XRF ANALYSES PERFORMED ON THE ENEOLITHIC COPPER OBJECTS FROM THE BUCHAREST MUNICIPALITY MUSEUM'S ARCHAEOLOGICAL COLLECTION

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Cuvinte cheie: *cupru, unelte, Eneolitic, Vidra, analize XRF*.

Abstract: *This study represents a technological approach on the copper artifacts from the South-eastern Romanian plain, during the Eneolithic period. All of the copper finds are part of the Archaeological collection of the Bucharest Municipality Museum and are related to important tell settlements: Vidra, Chitila-Fermă, Săruleşti. Firstly, the artifacts were submitted to morphological analyses, resulting in a reduced typological variation, as the majority of the objects were tools. Two new sets of XRF analyses performed on the Eneolithic objects curated at the Bucharest Municipality Museum archaeological collection are the main focus of the research, introducing new data regarding the emergence of metallurgy during the Eneolithic in the Gumelnița area.*

Rezumat: *Acest studiu constituie o abordare tehnologică asupra artefactelor din cupru din sud-estul României, din perioada eneolitică. Toate artefactele incluse în acest studiu fac parte din Colecția de Arheologie a Muzeului Municipiului București, provenind din așezările de tip tell de la Vidra, Chitila-Fermă și Săruleşti. În primul rând, piesele au fost supuse analizei morfologice, rezultând o variație tipologică redusă, majoritatea obiectelor studiate fiind unelte. Cercetarea se concentrează pe două noi seturi de analize XRF realizate pe piesele eneolitice din Colecția de Arheologie a Muzeului Municipiului București, introducând noi date privind apariția metalurgiei în arealul culturii Gumelnița.*

Introduction

This study focuses on the copper artifacts part of the Bucharest Municipality Museum's Archaeological Collection, attributed to the Eneolithic period. Firstly, we tried to identify all the artifacts made of copper that could be associated to the Eneolithic period. As the objects were not related to a certain archaeological site, the existing bibliography was really helpful because it allowed us to link the vast majority of the artifacts to those found during the earlier excavations at Vidra, Săruleşti and Chitila-Fermă. This study represents a morphological and technological approach on the Eneolithic artifacts from the indicated sites, showing similarities with other

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Gumelnița finds (**Plate I**), which allowed us to extend the existing technological data in this field. The artifacts were initially studied from a typological point of view and were divided into eight categories specific to the Gumelnița cultural area, the manufacturing techniques of these categories having been widely discussed by the researchers[1].

Secondly, the material was analyzed with an XRF equipment and the results indicated that the artifacts were manufactured from native copper, with low percentages of minor chemical elements, similar to the results obtained on other Gumelnița finds. Although the XRF analyses provided limited information regarding the source of the copper ore, it was possible to study the material in a non-destructive manner and investigate whether a technological pattern as reflected by the high percentage of copper and the poor presence of minor chemical elements applies to Eneolithic copper from the Gumelnița area in the southeastern Romania.

The main aim of this research is to expand the knowledge on the early stages of copper metallurgy during the Eneolithic across the Gumelnița region, using the artifacts in the Bucharest Municipality Museum's archaeological collection. Table 1 presents all the artifacts studied in this paper.

Archaeological background

The Vidra *tell* settlement was located on the northern part of the Sabar river and was actively excavated by Dinu V. Rosetti[2] between 1931 and 1933 and by Dinu V. Rosetti and Sebastian Morintz in 1958[3]. The stratigraphy of the *tell* indicated the presence of a Boian - Vidra occupation layer, as well as all Gumelnița cultural phases.

Another archaeological site included in this study is Chitila – Fermă, Mogoșoaia commune, Ilfov County. The site was initially discovered by Aristide Ștefănescu in 1972 and excavated by Vasile Boroneanț starting with 1982[4]. The occupational layers were assigned to the Boian and Gumelnița cultures. Chitila-Fermă is also known for a unique discovery within the Gumelnița area, a copper bracelet with overlapped ends[5].

Two items in the analyzed collection were found at the Săruleşti *tell*, located on the left side of the Mostiștea River and excavated in 1940 by Dinu V. Rosetti[6].

The copper artifacts found in the Bucharest Municipality Museum's Archaeology Collection

The present study focuses on 32 copper finds associated with the above mentioned *tells*. Their typological classification followed that of I. Mareș (2002), covering all copper finds from the Neo-Eneolithic period in Romania.

The following types were identified:

[1] Mareș 2002; Bem 1999-2000.
[2] Rosetti 1934, p. 6-30.
[3] Rosetti, Morintz 1961.
[4] Boroneanț 1992.
[5] Boroneanț 1992, p. 71.
[6] Comșa 1965; 1987b.

a) Vidra type hammer-axe (ID 28) (Plate IV c).
b) Miniature double axe (ID 30) (Plate IV b)
c) Chisels with rectangular cross-section (ID 1, 2, 7, 14) (Plate IV a)
d) Awls (Plates II-III).
   - Awls with a rectangular cross-section of the proximal end and a circular one towards the pointed end (ID 5, 8, 11, 12, 15, 16).
   - Awls with circular cross-section (ID 3, 4, 6, 10, 13, five of them with bone handle: ID 18, 19, 20, 21, 31).
   - Awls with rectangular cross-section (ID 9, 17).

e) Pins with double volute (ID 23, 24, 25, 26, 27) (Plate V).
f) Pin with a twisted rod (ID 22) (Plate V).
f) Hook (ID 29) (Plate IV a).
g) Bracelet with ovelapping ends (ID 32) (Plate V).

As a general observation, the studied copper material is dominated by tools: awls (12 out of which 5 preserved the bone handle), chisels (4) and hooks (1). In the tool category fall also the Vidra type hammer-axe and the miniature axe. The ornaments consisted of pins with double volute (5), a pin with a twisted rod (1) and the bracelet with the overlapping ends.

These copper artifacts have good analogies across the Kodjadermen-Gumelnița-Karanovo VI cultural area. However, the present paper only discusses analogies from other *tell* settlements as indicated in Plate I.

The vast majority of the studied artifacts are awls, a common typological category in the area. These artifacts are associated with everyday activities such as perforating wood, bone, antler, copper, gold, leather[7].

Awls represent a substantial category in the Gumelnița culture: the types identified in our collections were present at many Gumelnița *tell* settlements: Căscioarele-*Ostrovel*[8] Cernavodă[9], Cunești[10], Drăgănești-Olt[11], Glina[12], Gumelnița[13], Hârșova[14], Însurăței[15], Lișcoteanca[16], Luncavița[17] , Măriuța[18], Pietrele[19], Sultana-*Malu Roșu*[20], Vărăști[21], Vidra[22], Vitănești[23], Ziduri[24]. Some of the artifacts preserved their handles (made of bird or ovicaprid bones).

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[7] Leusch *et alii* 2017, p. 107.
[8] Bem 1999-2000, p. 161.
[9] Haşotti 1988-1989, p. 14.
[10] Comșa 1978, p. 114.
[11] Nica *et alii* 1995, p. 9, 17, fig. 15/1-5.
[12] Petrescu-Dîmbovița 1944, p. 69.
[13] Vl. Dumitrescu 1925; Comşa, Ionescu 1979, p. 80-81; Bem 1999-2000, p. 162.
[14] Galbenu 1962, p. 292; Haşotti 1988 – 1989, p. 7.
[15] Pandrea 1997, p. 36.
[16] Harţuche, Anastasiu 1976, p. 50.
[17] Micu, Belc 2005, p. 47.
[18] Şimon 2014, p. 28.
[19] Hansen 2006, p. 85.
[20] Lazăr *et alii* 2017.
[21] Comşa 1974, p. 87.
[22] Comșa 1978.

Within the Gumelnița area, Muntenia region, four Vidra type hammer-axes are known at Bucșani-*La Pod*[25], Teiu[26], Vidra[27] and Prundu[28]. Two of the Vidra hammer-axes appeared in clear archaeological contexts: the Vidra axe from Bucșani was discovered forced through the floor of the house, the axe from Teiu was found near a hearth. The hammer-axe from Vidra was discovered in an unclear archaeological context[29] and the hammer-axe from Prundu was discovered accidentally. A different situation is documented in the prehistoric Bulgarian region, where Vidra hammer-axes were also found in funerary context (Varna I necropolis, associated with a male grave found inside a dwelling at Hotnitsa[30]) and could be considered to be weapons. Research performed on the skeletal remains from Yunatsite, Ruse *tell* settlements indicate violent traumas, probably caused by hammer-axes[31]. These discoveries could indicate an unstable atmosphere across the Bulgarian area during the *Chalcolithic*[32]. Returning to the Romanian region, the wide distribution of the Vidra hammer-axes across the Gumelnița and Cucuteni-Tripolye cultural areas (Cherchejeni, Cucuteni, Izvoare, Mărgineni, Lupești[33]) demonstrates the social connections between these communities during the Eneolithic period. The Vidra type hammer-axes found within the Gumelnița area rather have a symbolical meaning, in contrast to those artifacts found within the Bulgarian territory which were most likely considered as weapons. Also, the existence of a miniature axe from Vidra[34] increases the symbolical function of these artifacts. The miniature objects could be connected to the ritual practices, as past people paid attention in the making of miniature objects such as clay or flint objects. The unicity of the copper miniature double axe within the Gumelnița area emphasizes the importance of the copper material, as well as the importance of the category of axes.

The category of copper ornaments includes the pins with double volute which appear at Căscioarele, Drăgănești-Olt[35], Gărăgău[36], Geangoiești[37], Gumelnița[38], Jilava[39], Măriuța[40], Morteni[41], Pietrele[42]Sărulești[43], Teiu[44],Vărăști, Vidra[45]; the pins

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[23] Andreescu *et alii* 1998, p. 85.
[24] Cristocea, Mandescu 2002.
[25] Bem 2002, p. 67.
[26] Vulpe 1975, p. 22, pl. 2/25.
[27] Rosetti 1934, p. 29, fig. 42.
[28] Vulpe 1975, p. 22, pl. 2/23.
[29] Rosetti 1934, p. 29.
[30] Boyadzhiev 2014, p. 167.
[31] Boyadzhiev 2014, p. 178.
[32] Boyadzhiev 2014, p. 178.
[33] Mareș 2002, p. 96.
[34] According to Aristide Ștefănescu and published in Mareș 2002, p. 330.
[35] Nica *et alii* 1995, p. 94.
[36] Bem 1999-2000, p. 162.
[37] Ilie, Neaga 2010, p. 79-99.
[38] Comșa 1965, p. 364.
[39] Comșa 1965, p. 365.
[40] Șimon 2014, p. 28.
[41] Bem 1999-2000, p. 162.
[42] Hansen *et alii* 2009, p. 60, Abb. 83.

with twisted rod at Glina and Vidra. Chisels are documented to have been discovered at Hârşova, Glina, Gumelniţa, Siliştea- Gumeşti, Vidra and hook heads at Căscioarele, Geangoieşti, Gumelniţa, Pietrele[46], Vidra.

Typological variations of bracelets with overlapped ends are known at Durankulak, in funerary context[47].

XRF Method

First chemical analyses on Eneolithic copper artifacts from Romania were performed by Siegfried Junghans and Edward Sangmeister in 1968. Recent XRF analyses were performed on copper artifacts from Luncaviţa[48], Sultana-*Malu Roşu*[49], Pietrele-*Măgura Gorgana*[50], as well as on the gold Eneolithic ornaments: Gumelniţa, Vlădiceasca, Chirnogi-*Şuviţa lui Ghiţan,* Chirnogi – *Şuviţa Iorgulescu*[51], Sultana-*Malu Roşu.*

The primary morphological analysis performed on the Eneolithic copper finds from the Bucharest Municipality Museum's Archaeological collection was followed by ED-XRF analysis, performed at the Bucharest Municipality Museum's Laboratory by Dr. Ingrid Poll[52]. The analyses were performed using fourth-generation Genius XRF portable spectrometer, manufactured by Skyray instruments, within the parameters: 38 kV, 30 mA, calibration curve: copper, acquisition time 60 seconds (Plate VI b).

The analyses were performed on clean, flat surfaces. Some of the objects were not included in this stage, because they are currently part of the Bucharest Municipality Museum's exhibition.

Analyzing the data derived from the XRF analyses, it can be observed that all objects are copper based finds with minor elements such as iron, nickel, zinc, tin, antimony and lead.

The content of iron between 0.009% and 10.55%. The latter value was detected in specimen #13, which is heavily corroded. The levels of nickel range between 0.02% to 1.2%, zinc values between 0.001% to 0.2%, tin between 0.009% to 1, 9 %, antimony 0.04% to 2%, lead 0.001% to 0.5 % (Diagrams 1, 2).

The second set of analyses was performed by Dr. Migdonia Georgescu at the National Museum of Romanian History using a Innovx Systems Alpha Series portable XRF spectrometer, SiPIN detector, 40kV voltage, 35mA intensity, acquisition time 120s (Plate VI a). The studied artifacts are rich in copper (94.57% - specimen 18;

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[43] Hansen *et alii* 2009.
[44] Hansen *et alii* 2009.
[45] Rosetti 1934, p. 23, 30.
[46] Hansen *et alii* 2009, p. 57, Abb. 79.1.
[47] Todorova, Vajsov 2001, p. 443, Tafel 33-35.
[48] Micu, Belc 2005, p. 48.
[49] Lazăr *et alii* 2017.
[50] Hansen 2008, p. 71.
[51] Cojocaru, Şerbanescu 2002, p. 88.
[52] On this occasion we would like to thank Dr. Ingrid Poll for the help in performing the ED-XRF analyses.

100% content of copper was detected in specimens #2 and #8.). The minor chemical elements such as titanium and iron derive from the soil composition while the presence of zirconium indicates sand - rich soils. These elements appear especially on heavily corroded surfaces. The content of iron ranges between 0.001% in specimen #14 and 6% in specimen 5. The highest content of iron appeared on the surface of specimen #5, where manganese was also detected, possibly indicating a cleaning treatment on the posterior surface of the item. Thus, a second analysis was performed on the posterior side but manganese was no longer detected, thus invalidating the presumed hypothesis. Furthermore, nickel values are situated within the limit of detection (0.001%) on the majority of the objects, with high values ranging between 0.05% in specimen #16 and 0.25% in specimen 17. Zirconium ranges between 0.02% in specimen #13 and 0.05% in specimen #18; lead between 0.03% in specimen #14 and 1.72% in specimen #1. Also, traces of silver were detected on 16 items. On the surface of specimen #4 were detected traces of gold (0.19%). Tin values range between 0.84% in specimen #32 and 1.35% in specimen #17.

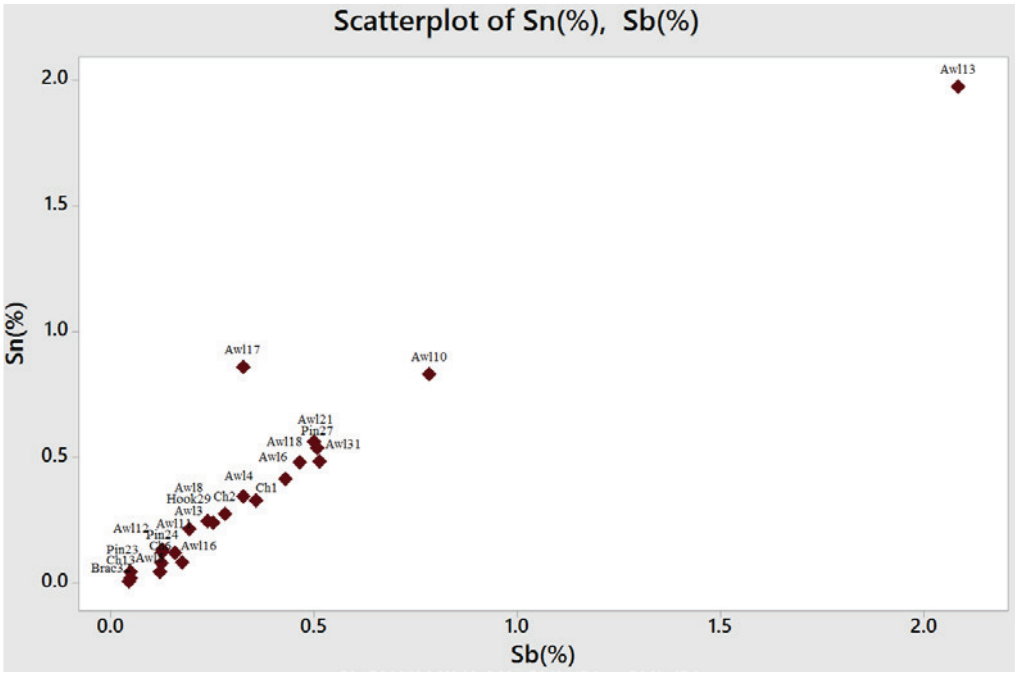

Diagram 1[53]**.** Diagram showing the variation of tin and antimony. Specimens grouped indicate a linear relation between tin and antimony. In specimens #10, #17, #13 high values of tin were found, ranging between 0.8%-1.9%. The antimony content varies between 0.044%-0.5%. Higher concentrations were found on the surface of specimens #10 – 0.784% and #13 – 2.085%, which could be considered as impurities, associated with native copper.

[53] The diagrams were realized using Minitab 17.1.0. version.

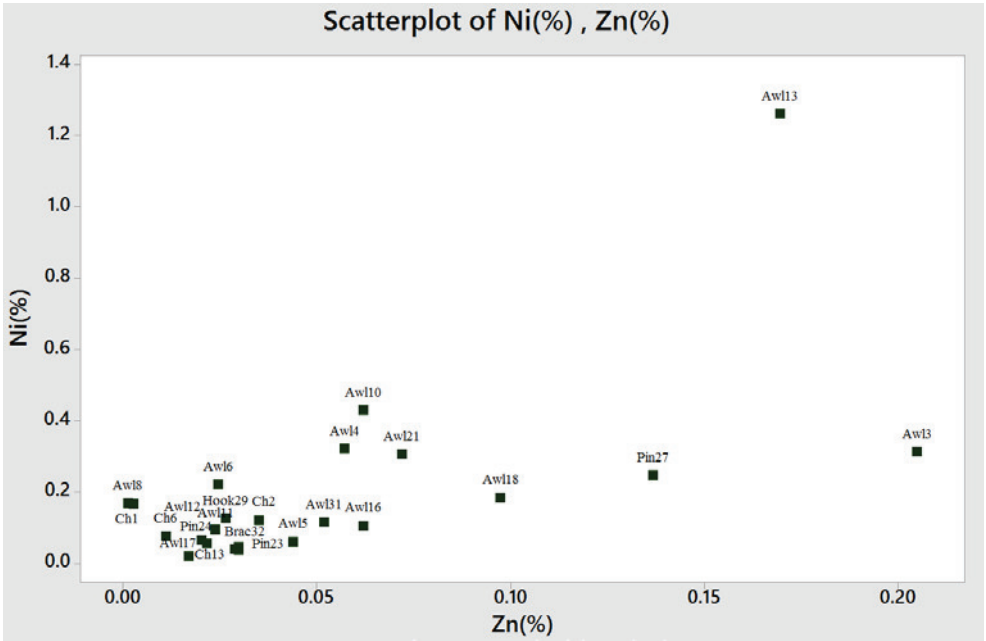

Diagram 2. Diagram showing the variations of Ni and Zn. Certain specimens group due to the reduced values of nickel (0.021-0.322%) and zinc (0.001-0.097%). Specimens #10, #4, #21, #18, #27, #13, #3 have higher values of nickel and zinc. (#10 – 0.429 % nickel, #13 – 1.260% nickel, 0.170% zinc).

Reduced values of the chemical elements (Sn < 1, Zn <2, Pb < 5) could be related to the provenance and/or production technology[54]. The high copper content (around 90% and higher) could indicate that the raw material source used in manufacturing these artifacts derived from high purity copper ores.

The main obstacle in performing the XRF analyses was represented by the corrosion and dirt found on the surface of a number of objects (e.g. the awls with bone handle #18, 21, 31, the pin with double volute #27; the bent awl #13.). Their presence influenced the results of the XRF analyses.

Finally, given the lack of raw copper sources within the Gumelnița area, various hypotheses can be advanced. The lead isotope analyses and chemical analyses of artifacts from Pietrele-*Măgura Gorgana* indicated as source of copper Majdanpek in Serbia and Celopec, Burgas, Ai Bunar in Bulgaria[55]. More information was provided by the study of the Vidra type hammer-axes found in Bulgaria, mainly in funerary contexts. These might have been manufactured using copper from Ai Bunar and Rudna Glava[56]. The copper used by the Gumelnița communities probably derived

[54] Pernicka 2014, p. 253.
[55] Hansen *et alii* 2008, p. 71.
[56] Todorova 1981, p. 37.

from the same sources, given the social networks created within the Kodjadermen-Gumelnița – Karanovo VI area.

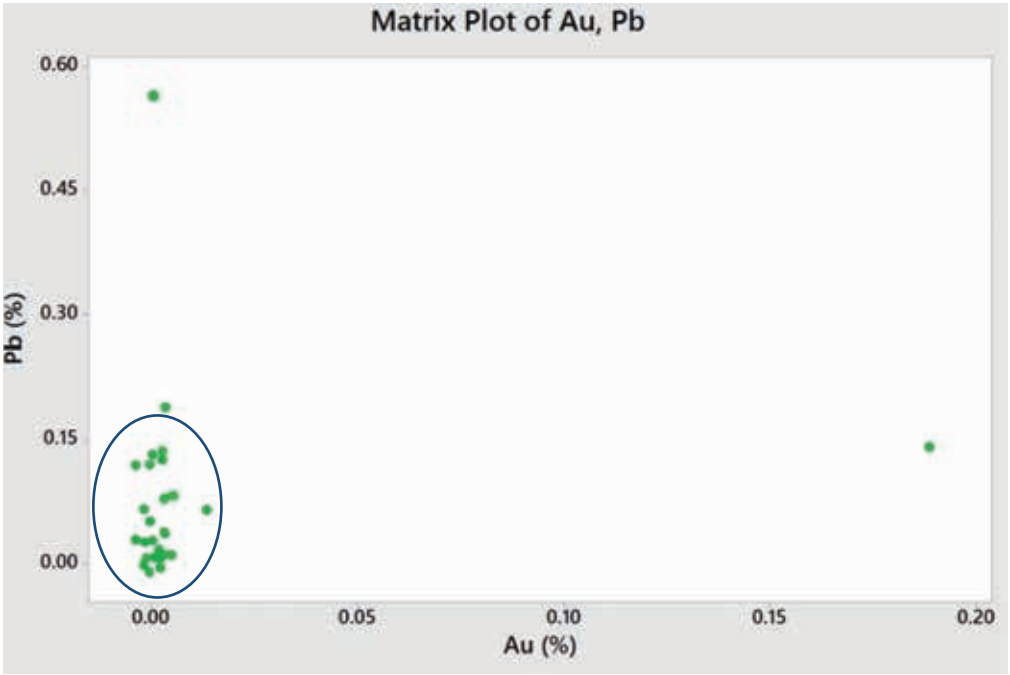

Diagram 3. Diagram showing the variations of Au and Pb. Specimen #4 is plotting differently from the rest of the group, with a value of 0.19%. High values of lead are detected in specimen #1 (0.56%) and specimen #27 – 0.18%.

Conclusions

The present study discusses the Eneolithic copper artifacts currently part of the Bucharest Municipality Museum's archaeological collection. The XRF analyses performed on the artifacts supplement the data regarding the metal finds from Vidra and Chitila-Fermă *tell* settlements. The two sets of analyses indicate that artifacts were made from native copper, low in all minor elements, similar to other Eneolithic copper artifacts from Southeastern Romania. Further research will include objects currently part of the permanent exhibition of the Bucharest Municipality Museum; a future aim is also gathering more information regarding the chemical composition of other Eneolithic artifacts in southeastern Romania which might indicate whether different prehistoric communities followed the same technological pattern in manufacturing copper artifacts.

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ID	Type	Provenance	Height (cm)	Thickness (cm)	Weight (g)	References
1	Chisel Fragment. Inv. No. 14382	Vidra *tell* Gumelnița layer	3,5 cm	0,4 cm	1 g	Comșa 1978, 111, fig. 2 (13).
2	Chisel Inv. No. 14383	Eneolithic	3,9 cm	0,2 cm	2,5 g	Unpublished
3	Awl Round cross-section Inv. No. 14384	Vidra *tell* Gumelnița layer	5,5 cm	0,3 cm	3 g	Comșa 1978, 111, fig. 2(14).
4	Awl Inv. No. 14386	Eneolithic	7,1 cm	0,4 cm	3,7 g	?
5	Awl Rectangular/ Round cross-section Inv. No. 14387	Vidra *tell* Gumelnița layer	9,4 cm	0,4 cm	4 g	Mareș 2002, pl. 6 (18).
6	Awl round cross-section Inv. No. 14389	Vidra *tell* Gumelnița layer	8,7 cm	0,3 cm	5,3 g	Comșa 1978, p. 111, fig. 2 (17).
7	Chisel Inv. No. 14390	Eneolithic	6,1 cm	0,5 cm	12,6 g	Comșa 1978, 111, fig. 2 (16).
8	Awl Rectangular/ round cross-section Inv. No. 14391	Vidra *tell* Gumelnița layer	7,4 cm	0,2 cm	1,7 g	Comșa 1978, 111, fig. 2 (7).
9	Awl Rectangular cross-section Inv. No. 14392	Eneolithic	10,3 cm	-	-	Comșa 1978, 111, fig. 2 (2). Currently exhibited.
10	Awl Round cross-section Inv. No. 14393	Vidra *tell* Gumelnița layer	9,2 cm	0,2 cm	2,3 g	Comșa 1978, 111, fig. 2 (12).
11	Awl Rectangular/ round cross-section Inv. No. 14394	Vidra *tell* Gumelnița layer	13,4 cm	0,4 cm	13,3 g	Comșa 1978, 111, fig. 2 (4).
12	Awl Rectangular/ round cross-	Eneolithic	10 cm	0,4 cm	8,1 g	Comșa 1978, 111, fig. 2 (6)?.

	section Inv. No. 14395					
13	Awl Round cross-section Inv. No. 14396	Vidra *tell* Gumelnița layer	12 cm	0,4 cm	7,9 g	Comșa 1978, 111, fig. 2 (8).
14	Chisel Inv. No. 14397	Eneolithic	7,2 cm	0,5 cm	7,8 g	?
15	Awl Rectangular/round cross-section Inv. No. 14398	Vidra *tell* Gumelnița layer	-	-	-	Comșa 1978, 111, fig. 2 (5). Currently exhibited.
16	Awl Rectangular /round cross-section Inv. No. 14400	Eneolithic	9,5 cm	0,4 cm	7,7 g	Comșa 1978, 111, fig. 2 (9).
17	Awl Rectangular Cross-section Inv. No. 14401	Vidra *tell* Gumelnița layer	9,7 cm	0,2 cm	3 g	Mareș 2002, pl. 6 (4).
18	Awl with bone handle Inv. No. 14402	Vidra *tell* Gumelnița layer	5,4 cm	-	4,9 g	Comșa 1978, 111, fig. 2 (19).
19	Awș with bone handle Inv. No. 14404	Vidra *tell* Gumelnița layer	8,6 cm	-	--	Comșa 1978, 111, fig. 2 (21). Currently exhibited.
20	Awl with bone handle Inv. No. 14405	Vidra *tell* Gumelnița layer	8,7 cm	-	-	Comșa 1978, 111, fig. 2 (22). Currently exhibited.
21	Awl with bone handle Inv. No. 14406	Vidra *tell* Gumelnița layer	6 cm	0,3 cm	5,3 g	Comșa 1978, 111, fig. 2 (20).
22	Pin with twisted rod Inv. No. 14407	Eneolithic	9,5 cm	-	-	Currently at dr. George Severeanu Museum.
23	Pin with double volute Inv. No. 14408	Vidra *tell*, Gumelnița layer	3,2 cm	1,5 cm	1,1 g	Comșa 1978, 113, fig. 4 (9).
24	Pin with double volute Inv. No. 14409	Vidra *tell* Gumelnița layer	6,5 cm	0,2 cm	6,4 g	Comșa 1978, 113, fig. 4 (10).
25	Pin with double volute Inv. No. 14410	Sărulești *tell* Gumelnița layer	12,76 cm	3,18 cm	-	Comșa 1978, 111, fig. 4 (11). Currently

						exhibited.
26	Pin with double volute Inv. No. 14411	Săruleşti Gumelnița layer	13 cm	2,4 cm	-	Comșa 1978, 113, fig. 4 (12). Currently exhibited.
27	Pin with double volute Inv. No. 14413	Vidra? Gumelnița layer	5,2 cm	2,1 cm	4,8 g	Unpublished. Studied in Junghans 1968, 244-245 (8843).
28	Vidra type axe Inv. No. 14415	Vidra *tell* Gumelnița layer	17,2 cm	-	-	Morintz, Rosetti, 1959; 176; pl. XII/14. Vulpe 1975 Junghans 1968, Tafel 29 (8720) Currently exhibited.
29	Hook Inv. No. 14451	Vidra *tell* Gumelnița layer	6,3 cm	0,4 cm	7,1 g	Comșa 1978, 113, fig. 4 (2).
30	Miniature Axe Inv. No. 15589	Vidra *tell* Gumelnița layer	8,2 cm	1,4 cm	?	Unpublished Studied in Junghans 1968, Tafel 30 (8724)
31	with bone handle Inv. No. 16149	Eneolithic	8,5 cm	0,3 cm	6,8 g	Unpublished.
32	Bracelet with superposed ends Inv. No. 173031	Chitila-Fermă *tell* 1982 Gumelnița layer	6,4 cm	1,4 cm	52,5 g	Boroneanț 1983, 71, fig. 1 (1).

Table 1. The Eneolithic copper artifacts from the Bucharest Municipality Museum's Archaeological collection (The objects can be found in **Plates II-V** based on the inventory number).

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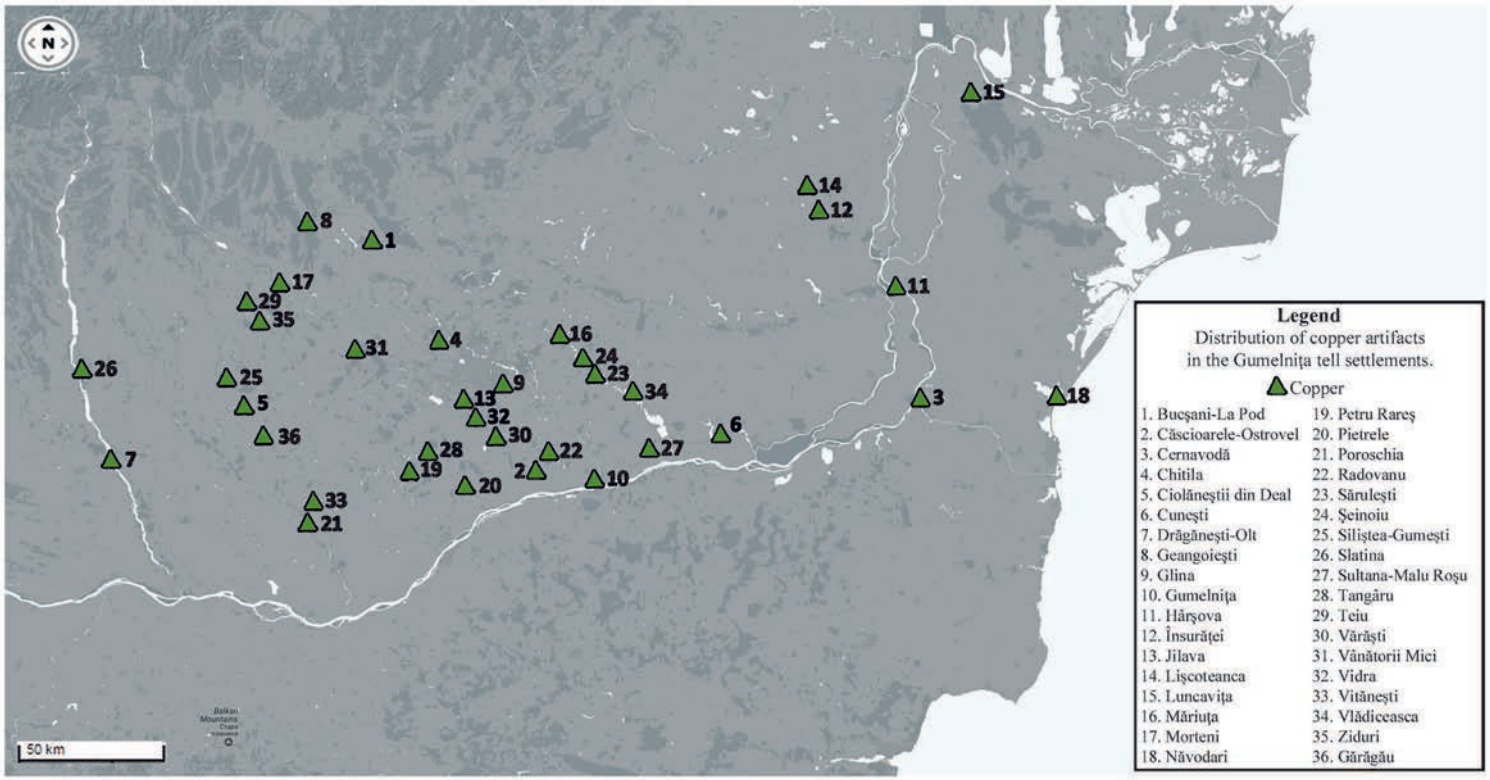

Plate I. Distribution of copper artifacts in the Gumelniţa *tell* settlements.

Plate II. Copper awls from the Bucharest Municipality Museum collection.

Plate III. Copper awls from the Bucharest Municipality Museum collection.

14382 14383 14390 14397 14451

Plate IV.a. Copper utensils from the Bucharest Municipality Museum Archaeological collection.

15589

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14415

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Plate V. Copper ornaments from the Bucharest Municipality Museum Archaeological collection.

		Elements (wt %)																				
Inv. No.	Area	Ti	Ti +/-	Mn	Mn +/-	Fe	Fe +/-	Ni	Ni +/-	Cu	Cu +/-	Zn	Zn +/-	Zr	Zr +/-	Ag	Sn	Sn +/-	Au	Au +/-	Pb	Pb +/-
14382	Middle	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	0.001	n.d.	**99.45**	0.15	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	n.d.	n.d.	n.d.	0.56	0.02
14383	Distal	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	0.001	n.d.	**100.00**	0.16	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
14384	Distal	0.33	0.04	n.d.	n.d.	2.50	0.03	0.001	n.d.	**97.05**	0.21	n.d.	n.d.	0.03	0	n.d.	n.d.	n.d.	n.d.	n.d.	0.09	0.01
14386	Proximal	n.d.	n.d.	n.d.	n.d.	0.66	0.02	0.001	n.d.	**99.00**	0.18	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	n.d.	0.19	0.02	0.15	0.01
14387(a)	Proximal	0.35	0.05	0.56	0.02	6.07	0.06	0.001	n.d.	**88.93**	0.24	0.62	0.03	1.75	0.02	0.001	n.d.	n.d.	n.d.	n.d.	1.72	0.06
14387(b)	Distal	n.d.	n.d.	n.d.	n.d.	0.04	0.01	0.001	n.d.	**99.92**	0.19	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	n.d.	n.d.	n.d.	0.03	0.01
14389	Middle	n.d.	n.d.	n.d.	n.d.	0.09	0.02	0.001	n.d.	**99.91**	0.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
14390	Middle, lateral	n.d.	n.d.	n.d.	n.d.	0.02	0.01	0.001	n.d.	**99.98**	0.14	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
14391	Proximal	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	0.001	n.d.	**100.00**	0.18	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
14393	Proximal	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	0.001	n.d.	**99.88**	0.22	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.12	0.02
14394	Middle	n.d.	n.d.	n.d.	n.d.	0.08	0.01	0.001	n.d.	**99.88**	0.16	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	n.d.	n.d.	n.d.	0.04	0.01
14395	Proximal	n.d.	n.d.	n.d.	n.d.	0.05	0.01	0.001	n.d.	**99.91**	0.16	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	n.d.	n.d.	n.d.	0.04	0.01
14396	Middle	0.220	0.040	n.d.	n.d.	1.75	0.03	0.001	n.d.	**97.94**	0.22	n.d.	n.d.	0.02	0	0.001	n.d.	n.d.	n.d.	n.d.	0.07	0.01
14397	Proximal	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	0.001	n.d.	**99.97**	0.15	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	n.d.	n.d.	n.d.	0.03	0.01
14400	Proximal	n.d.	n.d.	n.d.	n.d.	0.05	0.01	0.05	0.01	**99.83**	0.15	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	n.d.	n.d.	n.d.	0.07	0.01
14401	Middle	n.d.	n.d.	n.d.	n.d.	0.06	0.01	0.25	0.02	**98.19**	0.18	n.d.	n.d.	n.d.	n.d.	n.d.	1.35	0.04	n.d.	n.d.	0.14	0.01
14402	Middle	0.15	0.03	n.d.	n.d.	5.23	0.04	0.001	n.d.	**94.57**	0.19	n.d.	n.d.	0.05	0	0.001	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
14406	Distal	n.d.	n.d.	n.d.	n.d.	3.80	0.04	0.001	n.d.	**96.20**	0.22	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
14408	Volute	n.d.	n.d.	n.d.	n.d.	0.14	0.01	0.001	n.d.	**99.75**	0.22	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	n.d.	n.d.	n.d.	0.11	0.02
14409	Middle	n.d.	n.d.	n.d.	n.d.	0.13	0.01	0.001	n.d.	**99.83**	0.16	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.04	0.01
14413	Left volute	n.d.	n.d.	n.d.	n.d.	1.57	0.02	0.001	n.d.	**98.21**	0.18	n.d.	n.d.	0.03	0	0.001	n.d.	n.d.	n.d.	n.d.	0.18	0.02
14451	Middle	n.d.	n.d.	n.d.	n.d.	0.20	0.01	0.001	n.d.	**99.80**	0.16	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
16149	Distal	n.d.	n.d.	n.d.	n.d.	0.58	0.02	0.001	n.d.	**99.39**	0.21	n.d.	n.d.	0.03	0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
18064	Distal	n.d.	n.d.	n.d.	n.d.	0.33	0.02	0.18	0.02	**98.56**	0.27	n.d.	n.d.	n.d.	n.d.	n.d.	0.84	0.06	n.d.	n.d.	0.09	0.02
173031	Middle	n.d.	n.d.	n.d.	n.d.	0.03	0.01	0.001	n.d.	**99.94**	0.15	n.d.	n.d.	n.d.	n.d.	0.001	n.d.	n.d.	n.d.	n.d.	0.04	0.01

Plate VI.a. Results of the XRF analyses performed on the copper artefacts, using a Innovx Systems Alpha Series portable XRF-spectrometer, SiPIN detector, 40kV voltage, intensity 35mA, acquisition time 120s.
The analyses were performed by dr. Migdonia Georgescu at the National History Museum of Romania Laboratory.

	Elements (wt %)													
Inv. No.	**Fe(%)**	**Fe +/-**	**Ni(%)**	**Ni +/-**	**Cu(%)**	**Cu +/-**	**Zn(%)**	**Zn +/-**	**Sn(%)**	**Sn +/-**	**Sb(%)**	**Sb +/-**	**Pb(%)**	**Pb +/-**
14382	0.112	0.003	0.166	0.006	98.571	0.000	0.003	0.000	0.329	0.000	0.358	0.000	0.313	0.000
14383	0.074	0.002	0.121	0.004	98.990	0.138	0.035	0.001	0.276	0.006	0.282	0.007	0.092	0.014
14384	3.498	0.026	0.314	0.013	95.430	0.171	0.205	0.005	0.217	0.003	0.193	0.003	0.036	0.003
14386	0.311	0.005	0.322	0.014	98.394	0.177	0.057	0.002	0.346	0.007	0.326	0.007	0.092	0.009
14387	0.041	0.0009	0.062	0.002	99.569	0.125	0.044	0.001	0.045	0.001	0.121	0.003	0.003	0.0003
14389	0.075	0.002	0.221	0.008	98.585	0.162	0.025	0.001	0.415	0.010	0.431	0.011	0.090	0.010
14390	0.009	0.0002	0.077	0.002	99.551	0.124	0.011	0.0004	0.079	0.002	0.124	0.003	0.031	0.003
14391	0.100	0.003	0.169	0.006	99.035	0.148	0.001	0.000	0.240	0.005	0.253	0.006	0.058	0.006
14393	0.296	0.013	0.429	0.019	97.238	0.196	0.062	0.003	0.831	0.024	0.784	0.024	0.159	0.009
14394	0.014	0.0003	0.096	0.003	99.415	0.128	0.024	0.001	0.121	0.002	0.158	0.003	0.044	0.004
14395	0.021	0.0006	0.065	0.002	99.473	0.121	0.020	0.001	0.135	0.003	0.127	0.003	0.042	0.004
14396	10.557	0.082	1.260	0.076	83.579	0.272	0.170	0.006	1.972	0.025	2.085	0.027	0.205	0.022
14397	0.011	0.0003	0.037	0.001	99.757	0.109	0.030	0.001	0.009	0.0002	0.044	0.001	0.001	0.000
14400	0.026	0.0007	0.106	0.003	99.308	0.14	0.062	0.002	0.083	0.002	0.177	0.004	0.099	0.006
14401	0.127	0.004	0.021	0.0005	98.229	0.155	0.017	0.001	0.86	0.010	0.326	0.008	0.266	0.012
14402	2.763	0.02	0.185	0.007	95.856	0.147	0.097	0.003	0.482	0.006	0.465	0.006	0.043	0.004
14406	7.522	0.039	0.307	0.012	90.822	0.164	0.072	0.002	0.565	0.008	0.501	0.007	0.083	0.005
14408	0.054	0.001	0.046	0.001	99.162	0.113	0.030	0.001	0.045	0.001	0.048	0.001	0.507	0.014
14409	0.172	0.003	0.057	0.002	99.354	0.120	0.022	0.001	0.124	0.003	0.127	0.003	0.031	0.003
14413	5.099	0.03	0.247	0.009	93.170	0.157	0.137	0.004	0.537	0.007	0.509	0.007	0.193	0.009
14451	0.068	0.001	0.127	0.004	99.070	0.138	0.027	0.001	0.247	0.005	0.238	0.006	0.091	0.013
15589-middle	0.017	0.005	0.061	0.001	99.531	0.117	0.007	0.000	0.106	0.002	0.119	0.002	0.042	0.004
15589- edge	0.222	0.0005	0.201	0.0005	99.748	0.104	0.013	0.0006	0.027	0.0005	0.027	0.0005	0.036	0.003
16149	0.148	0.002	0.116	0.004	98.524	0.134	0.052	0.002	0.484	0.006	0.515	0.007	0.043	0.004
173031	0.018	0.0004	0.040	0.001	99.694	0.108	0.029	0.0009	0.019	0.0003	0.049	0.001	0.043	0.004

Plate VI. b. Results of the ED-XRF analyses performed on the copper artifacts, using an ED-XRF spectrometer, 38 kV, 30 mA, used time 60s, work curve: copper.
The analyses were performed by dr. Ingrid Poll at the Bucharest Municipality Museum Laboratory.