

<sup>74</sup> KELLER *et alii* 2012.

<sup>75</sup> MARCUS *et alii* 2020, Supplementary information, 4; FERNANDES *et alii* 2020, Supplementary information, 11–13.

<sup>76</sup> ANTONIO *et alii* 2019, Supplementary information, 34–35.

<sup>77</sup> DOLFINI 2013, 27–28, 41, 43, Fig. 11.

<sup>78</sup> DOLFINI 2013, 47.

<sup>79</sup> DOLFINI/ANGELINI/ARTIOLI 2020, 28/35.

presence of Urziceni-related descendants in these areas (Fig. 2b, #123–140; Fig. 4, #167; Fig. 5, #167–#169) could support their involvement in shared metallurgical activities.

## Malta

Three genomes belonging to a small ancestral population on the isolated island of Gozo<sup>80</sup> show Urziceni relatedness (Fig. 5, #48).

## France

Individuals from France who share IBD segments with Urziceni samples represent around 5% of the 206 ancient individuals retained. All of the samples have low coverage. They are from burials in the Paris Basin, Mont-Aimé, (Fig. 4, #51) and mostly from South France east of Toulouse: Grotte du Rouquet (Fig. 4, #50), sharing IBD tracts with four Urziceni samples, Dolmen des Peirières (Fig. 4, #52),<sup>81</sup> and Grotte Basse de la Vigne Perdue (Fig. 5, #53). The Grotte du Rouquet dates from the Languedocian Late Neolithic to the Early to Middle Vézaza culture. One of the individuals from the Grotte Basse de la Vigne Perdue is identified as probably belonging to the Chalcolithic Vézaza culture.<sup>82</sup> The burial rite in all locations indicates a strongly patrilineal society in which the predominant male lineage is of Western Hunter-Gatherer origin.<sup>83</sup> None of the individuals are described as buried with copper items, except the individuals from Grotte Basse de la Vigne Perdue.<sup>84</sup> An early IBD sample is included from the Hauts-de-France (Fig. 3, #49). It is a Middle Neolithic individual associated with the Michelsberg culture from a region with a high maternal hunter-gatherer contribution.<sup>85</sup> The fact that the samples identified as having distant Urziceni relatedness are buried as locals and in locations reserved for resident patrilineal could suggest that these individuals were well integrated into the local communities.

The gold artifacts at Pauilhac (Fig. 2b, #161) in Southwest France have received special attention. They are dated to the first half or the middle of the fourth millennium BCE and have been attributed to contact with Epi-Lengyel communities via the intermediate agency of the Square-Mouthed Pottery culture of northern Italy.<sup>86</sup> Nevertheless, the silver composition by weight of what is interpreted to be a gold diadem but looks like the template for the gold bird/human hybrids known from Bodrogkeresztúr culture is compatible with placer gold sourced from Valea Arieşului and Valea Pianului in northwestern Romania,<sup>87</sup> although this fact is not determinative. The presence of possible Urziceni-

descended individuals in the Pyrenees and southern France (Figs. 1b, 2b, and 3) makes a Bodrogkeresztúr attribution more plausible than it might otherwise be and suggests that incorporating information from ancient individuals with lower coverage may have heuristic value.

## The Aegean and Turkey

The IBD data suggests that Urziceni-related presence may have spread not only westward but also, albeit to a lesser extent, southeastward into the Aegean and Turkey. This was not expected from the bulk of the literature on the spread of metallurgy from the Carpathian region in Europe reviewed in the first section of this article. Nevertheless, the spread of ceramics with disk-shaped applied handles to the Aegean and Turkey has been discussed as reflecting the influence of the late Sălcuța IV-Herculane II-III disk-shaped applied handles horizon, which integrated Bodrogkeresztúr culture contributions.<sup>88</sup>

The oldest sample, dating from the fourth millennium BCE, is from the Alepotrypa Cave, Diros (Fig. 3, #54), in a site containing copper daggers.<sup>89</sup> LEUSCH *et alii* 2015 also mention a silver ring-idol dated to 4500–3200 BCE, although the stratigraphic context is uncertain.<sup>90</sup> Alepotrypa Cave is one of the Aegean sites that give evidence of ceramic fragments with applied disk-shaped handles of the late Sălcuța-Bodrogkeresztúr synthesis.<sup>91</sup> The ring-pendant shape is characteristic of the Carpatho-Balkan Chalcolithic.<sup>92</sup>

Metallurgy has been present in Crete since the Final Neolithic, locally the fourth millennium BCE.<sup>93</sup> The material culture in Crete and the Cyclades remained unchanged between the Final Neolithic and the Early Bronze Age.<sup>94</sup> The sample that shares an IBD tract with a Urziceni individual is from the late third millennium BCE Lasithi, Hagios Charalambos Cave ossuary (Fig. 5, #58).<sup>95</sup> The communal tomb contained gold decorative items that showed greater technical complexity than those from similar periods found elsewhere in Crete. It is not known whether the greater proficiency was due to local specialization or the arrival of foreign specialists.<sup>96</sup>

Metallurgy was present in the Cyclades since the end of the Final Neolithic and the Early Bronze Age.<sup>97</sup> An individual sharing an IBD tract with a Urziceni sample is from the first half of the third millennium BCE in Koufonisi (Fig. 4, #57). The sample has good coverage. Nearby Dhaskalio (Figs. 2b and 5, #150) was a major metal production center of the Early Bronze Age for the Cyclades, predominantly of arsenical copper, yielding substantial finds of metallurgical ceramics, tuyères, and crucible fragments.<sup>98</sup> Kastri, Syros

<sup>80</sup> ARIANO *et alii* 2022, 2671.

<sup>81</sup> BRUNEL *et alii* 2020, Supplementary information, 18/55. The sample from Dolmen des Peirières is categorized as Bell Beaker. See 29/55. It falls on the borderline between this article's second and third transect.

<sup>82</sup> SEGUIN-ORLANDO *et alii* 2021, e4.

<sup>83</sup> SEGUIN-ORLANDO *et alii* 2021, 1075–1978.

<sup>84</sup> SEGUIN-ORLANDO *et alii* 2021, e3–e4.

<sup>85</sup> BRUNEL *et alii* 2020, Fig. S3-1; Supplementary information, 33/55.

<sup>86</sup> ROUSSOT-LARROQUE 2008, 131, 120.

<sup>87</sup> ROUSSOT-LARROQUE 2008, 122. The value cited is 8–10% silver, which is within the range of values for placer gold from Valea Arieşului reported by BUGOI *et alii* 2008, Table 1, and Valea Pianului by CRISTEA 2012, Table 20.

<sup>88</sup> SĂLCEANU 2008, 131–135.

<sup>89</sup> OLALDE *et alii* 2018, Supplementary information, 21.

<sup>90</sup> LEUSCH *et alii* 2015, 357. Since the artifact is made of silver, Alepotrypa Cave is not marked as hosting metallurgical activity on the maps.

<sup>91</sup> SĂLCEANU 2008, 19, 43, 53, 142–143, 207, Table IV.

<sup>92</sup> MARAN 2021, 200.

<sup>93</sup> PAPADATOS 2007.

<sup>94</sup> CLEMENTE *et alii* 2021, Supplemental information, 4.

<sup>95</sup> LAZARIDIS *et alii* 2017, Supplementary information 1.

<sup>96</sup> LEGARRA HERRERO/MARTINÓN-TORRES 2021, 348, 356.

<sup>97</sup> GEORGAKOPOULOU 2007.

<sup>98</sup> RENFREW *et alii* 2022, 28.

(Figs. 2b and 5, #148), Kephala Petras, Crete (Figs. 2b and 5, #149), which show evidence of metallurgy,<sup>99</sup> Diros, Koufonisi, and Dhaskalio are in mutually accessible locations. SÁLCEANU 2008 notes, in addition, finds of pottery fragments with applied disk-shaped handles of the late Sălcută-Bodrogkeresztúr synthesis in various locations of the Peloponnese, the islands of Chios, Euboea, and Lesbos, as well as Kumtepe and Troy in Northwest Turkey.<sup>100</sup>

The fourth-millennium BCE settlement of Çamlıbel Tarlası, Turkey (Fig. 3, #55), yielded a sample of good coverage that shares an IBD segment with a Urziceni individual. The Chalcolithic site, dating from around 3590–3470 cal BCE, presents fragments of copper ore, slags, and crucibles that indicate metallurgical activity.<sup>101</sup> It also provides evidence of pyrotechnical activities, such as the burning of quicklime and charcoal. A feature of the settlement location is the nearby presence of copper ore outcrops. A notable find includes a casting mold for ring-shaped figurines.<sup>102</sup> Çamlıbel Tarlası is a variant of the late Chalcolithic culture of which Alişar Höyük is representative.<sup>103</sup>

Arslantepe, the mid-third-millennium BCE location of a sample of good coverage that shares an IBD tract with a Urziceni individual (Fig. 4, #56), is known for the metallurgical production of copper-nickel-arsenic alloys and a wide-ranging variety of extractive metallurgy from around 3700 BCE onward.<sup>104</sup> It is about 12 km away from the Euphrates and is situated at the juncture of diverse geographical and cultural zones.<sup>105</sup>

## Iberian Peninsula

Twelve percent of the DNA samples are from the Iberian Peninsula. The oldest samples are from locations dispersed throughout the peninsula. They include the Cova de Els Trocs in the Pyrenees (Fig. 3, #59), which in its third and latest period was used for burials,<sup>106</sup> a burial site near Cádiz that is thought to demonstrate social inequality (Fig. 3, #60),<sup>107</sup> a passage grave at La Mina from the beginning of Megalithism in the inner Iberian Peninsula (Fig. 3, #62),<sup>108</sup> and a cave in Lugar do Canto, Portugal (Fig. 3, #61), all of whose occupants presented cranial trauma.<sup>109</sup>

Samples from the second transect cluster in Basque Country or neighboring areas, and include the El Portalón cave,<sup>110</sup> a chamber built into a rock shelter at Las Yurdivas, Álava,<sup>111</sup> the dolmens at Mandubi Zelaia and Gentillari,<sup>112</sup> and the megalithic tomb of Alto de la Huesera<sup>113</sup> (Fig. 4, #65–#69). They are also present in the collective burial site

of Cova dels Galls Carboners, Catalonia (Fig. 4, #70)<sup>114</sup> and from commingled remains in a rock-cut tomb at Cabeço da Arruda and a hypogeum at Monte Canelas, both in Portugal (Fig. 4, #63, #64).<sup>115</sup>

Samples from the third transect include individuals from the north of the peninsula, in the caves of El Portalón and El Mirador (Fig. 5, #65, #74).<sup>116</sup> The Tagus estuary is noted as a source of innovation in the first half of the third millennium BCE.<sup>117</sup> The samples from Portugal are from Lorga da Dine cave (Fig. 5, #72)<sup>118</sup> and Cova da Moura (Fig. 5, #73), whose occupants had spent their early lives elsewhere than in the vicinity of the cave.<sup>119</sup> The south of the peninsula provides an individual from the cave at Sima del Angel (Fig. 5, #71)<sup>120</sup> and an individual from the early Argaric phase of Totana, La Bastida (Fig. 5, #75).<sup>121</sup>

Pre-Bell Beaker metallurgical activity in Iberia dates to the first half of the third millennium BCE. Metallurgical sites in Spain include Cabezo Juré, Valencina de la Concepción, Los Millares, Almizaraque, Cueva del Cañaveralejo, and Las Pilas, which are concentrated in the southern part of the peninsula (Fig. 5, #151–#154, #156, #158). Lugar Viejo III and Bauma del Serrat del Pont (Fig. 5, #155, #157) are in the north.<sup>122</sup> A unique find from Cerro Verdud dated to the first half of the fifth millennium BCE is believed to be evidence of early metallurgy.<sup>123</sup> If so, it would antedate the formation of Bodrogkeresztúr culture. Nevertheless, it remains an isolated find, and its dating has been subject to doubt, so it is not included in the maps.

LULL *et alii* 2011 have likened the metal artifacts and metallurgy of El Argar culture to developments in Southeast Europe, the Carpathian region, and the southern Alpine area, tentatively ascribed to Vučedol and Cetina cultures in the Southwest Balkans, extending into North Italy and the Alps, the Aegean, the Adriatic, and South Italy.<sup>124</sup> The northwestern Iberian Peninsula is the location of the El Milagro and El Aramo copper mines (Fig. 5, #170, #171).<sup>125</sup> In South Portugal, crucibles, tuyères, slags, and prills have been found in Castro de Chibanes, nearby Rotura and Pedrao,<sup>126</sup> and Outerio de Redondo (Fig. 5, #159, #160).<sup>127</sup>

Urziceni-related samples and locations for metallurgy tend to cluster in the north and the south, avoiding the central part of the Iberian Peninsula (Fig. 2b). Samples are mostly taken from rock burials, caves, and dolmens, perhaps reflecting a preference for probing those sites or a higher likelihood of preservation. They would indicate that Urziceni-descended individuals were integrated into the local communities.

<sup>99</sup> GEORGAKOPOULOU 2007, 131; PAPADATOS 2007, 160.

<sup>100</sup> SÁLCEANU 2008, 44–49.

<sup>101</sup> LEHNER/YENER 2014, 542–543.

<sup>102</sup> SCHOOP 2015, 55, 63–64.

<sup>103</sup> SKOURTANIOTI *et alii* 2020, e9.

<sup>104</sup> LEHNER/YENER 2014, 541–542.

<sup>105</sup> SKOURTANIOTI *et alii* 2020, e6.

<sup>106</sup> VILLALBA-MOUÇO *et alii* 2019.

<sup>107</sup> OLALDE *et alii* 2019, Supplementary materials, 20.

<sup>108</sup> HAAK *et alii* 2015, Supplementary information, 28.

<sup>109</sup> MARTINIANO *et alii* 2017, Supplement, Archaeological information.

<sup>110</sup> VALDOSIERA *et alii* 2018, Supplementary information.

<sup>111</sup> LIPSON *et alii* 2017, Supplementary information, 37.

<sup>112</sup> OLALDE *et alii* 2019, Supplementary materials, 41–43.

<sup>113</sup> LIPSON *et alii* 2017, Supplementary information, 35–36.

<sup>114</sup> OLALDE *et alii* 2019, Supplementary materials, 45.

<sup>115</sup> MARTINIANO *et alii* 2017, Supplement, Archaeological information.

<sup>116</sup> MATHIESON *et alii*, 2015, Supplementary information, 5.

<sup>117</sup> MARTINIANO *et alii* 2017, Supplement, Archaeological information.

<sup>118</sup> GONZÁLEZ-FORTES *et alii* 2019, Supplemental material, 5.

<sup>119</sup> MARTINIANO 2017 *et alii*, Supplement, Archaeological information.

<sup>120</sup> OLALDE *et alii* 2019, Supplementary materials, 25–27.

<sup>121</sup> VILLALBA-MOUÇO *et alii* 2021, Supplementary materials, 6/53.

<sup>122</sup> LA DUC *et alii* 2022.

<sup>123</sup> ROVIRA/MONTERO-RUIZ 2013; BARTELHEIM/PEARCE 2015.

<sup>124</sup> LULL *et alii* 2011, 385–386.

<sup>125</sup> VIDAL 2016, Fig. 1.

<sup>126</sup> VALERIO *et alii* 2023.

<sup>127</sup> CARDOSO 2021, 18–19.

## British Isles

The United Kingdom and Ireland have undergone substantial ancient DNA sampling. Samples from this area make up 34% of individuals who share IBD tracts with Urziceni (Fig. 1a). They are from the pre-Beaker period. European Farmers reached the British Isles after around 4000 BCE.<sup>128</sup> Most of the samples retained have no detected relatives in their local burial site, where this has been examined, and show up even in remote areas. Overall, they tend to aggregate in the western part of the British Isles (Figs. 2a, 3, and 4), with the exception of the northern tip of Scotland. There are very few samples in the third transect, as would be expected due to population movements in the Bell Beaker period beginning in the British Isles around 2450 BCE, leading to an approximately 90% population replacement by 1500–1000 BCE,<sup>129</sup> which is outside the period examined in this article.

In Scotland, samples in the first transect, including some from the most ancient Neolithic remains in Britain, are from caves, sometimes secondary burials of excarnated remains, passage tombs, and cairn burials (Fig. 3, #84–#86).<sup>130</sup> The samples from England in this transect, also some of the oldest in Britain, are from caves, long barrow funerary monuments, and chamber graves (Fig. 3, #76–#78, #80–#83), many in privileged locations.<sup>131</sup> The remains of an individual with Urziceni IBD sharing were recovered from a sheltered causeway monument near Brighton (Fig. 3, #82) that was the site of periodical ritual feasts and ceremonies.<sup>132</sup> In some cases, more information about burial and kinship is available. A child whose sample has good coverage is buried in a chambered tomb in Hazelton, Gloucestershire (Fig. 3, #79). He belonged to a male lineage unrelated to most of the individuals in the tomb. It is estimated that he descended from tomb occupants through a maternal line.<sup>133</sup>

Burial sites in Scotland from the second transect can be found as far north as the Orkney Islands and are also from chamber tombs, passage tombs, and cairns throughout northwestern Scotland (Figs. 2b and 4, #94–#101).<sup>134</sup> In the same transect, an individual showing perimortem blunt force trauma to the skull from Rhos Ddigre, Wales (Fig. 4, #93),<sup>135</sup> shares IBD segments with seven Urziceni individuals, although the sample has low coverage.

There are few samples in the last transect. The chamber tomb burial from the Orkney Islands (Fig. 5, #97)<sup>136</sup> is a case in point.

Monumental tombs of Ireland have been well studied and yield 18% of the samples sharing Urziceni IBD tracts. The samples are also mostly from the first and second transects. The oldest ones are from the earliest megalithic tombs in Ireland, including court tombs (Figs. 2b and 3, #87, #89–#91),<sup>137</sup> and the Annagh Cave Linkardstown cist (Fig. 4, #88), in which the individuals buried are probably all male and perhaps related.<sup>138</sup> The second transect includes individuals from elite tombs in Newgrange (Fig. 4, #104), Carrowkeel (Fig. 4, #106), and Millin Bay (Fig. 4, #103),<sup>139</sup> as well as Ardcroney (Fig. 4, #105) and Primrose Grange (Fig. 4, #102).<sup>140</sup> There are few samples in the last transect: Carrowkeel, Ireland (Fig. 5, #106) is a case in point.

The presence of Urziceni-related individuals in socially prominent burials may indicate that they were generally well-integrated into local society in the British Isles.

The consensus is that metallurgy in the British Isles is a Bell Beaker-related phenomenon.<sup>141</sup> Nevertheless, TIMBERLAKE 2009 notes Neolithic and pre-Neolithic activity related to exploring surface exposures of secondary copper minerals, such as at Parys Mountain. Furthermore, he suggests an association between Mesolithic campsites and areas of malachite and azurite extraction on Alderley Edge (Fig. 5, #173). Moreover, it is possible that there was some continuity between stone mining and the extraction of malachite on the Great Orme.<sup>142</sup> Later mining centers, such as Alderley Edge, the Great Orme, and Copa Hill (Fig. 5, #172), are within a five to six-day walking distance from each other. Parys Mountain is less than a three-day traveling distance to the Great Orme and less by sea. All locations mentioned are on the western part of the British Isles. According to BUDD *et alii* 1992, the earliest workings at these sites would have been loosely organized, small-scale exploitations separated by lengthy intervals.<sup>143</sup>

CASE 1966 entertained the possibility that there was a pre-Beaker metallurgy in Ireland that gave rise to the Castletownroche thick-butted axe. Castletownroche is less than a three-day traveling distance from the later Ross Island mine (Fig. 5, #174). According to CASE 1966, Pre-Beaker metallurgy might have hypothetically diffused westward from a Scandinavian source by the Middle Neolithic and ultimately originated in Central Europe. His dismissal of this possibility was based on the lack of similarity with metallurgy from the Fertile Crescent and the Aegean.<sup>144</sup> It was implicitly motivated by the Childean belief, current at the time, that European metallurgy originated in the Fertile Crescent and diffused to Central Europe through the mediating influence of Aegean civilizations.

The relatively strong showing of IBD sharing with Urziceni individuals in the British Isles, even with good coverage

<sup>128</sup> BRACE *et alii* 2019, 1/9.

<sup>129</sup> OLALDE *et alii* 2018, 4.

<sup>130</sup> OLALDE *et alii* 2018, Supplementary information, 55/212, 61–62/212, 64/212.

<sup>131</sup> PATTERSON *et alii* 2021, 65; BRACE *et alii* 2019, 2–3; OLALDE *et alii* 2018, Supplementary information, 95–97/212, 120–121/212; BRACE *et alii* 2019, Supplementary information, 3, 9–10.

<sup>132</sup> OLALDE *et alii* 2018, Supplementary information, 101–103/212.

<sup>133</sup> FOWLER *et alii* 2022, Supplementary information, Supplementary tables.

<sup>134</sup> OLALDE *et alii* 2018, Supplementary information, 54–55/212, 65–67/212, 59–60/212, 56–58/212, 56–57/212, 60–61/212; BRACE *et alii* 2019, Supplementary information, 7–8; DULIAS *et alii* 2022, Supplementary information, 4/61; OLALDE *et alii* 2018, Supplementary information, 54–55/212.

<sup>135</sup> OLALDE *et alii* 2018, Supplementary information, 78/212.

<sup>136</sup> OLALDE *et alii* 2018, Supplementary information, 56–58/212.

<sup>137</sup> CASSIDY *et alii* 2020, Supplementary information, 9–10, 26, 13–14, 12–13.

<sup>138</sup> CASSIDY *et alii* 2020, Supplementary information, 4–5.

<sup>139</sup> CASSIDY *et alii* 2020, Supplementary information, 17–20, 20–21, 21–22.

<sup>140</sup> CASSIDY *et alii* 2020, Supplementary information, 26; SÁNCHEZ-QUINTO *et alii* 2019, Supplement, 9–13.

<sup>141</sup> CASE 1966; TIMBERLAKE 2009.

<sup>142</sup> TIMBERLAKE 2009, 94–97.

<sup>143</sup> BUDD *et alii* 1992, 682–683.

<sup>144</sup> CASE 1966, 142, 144–146, Figs. 2 and 3.

samples, is unexpected. It is partly due to a more substantial sampling of the British Isles. The early appearance of Urziceni-related samples in the British Isles could signal the presence of individuals who did not participate in metallurgy. Alternatively, the case against pre-Beaker metallurgy in the British Isles might warrant cautious re-examination.

## DISCUSSION

Overall, the combination of information available, despite the lack of an archaeogenetic program for collecting ancient DNA to chart relationships among the earliest metallurgical communities in Europe, is compatible with a low-grade spread of metallurgy having had an element of person-to-person contact, traces of which can be tracked by IBD sharing links.

While it was generally supposed that the earliest diffusion of metallurgy westward stemmed from the Carpathian zone, archaeogenetic data helps identify the most likely vector of its north and westward movement. It is the communities that have received the cultural-archaeological label of Bodrogkeresztúr, although from the eastern, intra-Carpathian part of its range. The data from IBD-sharing confirms the expectation that metallurgy was transmitted by agents whose ancestors had had contact and admixed with southeastern European metallurgically capable communities of the Kodjadermen-Gumelnița-Karanovo VI complex, a characterization that fits some of the members who buried their dead in the Urziceni necropolis,<sup>145</sup> beyond the archaeologically attested integration with Sălcuța culture bearers.<sup>146</sup>

Furthermore, where familial groupings of siblings in the Urziceni necropolis could be detected based on genetic analyses, in all cases, the father was missing, and in approximately two-thirds of these groupings, so was the mother. That was not the case among nearby contemporary or near-contemporary Copper Age communities of the Great Hungarian Plain, which, based on burial location and genetic analyses, also exhibited a tight patrilocal and patrilineal organization.<sup>147</sup> The pattern noted may indicate parental migration among the Urziceni Bodrogkeresztúr. This point offers additional support for identifying the Urziceni intra-Carpathian Bodrogkeresztúr as a plausible vector for transmitting metallurgy further westward.

The familiarity of Urziceni individuals with obsidian resources in Southeast Slovakia could have been a factor in the initial stages of their northern displacement. The northward pattern of dispersion of ancient DNA samples from the intra-Carpathian area suggests it was oriented with respect to watercourses or coastal regions (Fig. 1a), reflecting settlement sites and most likely also transportation affordances.

### Discussion by transect

The northern route tracks through metallurgically active locations in Czechia, notably Makotřasy, which are

associated with Jordanów, Baalberge, and Funnel Beaker cultures; and Poland, from sites associated with the Brześć Kujawski Group and Funnel Beaker culture (Figs. 2b and 3). Metallurgy in the Lublin-Volhynia culture and the Wyciąże-Złotniki group, thought to originate from the Tisza River plain,<sup>148</sup> can now be seen as coming from further east. The vector of metallurgical know-how was likely to be Urziceni-related. While metallurgy is attributed to the Brześć Kujawski Group as early as 4500–4300 BCE,<sup>149</sup> the radiocarbon-dated human samples from this group are from between 4335–4058 cal BCE and 4233–3980 cal BCE,<sup>150</sup> which is within the period of activity of the Bodrogkeresztúr metallurgists.

The Funnel Beaker Baalberge Group in Czechia, with substantial metallurgical activity and Urziceni-descendant presence in Makotřasy, is a plausible candidate for the spread of Funnel Beaker-associated metallurgy in Lønt, Denmark (Figs. 2b, 3, and 5). A spread from the Ćmielów Funnel Beaker site, supported by the earlier Brześć Kujawski site belonging to the Lengyel culture in Poland, is also a possibility. These sites coincide with or are situated near locations where Urziceni descendants are detected.

Further west, the presence of a good coverage Urziceni-descended sample in the Pyrenees in the 4300–3500 BCE transect (Fig. 3) might argue that the gold artifact from Pauilhac in southern France, similar to a template for the bird-human hybrid figures typical of Bodrogkeresztúr-related iconography, is attributable to Urziceni-descendant activity. This transect may also show that the presence of a Urziceni-related descendant in Sardinia was early and that the path to the Iberian Peninsula at that stage could have been coastal.

It also suggests that the characteristic Bodrogkeresztúr ring idol-shaped artifact in Çamlıbel Tarlası, Turkey, could owe its source to the presence of Urziceni-related individuals, perhaps via unsampled Late or Post-Sălcuța genetic kin. The same could be said for involvement in silver metallurgy and silver ring-idol-shaped artifacts of the Aegean. MARAN 2021 believes that the silver artifacts of the Alepotrypa Cave should be dated to the first half of the fourth millennium BCE and that they are part of a network of objects and ore processing capabilities that also encompassed Hunyadihalom culture of eastern Hungary, which might antedate silver processing in West Asia and the Caucasus,<sup>151</sup> a view that is compatible with some of the findings in this article.

Finally, the 4300–3500 BCE transect suggests that the path of Urziceni-related individuals to the British Isles at the earliest stage could more likely have been through northern Europe. It tends not to substantiate a well-integrated Carpatho-Balkan Metallurgical Province extending to the Volga,<sup>152</sup> and incorporating the mediation of Skelya steppe communities.<sup>153</sup>

The 3500–2800 BCE transect shows that metallurgical activity that may be correlated with Urziceni-descendant

<sup>148</sup> WILK 2018.

<sup>149</sup> ZURKIEWICZ *et alii* 2023.

<sup>150</sup> FERNANDES *et alii* 2018.

<sup>151</sup> MARAN 2021, 206–207, 213–214.

<sup>152</sup> CHERNIKH, 1992, 50.

<sup>153</sup> RASSAMAKIN 1999, 111–112.

<sup>145</sup> VICAS 2021a; VICAS 2021b; CHINTALAPATI *et alii* 2022; SZECSENYI-NAGY *et alii* 2025.

<sup>146</sup> ROMAN 1971.

<sup>147</sup> SZECSENYI-NAGY *et alii* 2025, 12, Fig. 6.

presence is still detectable in Poland and associated with Funnel Beaker culture, although it is much reduced (Fig. 4). The presence of Urziceni descendants and metallurgical activity shifts to Italy, especially the Alpine region, as seen in the archaeological literature, but also extends to Sardinia and Central Italy and perhaps to South France. Urziceni-related descendants are present in western Iberia and the British Isles, with no corresponding mention of metallurgical activity, although TIMBERLAKE 2009 notes possible exploratory activity in the latter. The Urziceni-descendant presence and metallurgical activity in Arslantepe, Turkey, are significant, as the location hosted a longstanding metallurgical center that also had a record of interaction with Uruk.<sup>154</sup>

The 2800–2000 BCE transect reveals a shift in the presence of Urziceni-related descendants to the Iberian Peninsula, both its eastern and western coasts, and southern France (Fig. 5). For the Iberian Peninsula, a hypothesized similarity between Vučedol culture and El Argar metallurgy that LULL *et alii* 2011 had entertained might reflect a relation with descendants of Urziceni individuals.

Due to the very broad dating of Aegean sites, some locations straddle the last two transects. Grouping the second and third transects, metallurgical activity and Urziceni-descendant presence are represented in the Aegean. Lasithi, Diros, and Dhaskalio, a significant copper production center, share mutually accessible locations (Figs. 1b and 2b). The communal tomb at the Hagios Charalambos Cave ossuary in Lasithi, Crete, contained gold decorative items that LEGARRA HERRERO/MARTINÓN-TORRES 2021 believe might be evidence of foreign specialists.<sup>155</sup>

This transect also suggests that the connection with the Russian steppe was scant. There is only one sample of lower coverage from this area. It does not form part of a trail like lower coverage samples in the westward paths. The lack of an eastward spread through the Pontic-Caspian steppes past Verteba Cave in Southwest Ukraine is striking (Fig. 2b).

### Expectations and avenues of exploration

The fourth millennium BCE presence of Urziceni-related descendants in the Alpine region and Italy is consistent with the belief that metallurgical activity gravitated westward from earlier locations in Central Europe. The third millennium BCE presence of Urziceni-related descendants in southern France, the Iberian Peninsula, and the Aegean in the vicinity of areas that show metallurgical activity or mines calls for further investigation, although the fourth millennium BCE presence of Urziceni-related descendants in the Aegean and Turkey was anticipated by the detection of applied disk-shaped handle pottery in those locations.<sup>156</sup> IBD segment sharing information with pre-Beaker individuals in the British Isles is intriguing. It could suggest that reexamining the case for difficult-to-detect pre-Beaker metallurgy might be warranted.

Finally, beyond the fourth millennium BCE Tripylia individuals buried in Southwest Ukraine, IBD sharing with Urziceni samples in the period examined includes only one individual from the first half of the third millennium BCE in South Russia even though hundreds of copper artifacts were found as far as the Volga in the interval that preceded the abandoning of the Lower Danube Valley settlements, dated to 4250 BCE.<sup>157</sup> Signs of metallurgy in the Middle Volga are only dated to the late fourth millennium BCE and are attributed to a cultural influence from the Caucasus.<sup>158</sup>

Formulating hypotheses about the contrast between the west and southward movement of metallurgically capable Urziceni-descended individuals and the paucity of evidence of a corresponding eastward dispersion through the Pontic-Caspian steppes would call for a more in-depth discussion of differences in social organization, for which contributions from anthropology, as well as further evidence from ancient DNA, could be adduced.

### Preliminary remarks on social dimensions

Central and North Europe, areas that have received much attention in the literature on the spread of metallurgy, were occupied by Epi-Lengyel and Funnel-Beaker-related cultures. All of the individuals retained for mapping and sharing of IBD tracts with Urziceni samples in these areas are identified as belonging to the local cultures. In the archaeological description of burials, where it is available, they do not stand out as foreign or intrusive, even in the few instances where they are identified as outliers in genetic analyses. Genetic outlier status flags a higher farmer or hunter-gatherer admixture than other samples from the same area, something that would not have been visible to contemporaries nor to archaeological examination.

In some cases, genetic descendants of Urziceni individuals faced the same fate as other members of the community with which they were buried: victims of mass violence in a Lasinja culture site in Croatia or a Globular Amphora culture site in Poland. There are instances in Czechia where a Urziceni descendant received special treatment with a negative connotation, as part of a group burial in unusual bodily postures. There is, contrariwise, a positive valence implicitly attached to Urziceni distant descendants being buried in grave complexes thought to be reserved for the elite in France and, especially, the British Isles.

All told, Urziceni-related individuals appear to have assimilated into their host communities and are archaeologically invisible. Nevertheless, as a result of information from ancient DNA, attribution of native metallurgy to Lengyel and Epi-Lengyel communities and their variants extending into Central Europe may be plausibly formulated as metallurgy that developed by incorporating Urziceni-related facilitators and their descendants. The variety of such cultures or horizons that have been entertained for indigenous metallurgy in Central Europe suggests that communities of North and West Europe were open to accepting descendants of skilled newcomers.

<sup>154</sup> LEHNER/YENER 2015, 541.

<sup>155</sup> LEGARRA HERRERO/MARTINÓN-TORRES 2021, 348, 356.

<sup>156</sup> SÁLCEANU 2008.

<sup>157</sup> CHERNYKH/ORLOVSKA 2015; ANTHONY *et alii* 2022.

<sup>158</sup> PETERSON *et alii* 2016, 294.

Beginning in the fifth millennium BCE, Late Neolithic societies north and west of the Carpathian zone underwent an increase in hunter-gatherer admixture.<sup>159</sup> The individual with high hunter-gatherer admixture from Gura Baciului (Fig. 4, #1) might indicate that a similar process affected the intra-Carpathian area. Where there are ample native copper resources, hunter-gatherer social organization appears not to rule out the autonomous development of metalwork, as was the case in the North American Old Copper Complex of the Lake Superior region.<sup>160</sup> In Europe, indigenously initiated hunter-gatherer metalwork has not been reported, not even in the evidence from the British Isles. Moreover, the social organization of hunter-gatherers, with its low division of labor, would not have been amenable to the operations needed to process the sulfide ores of Central Europe.

Nonetheless, such processing occurred. Local Late Neolithic societies experiencing a resurgence of hunter-gatherer admixture or fresh ingress of such admixture may have accepted small metallurgically capable groups of individuals. There had to be enough such individuals to support the coordination and complementation needed for successful smelting. It has been suggested that a migration of metallurgists, if any occurred, could be placed in the context of pre-existing networks of communication,<sup>161</sup> which have been construed in terms of the exchange of Alpine jade axes.<sup>162</sup> Thus, Late Neolithic societies to the north and west of the Carpathian zone could have been amenable to maintaining communication networks with the metallurgically capable groups to which the individuals buried in the Urziceni necropolis belonged. However, an increase in hunter-gatherer admixture may have dampened the local learning of the technology.<sup>163</sup>

Rogers's model of the adoption of innovation, although referenced in discussions of the spread of metallurgy, has limited suitability since it was not intended for the spread of innovation in production. The ability to smelt the fahlores of central European ore deposits could not have been imparted solely through communication, as in storytelling, but was likely to have required apprenticeship, chains of complementary support, and face-to-face coordinated activity.<sup>164</sup> Contiguity with bordering archaeological cultures would not have been enough for initiating capability. Moreover, the Lasinja community in Croatia had genetic links with Urziceni, but there is insufficient evidence that it was metallurgically capable. Thus, a genetic link is not sufficient for transmitting metallurgical capability, as would be expected. It remains plausible that, in the early stages of transmission, it was a necessary condition that at least some metallurgically capable individuals operating collaboratively be physically present to impart their skills.

<sup>159</sup> PAPAC *et alii* 2021.

<sup>160</sup> EBERHARDT 2009.

<sup>161</sup> ROBERTS 2008, 36–37.

<sup>162</sup> PÉTREQUIN/KLASSEN/CASSEN 2012.

<sup>163</sup> A similar trend in the intra-Carpathian zone, as is perhaps suggested by the presence of an individual with high hunter-gatherer admixture at Gura Baciului, might be a factor in the reduced evidence of metallurgy in the early Cotofeni period.

<sup>164</sup> See HEEB 2014, 42–49, 107.

It has, indeed, been proposed that know-how was communicated over great distances by metallurgically capable clans or kinship groups and that metallurgical knowledge was the preserve of specialized lineages,<sup>165</sup> with the probable presupposition that these were male kinship groups. Some further clarification may be pending, as the males buried in the Urziceni necropolis had diverse Y-chromosomal lineages.<sup>166</sup> This point would tend to suggest that metallurgically capable Urziceni-related migrants might not have been organized by patrilineal detectable through Y-chromosome lineages. They may, instead, have been organized around individuals and families that offered complementary skills in support of fuel and materials preparation, smelting, and casting, irrespective of the paternal lines of the male collaborators. The evidence of missing female parents in the Urziceni necropolis would strengthen the hypothesis that women may have contributed to the collaborative work required for successful smelting. In contrast, the patrilocality and patrilineality revealed by the genetic studies of Megalithic societies may have been an added factor in curbing rather than facilitating the early spread of metallurgical competence throughout Europe. It may have impacted early metallurgy in the British Isles. Closer to the point of origin of the Urziceni Bodrogkeresztúr, patrilineality among the Tiszapolgár-Bodrogkeresztúr of Hungary might also have been a factor inversely related to the early adoption of metallurgical capability. Further probing of the social dimensions of the spread of metallurgy is called for.

## CONCLUSION

The purpose of this article was to address whether the agents of the diffusion of metallurgical capability in Europe around and after the last third of the fifth millennium BCE could be identified with greater precision. Ancient IBD information combined with evidence of metallurgical activity in Europe may help identify early agents of change, individuals related to Bodrogkeresztúr communities that buried their dead at Urziceni, and their general path of diffusion. The information also suggests that diffusion resulted from a low-grade displacement of metallurgically capable groups.

This study confirms that the bulk of the initial direction of spread was northward and westward into Central and Northern Europe, followed by movement into the Alpine region, particularly northern Italy. It also supports a connection between the spread of ring-shaped artifacts in the Aegean and Turkey and Urziceni relatedness, as well as a possible Urziceni-descendant presence in southern France, underpinning the presence of a gold artifact that bears similarities with Bodrogkeresztúr iconography.

This article raises the issue of the lack of an eastward spread of the agents of metallurgical knowledge into the Pontic-Caspian steppes in the fifth millennium BCE. Finally, using data about IBD links, this article brings out the relevance of information about a spread of Urziceni-

<sup>165</sup> KIENLIN/PERNICKA 2009, 274; KIENLIN 2016, 132–134; ROWLANDS 1971, 217–218.

<sup>166</sup> LAZARIDIS *et alii* 2022, Supplementary table.

descended individuals to areas thought to be unlikely, such as the Iberian Peninsula, or unexpected, such as the British Isles. Information about the latter may warrant a tentative reopening of the case for pre-Beaker metallurgy in the British Isles or a further examination of the social factors that could have impeded its diffusion.

Drawing on evidence from ancient DNA enables the formulation of new questions. For this reason alone, it offers valuable assistance in enhancing our ability to reconstruct some aspects of significant cultural events and developments. The early stages of the spread of metallurgy in Europe are among such developments. Some of their aspects may be open to constructive reexamination.

## REFERENCES

- ALLENTOFT *et alii* 2015  
Allentoft, M.E./Sikora, M./Sjögren, K.G./Rasmussen, S./Rasmussen, M./Stenderup, J./Damgaard, P.B./Schroeder, H./Ahlström, T./Vinner, L./Malaspinas, A.S./Margaryan, A./Higham, T./Chivall, D./Lynnnerup, N./Harvig, L./Baron, J./Della Casa, P./Dąbrowski, P./Duffy, P.R./.../Willerslev, E., Population genomics of Bronze Age Eurasia, *Nature* 522/7555, 167–172. <https://doi.org/10.1038/nature14507>
- ANTHONY *et alii* 2022  
Anthony, D.W./Khokhlov, A.A./Agapov, S.A./Agapov, D.S./Schulting, R./Olalde, I./Reich, D., The Eneolithic cemetery at Khvalynsk on the Volga River, *Praehistorische Zeitschrift* 97, 22–67. <https://doi.org/10.1515/pz-2022-2034>
- ANTONIO *et alii* 2019  
Antonio, M.L./Gao, Z./Moots, H.M./Lucci, M./Candilio, F./Sawyer, S./Oberreiter, V./Calderon, D./Devitofranceschi, K./Aikens, R.C./Aneli, S./Bartoli, F./Bedini, A./Cheronet, O./Cotter, D.J./Fernandes, D.M./Gasperetti, G./Grifoni, R./Guidi, A./La Pastina, F./.../Pritchard, J.K., Ancient Rome: A genetic crossroads of Europe and the Mediterranean, *Science* 366, 6466, 708–714. <https://doi.org/10.1126/science.aay6826>
- ARIANO *et alii* 2022  
Ariano, B./Mattiangeli, V./Breslin, E.M./Parkinson, E.W./McLaughlin, T.R./Thompson, J.E./Power, R.K./Stock, J.T./Mercieca-Spiteri, B./Stoddart, S./Malone, C./Gopalakrishnan, S./Cassidy, L.M./Bradley, D.G., Ancient Maltese genomes and the genetic geography of Neolithic Europe, *Current Biology* 32/12, 2668–2680.e6. <https://doi.org/10.1016/j.cub.2022.04.069>
- BARTELHEIM/PEARCE 2015  
Bartelheim, M./Pearce, M., Early metallurgy in Iberia and the Western Mediterranean. In: Fowler, C./Harding, J./Hofmann, D. (eds.), *The Oxford Handbook of Neolithic Europe* (Oxford: Oxford University Press), 693–710.
- BRACE *et alii* 2019  
Brace, S./Diekmann, Y./Booth, T.J./van Dorp, L./Faltyskova, Z./Rohland, N./Mallick, S./Olalde, I./Ferry, M./Michel, M./Oppenheimer, J./Broomandkoshbacht, N./Stewardson, K./Martiniiano, R./Walsh, S./Kayser, M./Charlton, S./Hellenthal, G./Armit, I./Schulting, R./.../Barnes, I., Ancient genomes indicate population replacement in Early Neolithic Britain, *Nature Ecology & Evolution* 3/5, 765771. <https://doi.org/10.1038/s41559-019-0871-9>
- BOGNÁR-KUTZIAN 1972  
Bognár-Kutzian, I., *The Early Copper Age Tiszapolgár Culture in the Carpathian Basin*, G. Dienes (trans.) (Budapest: Kiádo).
- BONDÁR 2019  
Bondár, M. *A késő rézkori fémművesség magyarországi emlékei* [Remembrance of Late Copper Age Metalwork in Hungary] (Budapest: Archaeolingua).
- BORONEANȚ *et alii* 2018  
Boroneanț, A./Virag, C./Astaloș, C./Bonsall, C., Sourcing obsidian from prehistoric sites in Northwest Romania, *Materiale si Cercetări Arheologice* (s. n.) 14, 13–23.
- BROZIO *et alii* 2023  
Brozio, J.P./Stos-Gale, Z./Müller, J./Müller-Scheeßel, N./Schultrich, S./Fritsch, B./Jürgens, F./Skorna, H., The origin of Neolithic copper on the central Northern European plain and in Southern Scandinavia: Connectivities on a European scale, *PLoS One* 18/5, e0283007. <https://doi.org/10.1371/journal.pone.0283007>
- BRUNEL *et alii* 2020  
Brunel, S./Bennett, E.A./Cardin, L./Garraud, D./Barrand Emam, H./Beylier, A./Boulestin, B./Chenal, F./Ciesielski, E./Convertini, F./Dedet, B./Desbrosse-Degobertiere, S./Desenne, S./Dubouloz, J./Duday, H./Escalon, G./Fabre, V./Gailledrat, E./Gandelin, M./.../Pruvost, M., Ancient genomes from present-day France unveil 7,000 years of its demographic history, *Proceedings of the National Academy of Sciences USA*, 117/23, 12791–12798. <https://doi.org/10.1073/pnas.1918034117>
- BUDD *et alii* 1992  
Budd, P./Gale, D./Pollard, A./Thomas, R./Williams, P., The early development of metallurgy in the British Isles, *Antiquity* 66/252, 677–686. <https://doi.org/10.1017/S0003598X00039375>
- BUGOI *et alii* 2008  
Bugoi, R./Cojocar, V./Constantinescu, B./Calligaro, T./Pinchon, L./Rörs, S./Salomon, J., Compositional studies on Transylvanian gold nuggets: Advantages and limitations of PIXE-PIGE analysis, *Nuclear Instruments and Methods in Physics Research B* 266, 2316–2319. <https://doi.org/10.1016/j.nimb.2008.03.044>
- CARDOSO, J. L. 2021  
Cardoso, J.L. The fortified Chalcolithic settlement of Outeiro Redondo (Sesimbra, Portugal). An account of the excavations conducted between 2005 and 2016, *Madrider Mittelungen* 62, 34–99. <https://doi.org/10.34780/5t5b-rg2e>
- CASE 1966  
Case, H., Were Beaker people the first metallurgists in Ireland? *Palaeohistoria* 12, 141–177.
- CASSIDY *et alii* 2020  
Cassidy, L.M./Maoldúin, R.Ó./Kador, T./Lynch, A./Jones, C./Woodman, P.C./Murphy, E./Ramsey, G./Dowd, M./Noonan, A./Campbell, C./Jones, E.R./Mattiangeli, V./Bradley, D.G., A dynastic elite in monumental Neolithic society, *Nature* 82/7812, 384–388. <https://doi.org/10.1038/s41586-020-2378-6>
- CHERNYKH 1992  
Chernykh, E.N., *Ancient metallurgy in the USSR: The Early Metal Age*, Wright, S. (trans.) (Cambridge, UK: Cambridge University Press).
- CHERNYKH/ORLOVSKA 2015  
Chernykh, E.N./Orlovskaya, L.B., Radiocarbon chronology of the Carpatho-Balkan metallurgical province, Abstract. In:

- (n.e.), 4<sup>th</sup> Balkan Early Metallurgy Symposium (10<sup>th</sup>-12<sup>th</sup> May 2015, Târgu Jiu, Romania), Program and Abstracts, (Târgu Jiu: n.p.), 18-21.
- CHINTALAPATI *et alii* 2022  
The spatiotemporal patterns of major human admixture events during the European Holocene, *eLife* 11, e77625. <https://doi.org/10.7554/eLife.77625>
- CLEMENTE *et alii* 202  
Clemente, F./Unterländer, M./Dolgova, O./Amorim, C.E.G./Coroado-Santos, F./Neuenschwander, S./Ganiatou, E./Cruz Dávalos, D.I./Anchieri L./Michaud, F./Winkelbach, L./Blöcher, J./Arizmendi Cárdenas, Y.O./Sousa da Mota, B./Kalliga, E./Souleles, A./Kontopoulos, I./Karamitrou-Mentessidi, G./Philaniotou, O./.../Papageorgopoulou, C., The genomic history of the Aegean palatial civilizations, *Cell* 184/10, 2565-2586.e21. <https://doi.org/10.1016/j.cell.2021.03.039>
- CRISTEA 2012  
Cristea, D., *Studiul aurului din România în vederea stabilirii provenienței obiectelor arheologice din patrimoniul cultural național* [Study of gold from Romania for establishing the provenance of archaeological artifacts belonging to the national cultural patrimony], University of Bucharest, Summary of PhD dissertation.
- ČATAJ 2018  
Čataj, L., The Lasinja culture. In: Balen, J./Miloglav, I./Rajković, D. (eds.), *Back to the past—Copper Age in northern Croatia* (Zagreb/Osijek: Arheološki muzej u Zagrebu/Filozofski fakultet Sveučilišta u Zagrebu/Arheološki muzej Osijek), 25–47. <https://doi.org/10.17234/9789531758185>
- DIACONESCU 2014  
Diaconescu, D., Considerations concerning the chronology of the Early Copper Age Tiszapolgár culture, *Præhistorische Zeitschrift* 89/2, 219–241. <https://doi.org/10.1515/pz-2014-0016>
- DIACONESCU 2009  
Diaconescu, D., *Cultura Tisapolgár în România (Alba Iulia: Altip)*.
- DOLFINI 2013  
Dofini, A., The Emergence of metallurgy in the Central Mediterranean region: A new model, *European Journal of Archaeology* 16/10, 21–62. <https://doi.org/10.1179/1461957112Y.0000000023>
- DOLFINI/ANGELINI/ARTIOLI 2020  
Dofini A./Angelini, I./Artioli, G., Copper to Tuscany—Coals to Newcastle? The dynamics of metalwork exchange in early Italy, *PLoS One* 215/1, e0227259. <https://doi.org/10.1371/journal.pone.0227259>
- DULIAS *et alii* 2022  
Dulias, K./Foody, M.G.B./Justeau, P./Silva, M./Martiniano, R./Oteo-García, G./Fichera, A./Rodrigues, S./Gandini, F./Meynert, A./Donnelly, K./Aitman, T.J./Scottish Genomes Partnership/Chamberlain, A./Lelong, O./Kozikowski, G./Powlesland, D./Waddington, C./Mattiangeli, V./Bradley, D.G./.../Richards, M.B., Ancient DNA at the edge of the world: Continental immigration and the persistence of Neolithic male lineages in Bronze Age Orkney, *Proceedings of the National Academy of Sciences of the United States of America* 119/8, e2108001119. <https://doi.org/10.1073/pnas.2108001119>
- EBERHARDT 2009  
Eberhardt, K.L., Copper working technologies, context of use, and social complexity in the Eastern Woodlands of Native North America, *Journal of World Prehistory* 22, 213–235. <https://doi.org/10.1007/s10963-009-9020-8>
- FERNANDES *et alii* 2020  
Fernandes, D.M./Mittnik, A./Olalde, I./Lazaridis, I./Cheronet, O./Rohland, N./Mallick, S./Bernardos, R./Broomandkhoshbacht, N./Carlsson, J./Culleton, B.J./Ferry, M./Gamarra, B./Lari, M./Mah, M./Michel, M./Modi, A./Novak, M./Oppenheimer, J./Sirak, K. A./.../Reich, D., The spread of steppe and Iranian-related ancestry in the islands of the western Mediterranean, *Nature Ecology & Evolution* 4/3, 334–345. <https://doi.org/10.1038/s41559-020-1102-0>
- FERNANDES *et alii* 2018  
Fernandes, D.M./Strapagiel, D./Borówka, P./Marciniak, B./Żądzińska, E./Sirak, K./Siska, V./Grygiel, R./Carlsson, J./Manica, A./Lorkiewicz, W./Pinhasi, R., A genomic Neolithic time transect of hunter-farmer admixture in central Poland, *Scientific Reports* 8/1, 14879. <https://doi.org/10.1038/s41598-018-33067-w>
- FRANK/PERNICKA 2012  
Frank C./Pernicka E., Copper artifacts of the Mondsee group and their possible sources. In: Midgley, M. S./Sanders, J. (eds.), *Lake Dwellings after Robert Munro. Proceedings from the Munro International Seminar: The Lake Dwellings of Europe; 2010 Oct 22–23; University of Edinburgh* (Leiden: Sidestone Press), 113–138.
- FOWLER *et alii* 2022  
Fowler, C./Olalde, I./Cummings, V./Armit, I./Büster, L./Cuthbert, S./Rohland, N./Cheronet, O./Pinhasi, R./Reich, D., A high-resolution picture of kinship practices in an Early Neolithic tomb, *Nature* 601/7894, 584–587. <https://doi.org/10.1038/s41586-021-04241-4>
- FURTWÄNGLER *et alii* 2020  
Furtwängler, A./Rohrlach, A.B./Lamnidis, T.C./Papac, L./Neumann, G.U./Siebke, I./Reiter, E./Steuri, N./Hald, J./Denaire, A./Schnitzler, B./Wahl, J./Ramstein, M./Schuenemann, V.J./Stockhammer, P.W./Hafner, A./Lösch, S./Haak, W./Schiffels, S./Krause, J., Ancient genomes reveal social and genetic structure of Late Neolithic Switzerland, *Nature Communications* 11/1, 1915. <https://doi.org/10.1038/s41467-020-15560-x>
- GAMBA *et alii* 2014  
Gamba, C./Jones, E.R./Teasdale, M.D./McLaughlin, R.L./Gonzalez-Fortes, G./Mattiangeli, V./Domboróczki, L./Kóvári, I./Pap, I./Anders, A./Whittle, A./Dani, J./Raczky, P./Higham, T.F./Hofreiter, M./Bradley, D.G./Pinhasi, R., Genome flux and stasis in a five millennium transect of European prehistory, *Nature Communications* 5, 5257. <https://doi.org/10.1038/ncomms6257>
- GEBAUER *et alii* 2021  
Gebauer, A./Sørensen, L./Taube, M./Wielandt, D., First metallurgy in Northern Europe: An Early Neolithic crucible and a possible tuyère from Lønt, Denmark, *European Journal of Archaeology* 24/1, 27–47. <https://doi.org/10.1017/ear.2019.73>
- GELABERT *et alii* 2022  
Gelabert, P./Schmidt, R. W./Fernandes/D. M./Karsten, J. K./Harper, T. K./Madden, G. D./Ledogar, S. H./Sokhatsky, M./Oota, H./Kennett, D. J./Pinhasi, R., Genomes from Verteba cave suggest diversity within the Trypillians in Ukraine, *Scientific Reports* 12/1, 7242. <https://doi.org/10.1038/s41598-022-11117-8>
- GEORGAKOPOULOU 2007  
Georgakopoulou, M., Metallurgical activities in Early Cycladic settlements: The case of Daskaleio-Kavos. In: Day,

- P.M./Doonan, R.C.P. (eds.), *Metallurgy in the Early Bronze Age Aegean* (Barnsley, UK: Oxbow Books), 123–133.
- GONZÁLEZ-FORTES *et alii* 2017  
González-Fortes, G./Jones, E. R./Lightfoot, E./Bonsall, C./Lazar, C./Grandal-d'Anglade, A./Garralda, M. D./Drak, L./Siska, V./Simalcsik, A./Boroneanț, A./Vidal Romani, J. R./Vaquero Rodríguez, M./Arias, P./Pinhasi, R./Manica, A./Hofreiter, M., Paleogenomic evidence for multi-generational mixing between Neolithic farmers and Mesolithic hunter-gatherers in the Lower Danube Basin, *Current Biology* 27/12, 1801–1810.e10. <https://doi.org/10.1016/j.cub.2017.05.023>
- GONZÁLEZ-FORTES 2019  
González-Fortes, G./Tassi, F./Trucchi, E./Henneberger, K./Paijmans, J.L.A./Diez-Del-Molino, D./Schroeder, H./Susca, R.R./Barroso-Ruiz, C./Bermudez, F.J./Barroso-Medina, C./Bettencourt, A.M.S./Sampaio, H.A./Grandal-d'Anglade, A./Salas, A./de Lombera-Hermida, A./Fabregas Valcarce, R./Vaquero, M./Alonso, S./Lozano, M./.../Barbujani, G., A western route of prehistoric human migration from Africa into the Iberian Peninsula, *Proceedings, Biological Sciences* 286/1895, 20182288. <https://doi.org/10.1098/rspb.2018.2288>
- GRESKY *et alii* 2016  
Gresky, J./Batieva, E./Kitova, A./Kalmykov, A./Belinskiy, A./Reinhold, S./Berezina, N., New cases of trepanations in Southern Russia in the context of previous research: Possible evidence for a ritually motivated tradition of cranial surgery? *American Journal of Physical Anthropology* 160/4, 665–682. <https://doi.org/10.1002/ajpa.22996>
- HAAK *et alii* 2015  
Haak, W./Lazaridis, I./Patterson, N./Rohland, N./Mallick, S./Llamas, B./Brandt, G./Nordenfelt, S./Harney, E./Stewardson, K./Fu, Q./Mittnik, A./Bánffy, E./Economou, C./Francken, M./Friederich, S./Pena, R. G./Hallgren, F./Khartanovich, V./Khokhlov, A./.../Reich, D., Massive migration from the steppe was a source for Indo-European languages in Europe, *Nature*, 522/7555, 207–211. <https://doi.org/10.1038/nature14317>
- HANSEN 2015  
Hansen, S., Pietrele-A lakeside settlement, 5200-4250 BC. In: Hansen, S./Raczky, P./Reingruber, A. (eds.), *Neolithic and Copper Age between the Carpathians and the Aegean Sea. Chronologies and technologies from the 6th to the 4th Millennium BC* (Bonn: Habelt), 273–293.
- HEEB 2014  
Heeb, J.M., *Copper Shaft-Hole Axes and Metallurgy in South-Eastern Europe: An integrated approach* (Oxford: Archaeopress).
- HEYD/WALKER 2015  
Heyd, V./Walker, K., The first metalwork and expressions of social power. In: Fowler, C./Harding, J./Hofmann, D. (eds.), *The Oxford Handbook of Neolithic Europe* (Oxford: Oxford University Press), 673–691.
- HÖPPNER *et alii* 2005  
Höppner, B./Bartelheim, M./Huijsmans, M./Krauss, R./Martinek, K.-P./Pernicka, E./Schwab, R., Prehistoric copper production in the Inn Valley (Austria), and the earliest copper in Central Europe, *Archaeometry* 47/2, 293–315. <https://doi.org/10.1111/j.1475-4754.2005.00203.x>
- KELLER *et alii* 2012  
Keller, A./Graefen, A./Ball, M./Matzas, M./Boisguerin, V./Maixner, F./Leidinger, P., Backes, C., Khairat, R./Forster, M./Stade, B./Franke, A./Mayer, J./Spangler, J./McLaughlin, S./Shah, M./Lee, C./Harkins, T.T./Sartori, A./Moreno-Estrada, A./.../Zink, A., New insights into the Tyrolean Iceman's origin and phenotype as inferred by whole-genome sequencing, *Nature Communications* 3, 698. <https://doi.org/10.1038/ncomms1701>
- KIENLIN 2016  
Kienlin, T.L., Some thoughts on evolutionist notions in the study of early metallurgy. In: Bartelheim, M./Horejs, B./Krauß R. (eds.), *Von Baden bis Troia. Ressourcennutzung, Metallurgie und Wissenstransfer* (Rahden: Leidorf), 123–137.
- KIENLIN/PERNICKA 2009  
Kienlin, T.L./Pernicka, E., Aspects of the production of Copper Age Jászladány type axes. In: Kienlin, T.L./Roberts, B.W. (eds.), *Metal and Societies* (Bonn: Habelt), 258–276.
- KLIMSCHA 2017  
Klimscha, F., The diffusion of know-how within spheres of interaction: Modelling prehistoric innovation processes between South-West Asia and Central Europe in the 5<sup>th</sup> and 4<sup>th</sup> Millennia BC. In: Stockhammer, P.H./Maran, J. (eds.), *Appropriating Innovations: Entangled Knowledge in Eurasia, 5000-1500 BCE* (Oxford: Oxbow), 149–160.
- KOWALSKI *et alii* 2019  
Kowalski, Ł./Adamczak, K./Garbacz-Klempka, A./Degryse, P./Stos-Gale Z./Kozicka, M./Chudziak, W./Krzyszowski, A./Jedynak, A., Back to the Eneolithic: Exploring the Rudki-type ornaments from Poland, *Archaeological and Anthropological Sciences*, 11, 4355–4377. <https://doi.org/10.1007/s12520-019-00825-4>
- LA DUC *et alii* 2022  
La Duc, E./Montero-Ruiz, I./Freestone, I.C./Fanlo Loras, J./Jabalquinto Expósito, I.M./Martín de la Cruz, J.C./Pérez-Lambán, F./Picazo Millán, J.V./Martín-Torres, M., Diverse strategies for copper production in Chalcolithic Iberia, *Journal of Archaeological Science: Reports* 46. <https://doi.org/10.1016/j.jasrep.2022.103683>
- LAZARIDIS *et alii* 2022  
Lazaridis, I./Alpaslan-Roodenberg, S./Acar, A./Açikkol, A./Agelarakis, A./Aghikyan, L./Akyüz, U./Andreeva, D./Andrijašević, G./Antonović, D./Armit, I./Atmaca, A./Avetisyan, P./Aytak, A.İ./Bacvarov, K./Badalyan, R./Bakardzhiev, S./Balen, J./Bejko, L./Bernardos, R./.../Davtyan, R., The genetic history of the Southern Arc: A bridge between West Asia and Europe, *Science* 377, 6609. <https://doi.org/10.1126/science.abm4247>
- LAZAROVICI/LAZAROVICI/CONSTANTINESCU 2015  
Lazarovici, G./Lazarovici, C.M./Constantinescu, B., New Data and Analyses on Gold Metallurgy during the Romanian Copper Age. In: Hansen, S./Raszky, P./Anders, A./Reingruber, A. (eds.), *Neolithic and Copper Age Between the Carpathian and the Aegean Sea*. (Bonn: Habelt), 325–352.
- LEGARRA HERRERO/MARTINÓN-TORRES 2021  
Legarra Herrero, B./Martín-Torres, M., Heterogeneous production and enchainment consumption: Minoan gold in a changing world (ca. 2000 BCE), *American Journal of Archaeology* 125/3, 333–360. <https://doi.org/10.3764/aja.125.3.0333>
- LEHNER/YENER 2014  
Lehner, J.W./Yener, K.A., Organization and specialization of early mining and metal technologies in Anatolia. In Roberts B.W. and Thornton C.P. (eds.), *Archaeometallurgy in Global Perspective. Methods and Syntheses* (New York: Springer), 529–558.

- LEUSCH *et alii* 2015  
Leusch, V./Armbruster, B./Pernicka, E./Slavčev, V., On the invention of metallurgy: The gold objects from the Varna I cemetery (Bulgaria)–Technological consequence and inventive creativity, *Cambridge Archaeological Journal* 25/1, 353–376. <https://doi.org/10.1017/S0959774314001140>
- LIPSON *et alii* 2017  
Lipson, M./Szécsényi-Nagy, A./Mallick, S./Pósa, A./Stégmár, B./Keerl, V./Rohland, N./Stewardson, K./Ferry, M./Michel, M./Oppenheimer, J./Broomandkoshbacht, N./Harney, E./Nordenfelt, S./Llamas, B./Gusztáv Mende, B./Köhler, K./Oross, K./Bondár, M./Marton, T./.../Reich, D., Parallel palaeogenomic transects reveal complex genetic history of early European farmers, *Nature*, 551/7680, 368–372. <https://doi.org/10.1038/nature24476>
- LUCA 1999  
Luca, S.A., *Sfârșitul eneoliticului pe teritoriul intracarpatic al României–Cultura Bodrogkeresztúr* [The end of the Eneolithic on the intracarpathian territory of Romania–The Bodrogkeresztúr Culture] (Muzeul Național al Unirii, Alba Iulia).
- LUCA 2000  
Luca, S.A., Répertoire des découvertes de la culture Bodrogkeresztur sur le territoire de Roumanie, *Cercetari Arheologice* 11, 1, 305–316.
- LULL *et alii* 2011  
Lull, V./Micó, R./Risch, R., El Argar and the beginning of class society in the Western Mediterranean. In: Hansen, S./Müller, J. (eds), *Sozialarchäologische Perspektiven: Gesellschaftlicher Wandel 5000–1500 v. Chr. zwischen Atlantik und Kaukasus* (Mainz: Zabern), 381–414.
- MALMSTRÖM *et alii* 2019  
Malmström, H./Günther, T./Svensson, E.M./Juras, A./Fraser, M./Munters, A.R./Pospieszny, Ł./Törv, M./Lindström, J./Götherström, A./Storå, J./Jakobsson, M., The genomic ancestry of the Scandinavian Battle Axe Culture people and their relation to the broader Corded Ware horizon, *Proceedings Biological Sciences* 286/1912, 20191528. <https://doi.org/10.1098/rspb.2019.1528>
- MALLICK *et alii* 2024  
Mallick, S./Micco, A./Mah, M./Ringbauer, H./Lazaridis, I./Olalde, I./Patterson, N./Reich, D., The Allen Ancient DNA Resource (AADR): A curated compendium of ancient human genomes, *Scientific Data* 11, 182. <https://doi.org/10.1038/s41597-024-03031-7>
- MALLICK/REICH 2023  
Mallick, S./Reich, D., *The Allen Ancient DNA Resource (AADR): A curated compendium of ancient human genomes*, <https://doi.org/10.7910/DVN/FFIDCW>, Harvard Dataverse, V8.
- MARAN 2021  
Maran, J., Attica and the origins of silver metallurgy in the Aegean and the Carpatho-Balkan zone. In: Kalogeropoulos, K./Vassilikou, D./Tiverios, M. (eds.), *Sidelights on Greek Antiquity* (Berlin: De Gruyter), 197–225. <https://doi.org/10.1515/9783110699326-010>
- MARCUS *et alii* 2020  
Marcus, J.H./Posth, C./Ringbauer, H., Lai, L./Skeates, R./Sidore, C./Beckett, J./Furtwängler, A./Olivieri, A./Chiang, C.W.K./Al-Asadi, H./Dey, K./Joseph, T.A./Liu, C.C./Der Sarkissian, C./Radzevičiūtė, R./Michel, M./Gradoli, M.G./Marongiu, P./Rubino, S./.../Novembre, J., Genetic history from the Middle Neolithic to present on the Mediterranean island of Sardinia, *Nature Communications*, 11, 1, 939. <https://doi.org/10.1038/s41467-020-14523-6>
- MAREȘ/URSU 2002  
Mareș, I./Ursu, C.-E., *Metalurgia aramei în Neo-Eneoliticul României* (Suceava: Editura Bucovina Istorică).
- MARTINIANO *et alii* 2017  
Martiniano, R./Cassidy, L.M./Ó'Maoldúin, R./McLaughlin, R./Silva, N. M./Manco, L./Fidalgo, D./Pereira, T./Coelho, M.J./Serra, M./Burger, J./Parreira, R./Moran, E./Valera, A.C./Porfirio, E./Boaventura, R./Silva, A.M./Bradley, D.G., The population genomics of archaeological transition in west Iberia: Investigation of ancient substructure using imputation and haplotype-based methods, *PLoS Genetics* 13/7, e1006852. <https://doi.org/10.1371/journal.pgen.1006852>
- MATHIESON *et alii* 2018  
Mathieson, I./Alpaslan-Roodenberg, S./Posth, C./Szécsényi-Nagy, A./Rohland, N./Mallick, S./Olalde, I./Broomandkoshbacht, N./Candilio, F./Cheronet, O./Fernandes, D./Ferry, M./Gamarra, B./Fortes, G.G./Haak, W./Harney, E./Jones, E./Keating, D./Krause-Kyora, B./Kucukkalipci, I./.../Reich, D., The genomic history of southeastern Europe, *Nature* 555/7695, 197–203. <https://doi.org/10.1038/nature25778>
- MATHIESON *et alii* 2015  
Mathieson, I./Lazaridis, I./Rohland, N./Mallick, S./Patterson, N./Roodenberg, S.A./Harney, E./Stewardson, K./Fernandes, D./Novak, M./Sirak, K./Gamba, C./Jones, E.R./Llamas, B./Dryomov, S./Pickrell, J./Arsuaga, J.L./de Castro, J.M./Carbonell, E./Gerritsen, F./.../Reich, D. (2015). Genome-wide patterns of selection in 230 ancient Eurasians, *Nature* 528/7583, 499–503. <https://doi.org/10.1038/nature16152>
- MATUSCHIK 1998  
Matuschik I., Kupferfunde und Metallurgie-Belege, zugleich ein Beitrag zur Geschichte der kupferzeitlichen Dolche Mittel-, Ost- und Südeuropas. In: Mainberger M. (ed.), *Das Moordorf von Reute. Archäologische Untersuchungen in der jungneolithischen Siedlung Reute-Schorrenried* (Staufen i. Br.: Teraqua CAP), 207–255.
- MERKL 2010  
Merkel, M.B., Bell Beaker metallurgy and the emergence of fahlore-copper use in Central Europe, *Interdisciplinaria Archaeologica Natural Sciences in Archaeology* 1/1-2, 19–27. <https://doi.org/10.24916/iansa.2010.1-2-2>
- MERKL/STEINIGER/STRAHM 2013  
Merkel, M./Steiniger, D./Strahm, C., Les Alpes à l'aube de la métallurgie. In: Borrello M.A. (ed.), *Les Hommes préhistoriques et les Alpes* (Oxford: British Archaeological Reports), 175–194.
- NARASIMHAN *et alii* 2019  
Narasimhan, V.M./Patterson, N./Moorjani, P./Rohland, N./Bernardos, R./Mallick, S./Lazaridis, I./Nakatsuka, N./Olalde, I./Lipson, M./Kim, A.M./Olivieri, L.M./Coppa, A./Vidale, M./Mallory, J./Moiseyev, V./Kitov, E./Monge, J./Adamski, N./Alex, N./.../Reich, D., The formation of human populations in South and Central Asia, *Science* 365, 6457. <https://doi.org/10.1126/science.aat7487>
- NOVAK *et alii* 2021  
Novak, M./Olalde, I./Ringbauer, H./Rohland, N./Ahern, J./Balén, J./Janković, I./Potrebica, H./Pinhasi, R./Reich, D., Genome-wide analysis of nearly all the victims of a 6200 year old massacre, *PLoS One*, 16, 3. <https://doi.org/10.1371/journal.pone.0247332>
- OLALDE *et alii* 2018  
Olalde, I./Brace, S./Allentoft, M.E./Armit, I./Kristiansen,

- K./Booth, T./Rohland, N./Mallick, S./Szécsényi-Nagy, A./Mittnik, A./Altena, E./Lipson, M./Lazaridis, I./Harper, T.K./Patterson, N./Broomandkoshbacht, N./Diekmann, Y./Faltyskova, Z./Fernandes, D./Ferry, M./.../Reich, D., The Beaker phenomenon and the genomic transformation of northwest Europe, *Nature* 555/7695, 190–196. <https://doi.org/10.1038/nature25738>
- OLALDE *et alii* 2019  
Olalde, I./Mallick, S./Patterson, N./Rohland, N./Villalba-Mouco, V./Silva, M./Dulias, K./Edwards, C.J./Gandini, F./Pala, M./Soares, P./Ferrando-Bernal, M./Adamski, N./Broomandkoshbacht, N./Cheronet, O./Culleton, B.J./Fernandes, D./Lawson, A.M./Mah, M./Oppenheimer, J./.../Reich, D., The genomic history of the Iberian Peninsula over the past 8000 years, *Science* 363/6432, 1230–1234. <https://doi.org/10.1126/science.aav4040>
- PAPAC *et alii* 2021  
Papac, L./Ernée, M./Dobeš, M./Langová, M./Rohrlach, A.B./Aron, F./Neumann, G.U./Spyrou, M.A./Rohland, N./Velemínský, P./Kuna, M./Brzobohatá, H./Culleton, B./Daněček, D./Danielisová, A./Dobisíková, M./Hložek, J./Kennett, D.J./Klementová, J./Kostka, M./.../Haak, W., Dynamic changes in genomic and social structures in third millennium BCE central Europe, *Science Advances* 7/35, eabi6941. <https://doi.org/10.1126/sciadv.abi6941>
- PAPADATOS 2007  
Papadatos, Y., The beginning of metallurgy in Crete: New evidence from the FN-EM I settlement at Kephala Petras, Siteia. In: Day, P.M./Doonan, R.C.P. (eds.), *Metallurgy in the Early Bronze Age Aegean* (Barnsley, UK: Oxbow Books), 154–167.
- PATTERSON *et alii* 2021  
Patterson, N./Isakov, M./Booth, T./Büster, L./Fischer, C.E./Olalde, I./Ringbauer, H./Akbari, A./Cheronet, O./Bleasdale, M./Adamski, N./Altena, E./Bernardos, R./Brace, S./Broomandkoshbacht, N./Callan, K./Candilio, F./Culleton, B./Curtis, E./Demetz, L./.../Reich, D., Large-scale migration into Britain during the Middle to Late Bronze Age, *Nature* 601/7894, 588–594. <https://doi.org/10.1038/s41586-021-04287-4>
- PĂTROI 2010  
Pătroi, C.N., The Gumelnița Character of the Eneolithic Culture Sălța. *Oltenia. Studii și Comunicări. Arheologie-Istorie* 22, 2010, 7–12.
- PENSKE *et alii* 2023  
Penske, S./Rohrlach, A.B./Childebayeva, A./Gnecchi-Ruscone, G./Schmid, C./Spyrou, M.A./Neumann, G.U./Atanassova, N./Beutler, K./Boyadzhiev, K./Boyadzhiev, Y./Bryukov, I./Chohadzhiev, A./Govedarica, B./Karacak, M./Krauss, R./Leppek, M./Manzura, I./Privat, K./Ross, S./.../Haak, W., Early contact between late farming and pastoralist societies in southeastern Europe, *Nature* 620/7973, 358–365. <https://doi.org/10.1038/s41586-023-06334-8>
- PERNICKA *et alii* 1993  
Pernicka E./Begemann F./Schmitt-Strecker S./Wagner G.A., Eneolithic and Early Bronze Age copper artefacts from the Balkans and their relation to Serbian copper ores, *Praehistorische Zeitschrift* 68/1, 1–55. <https://doi.org/10.1515/prhz.1993.68.1.1>
- PETERSON *et alii* 2016  
Peterson, D.L./Northover, P./Salter, C./Maldonado, B./Anthony, D.W., Bronze Age Metallurgy in the Middle Volga. In: Anthony, D.W./Brown, D.R./Khokhlov, A.A./Kuznetsov, P.F./Mochalov, O.D. (eds.), *A Bronze Age Landscape in the Russian Steppes: The Samara Valley Project* (Los Angeles: The Cotsen Institute of Archaeology Press), 291–332.
- PÉTREQUIN/KLASSEN/CASSEN 2012  
Pétrequin, P./Klassen, I./Cassen, S., Alpine axes and early metallurgy. In: Pétrequin, P./Cassen, S./M. Errera, M./Klassen, L./Sheridan, A./Pétrequin, A.-M. (eds.), *Jade. Grandes haches alpines du Néolithique européen. Ve et IVe millénaires av. J.-C.* (Besançon: Presses universitaires de Franche-Comté et centre de recherche archéologique de la Vallée de l'Ain), 1280–1309.
- RADIVOJEVIĆ/GRUJIĆ 2017  
Radivojević, M./Grujić, J., Dataset for *Community structure of copper supply networks in the prehistoric Balkans: An independent evaluation of the archaeological record from the 7th to the 4th millennium*, Apollo–University of Cambridge Repository. <https://doi.org/10.17863/CAM.9599>
- RADIVOJEVIĆ/ROBERTS 2021A  
Radivojević, M./Roberts, B.W., Balkan metallurgy and society, 6200–3700 BC. In: Radivojević, M./Roberts, B.W./Marić, M./Kuzmanović Cvetković, J./Rehren, T. (eds.), *The Rise of metallurgy in Eurasia* (Oxford: Archaeopress), 11–37.
- RADIVOJEVIĆ/ROBERTS 2021B  
Radivojević, M./Roberts, B.W., Balkan metallurgy in a Eurasian context. In: Radivojević, M./Roberts, B.W./Marić, M./Kuzmanović Cvetković, J./Rehren, T. (eds.), *The Rise of metallurgy in Eurasia* (Oxford: Archaeopress), 601–618.
- RASSAMAKIN 1999  
Rassamakin, Y., The Eneolithic of the Black Sea Steppe: Dynamics of Cultural and Economic Development 4500–2300 BC. In: Levine, M./Rassamakin, Y./Kislenko, A./Tatarintseva, N. (eds.), *Late Prehistoric Exploitation of the Eurasian Steppe* (Cambridge: McDonald Institute for Archaeological Research), 59–182.
- REINGRUBER 2015  
Reingruber, A., Absolute and relative chronologies in the Lower Danube Area during the 5th Millennium BC. In: Hansen, S./Raczky, P./Anders, A./Reingruber A. (eds.), *Neolithic and Copper Age between the Carpathians and the Aegean Sea: Chronologies and technologies from the 6th to 4th Millennium BC* (Bonn: Habelt), 301–24.
- RENFREW *et alii* 2022  
Renfrew, C./Boyd, M.J./Athanasoulis, D./Brodie, N./Carter, T./Dellaporta, K./Floquet, M./Gavalas, G./Georgakopoulou, M./Gkouma, M./Hilditch, J./Krijnen, A./Legaki, I./Margaritis, E./Marthari, M./Moutafi, I./Philaniotou, O./Sotirakopoulou, P./Wright, J., The sanctuary at Keros in the Aegean Early Bronze Age: from centre of congregation to centre of power, *Journal of Greek Archaeology* 7, 1–36. <https://doi.org/10.32028/jga.v7i.1709>
- RINGBAUER *et alii* 2023  
Ringbauer, H./Huang, Y./Akbari, A./Mallick, S./Patterson, N./Reich, D., aNCBD–Screening for identity by descent segments in human ancient DNA, *bioRxiv: the preprint server for biology*, 2023.03.08.531671. <https://doi.org/10.1101/2023.03.08.531671>
- RINGBAUER *et alii* 2024  
Ringbauer, H./Huang, Y./Akbari, A./Mallick, S./Patterson, N./Reich, D., Accurate detection of identity-by-descent segments in human ancient DNA, *Nature Genetics* 56/1, 143–151. <https://doi.org/10.1038/s41588-023-01582-w>
- ROBERTS 2008  
Roberts, B., Migration, craft expertise and metallurgy: Analysing the ‘spread’ of metallurgy in Western Europe,

- Archaeological Review from Cambridge* 23/2, 27–45.
- ROGERS 1983 (1962)  
Rogers, E., *Diffusion of Innovations*, 3rd ed. (London: MacMillan). Original date of publication: 1962.
- ROMAN 1971  
Roman, P.I., Strukturänderungen des Endäneolithikums im Donau-Karpaten-Raum. *Dacia* 15, 31–161.
- ROSENSTOCK/SCHARL/SCHIER 2016  
Rosenstock, E./Scharl, S./Schier, W., Ex oriente lux?—Ein Diskussionsbeitrag zur Stellung der frühen Kupfermetallurgie Südeuropas. In: Bartelheim, M./Horejs, B./Krauß, R. (eds.), *Von Baden bis Troia: Ressourcennutzung, Metallurgie, und Wissenstransfer* (Rahden: Leidorf), 59–122.
- ROTEA *et alii* 2023  
Rotea, M./Bodea, M./Răchită, M./Sava, T./Mănăilescu, C., First <sup>14</sup>C dating for a cultic feature (L1) of the Bodrogkeresztúr culture from Fundătura-Şesuu Mare (Cluj County), *Revista Bistriţei* 37, 9–26.
- ROUSSOT-LARROQUE 2008  
Roussot-Larroque, J., La “sépulture du chef” de Pauilhac (Gers), *Préhistoire du Sud-Ouest* 16/1, 91–142.
- ROVIRA/MONTERO-RUIZ 2013  
Rovira, S./Montero-Ruiz, I., Iberia: Technological development of prehistoric metallurgy. In: Burmeister, S./Hansen, S./Kunst, M./Müller-Scheeßel, N. (eds.), *Metal matters; Innovative technologies and social change in prehistory and antiquity* (Rahden: Leidorf), 231–239.
- ROWLANDS 1971  
Rowlands, M.J., The Archaeological interpretation of Prehistoric metalworking, *World Archaeology* 3/2, 210–224. <https://doi.org/10.1080/00438243.1969.9979502>
- SĂLCEANU 2008  
Sălceanu, I. *Sălcuţa IV-Herculane II-III* (Satu Mare: Solstiţiu).
- SÁNCHEZ-QUINTO *ET ALII* 2019  
Sánchez-Quinto, F./Malmström, H./Fraser, M./Girdland-Flink, L./Svensson, E. M./Simões, L.G./George, R./Hollfelder, N./Burenhult, G./Noble, G./Britton, K./Talamo, S./Curtis, N./Brzobohata, H./Sumberova, R./Götherström, A./Storå, J./Jakobsson, M., Megalithic tombs in western and northern Neolithic Europe were linked to a kindred society, *Proceedings of the National Academy of Sciences of the United States of America*, 116/19, 9469–9474. <https://doi.org/10.1073/pnas.1818037116>
- SCHARL 2016  
Scharl, S., Patterns of innovation transfer and the spread of copper metallurgy to Central Europe, *European Journal of Archaeology* 19/2, 215–244. <https://doi.org/10.1080/14619571.2016.1147313>
- SCHAUER *et alii* 2021  
Schauer, P./Shennan, S./Bevan, A./Colledge, S./Edinburgh, K./Kerig, T./Parker Pearson, M., Cycles in stone mining and copper circulation in Europe 5500–2000 BC: A view from Space, *European Journal of Archaeology* 24/2, 204–225. <https://doi.org/10.1017/ea.2020.56>
- SCHOOP 2015  
Schoop, U.-D., Çamlıbel Tarlası: Late Chalcolithic settlement and economy in the Budaközü Valley (north-central Anatolia). In: Steadman, S.R./McMahon, G. (eds.), *The Archaeology of Anatolia: Recent Discoveries (2011–2014)*, Vol. I. (Newcastle upon Tyne: Cambridge Scholars Publishing), 46–68.
- SCHREINER/HEYD/PERNICKA 2012  
Schreiner, M./Heyd, V./Pernicka, E., Kupferzeitliches Metall in der Westslowakei. In: Kujovský, R./Mitáš, V. (eds.), *Václav Furmáněk a doba bronzová. Zborník k sedemdesiatym narodeninám* [Václav Furmáněk and the Bronze Age. Proceedings for his seventieth birthday] (Archeologický ústav slovenskej akadémie vied: Nitra), 355–366.
- SCHROEDER *et alii* 2019  
Schroeder, H./Margaryan, A./Szmyt, M./Theulot, B./Włodarczak, P./Rasmussen, S./Gopalakrishnan, S./Szczepanek, A./Konopka, T./Jensen, T.Z.T./Witkowska, B./Wilk, S./Przybyła, M.M./Pospieszny, Ł./Sjögren, K.G./Belka, Z./Olsen, J./Kristiansen, K./Willerslev, E./Frei, K.M./.../Allentoft, M.E., Unraveling ancestry, kinship, and violence in a Late Neolithic mass grave, *Proceedings of the National Academy of Sciences of the United States of America* 116/22, 10705–10710. <https://doi.org/10.1073/pnas.1820210116>
- SEGUIN-ORLANDO *et alii* 202  
Seguin-Orlando A./Donat, R./Der Sarkissian, C./Southon, J./Thèves, C./Manen, C./Tchérémissinoff, Y./Crubézy, E./Shapiro, B./Deleuze, J.F./Dalén, L./Guilaine, J./Orlando L., Heterogeneous Hunter-Gatherer and Steppe-Related ancestries in Late Neolithic and Bell Beaker genomes from present-day France, *Current Biology* 31/5, 1072–1083.e10. <https://doi.org/10.1016/j.cub.2020.12.015>
- SKOGLUND *et alii* 2014  
Skoglund, P./Malmström, H./Omrak, A./Raghavan, M./Valdiosera, C./Günther, T./Hall, P./Tambets, K./Parik, J./Sjögren, K.G./Apel, J./Willerslev, E./Storå, J./Götherström, A./Jakobsson, M., Genomic diversity and admixture differs for Stone-Age Scandinavian foragers and farmers, *Science* 3/44, 6185, 747–750. <https://doi.org/10.1126/science.1253448>
- SKOURTANIOTI *et alii* 2020  
Skourtanioti, E./Erdal, Y.S./Frangipane, M./Balossi Restelli, F./Yener, K.A./Pinnock, F./Matthiae, P./Özbal, R./Schoop, U.D./Guliyev, F./Akhundov, T./Lyonnet, B./Hammer, E.L./Nugent, S.E./Burri, M., Neumann, G.U./Penske, S./Ingman, T./Akar, M./Shafiq, R./Palumbi, G./Eisenmann, S./D’Andrea, M./Rohrlach, A.B./Warinner, C./Jeong, C./Stockhammer, P.W./Haak, W./Krause, J., Genomic history of Neolithic to Bronze Age Anatolia, Northern Levant, and Southern Caucasus, *Cell* 181/5, 1158–1175.e28. <https://doi.org/10.1016/j.cell.2020.04.044>
- STOS-GALE/GALE 2009  
Stos-Gale, Z.A./Gale, N.H., Metal provenancing using isotopes and the Oxford archaeological lead isotope database (OXALID), *Archaeological and Anthropological Sciences* 1/3, 195–213. <https://doi.org/10.1007/s12520-009-0011-6>
- STRAHM 2005  
Strahm, C., L’introduction et la diffusion de la métallurgie en France. In: Ambert, P./Vaquer, J. (eds.), *La première métallurgie en France et dans les pays limitrophes. Carcassonne 28-30 Septembre 2002, actes du colloque international* (Paris: Société préhistorique française), 27–36.
- STRAHM 2007  
Strahm, C., L’introduction de la métallurgie en Europe. In: Guilaine, J. (ed.), *Le Chalcolithique et la construction des inégalités, tome 1: Le continent européen* (Paris: Errance), 49–71.
- SZECSENYI-NAGY *et alii*. 2025  
Szecsenyi-Nagy, A./Virag, C./Jakab, K./Rohland, N./Ringbauer, H./Anders, A./Raczky, P./Hajdu, T./Kiss, K./Szeniczey, T./Evinger, S./Keszi, T./Virag, Z.M./Cheronet,

- O./Mallick, S./Akbari, A./Pinhasi, R./Reich, D./Siklosi, Z., Ancient DNA reveals diverse community organizations in the 5th millennium BCE Carpathian Basin, *Nature Communications* 16/5318. <https://doi.org/10.1038/s41467-025-60368-2>
- SZÜCS-CSILLIK/VIRAG 2016  
Szücs-Csillik, I./Virag, C., The orientation of the dead at Urziceni necropolis. In: Micle, D./Stavila, A./Oprean, C./Fortiu, S. (eds.), *ArheoVest IV, Vol. 2* (Szeged: Jate Press), 591–599.
- TURCK 2010  
Turck, R., *Die Metalle zur Zeit des Jungneolithikums in Mitteleuropa: Eine sozialarchäologische Untersuchung* (Bonn: Habelt).
- TIMBERLAKE 2009  
Timberlake, S., Copper mining and metal production at the beginning of the Bronze Age. In: Clark, P. (ed.), *Bronze Age connections: Cultural contacts in Prehistoric Europe* (Oxford: Oxbow Books), 94–121.
- VALDOSIERA *et alii* 2018  
Valdiosera, C./Günther, T./Vera-Rodríguez, J.C./Ureña, I./Iriarte, E./Rodríguez-Varela, R./Simões, L.G./Martínez-Sánchez, R.M./Svensson, E.M./Malmström, H./Rodríguez, L./Bermúdez de Castro, J.M./Carbonell, E./Alday, A./Hernández Vera, J.A./Götherström, A./Carretero, J.M./Arsuaga, J.L./Smith, C.I./Jakobsson, M., Four millennia of Iberian biomolecular prehistory illustrate the impact of prehistoric migrations at the far end of Eurasia, *Proceedings of the National Academy of Sciences of the United States of America* 115/13, 3428–3433. <https://doi.org/10.1073/pnas.1717762115>
- VALERIO *et alii* 2023  
Valério, P./Soares, J./Alves, L.C./Araújo, M.F./Tavares da Silva, C., Chalcolithic copper production and use in the western end of the Iberian Peninsula: The testimony of Castro de Chibanes (Portugal), *Journal of Archaeological Science: Reports*, 48, 103868. <https://doi.org/10.1016/j.jasrep.2023.103868>
- VICAS 2021a  
Vicas, A., Mining data on the spread of early metallurgy: Revisiting the Carpathian hypothesis with ancient genomes. *Studia Antiqua et Archaeologica* 26/2, 149–169. <https://doi.org/10.47743/saa-2020-26-2-2>
- VICAS 2021b  
Vicas, A., Seeking opportunity: Mobility and transmission of innovation in the Chalcolithic, *Ziridava, Studia Archaeologica* 35, 23–48.
- VIDAL 2012  
Vidal, R. La minería metálica prehistórica en la península Ibérica, *Lurralde: investigación y espacio* 35, 67–78. <https://doi.org/10.52748/lurralde.2012.35.5>
- VILLALBA-MOUCO *et alii* 2019  
Villalba-Mouco, V./van de Loosdrecht, M.S./Posth, C./Mora, R./Martínez-Moreno, J./Rojo-Guerra, M./Salazar-García, D.C./Royo-Guillén, J.I./Kunst, M./Rougier, H./Crevecoeur, I./Arcusa-Magallón, H./Tejedor-Rodríguez, C./García-Martínez de Lagrán, I./Garrido-Pena, R./Alt, K.W./Jeong, C./Schiffels, S./Utrilla, P./Krause, J./.../Haak, W., Survival of Late Pleistocene hunter-gatherer ancestry in the Iberian Peninsula, *Current Biology* 29/7, 1169–1177.e7. <https://doi.org/10.1016/j.cub.2019.02.006>
- VILLALBA-MOUCO *et alii* 2021  
Villalba-Mouco, V./Oliart, C./Rihuete-Herrada, C./Childebayeva, A./Rohrlach, A.B./Fregeiro, M.I./Celdrán Beltrán, E./Velasco-Felipe, C./Aron, F./Himmel, M./Freund, C./Alt, K.W./Salazar-García, D.C./García Atiénzar, G./de Miguel Ibáñez, M.P./Hernández Pérez, M.S./Barciela, V./Romero, A./Ponce, J./Martínez, A./.../Haak, W., Genomic transformation and social organization during the Copper Age–Bronze Age transition in southern Iberia, *Science Advances* 7/47, eabi7038. <https://doi.org/10.1126/sciadv.abi7038>
- WESTNER *et alii* 2021  
Westner, K.J./Rose, T./Klein, S./Hsu, Y.-K., GlobalID–Global Lead Isotope Database. V. 1.0. *GFZ Data Services*. <https://doi.org/10.5880/figeo.2021.031>
- WILK 2018  
Wilk, S., Can we talk about the Copper Age in Lesser Poland? Contribution to the discussion. In: Valde-Nowak, P./Sobczyk, K./Nowak, M./Żrałka, J. (eds.), *Multas per Gentes et Multa per Saecula* (Cracow: Institute of Archaeology, Jagiellonian University), 485–494.
- ŻURKIEWICZ *et alii* 2023  
Żurkiewicz, D./Strózyk, T./Garbacz-Klempka, A./Szmyt, M./Silka, P., the earliest traces of metallurgy in Greater Poland: Tuyère from Kotowo, Poland, *Documenta Praehistorica* 50, 420–433. <https://doi.org/10.4312/dp.50.9>

## APPENDIX

Locations in Figures. Geographical coordinates and dates are in the Supplement to this article.

**Ancient DNA samples**

- 1 Gura Baciului, Romania
- 2 Potočani, Croatia
- 3 Osijek Hermanov Vinograd (Beli Manastir), Croatia
- 4 Podlokanj, Serbia
- 5 Nemesnádudvar-Papföld, M9/7 lh, Hungary, 46.334774, 19.053945
- 6 Alsónyék, site 11, Hungary, 46.204523, 18.729916
- 7 Proletár dúlő, Hungary, 47.63868, 17.36453
- 8 Abony-Turjányos dúlő, Hungary, 47.189141, 20.004795
- 9 Budakalász-Luppa csárda, Hungary, 47.62094, 19.04494
- 10 Apc-Berekalya, Hungary, 47.167, 19.833
- 11 Alsonemedi, Hungary, 47.31875, 19.833
- 12 Mezőcsát-Hörcsögös, Hungary, 47.809892, 20.889267
- 13 Balatonlelle-Felső-Gamász, Hungary, 46.78469, 17.731714
- 14 Ternopil Oblast, Vertheba Cave, Ukraine
- 15 Konary, Poland
- 16 Oslonki, Poland
- 17 Pikutkowo, Poland
- 18 Koszyce, Poland
- 19 Wilczyce, Poland
- 20 Kornice, Poland
- 21 Makotřasy, Czech Rep.
- 22 Tuchoměřice, Czech Rep.
- 23 Neratovice, Czech Rep.
- 24 Bilina, Czech Rep.
- 25 Kolín-Štáralka, Czech Rep.
- 26 Březno u Loun, Czech Rep.
- 27 Louny, Dobroměřice, Czech Rep.
- 28 Blšany, Czech Rep.
- 29 Předměřice, Czech Rep.
- 30 Radosevice, Czech Rep.
- 31 Čachovice, Czech Rep.
- 32 Hostivice, Czech Rep.
- 33 Prague-Stodůlky, Czech Rep.
- 34 Roudnice nad Labem, Czech Rep.
- 35 Singen, Germany
- 36 Alburg-Lerchenhaid, Germany
- 37 Kyndelöse, Denmark
- 38 Gökhem, Sweden
- 39 Ansarve, Sweden
- 40 Anghelu Ruju, Sard., Italy
- 41 Carbonia, CI, Cannas di Sotto, Sard., Italy
- 42 Grotta Continenza, Italy
- 43 Lombardy, Remedello di Sotto, Italy
- 44 Tisenjoch, Italy
- 45 Serra Cabriles, Sardinia, Italy = 47
- 46 Su Crocefissu, Sardinia, Italy, 40.8101044, 8.4422073
- 46 Porto Torres, SAS, Su Crucifissu Mannu, Sardinia, Italy, 40.810297, 8.444178
- 47 Sennori, SS, Serra Crabiles, Sardinia, Italy
- 48 Xaghra Circle (Gozo), Malta
- 49 Hauts-de-France (North), Beaurieux, la Plaine, France
- 50 La Clape, Grotte du Rouquet, France
- 51 Marne, Mont-Aimé hypogée II, France, 48.858472, 3.995887
- 51 Marne, Mont-Aimé hypogée I, France, 48.858874, 3.996466
- 52 Occitanie (South), Villedubert, Dolmen des Peirières, France
- 53 La Clape, Grotte Basse de la Vigne Perdue, France
- 54 Alepotrypa Cave, Greece
- 55 Çorum Province, Çamlıbel Tarlası, Turkey
- 56 Malatya Province, Arslantepe, Turkey
- 57 Cyclades Islands, Koufonisi, Greece
- 58 Crete, Lasithi, Greece
- 59 Cova de Els Trocs, Spain
- 60 Cádiz, San Fernando, Campo de Hockey, Spain
- 61 Lugar do Canto, Portugal
- 62 La Mina (Castilla y León, Soria, Alcubilla de las Peñas)
- 63 Cabeço da Arruda I, Portugal
- 64 Monte Canelas I (Faro, Alcalar), Portugal
- 65 El Portalón, Spain
- 66 Las Yurdinas II, Basque Country, Spain
- 67 Mandubi Zelaia (Basque Country, Gipuzkoa, Ezkio-Itsaso), Spain
- 68 Jentilarri (Basque Country, Gipuzkoa, Enirio-Aralar), Spain
- 69 Alto de la Huesera (Basque Country, Álava, Laguardia), Spain
- 70 Galls Carboners (Catalonia, Tarragona, Mont-ral), Spain
- 71 Sima del Ángel (Andalusia, Córdoba, Lucena), Spain
- 72 Lorga da Dine, Portugal
- 73 Cova da Moura, Portugal
- 74 El Mirador, Spain
- 75 Murcia, Totana, La Bastida, Spain
- 76 Attermire Scar, Great-Britain
- 77 Burn Ground, Great-Britain
- 78 North Yorkshire, Ingleborough Hill, Fox Holes Cave, England, Great-Britain
- 79 Gloucestershire, Cheltenham, Hazleton North, England, Great-Britain
- 80 England, Somerset, Burrington Combe, Aveline's Hole, England, Great-Britain
- 81 Fussell's Lodge (England, Wiltshire, Salisbury), Great-Britain
- 82 Sussex, Brighton, Whitehawk, England, Great-Britain
- 83 Derbyshire, Brassington, Carsington Pasture Cave, England, Great-Britain
- 84 Distillery Cave (Scotland, Argyll), Great-Britain
- 85 Argyll and Bute, Oban, Raschoille Cave, Scotland, Great-Britain
- 86 Tulloch of Assery, Scotland, Great-Britain

- 87 Poul nabrone, Ireland
- 88 Annagh, Ireland
- 89 Ashley park, Ireland
- 90 Park nabinnia, Ireland
- 91 Cohaw, Ireland
- 92 Eton Rowing Course (England, Buckinghamshire), Great-Britain
- 93 Denbighshire, Rhos Ddigre, Wales, Great-Britain
- 94 Clachaig (Scotland, Isle of Arran, Lagg), Great-Britain
- 95 Unstan Chamber Tomb (Scotland, Orkney), Great-Britain
- 96 Point of Cott (Scotland, Orkney), Great-Britain
- 97 Isbister (Scotland, Orkney), Great-Britain
- 98 Holm of Papa Westray North (Scotland, Orkney), Great-Britain
- 99 Quoyness (Scotland, Orkney), Great-Britain
- 100 Sutherland, Embo, Scotland, Great-Britain
- 101 Isle of Skye, Strathglebe, Scotland, Great-Britain
- 102 Primrose Grange (County Sligo), Ireland
- 103 Millin Bay, Ireland
- 104 Newgrange, Ireland
- 105 Ardcrony, Ireland
- 106 Carrowkeel, Ireland
- 107 Temrta IV, Russia

#### **Evidence of copper metallurgy**

- 21 Makotřasy, Czech Rep.
- 40 Anghelu Ruju, Sard., Italy
- 55 Çorum Province, Çamlıbel Tarlası, Turkey
- 56 Malatya Province, Arslantepe, Turkey
- 108 Handlová, Slovakia
- 109 Nitriansky Hrádok, Slovakia
- 110 Slovenské Pravno, Slovakia
- 111 Sucha nad Parnou, Slovakia
- 112 Brześć Kujawski, Poland
- 113 Złota-Grodzisko, Poland
- 114 Kotowo, Poland
- 115 Złotniki, Poland
- 116 Ćmielów, Swietokrzyshkie, Poland
- 117 Las Stocki (sic), Poland
- 118 Złota, Poland
- 119 Lønt, Denmark
- 120 Bisamberg, Austria
- 121 Oberpullendorf, Austria
- 122 Keutschacher See
- 123 Brixlegg, Austria
- 124 Bottegghino, Italy
- 125 Santa Maria in Selva, Italy
- 126 Orti Bottagone, Italy
- 127 Gródek Nadbużny, Lublin, Poland
- 128 Janówek, Lower Silesia, Poland
- 129 Millan (Meluno), Italy

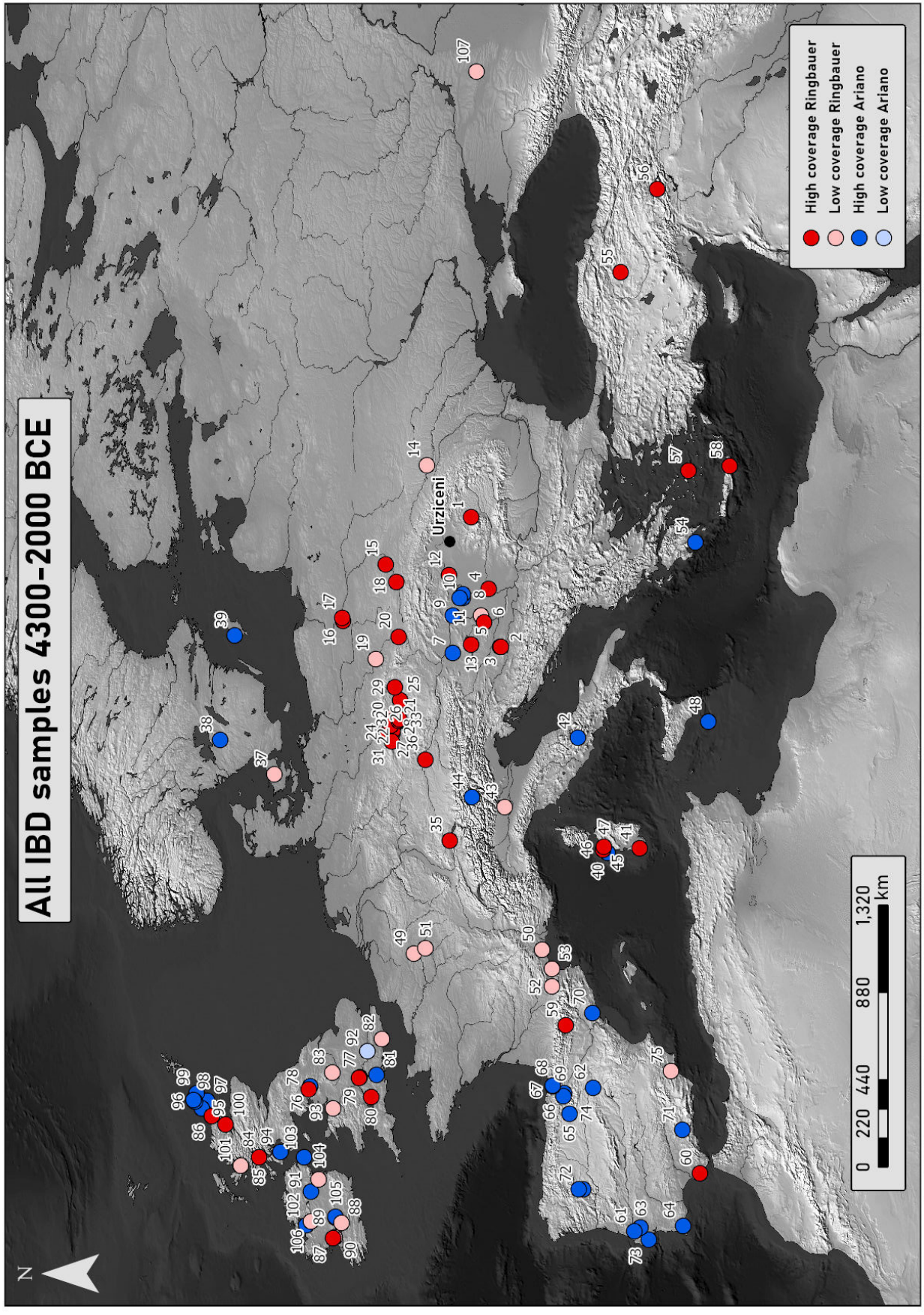
- 130 Gudon, Italy
- 131 Romagnano Loch, Italy
- 132 Riparo Gaban, Italy
- 133 Acquaviva di Besnello, Italy
- 134 Montesei di Serso, Italy
- 135 Croz del Cius, Italy
- 136 Lovere, Italy
- 137 Neto-Via Verga, Italy
- 138 Podere Pietrino, Italy
- 139 San Carlo, Italy
- 140 Monte d'Accoddi, Italy
- 141 Biriai, Italy
- 142 Lipari acropolis, Italy
- 143 Villafrati, Italy
- 144 Case Bastione, Italy
- 145 Saint Véran, France
- 146 Le Fortin du Saut, France
- 147 Monte Covolo, Italy
- 148 Kastri, Greece
- 149 Kephala Petras, Greece
- 150 Dhaskalio, Greece
- 151 Cabezo Juré (Alosno, Huelva), Spain
- 152 Valencina de la Concepción (Seville), Spain
- 153 Los Millares (Santa Fe de Mondújar, Almería), Spain
- 154 Almizaraque (Cuevas del Almanzora, Almería), Spain
- 155 Lugar Viejo III (María de Huerva), Spain
- 156 Cueva del Cañaveralejo (Adamuz), Spain
- 157 Bauma del Serrat del Pont, Spain
- 158 Las Pilas (Mojácar), Spain
- 159 Castro de Chibanes, Portugal
- 160 Outerio Redondo, Portugal

#### **Select gold finds**

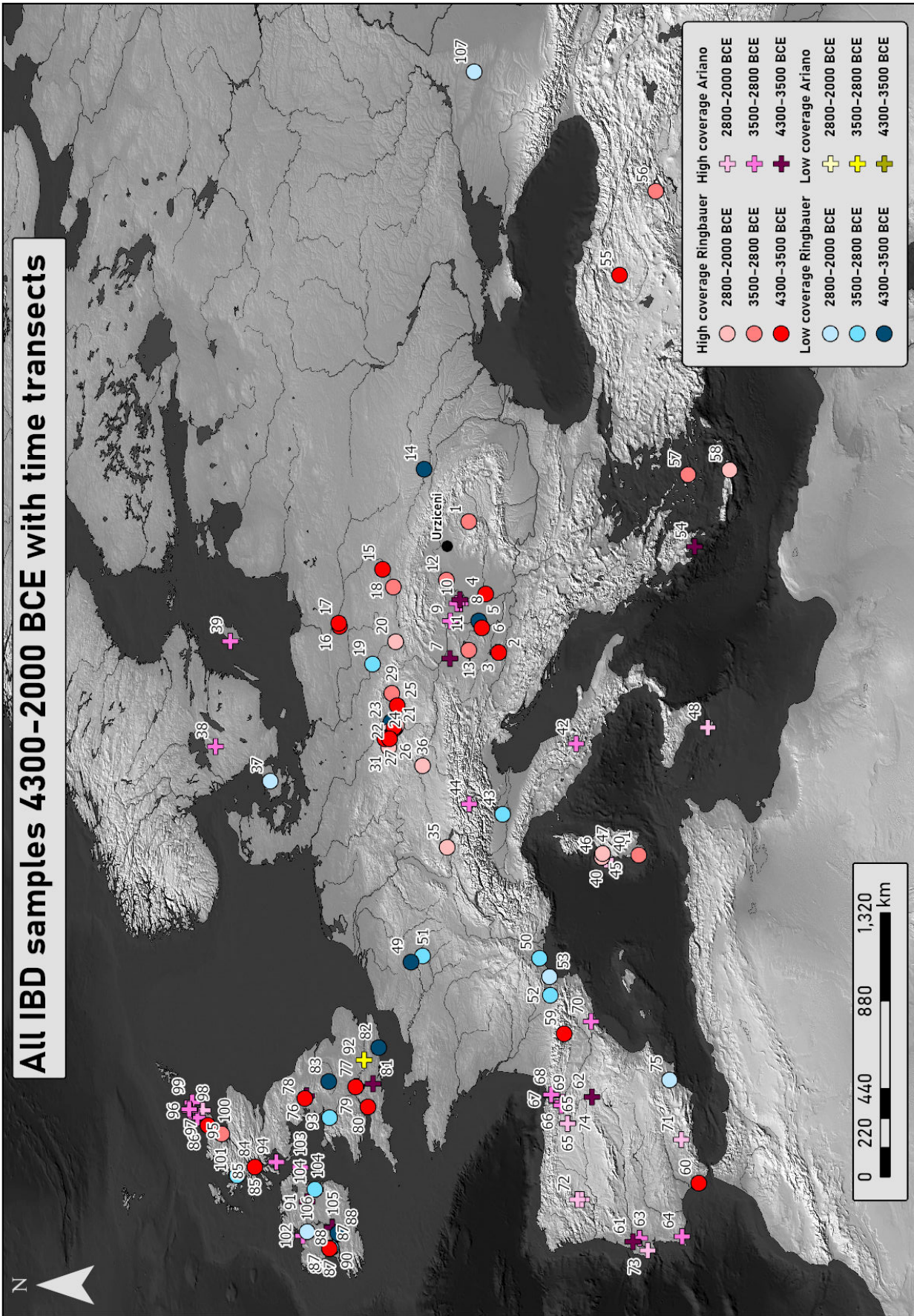
- 58 Crete, Lasithi, Hagios Charalambos, Greece
- 161 Pauilhac, France

#### **Evidence of copper mining**

- 162 Libiola, Italy
- 163 Monte Loreto, Italy
- 164 Buca di Spaccasasso, Italy
- 165 Poggio Malinverno, Italy
- 166 Grotta della Monaca, Italy
- 145 Saint Véran, France
- 167 Pioch Farrus, Cabrières, France
- 168 La Capitelle du Broum, Péret, France
- 169 Roque Fenestré, Cabrières, France
- 170 Cangas de Onís (El Milagro), Spain
- 171 Riosa (El Aramo), Spain
- 172 Copa Hill, Great Britain
- 173 Alderley Edge, Great Britain
- 174 Ross Island, Ireland



**Fig. 1a.** All IBD samples 4300–2000 BCE by publication source and coverage. Samples that share identical locations are represented by one symbol; higher-coverage samples are foregrounded over lower-coverage samples. The numbers key is in the Appendix.



**Fig. 1b.** All IBD samples 4300-2000 BCE by publication source, coverage, and time transect. Repeated numbers are due to slightly different coordinates for the same location or the same location being present in different time transects. The numbers key is in the Appendix.

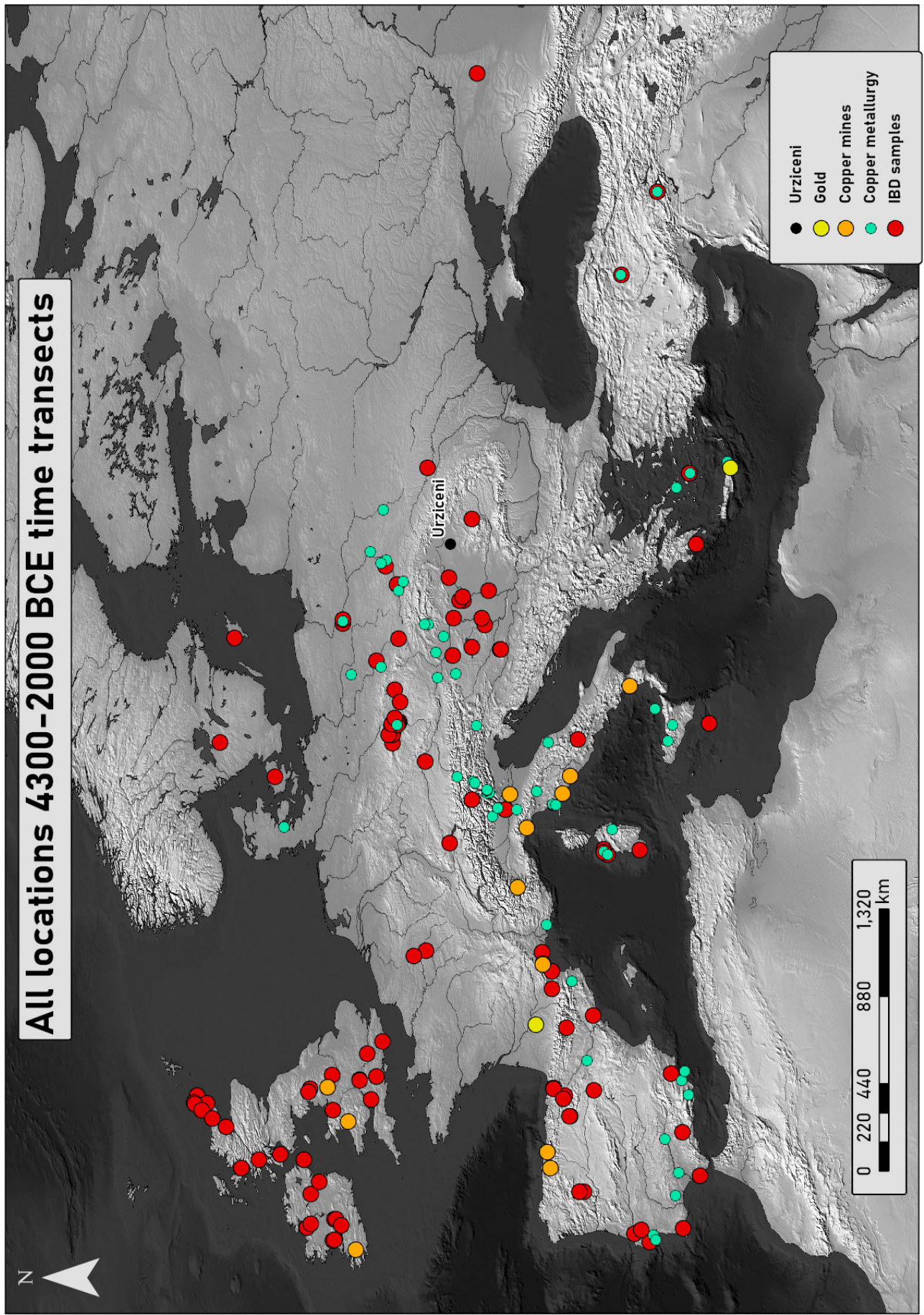
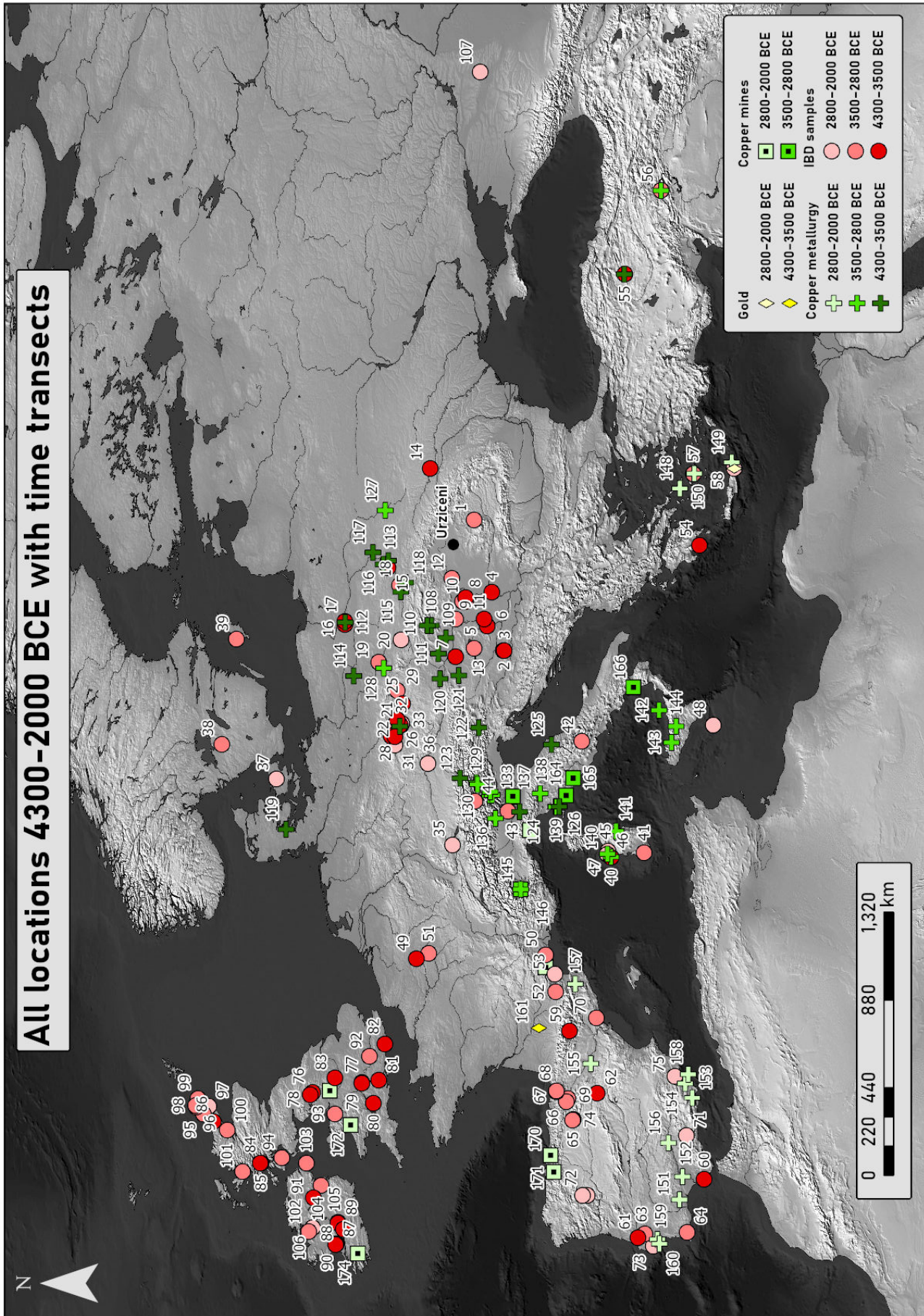


Fig. 2a. All locations 4300-2000 BCE, not distinguished by time transects.



**Fig. 2b.** All locations 4300–2000 BCE with time transects. Some numbers in the map are omitted for legibility. The numbers key is in the Appendix.

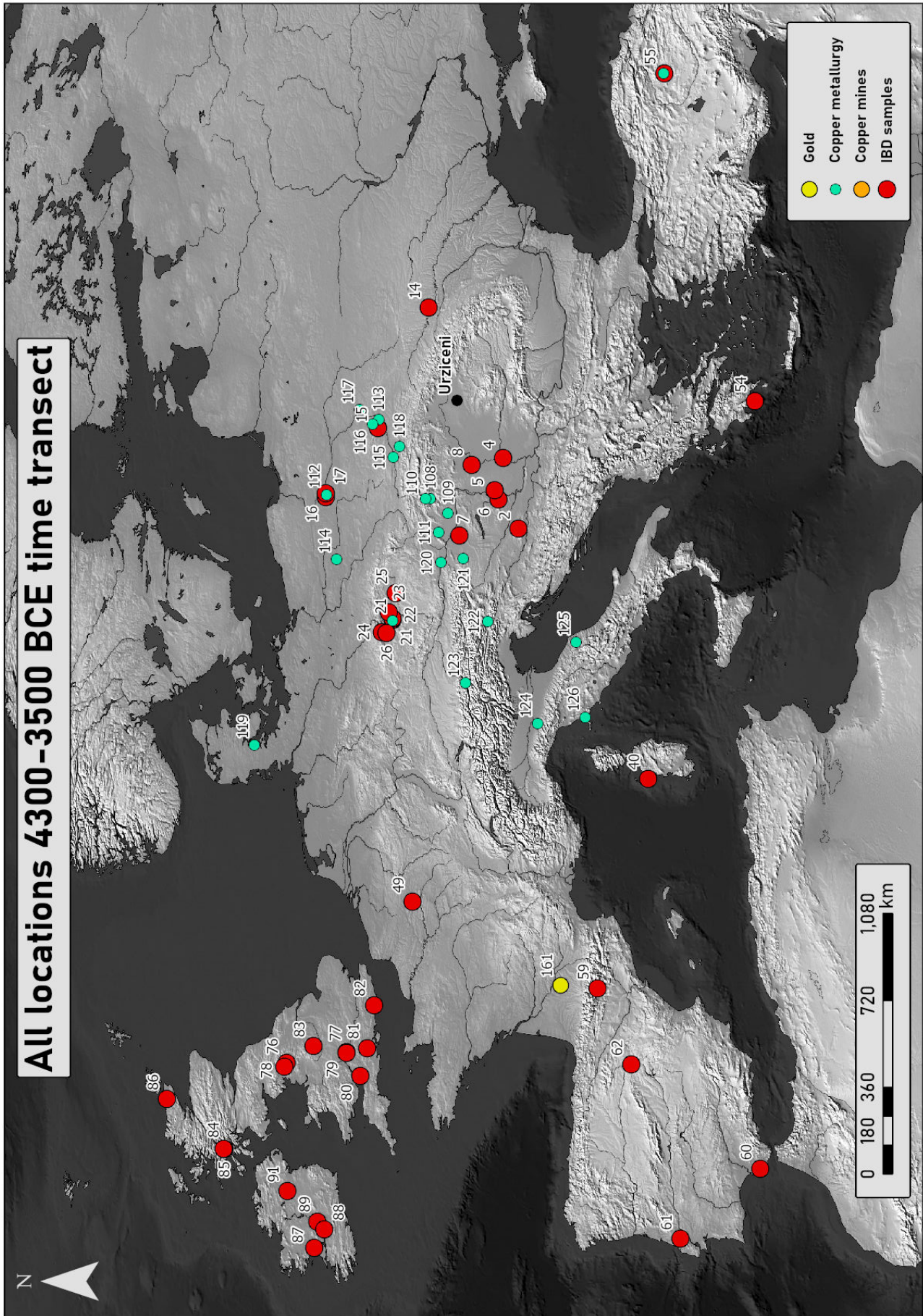
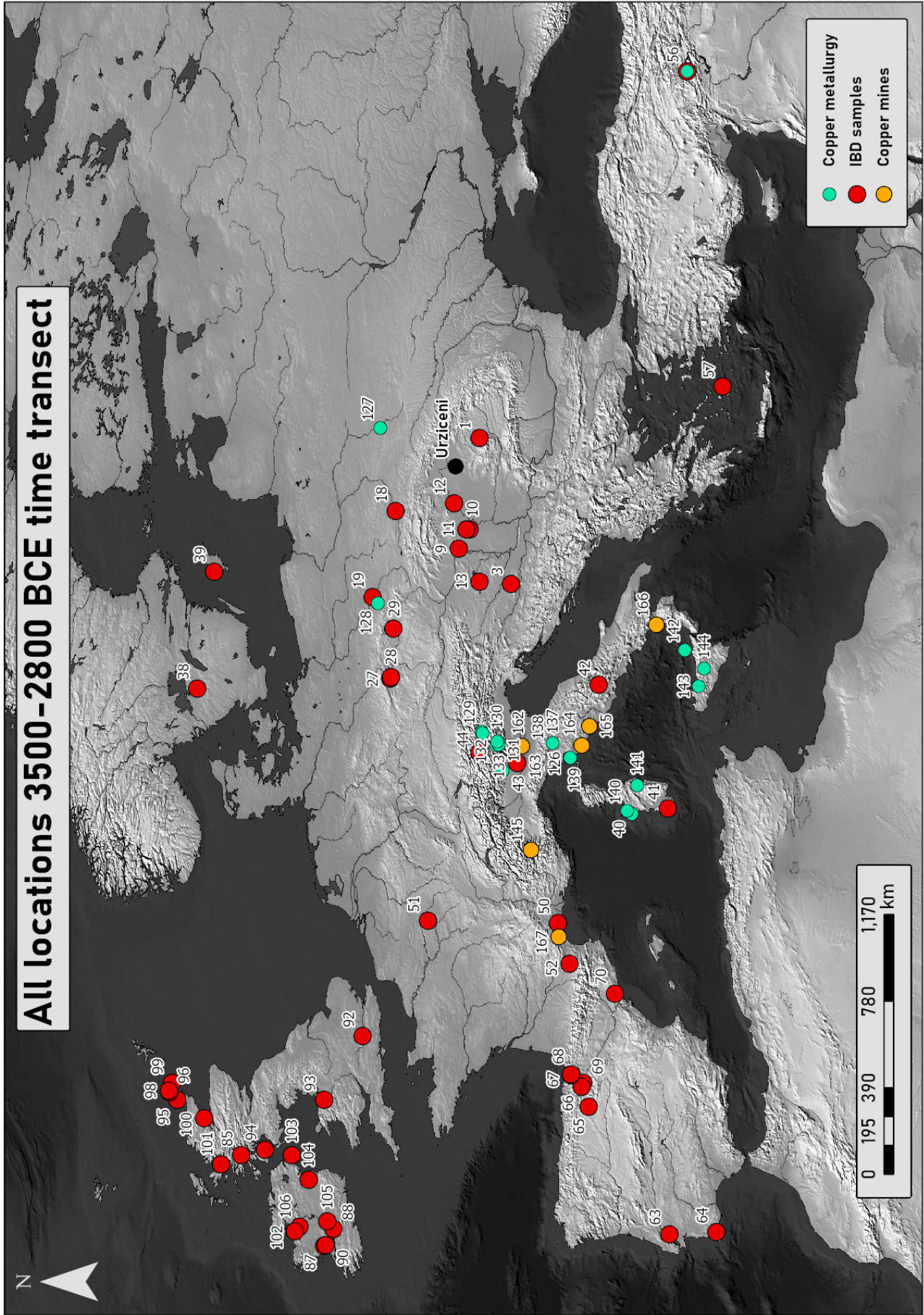


Fig. 3. All locations 4300-3500 BCE time transect. The numbers key is in the Appendix.



**Fig. 4.** All locations 3500–2800 BCE time transect. The numbers key is in the Appendix.

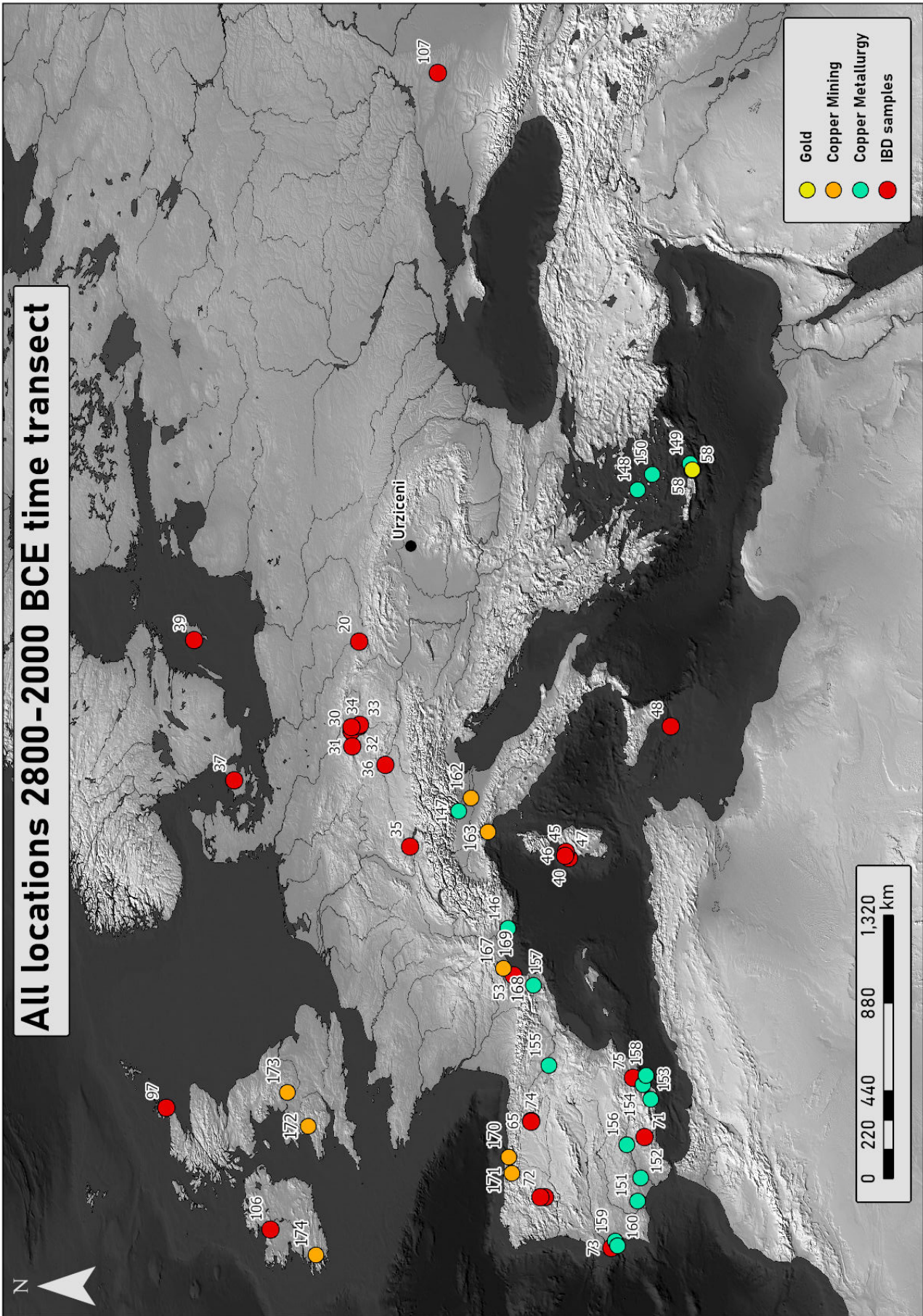


Fig. 5. All locations 2800–2000 BCE time transect. The numbers key is in the Appendix.