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STUDIA ARCHAEOLOGICA

38

2024

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STUDIA ARCHAEOLOGICA

38
2024

Editura MEGA
Cluj-Napoca
2024

MUSEUM ARAD

In Romania, the periodical can be obtained through subscription or exchange, sent as post shipment, from Museum Arad, Arad, Piata G. Enescu 1, 310131, Romania.
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Layout: Francisc Baja, Florin Mărginean, Victor Sava

DTP: Petru Ureche

ISSN 2392–8786

editura
MEGA

Editura Mega | www.edituramega.ro
e-mail: mega@edituramega.ro

This volume is dedicated to Tudor Soroceanu at 80 years

Acest volum este dedicat lui Tudor Soroceanu cu ocazia împlinirii a 80 de ani

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Thoughts and words about metals, metalworking and a regional power hub east of the Carpathians during the Middle Bronze Age

Neculai Bolohan, Ana Drob

Abstract: For a long time, the period of the Middle Bronze Age east of the Carpathians has been known based on two features represented by strongholds and the pottery package. Over the course of the last quarter of this century, the research results of the Siliștea and Costișa sites, Neamț county, composed the support of a new type of archaeological data reading and integration. Amongst, the multiple analysis of metal artefacts outlined an updated image on source or finished products mobility, technological processes' traces, new history of personal objects and long-distance connectivity. All of these begin to gain consistency by forging archaeological observations with those obtained as a result of archaeometric analyses.

Key-words: Eastern Romania; Middle Bronze Age; stronghold; metals; multiple analysis.

Introduction

The history of a lot of metal items designed for a particular purpose yielded by a Middle Bronze Age stronghold may complete the necessary understanding of the image of a place and an area far from raw material sources with little data regarding the development of a local technology or less visible components – connections, embellishment traditions and significance. Finds of metal objects in archaeological contexts and adequate stratigraphic conditions produce the expected chronological breeze. The descriptive methodology is activated, the typological method provides the taxonomical framework, and the comparative method would bind all the results; an approach with a long history and appreciable results, with constant methodological improvements and narrative reconsiderations. This paper is but a phase in the valuation of the metal finds yielded by the site at Siliștea-*Pe Cetățuie*, Români commune, Neamț county. This time, we chose to attempt bringing together typological-chronological and archaeometric data and conclusive propositions. It is just the beginning of an approach aimed at compiling several resembling objects and delivering more euphony to an archaeological text!

To one of the authors, the current contribution is the fulfilment of a curiosity kindled forty years ago by another archaeologist based in Bucharest, proficient in the Bronze Age, which told me/us about "my friend Tudor Soroceanu" and the post colloquia on the topic of the south-western Romanian Bronze Age.

There, we had the opportunity to read, meet, get acquainted!

Many Happy Returns!

In 2000, when the archaeological research of Siliștea-*Pe Cetățuie*, Români commune, Neamț county, commenced, the available information consisted of a general set of data on Middle Bronze Age period in the Cracău-Bistrița depression and a few discussions with Professors Alexandru Vulpe and Mihail Zămoșteanu, the ones who had firstly investigated and termed ahabitation level in the site at Costișa-*Cetățuia*, Costișa commune, Neamț county[1] as dating from the Middle Bronze Age. At the time, data on metalworking and metal objects specific to this period in the eastern region of the Carpathians were scarce. The resumption of the archaeological investigations at Costișa and the opening of those at Siliștea led to the discovery of a lot of metal artefacts of a remarkable typological and chronological value for the two sites and the Middle Bronze Age[2] (Fig. 1).

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[1] Popescu 2017, 5-15.

[2] Bolohan 2003, 195-206; Bolohan 2010, 229-244; Bolohan 2016, 73-86; Bolohan *et al.* 2001, 229; Bolohan, Munteanu 2001, 47-50; Bolohan *et al.* 2002, 287-289; Bolohan, Bilavschi 2003, 292-293; Bolohan, Bilavschi 2004, 309-311; Bolohan,

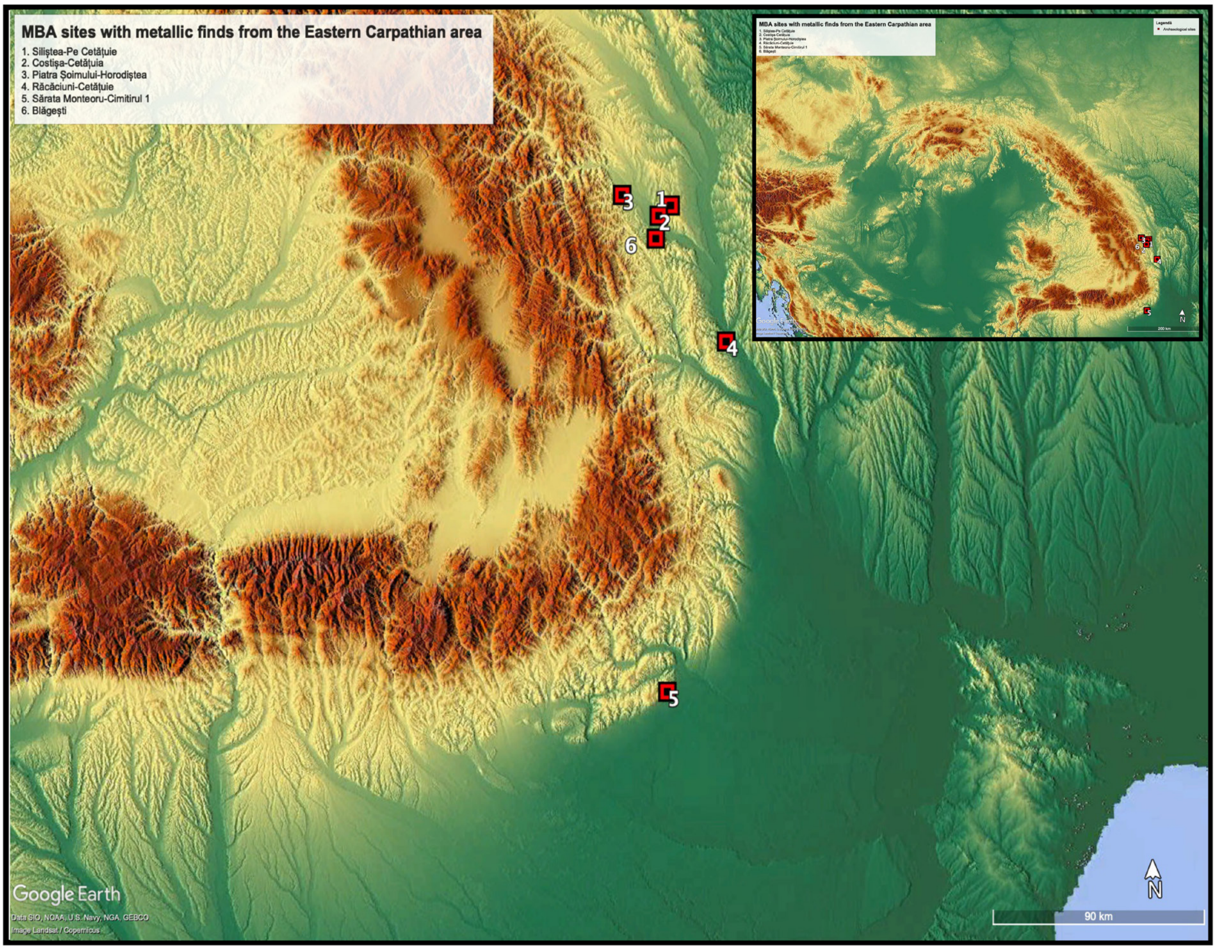

Fig. 1. Location of the sites mentioned in the text: 1. Siliștea-*Pe Cetățuie*; 2. Costișa-*Cetățuia*; 3. Piatra Șoimului-*Dealul Horodiștea*; 4. Răcăciuni-*Cetățuia*; 5. Sărata Monteoru-*Cimitirul 1*; 6. Blăgești.

The archaeological research of a stronghold yields various data on the location, the area or regional control, communication pathways, building system, internal layout, internal structures, osteoarchaeological or palaeobotanical remains and the archaeological materiality. In this context, after the extension of the research units in order to check the plan of a habitation system, a few metal objects were also identified. Most were discovered in the area with extensive inhabitancy traces and just one object was found at the base of the filling of the settlement's second defensive ditch.

Context

Diversified integration and understanding of archaeological materiality led to working hypotheses and remarkable results concerning the livelihood of a Middle Bronze Age community east of the Carpathians. Beside the general analysis of clay, stone, flint, or bone objects which certifies certain previous views or open new horizons of approach, the find of a lot of metal objects implies, in this case, diversified methodology. Presumptions are replaced by a few interpretations leading to insights relative to the artefacts' raw material, production, use and discontinuance, society, and long-distance connection issues.

The progress of the archaeological research conducted at Siliștea-*Pe Cetățuie* resulted in the identification of a stronghold with at least two ditches[3] on Cetățuia hill. The remains of two ditches and two houses located towards the southern side of the site, in the northern proximity of the first

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Crețu 2004, 55-76; Bolohan *et al.* 2015, 131-146; Bolohan, Gafincu 2017, manuscript; Bolohan, Gafincu 2018, manuscript; Bolohan *et al.* 2019, manuscript; Bolohan, Drob 2023, 97-136; Popescu, Băjenaru 2004, 277-294; Popescu, Băjenaru 2008, 5-22; Popescu, Băjenaru 2015, 35-43.

[3] For details regarding the progress and content of the research see, Bolohan, Asăndulesei 2013, 339-246; Bolohan, Drob 2023, 97-137.

ditch, were investigated. The general appearance of the habitation structure traces seems rather disturbed, which means that the place was abandoned in a hurry. Within the excavation area, were also unearthed a few undisturbed features represented by firing installations, waste pits, traces of meat offerings, small or miniature vessels. The metal objects, except for two casting scrap pieces identified within the area of Square α/2003, are dress or jewellery items. Almost all were discovered in the habitation structures' area, investigated in the research units SI, Square A and C. Just one metal object, namely a double-spiralled hair ring was found at – 0.94 m, towards the lower part of SIII, the second excavated ditch.

Metal objects

Until 2019, eleven metal items catalogued as jewellery or dress items have been identified. These are represented by a batch of five items, worked of double-spiralled copper wire[4] with twisted endings and circular section, generically termed *Noppenringe*[5]. The wire of which these were made by drawing and hammering is between 1.80 mm and 2.87 mm thick. The different diameter of the wire thread is given by its use with *Noppenringe* of different sizes. All items belong to the class of large items[6]. The examined morphological details – twisted ends, number of coils, number of wire twists, beside the find contexts – complete the history of discussed artefacts[7]. These emerged in excavation units SI/2001, squares 12-14, 16 (three exemplars), Square A/2000 (one exemplar), SIII/2017 (one exemplar) (Pl. 1). The first discovered artefact was deemed a useful cultural marker for chronological framing and estimation whether certain connection elements with the middle Danube basin of the Únětice environment may be identified. This batch of metal objects is found mostly in burial contexts as early as the Clopice-Veselé period, characterised by corded pottery, and the ancient period of the Nitra culture[8]. Finds of this type expands a generous timeline between the end of the Early Bronze Age and late Middle Bronze Age in Central Europe[9] up to the east of the Carpathians[10]. In the area discussed here, all *Noppenringe* associate with inhabitancy structures. Exemplars no. 1 and 5 are very close in size and seem to have been part of a unitary set of jewellery items.

1. *Noppenringe* – N.I. 19.919, Square A, 2000, (Pl. 4/1)[11].
   - wire diameter = 2.87 mm,
   - outer diameter = 34.2 mm,
   - one simple and one double wire coil.
2. *Noppenringe* – N.I. 19.920, SI, squares 12-13, 2001, (Pl. 4/2).
   - wire diameter = 1.80 mm,
   - outer diameter = 43.3 mm,
   - one simple and one double wire coil.
3. *Noppenringe* – N.I. 19.921, SI, squares 12-13, 2001, (Pl. 4/3).
   - wire diameter = 2.16 mm,
   - outer diameter = 36.8 mm,
   - one simple and one double wire coil.

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[4] After the summer of 2001 archaeological investigation, three *Noppenringe* were delivered to the History Museum of Piatra Neamț, where the green patina was removed, thus resulting three "shiny", coppery objects. This was the first step in recognizing the raw material used for their making. Bolohan, Munteanu 2001, 49, Pl. 40/1-3.

[5] These were typologically ascribed after a discussion with Professor Mircea Petrescu-Dîmbovița in July 2001, who also guided us to the first bibliographical source, Petrescu-Dîmbovița 1998, 15, 188-189, Taf. 163/2388 (n.m. Neculai Bolohan). In order to assess the definition of this artefact type, see Neugebauer 1994, Abb. 34; see also the highly useful approach, quantitative, typological, and combinatory and the suggested classifications by Lutteropp 2009, 138-139, Abb. 14, 16.

[6] Reiter 2020, Abb. 55/4-5.

[7] Consistent results on these objects' history – raw material, technology, typology, contextual analysis – were obtained based on the research results of known burial contexts like those at Frazhausen I. Neugebauer-Maresch-Neugebauer 1997, 50; Gemeinlebarn, Neugebauer 1991, 29, 30, Abb. 5.

[8] Schalk 1999, 99.

[9] A few similar finds, worked in bronze or gold, were recorded up to Jutland. Mörtz 2009, 221-237.

[10] We have not resumed here the many parallels for the described artefacts. See Bolohan 2003, 197, Pl. 9/a-c; Bolohan, Crețu 2004, 60, Pl. 13/a-e; Bolohan 2010, 229-244; Bolohan, Asăndulesei 2013, 399-246.

[11] During the completion of this paper, we had no direct access to the examination of all *Noppenringe* 1-3 specific details.

4. *Noppenringe* – SI, square 16, 2003, (Pl. 5).
   - wire diameter = 2.27 mm,
   - outer diameter = 31.90 mm,
   - weight = 15.260 g,
   - one simple and one double wire coil.
5. *Noppenringe* – SIII, square A3, 2017, (Pl. 6).
   - wire diameter = 1.90 mm,
   - outer diameter = 33.92 mm,
   - weight = 13.151 g,
   - one simple and one double wire coil.

The second class is represented by a single artefact worked of a copper bar with almost circular section, of which a bracelet was made. It is part of a common type produced of circular section copper bar, undecorated, overlapping ends and cutting marks on the ends.

6. Bracelet – Square C, the south-east corner, 2003, (Pl. 7).
   - bar diameter = 5.79 mm,
   - outer diameter = 49.62 mm,
   - weight = 28.554 g,
   - overlapping ends,
   - hammering and smithing traces are visible in the form of very fine lines (Pl. 7/4, 6); chisel cutting marks on one of the ends (Pl. 7/5).

Wire rings/loops that seem to belong to the class of jewellery items.

7. Ring – SI, square 12. 2002, (Pl. 8).
   - wire diameter = 1.99 mm,
   - outer diameter = 22.63 mm,
   - weight = 1.950 g,
   - open-ended form,
   - circular section wire, with cutting marks by the ends.
8. Ring of two twisted wire pieces – SI, square 16, 2003, (Pl. 9).
   - wire diameter = 1.59 and 1.50 mm,
   - outer diameter = 20.37 mm,
   - weight = 2.365 g,
   - closed form,
   - two short, parallel, circular section wire pieces and sharp, twisted ends.
9. Loop – Square C, square E (Pl. 10).
   - wire diameter = 1.09 mm,
   - outer diameter = 7.20 mm,
   - weight = 1.125 g,
   - closed, fragmentary form,
   - two short, parallel wire pieces of thin, bronze wire of a square section.

In the excavated area, namely Square α/2003, there were identified two metal scrap pieces, one of copper (no. 10) and the other, of bronze (no. 11)[12], which most likely resulted from the casting of some artefacts. Their analysis evidence different elemental composition, yet each of these has enough compositional similarities with one or the other objects found in the excavation area. The described results pose new questions concerning the possibility that several final products were completed, in this case, one simple loop, procedure which does not entail any technological skills, even within the habitation structure framework.

Methodology

The microscopic and physical-chemical analyses allow a series of detailed observations related to the structure and microstructure of the studied objects, secondary products, use-wear traces, chemical compositions and compounds of the alloy and corrosion.

12 See below paragraph *Results*.

The samples were weighed with a digital scale model: Partner AS220/C/2.

Optical microscopy was carried out with a Zeiss Imager.a1M microscope, AXIOCAM incorporated camera and AxionVision Release 4.7.1 software.

The elemental analysis made using a SEM scanning electron microscope, VEGA II LSH (Tescan) model, coupled with a EDX detector, type Quantax QX2 (Bruker). The obtained SEM microphotographs were constituted by backscattered electrons (BSE) for different magnifications of the alloy and corrosion, without covering the samples with carbon or metal.

The XRF analysis of the three restored items in the collection of the History and Archaeology Museum of Piatra Neamț[13] was performed in 2015. Measurements were taken with the aid of a handheld tool (Niton XLt900, Fa. Thermo Scientific), using a silver anode and 50kV X-ray voltage. The analysed surface is of ca. 8 mm in diameter for the large items and of 3 mm for the smaller objects. The material composition was acquired at a depth of 0.01 mm, some elements being determined only for the object's surface.

The XRF analysis of the non-restored items was conducted in 2024 with a handheld device of type S1 TITAN 800 (Bruker)[14], equipped with a high-performance graphene window silicon drift detector (SDD). The surface of analysis is of 8 mm at 50kV voltage, using the GeoExploration application, usable in mining and mineral analysis. Results were processed with the aid of the software provided by the manufacturer, Bruker's Instrument Toolbox.

In the case of the corroded copper alloys, the corrosion crust composition is not representative for the entire object and does not represent the alloy's real composition. Some elements like tin, lead, or silver segregate towards to the surface via certain corrosion processes, which determines excessive concentrations compared to the object's real composition. Furthermore, some elements result from the corrosion crust formed during the post-depositional processes.

Results

The optical microscopy and scanning analysis of the metal items have evidenced the presence of several corrosion structure types, which depending on the object, present certain peculiarities.

In this regard, numerous studies show that the transition from the original state of the artifact, that prior to abandonment, to that presented at the time when it is recovered from the archaeological site, is evidenced by the changes occurring over the course of a long time span, especially through the corrosion crust formed subsequent to the action of internal and external factors and natural, chemical and electrochemical processes[15]. For instance, the iron and manganese from an archaeological site may accumulate as a result of microbiological activities[16], being often found as corrosion crust elements.

Thus, in some copper alloy items, the transition of basic metals into primary or secondary chemical compounds (oxides, chlorides, carbonates, etc.), occurred partially, the metal core being covered with a layer of copper oxide, orange-red in colour, on top of which there is a green layer, composed of copper chlorides, while others were completely mineralized, their shape being supported by corrosion products[17].

Jewellery items

Noppenringe

In the case of the two analysed *Noppenringe* (Pl. 5 and 6) are visible both flat, homogenous corrosion surfaces, active and in a continuous oxidation process and non-productive surfaces, where only secondary processes occur (under environmental influence). Among identified secondary products,

[13] The copper items with inventory nos. 19919, 19920, 19921 discovered during the 2000 and 2001 campaigns benefited in 2015 of a set of XRF tests carried out by the team supervised by Prof. dr. Ernst Pernicka with the Curt-Engelhorn-Zentrum Archäometrie an Der Universität Heidelberg and Institut für Geowissenschaften Universität, Heidelberg, dr. Nikolaus Boroffka with the Deutsches Archäologisches Institut, Eurasien-Abteilung, and Dr. Bianka Nessel, Institut für Geowissenschaften, Universität Heidelberg), whom we thank for initiative and support.

[14] The equipment belongs to the Laboratory of Applied Meteorology and Climatology RA-05 of the Integrated Research Centre for the investigation of atmospheric aerosols in Romania-Recent Air, "Alexandru Ioan Cuza" University of Iași. We thank here Professor Silviu Gurlui and Dr. Vasile Pelin for having kindly offered their support during the performance of the analyses.

[15] Robbiola *et al.* 1998, 2083-2111; Robbiola, Portier 2006, 1-12; Domenech-Carbo 2010, 349-351; Sandu *et al*. 2012, 1646-1652.

[16] Scott 2002, 39.

[17] Mircea *et al.* 2012a, 179-178; Nørgaard 2017, 101-122.

carbonates are represented by green malachite (Pl. 5/a-d; Pl. 6/a-d), the azurite being also visible[18] (Pl. 5/a-d), bluish, present only in some areas of the corrosion crust[19]. Even more, microscopically, some fine fissures of the corrosion crust (Pl. 5/a), with some flaking areas (Pl. 5/b, d; Pl. 6/b-d) were evidenced. Furthermore, the depositional environment also determined the emergence of chlorides, represented by the whitish areas.

The EDX analysis was performed on both the metal core as well as the surfaces in order to identify alloy elements and the corrosion crust of the two *Noppenringe*. The obtained results indicate that copper was used in their making (Pl. 2/1), the XRF data completing information (Pl. 3/2) by showing more consistent trace elements (Sn, As, Ni, Pb, Ag, Fe) and ones at the detection limit (Cr, Mn, Ta, Ce, Co). Thus, the melted copper is relatively pure, with only a few parts per million of typical impurities like silver, arsenic, gold, antimony, lead and so on[20]. The XRF investigations performed on the three cleaned *Noppenringe* (Pl. 3/1; Pl. 4) present the same elements, suggesting in this case that all the five *Noppenringe* type items were copper made.

The surface analysis indicated elements specific to corrosion products[21] (Pl. 2/2) like malachite[22] ($Cu_2[(OH)_2 | CO_3]$) and cuprite (Cu_2O), yet also elements like Cl and S, these resulting from nantokite[23] (CuCl), atacamite ($Cu_2Cl(OH)_3$) and brochantite ($Cu_4SO_4(OH)_6$), elements from soil contamination over the course of the depositional processes (C, P, Al, Si, K, Ca, Na, Mg, Fe)[24] being also present. Also, one may not exclude the presence of phosphates like the sampleite ($NaCaCu_5(PO_4)_4Cl•5H_2O$), zapalite ($Cu_3Al_4(PO_4)_3(OH)_9•4H_2O$) or libethenite ($Cu_2(PO_4)$ (OH), frequently associated with the other identified secondary products.

Technologically, the performed SEM micrographs (Pl. 5/3, 4, 4; Pl. 6/3, 4) highlights the flattening of the two twisted endings, thus indicating that the items were worked while still hot, when the metal is sufficiently malleable to change form. Even more, the scanning microscopy also noted hammering traces of the wire used to create the items (Pl. 6/ 5, 6), thus partially sketching a series of procedures used in the technological chain of *Noppenringe* type jewellery items making. Thus, in a first phase, the wire was made by careful hammering to obtain the desired uniformity. The bending or modelling process of the item seems to have taken place when the metal was cold, while end twisting was accomplished when these were heated, aspect determined by both practical elements, like increased resistance to detachment , as well as for aesthetic reasons, as this procedure allowed smooth levelling of the spiral ends.

Bracelet

The optical microscopy images of the bracelet show the existence of a corrosion crust in relief, with an alveoli structure and specific products, like cuprite, malachite, and azurite (Pl. 7/a-f). The SEM micrographs performed on a flaking area of the corrosion crust evidence the presence of a second corrosive layer, flat, with elements of physical decay, like fine cracks and flaking (Pl. 7/1). Technologically, the bracelet was made also by hammering, resulted traces being visible via the scanning microscopy (Pl. 7/3-6). Both ends seem to have been "cut" by drawing and tearing the heated metal[25], an argument in this respect being their shape, but also a microscopic trace resulted subsequent this procedure (Pl. 7/5).

The EDX elemental composition (Pl. 2/1) carried out on the metal core indicates the use of copper, with more consistent traces of nickel, aspect also supported by the XRF investigations (Pl. 3/2), which illustrates the presence of elements like tin, arsenic and silver, beside other elements found at the detection limit (Fe, Pb, Cr, Mn, Ta).

The elemental analysis of the corrosion crust (Pl. 2/2) confirms the microscopic observations, by showing the presence of carbonates (cuprite, malachite), chlorides (nantokite, atacamite), sulphates (brochantite) and phosphates (sampleite, zapalite, libethenite).

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18 Mircea *et al.* 2012b, 1467; Oudbashi *et al.* 2016, 1-11.
19 Baron *et al.* 2014, 334.
20 Scott 2002, 37.
21 Mircea *et al.* 2012b, 1473.
22 Baron *et al.* 2014, 335.
23 Payer *et al.* 1995, 66.
24 Mircea *et al.* 2012b, 1472.
25 Siklósi *et al.* 2022, Fig. 17.

Ring

The analysed ring displays surfaces with flat corrosion, yet also in relief, with complete or broken alveoli structures (Pl. 8/a-f). Also, are visible non-productive or active corrosion areas, where products like malachite, azurite, and cuprite are present. The scanning microscopy evidenced the existence of a flat corrosion crust, with fine cracking, where the broken alveoli structures are very well defined (Pl. 8/1). Technologically, on this item were identified hammering traces in the form of thin and flat lines, parallel to the object's length (Pl. 8/a-b). Also, the ends of the item are flat, which shows that they were cut with a sharp object, which had no effect on their shape (Pl. 8/3, 4).

The elemental composition indicates the item was made of copper (Pl. 2/1), with trace elements in higher values (Sn, As, Ni, Pb, Ag) or by the limit of detection (Pl. 3/2), which show in this case too, the working of a native copper ore.

Elements present on surfaces are specific to corrosion products (Pl. 2/2) like malachite, cuprite, nantokite and atacamite, with the possible existence of phosphates or the elements resulting from soil contamination.

Ring of two twisted wire pieces

The microscopic observations carried out for the two-piece twisted wire ring evidenced the presence of a preponderantly flat corrosion crust, with elements of physical decay like for instance fine cracks and flaking areas (Pl. 9/a-f). In this item are noticeable three types of layered corrosion (Pl. 9/d, e; 1), starting from the interior towards the exterior: one primary (active), one secondary (non-productive) and one of contamination with soil elements. Thus, the identified corrosion products are as follows: cuprite, malachite, azurite, nantokite and atacamite, the latter being visible especially in the active area.

Technologically, the item evidences manufacturing similarities with the *Noppenringe*, the twisted endings being made in the same manner, namely by the metal heating and twisting (Pl. 9/3). Furthermore, on this item are visible, through scanning microscopy, the traces of tools used to perform this twisting procedure (Pl. 9/3, 4). The other end of the item has a straight side, which indicates the use of a sharp tool to cut the metal (Pl. 9/5).

The elemental composition of the item (Pl. 2/1) highlighted the use of an alloy of copper (91%) with lead (5%), with traces of arsenic and nickel, the XRF analysis indicating the presence of tin and silver (Pl. 3/2). The 5% concentration shows the clear intention to alloy these elements[26], being known and agreed that adding lead in small quantities reduces the alloy's melting point and increases metal fluidity, thus allowing both the casting as well as easy modelling of certain objects.

Regarding the corrosion products, beside those identified microscopically, specific to copper, cerusite ($PbCO_3$) was also identified elementally, with the possible presence of hydrated compounds caused by environmental conditions (Pl. 2/2).

Loop

The performed microscopic analysis of the loop shows the presence of a corrosion crust in relief, with many irregularities and alveoli structures (Pl. 10/a-f). The SEM micrographs show the presence of soil mineral granules integrated in the corrosion crust, thus contributing to its irregular appearance (Pl. 10/a; 2).

Elementally, it was noted that the item was bronze made (Pl. 2/1), the alloy being composed of copper (78%), tin (4%) and lead (8%), with trace elements like nickel, manganese, iron, and silver (Pl. 3/2).

Copper in alloy with a 5-10% tin concentration[27] would have led to a golden-yellow colour of the object, thus making it attractive to sight, aspect still visible microscopically on some of its areas (Pl. 10/f). The appreciable lead concentration, in this case too, offers metal malleability, which makes it more suitable for modelling small size items, like the case of the discussed loop. In the SEM images of the metal core is noticeable the segregation process of the lead in the form of whitish areas (Pl. 10/2), their sizes having no negative impact on the object quality. The loop could represent a decorative/

[26] Pernicka 2014, 256.
[27] Cornacchia *et al.* 2020, 806-817.

functional element, attached to a *Noppenringe,* as proven by the exemplar discovered in 2000 (Pl. 3/1). In this case, we are dealing with finished objects made of different metals joined to create a single jewellery item that would include both copper as well as the precious bronze.

The SEM micrographs performed on the object show that the wire of which the loop was made is rectangular in section and made by hammering (Pl. 10/3). Also, one of the ends presents the trace of a tool, most likely used for its cutting (Pl. 10/4).

The corrosion products present on the object surface are represented by copper and lead carbonates, sulphates, phosphates, and few chlorides, like tin oxides (SnO_2)[28]. Also, there are present a series of elements resulting from soil contamination, which thus provided increased metal protection (Pl. 2/2).

Casting scrap

Large casting scrap

The microscopic analysis of the large casting scrap, both optical and scanning, evidenced a flat and homogeneous corrosion crust (Pl. 11/a; 1). The secondary products are mainly represented by cuprite and malachite, azurite being also visible in certain areas (Pl. 11/a-f).

Technologically, the scrap exhibits casting cracks (Pl. 11/3) and irregularities (Pl. 11/4), one of the ends appearing in the form of a burr (Pl. 11/5) and the other indicating cuts and breaks (Pl. 11/6).

Compositionally, the casting scrap is composed of copper (92%) alloyed with lead (4%), exhibiting significant similarities with the twisted loop (Pl. 2/1). Also, the XRF analysis (Pl. 3/2) indicated the presence of specific trace elements, like nickel, tin, arsenic, silver, lead, and iron, but also of elements at detection limit (Cr, Mn, Ta, Co, Ce).

The corrosion products identified elementally are represented by copper carbonates, traces of chlorides (nantokite, atacamite), the lead carbonate, most likely in the form of cerusite (Pl. 2/2) being identified as well.

Small casting scrap

The microscopic analysis of the small casting scrap indicates the presence of dendrite structure corrosion products[29] (Pl. 12/e, f) of cuprite and malachite type, and also of chlorides visible in whitish areas (Pl. 12/a-f). The regular structure of these secondary products results from the casting process[30], in this case, the item's non-functional nature (Pl. 12/1-4) being supported by the microscopic arguments.

Compositionally, the small casting scrap consists of copper (71%), tin (7%), lead (8%) and more consistent traces of nickel (0.9%), being thus made of a bronze alloy with a high lead content (Pl. 2/1), similarly to the small loop. Beside these main elements, there were also identified some traces of arsenic, silver, manganese, iron, caesium, and cobalt (Pl. 3/2).

The corrosion crust (Pl. 2/2) is composed of carbonates, phosphates, and chlorides, present owing to the copper and its post-depositional derivatives. Lead carbonates and tin oxides are also found as secondary elements of the metals present in the alloy.

Discussion

A proposition to classify the bronze objects of the northern space divided these into six identified, simplified, and added classes based on their copper, tin, and impurities content. Accordingly, the items from Siliștea site may be framed in four of the six classes, namely copper with tin as impurity (trace-0.126%), copper with tin (0.127-2.0%), bronze with average content of tin (4.01-7.95%) and bronze with high content of tin (7.96->10%). The peculiarities of each class are represented by the tin quantity, which may be present naturally in copper, may be intentionally added or not to copper or could be the result of re-melting (mixture between the copper and bronze objects), bronze with a content of 6-8% tin and bronze with a very high content of tin, which makes the objects to crack, thus less resistant[31].

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[28] Scott 2002, 11.
[29] Scott 2002, 11.
[30] Garbacz-Klempka *et al.* 2024, Fig. 42.
[31] Vandkilde 1990, 123.

In the attempt to identify possible compositional connections, we considered the main and trace elements present in several batches of items analysed chemically, like Cu, Sn, As, Ni, Pb, Ag and Fe. In the database (Pl. 13) were included metal objects of the Middle Bronze Age from the east-Carpathian area, where, beside the eleven items from the Siliștea-*Pe Cetățuie* site were also added four items from the Costișa site[32] and fourteen items from the Blăgești deposit (Bacău)[33].

The compositional data were analysed in Excel using the "data analysis" tool[34], recording cases where a total value majority may be ascribed to just one factor. Thus, graphs which correlate connections between chemical elements and possible errors (expressed in percentages) were drawn up.

An identified correlation is that between Cu and As (Pl. 14/1), these elements grouping in two clusters with one exception (11). The first group evidences that copper values comprised between 20-80% include arsenic values between 0-2%, there being included seven items from the Siliștea bacth (4-10). In this case too, it is possible that the analyses carried out on corroded objects had influenced final data. The second group, where all remaining analysed items frame, shows that over 80% copper values have an arsenic content of maximum 0.07%.

The correlations between copper and lead is also interesting (Pl. 14/2), being identified two groups, where three exceptions are present. The first group represents the objects with Cu concentrations comprised between 20-60% and has Pb values varying between 0.01-0.17%, with one exception represented by an item at Siliștea (9), where lead values are of 0.52%. The second group includes objects where Cu is in a proportion of over 80% and Pb values between 0.00-0.12%, there too being identified two exceptions, a fragment from the deposit of Blăgești and the Monteoru lock-ring from Costișa, whose lead concentrations reach 0.25%.

There were identified connections between the larger quantity of Fe and a small Cu concentration (Pl. 14/3). These results may also be influenced by the fact that the XRF analyses were performed both on cleaned areas and areas with corrosion products, thus partially altering data analysis. Nevertheless, it is noted that although the Cu percentage may vary between 40-99%, the Fe value varies between 0 and 0.5% in most cases, except the three items of Siliștea (9,10,11) where iron values are comprised between 0.8-1.5% and copper values are below 40%.

The Cu concentration determines the silver quantity as well (Pl. 14/4), two groups thus being identified. The first is represented by copper values between 20 and 60%, which determine silver concentrations between 0.01 and 0.1%. To the second class pertain objects whose Cu concentration exceeds 80%, while silver is found in proportions of up to 0.25%, the majority ranging between 0.05-0.18%.

Other correlations exist between tin and iron (Pl. 14/5), they are grouping in a single cluster with five samples that do not adhere to this trend, represented by the items with tin over 2% of Costișa and Siliștea, where iron concentrations vary. Instead, in most samples, tin values are of maximum 0.5%, while those of iron of up to maximum 0.85%. The analysed data base also highlights the connection between Sn and Pb (Pl. 14/6), forming just one consistent group, except for, in this case as well, the bronze samples. In these objects, tin values are over 2%, while those of led vary between 0-0.5%. For samples whose tin concentrations are up to 1%, lead does not exceed 0.25% values. Furthermore, Sn is correlated with Ag as well (Pl. 14/7), and in this case exceptions are represented by the bronze objects, where silver values are of maximum 0.06%. In the case of items where tin is below 1%, silver values are comprised between 0 and 0.25%, the majority ranging between 0.06 and 0.015%.

Thus, after these chemical comparisons and correlations, a few trends relative to the composition of the analysed objects may be noted. Copper connects with arsenic, lead, iron and silver, these elements being thus the result of natural occurrences in the copper ores used for the making of the objects. Connections between tin and iron, as well as tin and silver were also identified, which is explained as well by the natural occurrence of these elements in the ores. For all elements there were also identified items outside the formed clusters, determined by the analysis performed on uncleaned items, which results in significant differences among the final chemical compositions.

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32 Popescu *et al.* 2017, 116-156.
33 Munteanu *et al.* 2022-2023, 121-140.
34 https://support.microsoft.com/en-us/office/analyze-data-in-excel-3223aab8-f543-4fda-85ed-76bb0295ffc4

Conclusions

Most objects discovered to date in the Siliștea-*Pe Cetățuie* settlement are made of copper, trace elements like arsenic, nickel or silver being also identified. The presence of bronze was established for two small size items, a loop, and a casting scrap, these too exhibiting a series of specific trace elements. Even more, identification of copper or bronze items alloyed with lead underlines significant knowledge on the properties which metals acquired following this procedure. Compositionally, the large casting scrap displays important similarities with the two-piece twisted wire ring, both having significant lead concentrations. The small casting scrap compositionally corresponds with the loop, similarly small sized, which records that local metalworking technologies were experimented within the settlement. The results of the typological and compositional analysis made here plead for the acknowledgement of long-distance trade between the east of the Carpathians and an area from central Europe, likely Slovakia, within the system of Middle Bronze Age connections. The presence of the two metal scrap pieces could be indicative of finishing know-how or the local production of certain metal objects, which could be a working hypothesis.

With regards to the finds from the east-Carpathian area, the jewellery objects of the bracelet, loop and ring type were discovered in the sites of Siliștea, Costișa[35], Piatra-Șoimului[36] (Neamț county), Răcăciuni (Bacău county)[37], Sărata Monteoru (Buzău county)[38] and the Blăgești deposit (Bacău county)[39].

Two *Noppenringe* type examples from the Costișa settlement were discovered one in the Costișa layer and one in the Monteoru layer. The lock-rings[40] identified associated with Costișa pottery have a high Sn content (7.5/16.8%) and a few trace elements (Fe, As, Ni), while that identified in the Monteoru deposition is characterised by a Cu alloy with little Sn (2.6%) and traces of Pb, Ag, Ni and Fe. Other found jewellery objects are represented by a *saltaleone* (in the Monteoru deposition)[41] and a discoid spiral (imbedded in a few adobe pieces in the Costișa level)[42], both being made of Cu with traces of As and Ni (Pl. 13).

The Blăgești deposit consists of fourteen jewellery items (two multi-spiral collars, two multi-spiral bracelets, two double-wire bracelets with overlapping ends, six double wire loops, a decorated disk, an undetermined fragmentary item), framed by late third and early second millennium BC, in the Nitra-Únětice cultural phase. Their parallels were established in the Central European space, which thus supports long-distance exchanges between these areas. Compositional analyses have indicated that the objects are made of copper (98-99%), with trace elements of tin, arsenic, zinc, and lead[43](Pl. 13). Typologically[44] and compositionally, the items in the mentioned deposit show significant similarities with the finds of Siliștea-*Pe Cetățuie*, thus reinforcing original notes concerning the use of metal goods from Central Europe in the east-Carpathian area[45] during an early phase of the Middle Bronze Age.

For the copper items of the discussed rings type yielded by the Siliștea-*Pe Cetățuie* site, similar compositions were found in the cemetery of Przecławice, Lower Silesia, Poland. Compositional studies performed on five similar items originating from three inhumations (graves 31-33) dated to phases III/IV of the Únětice culture, prove they were made of copper (over 95%), with a few minor trace elements, which would compositionally correspond to the east alpine copper or the Ösenring copper. These were produced of fahlore type copper[46]. The quoted study focused on a comparison between several metal objects originating from several sites in Lower Silesia, which belonged to the Bronze Age cultures from the SW area of Poland; thus, it was identified that the Przecławice finds are an exception in this area and that in the Únětice communities there existed different working strategies for making jewellery items, made exclusively of copper, in contrast with weapons, which were bronze made[47].

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35 Popescu *et al.* 2017, 116-156.
36 Vulpe 1940, 20; Petrescu-Dîmbovița 1998, 189, Taf. 163/2388. The copper ring is today lost.
37 Petrescu-Dîmbovița 1998, 189, Taf. 163/2387.
38 Zaharia 1959, 107-109, 115, Abb. 1/7; 4/7; Motzoi-Chicideanu 2011, II, Pl. 177.
39 Munteanu *et al.* 2022-2023, 121-140.
40 Popescu *et al.* 2017, 117, fig. 12/1-2, Table 1.
41 Popescu *et al.* 2017, 124, fig. 13/3, Table 1.
42 Popescu *et al.* 2017, 124, fig. 13/4, Table 1.
43 Munteanu *et al.* 2022-2023, 121-131/Fig. 4-6, 132/Table 1.
44 Bolohan 2003, 197, Pl. 9/a-c; Bolohan, Crețu 2004, 60, Pl. 13/a-e; Bolohan 2010, 229-244; Bolohan, Asăndulesei 2013, 339-346.
45 This view was moderately suggested, within the context of the Răcăciuni burial analysis, also by E. Tudor, 1973, 288.
46 Puziewicz *et al.* 2015, 653-676, fig. 3; Table 3.
47 Puziewicz *et al.* 2015, 675.

Nevertheless, the performed analyses observed that discussed objects exhibit the chemical signature of Central European mines, especially those in Slovakia[48], which is further supported by the parallels established for part of the investigated items. The accurate identification of metal origin areas, as recently proven[49], is a difficult process since the "mixture" of copper that originates from several areas during a phase before alloying, impacts the mixture of oligoelements, consequence which should be considered when interpreting chemical data obtained from finished products.

The discussed batch of objects is mainly composed of dress or jewellery objects which, commonly, are found in female burial contexts in the Central-European area of the Early Bronze Age. In the east-Carpathian area, one may recognize the cultural discontinuity between the Early Bronze Age and the beginning of the Middle Bronze Age visible within settlements, pottery, metalworking, dress code and its associated objects.

Most metal artefacts of Siliștea-*Pe Cetățuie* were worked of copper and other chemical elements referencing a source area located most likely in Slovakia. The analyses results, given all the above[50], for the Siliștea lot would suggest they belong to the material group SAMA[51]. The extension of copper use or the concurrent copper and bronze use seems to be specific to a transition period, of search for the ideal mixture between copper and tin. The inclusion of natural alloys in the metalworking process seems to be constant during the Reinecke A0 period. Surely, why these metal objects were present there would be consistently understood in the context of a larger scale analysis that should include other special objects or made of particular materials[52] associated with the common materiality of Costișa finds.

The metal resulted after using copper with metal impurities in the area east of the Carpathians by Early Middle Bronze Age resembles to a good extent the chemical signature of the impure copper of central-European origin yielded by the finds in central Jutland[53]. Such similarity is indicative of continuous use of a material[54] that was successful or had a similar behaviour with communities located by the fringe of copper and bronze metalworking.

The presence of copper and bronze metal finds in the east-Carpathian band, rather numerous in the Cracău-Bistrița depression, in the strongholds of Costișa and Siliștea, recently completed by the metal deposition find at Blăgești, require a differentiated approach mechanism of the role which a highly communication potential area had. This compels complete answers and explanations regarding for instance the clear delimitation of burial rite and ritual elements specific to settled communities, inhabiting fortified structures; establishment of social roles and material attributes and the content of metalworking know-how conveyance and where the finished products went; diversification of data used to recognize connectivity with Central Europe; the role of a social elite that has the same preferences in acquiring and displaying of certain metal items ever-present in Central Europe and hardly ever east of the Carpathians.

Acknowledgments

This work was supported for Ana Drob by a grant of the „Alexandru Ioan Cuza" University of Iași, within the Research Grants program, Grant UAIC, code GI-UAIC-2023-03.

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48 Marcoux *et al.* 2002, 173-184; Ling *et al.*2014, 106-132; Pernicka *et al.*2016a, 39, 41, 19-55; Pernicka *et al.* 2016b, 78, 82; Brügmann *et al.* 2017, 103-114; Nessel *et al*. 2019, 5-7; Mödlinger, Trebsche 2020, 1-15; Mödlinger *et al.* 2021, 1-33.

49 Komsek *et al.* 2020, 1-21.

50 See *supra* chapter Methodology.

51 Schalk 1999, 99.

52 Motzoi-Chicideanu 2011, I, 424-428; Popescu *et al.* 2017, 129 and note 102.

53 Vankilde 1990, 120-122.

54 Concurrent use of copper and bronze by Early Bronze Age has also been noted by Zaharia 1959, 108.

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WEBSOUCE

The Composition and Microstructural Variation of the Bronze Age Metal Ornaments from Lower Silesia (South-West Poland): Chemical Analytical and Archaeological Aspects

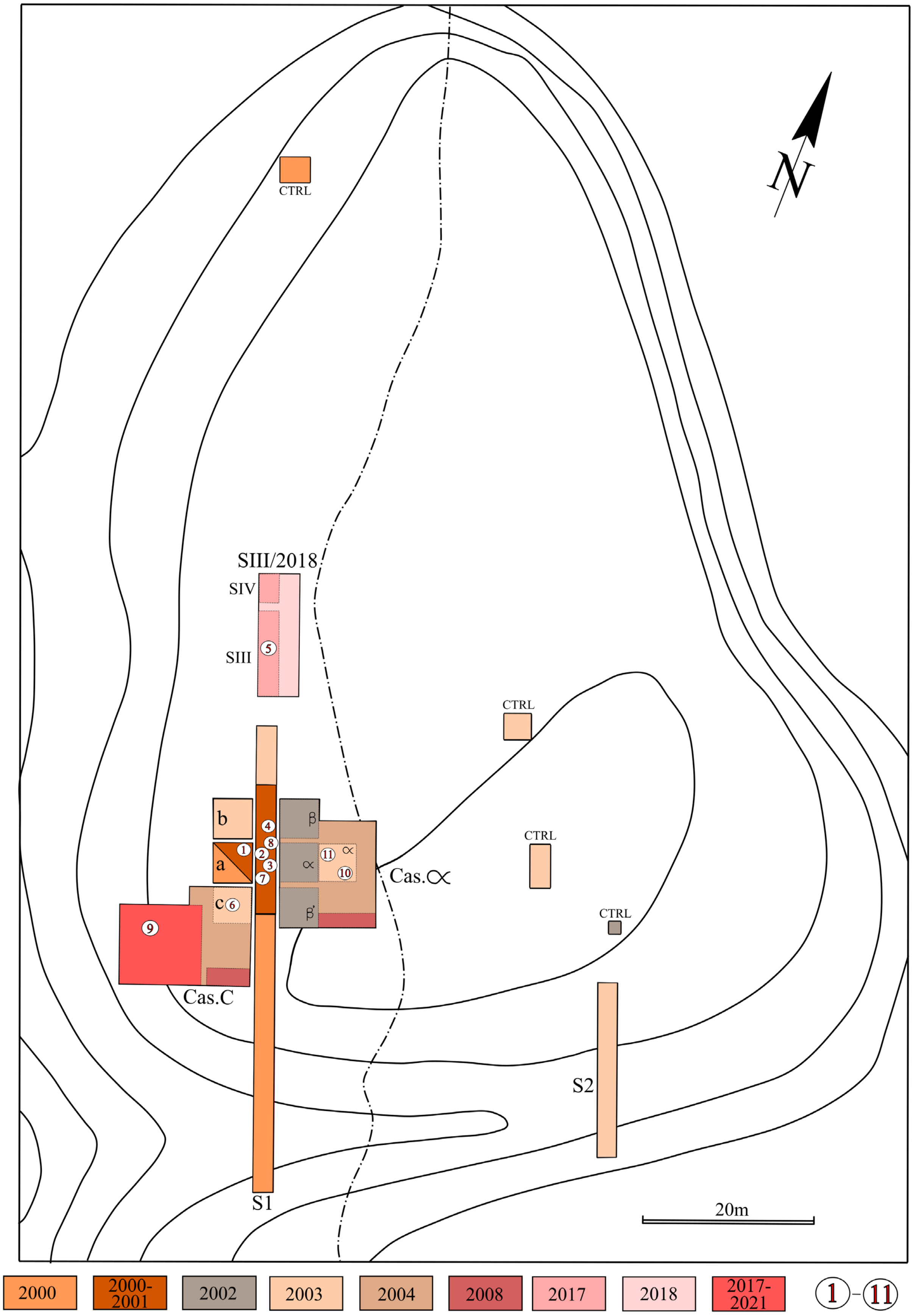
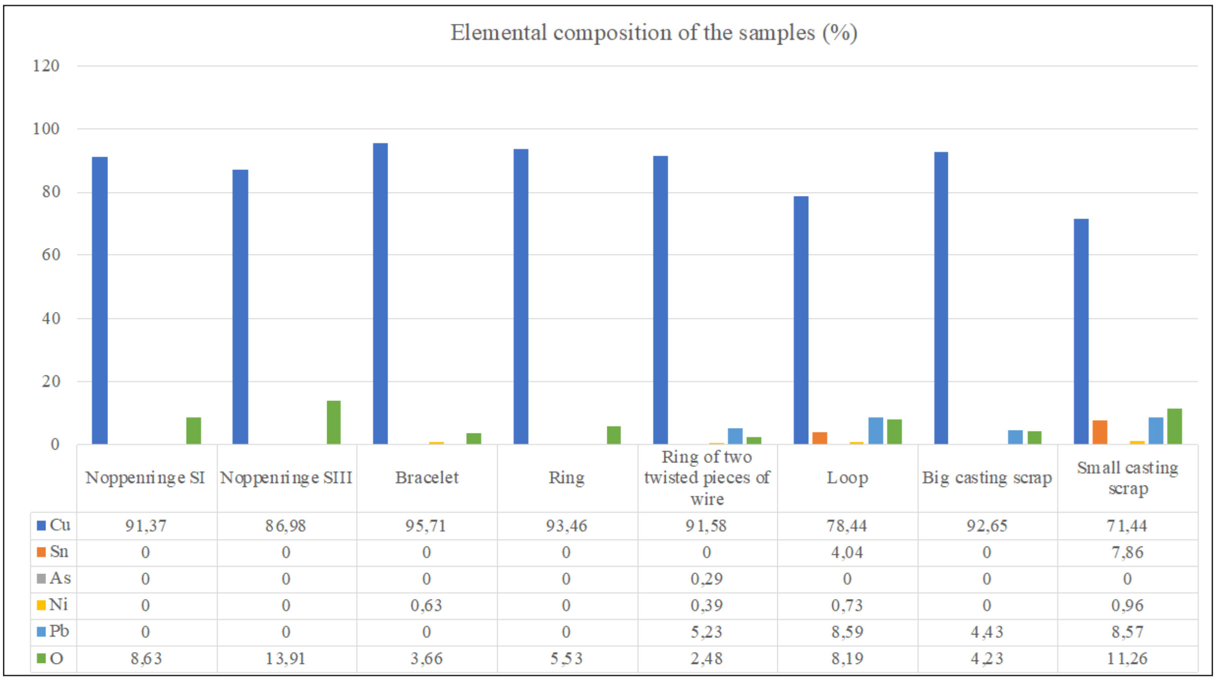


Plate 1. Findspot of metal items yielded by the archaeological research campaigns of 2000-2019 (1-*Noppenringe*/19919; 2-*Noppenringe*/19920; 3-*Noppenringe*/19921; 4-*Noppenringe* SI; 5-*Noppenringe* SIII; 6-Bracelet; 7-Ring; 8- Ring of two wire pieces; 9- Loop 10- Large casting scrap; 11- Small casting scrap).



1.

Nr.crt.	Cu	Sn	As	Ni	Pb	O	C	Si	P	Cl	Al	Ca	K	Fe	Mg	Ti	S
Metal 4/ *NoppenringeSI*	91,37	-	-	-	-	8,63	-	-	-	-	-	-	-	-	-	-	-
Corrosion 4/ *NoppenringeSI*	26,91	-	-	-	-	43,52	2,35	12,49	2,49	0,31	4,00	2,00	1,72	2,10	1,62	0,46	-
Metal 5/ *Noppenringe* SIII	86,98	-	-	-	-	13,91	-	-	-	-	-	-	-	-	-	-	-
Corrosion 5/ *NoppenringeSIII*	74,41		--	-	-	17,78	2,39	1,24	1,50	0,26	0,60	0,43	0,48	0,43	0,36	-	0,13
Metal 6/ Bracelet	95,71	-	-	0,63	-	3,66	-	-	-	-	-	-	-	-	-	-	-
Corrosion6/ Bracelet	10,22	-	-	-	-	42,00	1,75	24,25	1,42	0,59	7,47	3,16	3,06	3,69	1,06	0,97	0,34
Metal 7/Ring	93,46	-	-	-	-	5,53	-	-	-	-	-	-	-	-	-	-	-
Corrosion7/ Ring	39,03	-	-	-	-	35,60	4,23	12,30	0,98	0,63	3,09	0,91	1,20	1,12	0,91	-	-
Metal 8/Ring of two twisted wiresv	91,58	-	0,29	0,39	5,23	2,48	-	-	-	-	-	-	-	-	-	-	-
Corrosion8/ Ring of two twisted wires	55,87	-	0,28	-	4,89	29,57	1,63	0,20	4,97	0,17	0,37	1,47	-	-	0,44	-	0,12
Metal 9/loop	78,44	4,04	-	0,73	8,59	8,19	-	-	-	-	-	-	-	-	-	-	-
Corrosion9/loop	45,44	15,71	-	1,32	12,41	8,36	-	1,19	4,23	0,31	3,69	-	-	2,84	4,35	-	0,14
Metal 10/Big cast scrap	92,65	-	-	-	4,43	4,23	-	-	-	-	-	-	-	-	-	-	-
Corrosion 10/ Big cast scrap	52,95	-	-	-	5,29	26,80	1,72	2,70	5,56	0,41	0,98	1,49	-	1,07	1,02	-	-
Metal 11/Small cast scrap	71,44	7,86	-	0,96	8,57	11,26	-	-	-	-	-	-	-	-	-	-	-
Corrosion 11/ Small cast scrap	38,99	11,38	-	0,99	6,61	12,63	6,36	7,59	5,41	0,50	2,93	-	-	5,49	1,10	-	-

2.

Plate 2. Chemical composition (EDX) of the discussed items expressed in % (1 metal; 2 corrosion).

Sample	Object	Cu	Sn	Sb	As	Ni	Pb	Ag	Fe	Co
1	*Noppenringe*/19921	99,1	0,04	<LOD	0,68	<LOD	0,03	0,08	0,03	<LOD
2	*Noppenringe*/19200	99,3	0,05	<LOD	0,54	<LOD	<LOD	0,07	0,04	<LOD
3	*Noppenringe*/19919	99,8	0,01	<LOD	0,07	<LOD	0,02	<LOD	0,06	<LOD

1.

Sample	Object	Cu	Sn	As	Ni	Pb	Ag	Fe	Cr	Mn	Ta	Ce	Co
4	*Noppenringe*SI	35,97	0,16	0,84	0,12	0,17	0,10	0,31	0,01	0,02	0,01	0,03	0,01
5	*Noppenringe*SIII	50,79	0,39	0,63	0,16	0,14	0,06	0,03	0,01	0,01	<LOD	0,06	<LOD
6	Bracelet	40,84	0,08	0,03	0,12	0,01	0,09	0,02	0,01	0,01	0,01	<LOD	<LOD
7	Ring	52,29	0,07	0,08	0,19	0,07	0,06	0	0,01	0,01	0,01	<LOD	<LOD
8	Ring of two twisted wires	63,77	0,13	1,65	0,22	0,12	0,04	0	0,01	0,01	<LOD	<LOD	<LOD
9	Loop	25,96	4,76	1,38	0,13	0,52	0,01	0,91	<LOD	0,03	<LOD	0,03	<LOD
10	Big cast scrap	25,83	0,13	0,03	0,25	0,07	0,08	0,84	0,01	0,02	0,02	0,03	0,02
11	Small cast scrap	26,97	11,31	4,64	0,82	0,17	0,06	1,50	<LOD	0,02	<LOD	0,02	0,01

2.

Plate 3. Chemical composition (XRF) of the discussed items expressed in ppm
(1 cleaned *Noppernringe*; 2 un-cleaned items).

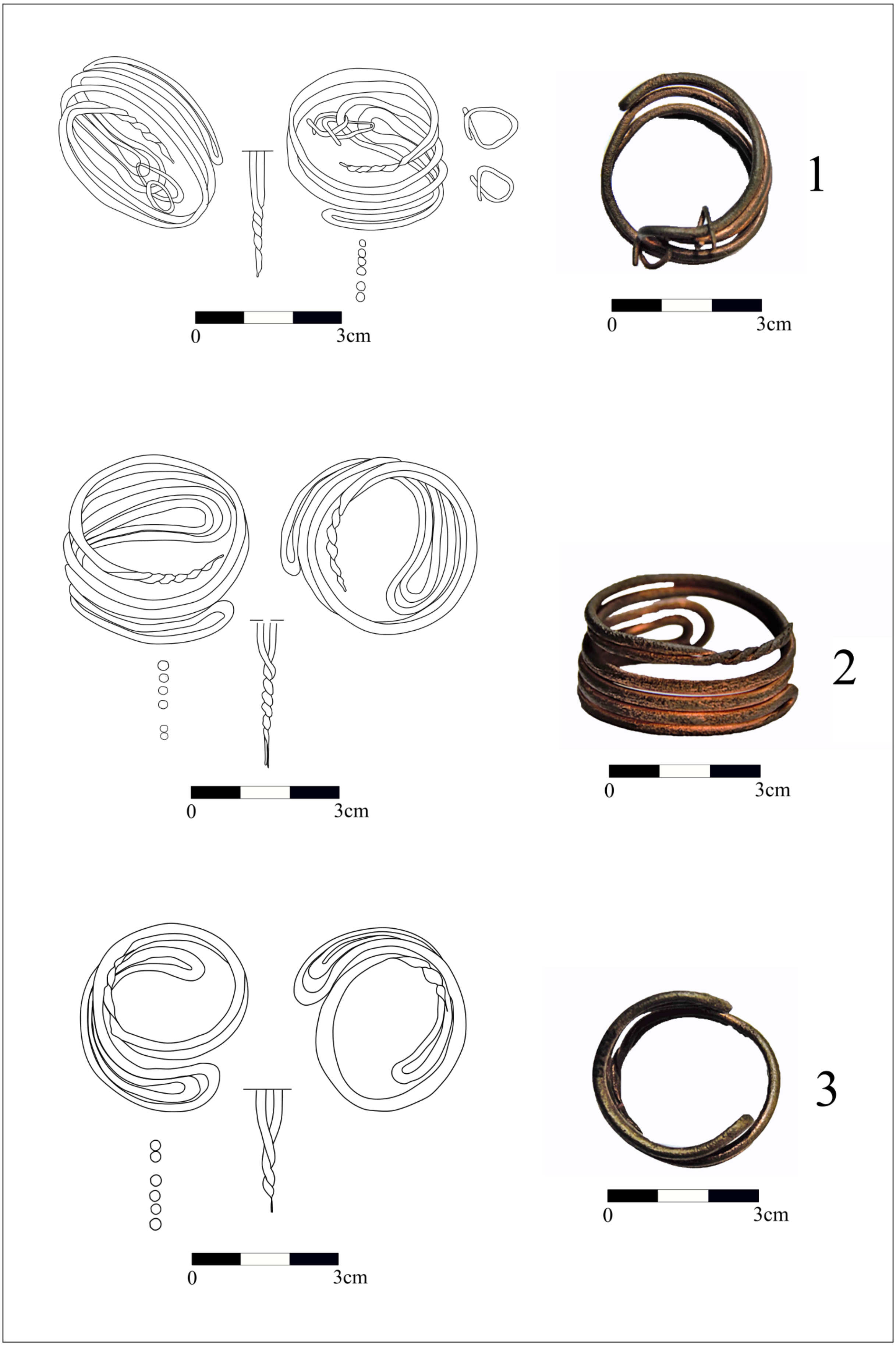


Plate 4. Lock-rings of type *Noppenringe* discovered during 2000 and 2001 at Siliștea-*Pe Cetățuie* (1-Object 1/*Noppenringe*/19919; 2-Object 2/*Noppenringe*/19920; 3-Object 3/*Noppenringe*/19921).

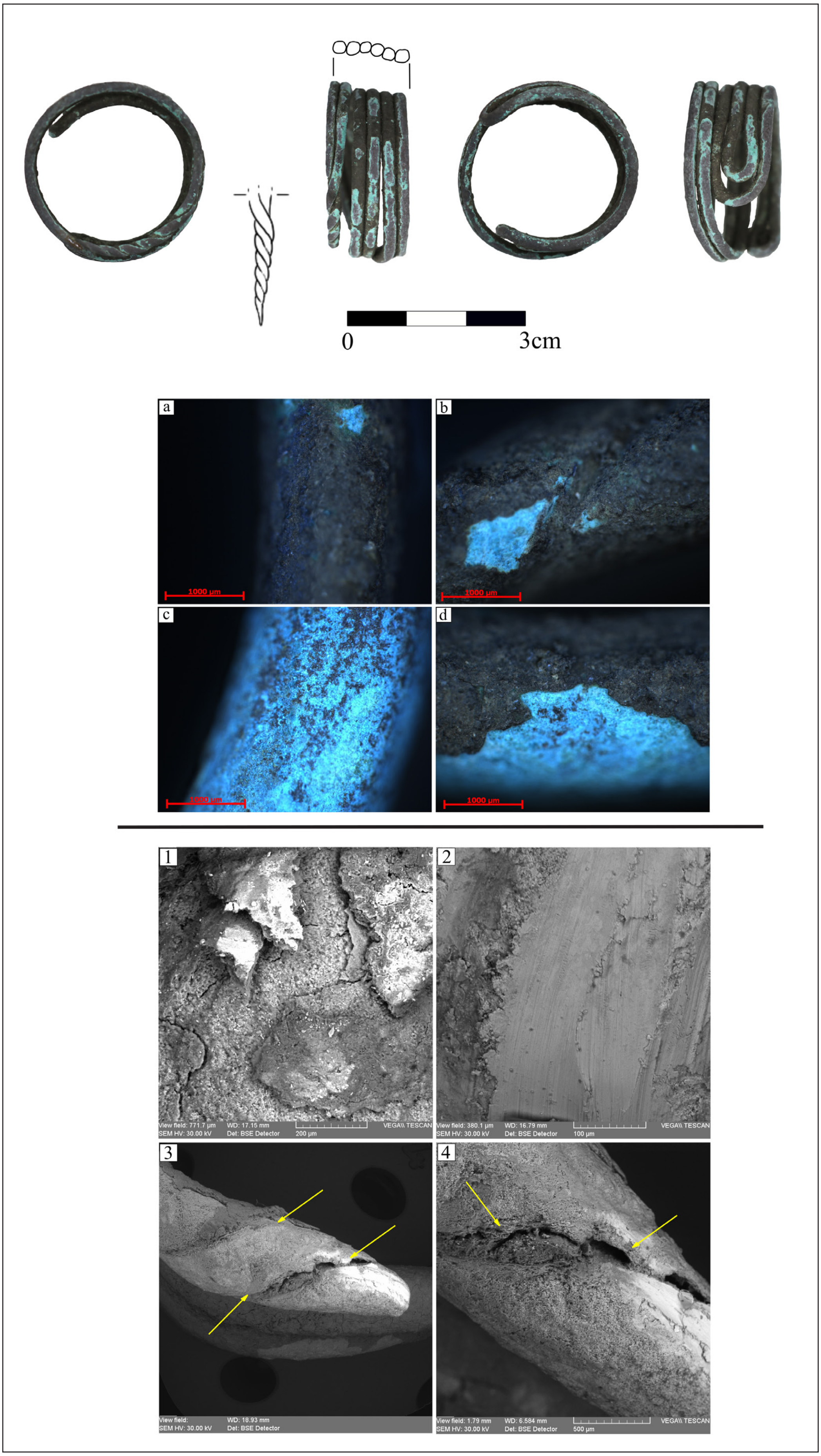


Plate 5. Object 4/*Noppenringe*SI: a-d optical microscopy images; 1-4 SEM micrographs.

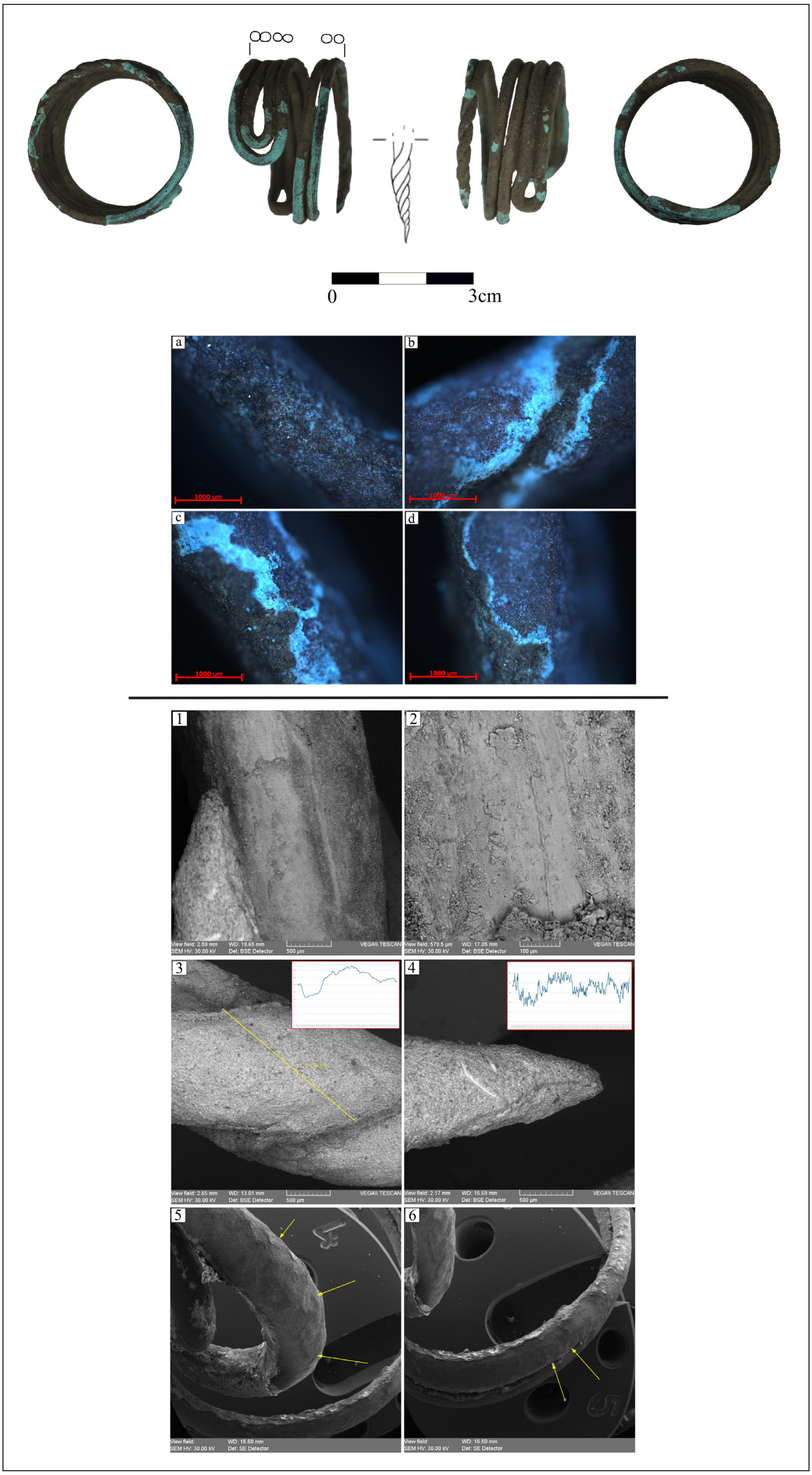


Plate 6. Object 5/*Noppenringe* SIII: a-d optical microscopy images; 1-6 SEM micrographs.

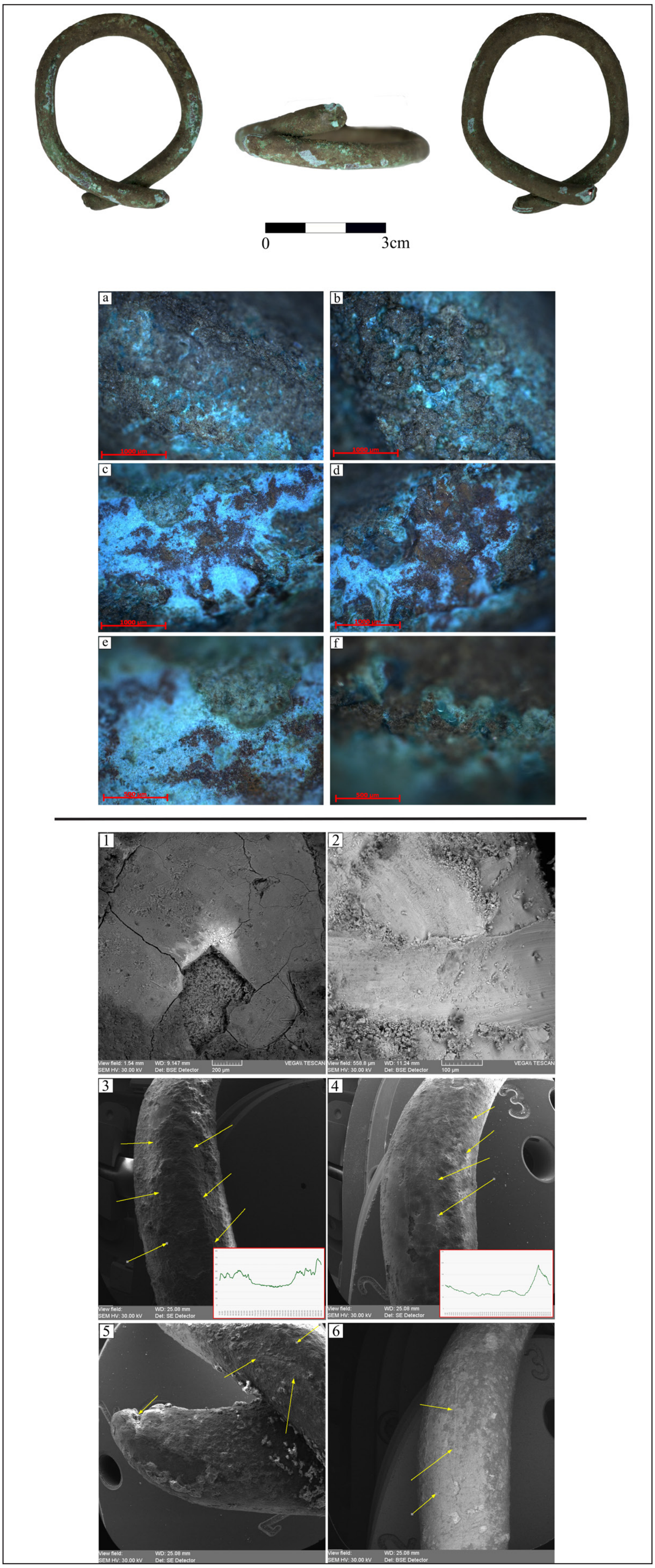


Plate 7. Object 6/Bracelet: a-f optical microscopy images; 1-6 SEM micrographs.

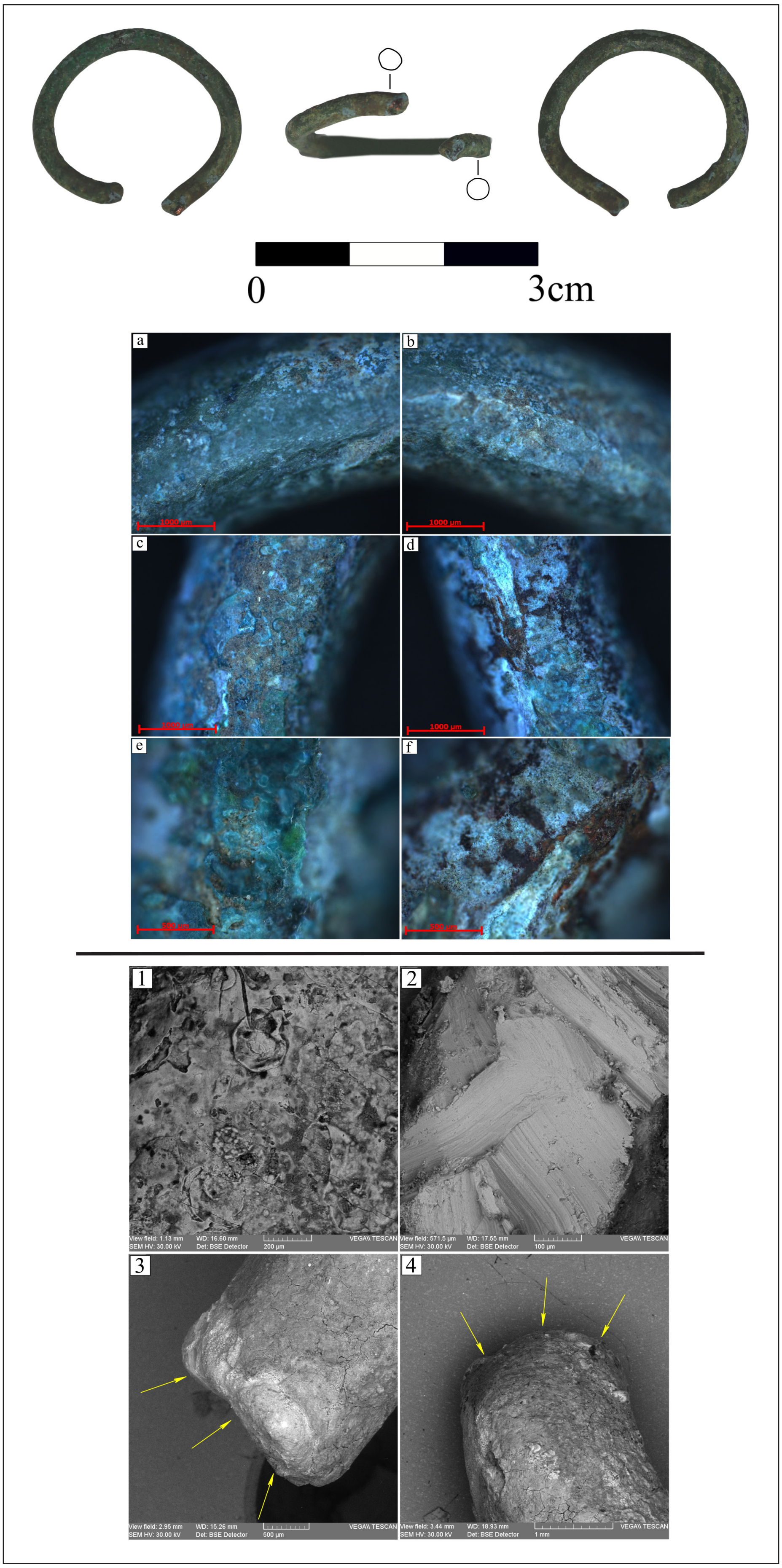


Plate 8. Object 7/Ring: a-f optical microscopy images; 1-4 SEM micrographs.

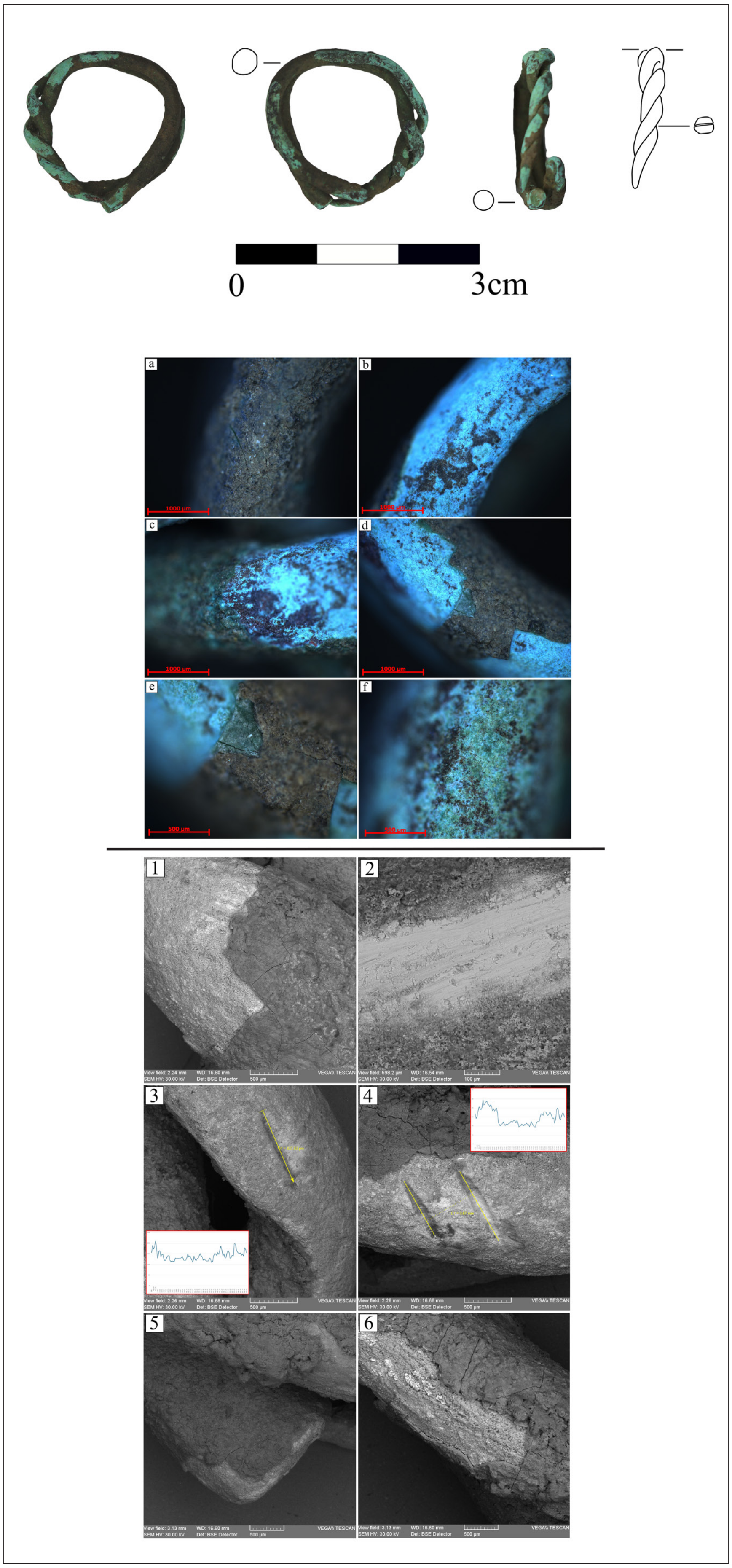


Plate 9. Object 8/Ring of two wire pieces: a-f optical microscopy images; 1-6 SEM micrographs.

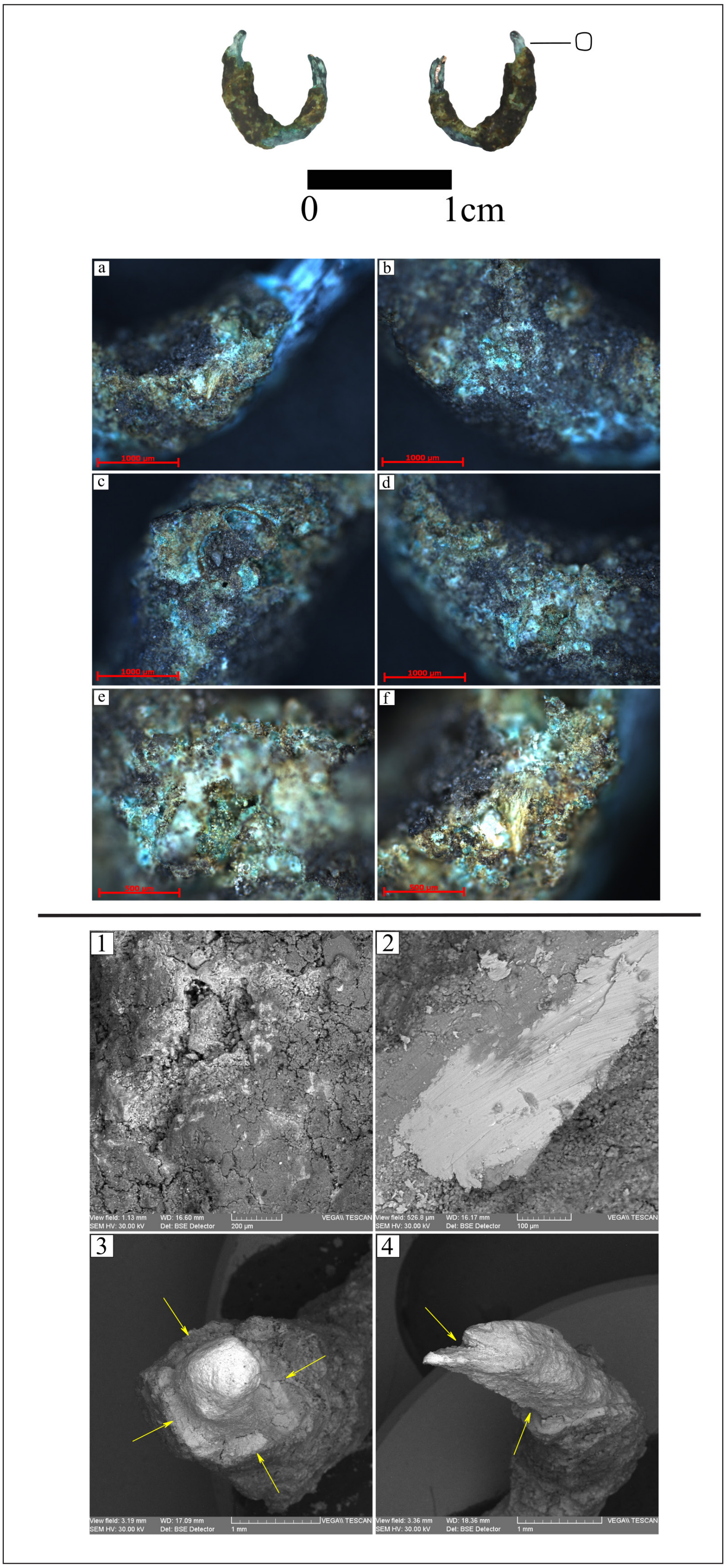


Plate 10. Object 9/Loop: a-f optical microscopy images; 1-4 SEM micrographs.

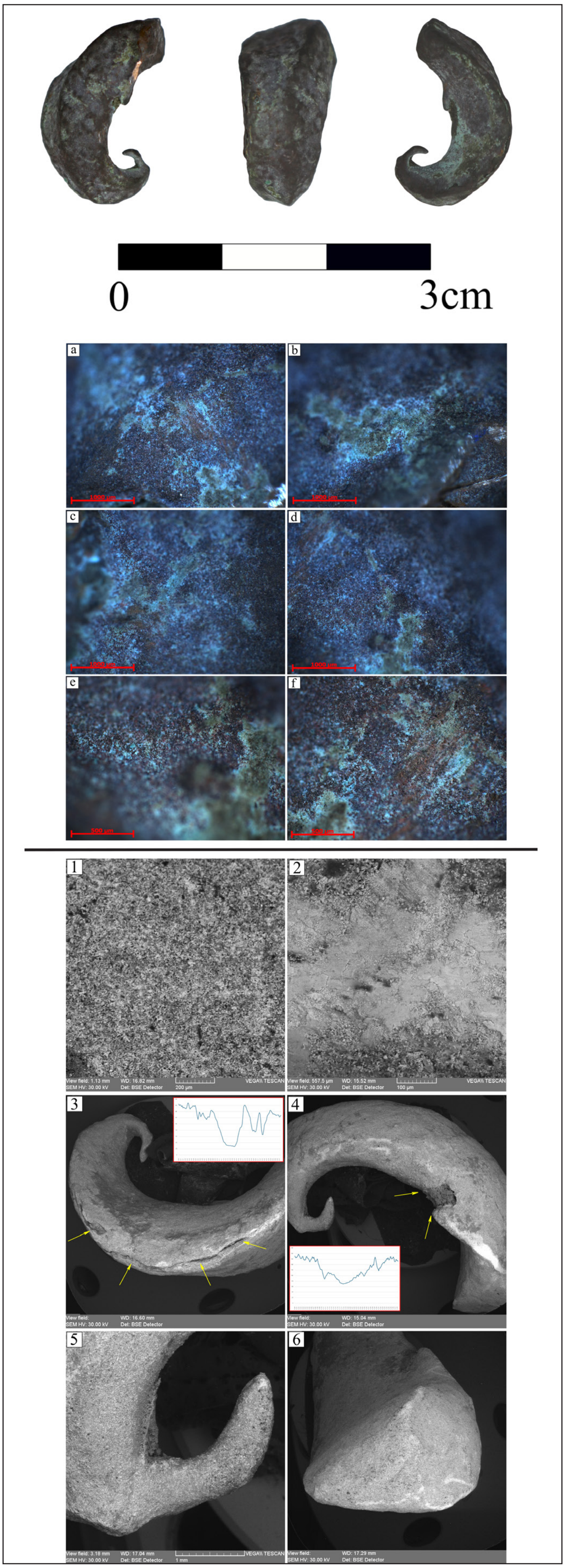


Plate 11. Object 10/Large casting scrap: a-f optical microscopy images; 1-6 SEM micrographs.

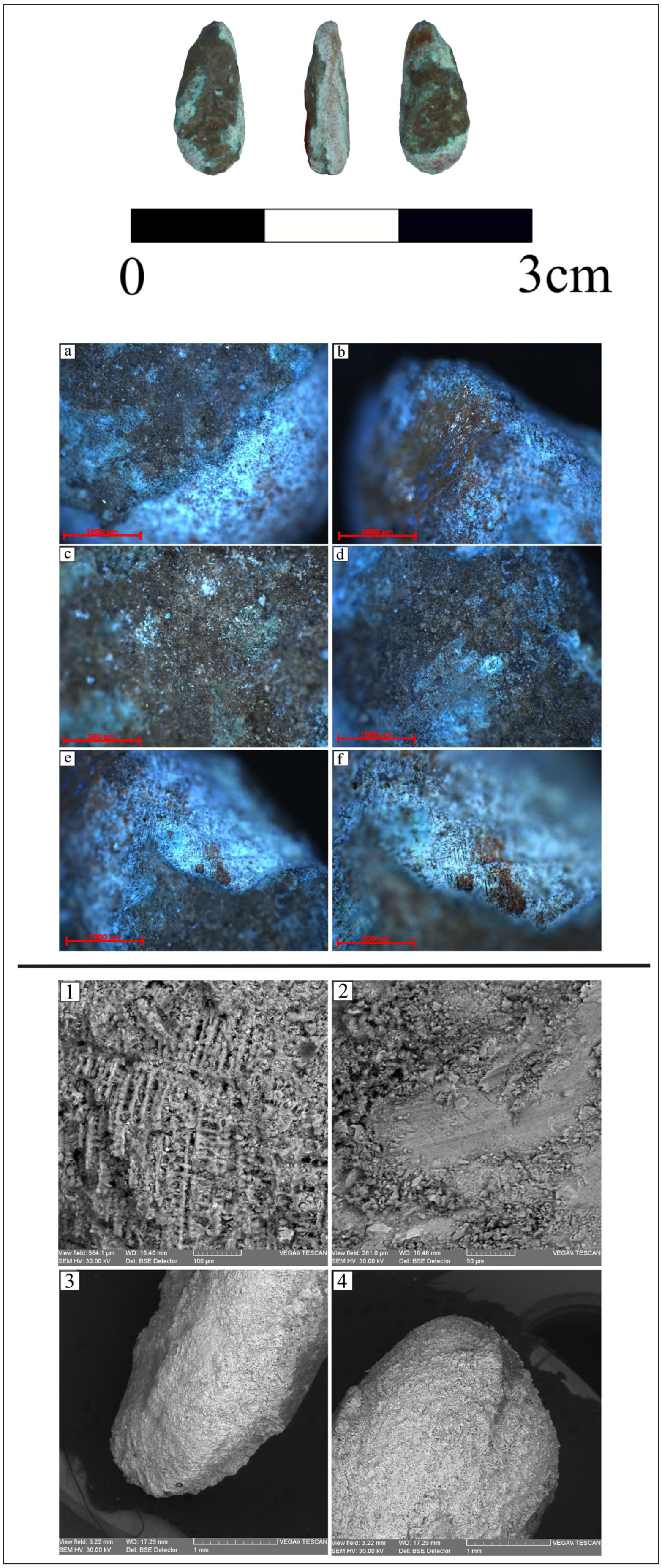


Plate 12. Object 11/Small casting scrap: a-f optical microscopy images; 1-4 SEM micrographs.

Sample	Cu	Sn	As	Ni	Pb	Ag	Fe
1/Noppenringe 19919	99,1	0,04	0,68	<LOD	0,03	0,08	0,03
2/Noppenringe 19920	99,3	0,05	0,54	<LOD	<LOD	0,07	0,04
3/Noppenringe 19921	99,8	0,01	0,07	<LOD	0,02	<LOD	0,06
4/Noppenringe SI	35,97	0,16	0,84	0,12	0,17	0,1	0,31
5/Noppenringe SIII	50,79	0,39	0,63	0,16	0,14	0,06	0,03
6/Bracelet	40,84	0,08	0,03	0,12	0,01	0,09	0,02
7/Ring	52,29	0,07	0,08	0,19	0,07	0,06	0
8/Ring of two twisted wires	63,77	0,13	1,65	0,22	0,12	0,04	0
9/Loop	25,96	4,76	1,38	0,13	0,52	0,01	0,91
10/Big cast scrap	25,83	0,13	0,03	0,25	0,07	0,08	0,84
11/Small cast scrap	26,97	11,31	4,64	0,82	0,17	0,06	1,5
Costișa-Costișa/hair ring	82,7	16,8	0	<LOD	0	0	0,5
Costișa-Costișa/hair ring	91,5	7,5	0,35	0,1	<LOD	<LOD	0,2
Costișa-Monteoru/hair ring	96,2	2,6	<LOD	0,05	0,25	0,05	0,6
Costișa/Saltaleone	99,85	0	0	0	0	0	0,6
Costișa/spiral	99,5	0	0,1	0,1	0	0	0,3
Blăgești/neck-ring	99,11	0,19	0,34	0	0,03	0	0
Blăgești/neck-ring	99,05	0,22	0,33	0	<LOD	0	0
Blăgești/neck-ring	98,52	0,2	0,78	0	0,13	0	0
Blăgești/neck-ring	98,61	0,22	0,71	0	0,11	0	0
Blăgești/Bracelet	99,23	0,16	0,22	0	0,07	0	0
Blăgești/Bracelet	99,18	0,21	0,16	0	0,03	0	0
Blăgești/Bracelet	99,12	0,24	0,16	0	0,08	0	0
Blăgești/Bracelet	99,18	0,19	0,21	0	0,02	0	0
Blăgești/Bracelet	98,9	0,35	0,21	0	0,08	0	0
Blăgești/Bracelet	98,76	0,25	0,45	0	0,12	0	0
Blăgești/Bracelet	98,76	0,26	0,52	0	0,1	0	0
Blăgești/Bracelet	98,95	0,35	0,19	0	0,09	0	0
Blăgești/Bracelet	98,94	0,3	0,31	0	0,09	0	0
Blăgești/Ring	98,91	0,37	0,2	0	0,08	0	0
Blăgești/Ring	99,12	0,43	<LOD	0	0,05	0	0
Blăgești/Ring	98,78	0,23	0,33	0	0,06	0	0,27
Blăgești/Ring	98,94	0,26	0,43	0	0,04	0	0
Blăgești/Ring	98,9	0,3	0,31	0	0,07	0	0
Blăgești/Ring	98,26	0,5	<LOD	0	0,09	0,17	0,37
Blăgești/Ring	98,9	0,21	0,08	0	0,09	0,14	0,16
Blăgești/Fragment	96,67	0,7	0,53	0	0,24	0,25	0,83
Blăgești-Fragment	97,64	0,55	<LOD	0	0,13	0,18	0,85
Blăgești/Ring	98,93	0,43	<LOD	0	0,07	0	0
Blăgești/Ring	99,15	0,15	0,19	0	0,1	0	0
Blăgești/Ring	98,92	0,27	0,33	0	0,07	0	0
Blăgești/Ring	98,8	0,13	0,27	0	0,08	0	0,36
Blăgești/Ring	98,95	0,53	<LOD	0	0,1	0	0
Blăgești/Ring	98,93	0,37	<LOD	0	0,04	0,14	0
Blăgești/Ring	99,26	0,25	<LOD	0	<LOD	0,12	0
Blăgești/Ring	99,25	0,23	<LOD	0	<LOD	0,13	0
Blăgești/Disc	99,26	0,19	0,13	0	0,1	0	0
Blăgești/Disc	98,78	0,28	0,12	0	0,13	0	0,24
Blăgești/Neddle (?)	98,43	0,3	0,2	0	<LOD	0,15	0,43

Plate 13. Database of XRF compositions of the Middle Bronze Age items in the east-Carpathian area.

Plate 14. Compositional correlations between the discussed metal items:
1 Cu-As; 2 Cu-Pb; 3 Fe-Cu; 4 Ag-Cu; 5 Sn-Fe; 6 Sn-Pb; 7 Sn-Ag.