A. GARBACZ-KLEMPKA, M. WOŁOSZYN, T. DZIEŃKOWSKI, Z. KWAK, P. DŁUGOSZ, K. SAJA
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THE TECHNOLOGY TRANSFER OF NON-FERROUS ALLOYS CASTING DURING THE MIDDLE AGE

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The article reports on the findings from the metallographic analysis of 13th c. archaeological objects from Chełm (eastern Poland). The group submitted for analysis includes jeweller's dies used in the production of women's ceremonial ornaments, crucibles and bronze ornaments.
The Mongol invasion of 13th c. had caused craftsmen from central areas of East Europe to flee and seek shelter in the western parts of Rus. It may be safe to interpret the finds from Chełm as the remains of a jeweller's workshop, the site of casting and working copper alloys and silver.
The analysis of the technology used in casting copper alloys and silver in the jeweller's workshop were made using optical microscopy, X-ray spectroscopy and X-ray radiography.

Keywords: archaeometallurgy, casting, copper and silver alloys, chemical composition, images

INTRODUCTION

The present article discusses evidence for the production in Chełm during the 13th c. the so-called kolts, metal ceremonial women's pendants, typical for the elite of Kievan Rus [1] using casting and jewellery-making techniques. Finds include small crucibles used in melting non-ferrous metals.

If not for the Mongol invasion of 13th c., the ornaments would have continued to be made only in the traditional centres of Rus like Kiev and Novgorod. The Mongol invasion brought about a transfer of craftsmen and their technological knowhow also to the peripheries of Rus.

Similar workshops from central and western Europe specialized mostly in casting objects of copper and its alloys [2 – 4].

ARCHAEOLOGICAL FINDS AND THEIR CONTECTS

The centre at Chełm founded in the 13th c. by the Rus'ian duke Daniel Romanovich consisted of a stronghold with a masonry residence of the duke and the bishop, a suburb settlement protected by a rampart and an open settlement [5]. Excavations documented several hundred features, the relics of buildings serving domestic, utility for production purposes (eg. metalworking, jewellerys' workshops). The abundance of small finds, eg, metal objects reflects the intensity of occupation. Craftsmen's workshops were identified both within the suburb and the open settlement. The artefacts analysed here derive from these two contexts.

EXPERMINETAL

The archaeological artefacts associated with the production of the jeweller's workshop were subjected to metallographic analyses to recognize the alloys used and the technological know-how of the craftsmen operating in Chełm.

The macrostructure analysis was performed using a NIKON SMZ 745Z stereoscopic microscope. The quantitative determination of the elemental composition was performed by X-ray fluorescence spectrometry (XRF) using energy dispersive X-ray fluorescence spectrometer Spectro Midex. The X-ray examinations of the crucibles were performed on an X-ray device, type MU 2000 Xylon.

RESULTS AND DISCUSSION

Dies for making jewellery

The most significant object which helps to identify the speciality of the workshop in Chełm are jeweller's dies used in making metal women's ornaments - kolts (Figure 1a, b).

Kolts are ornaments known for the territory of Rus, but only a limited number of traces of production of these ornaments has been recorded, e.g the remains of jewellers' workshops in Serensk (northern Russia; 13th

A. Garbacz-Klempka, Z. Kwak, AGH University of Science and Technology, Faculty of Foundry Engineering, Krakow, Poland. M. Wołoszyn, University of Rzeszów, Poland; GWZO, Leipzig, Germany; A. von Humboldt Foundation, Return Fellowship. T. Dzieńkowski, University of Lublin, Institute of Archaeology, Lublin, Poland. P. Długosz, K. Saja, Foundry Research Institute, Kraków, Poland.

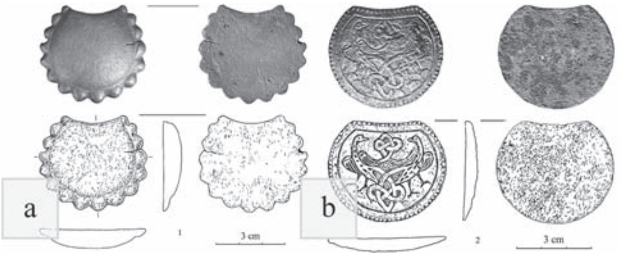

Figure 1 a) and b) Cast bronze dies used in shaping women's ornaments – kolts

c.) [6]. The dies were cast of tin bronze or tin-lead bronze in two-part stone moulds. They were used during the first stage of production (Figure 1a) in moulding a piece of silver or gold sheet to a rounded shape, drawn on the anvil from an ingot cast beforehand. During the second stage a die with a design (Figure 1b) was used to give form to the decoration on the worked piece [7-8].

The results of research confirm that the dies were cast of tin bronze (Table 1). Their underside retains a porous surface characteristic for cast pieces. Die No.144.436 is similar in its chemical profile to the die from the jewellery workshop at Serensk (Table 1, Ser 2243). Die W92 differs by having a substantial tin content, at ca. 19 % and a higher content of silver, antimony and arsenic.

Table 1 **Chemical composition of cast jeweller's dies from Chełm, and for comparison, of the die from Serensk (Russia) [6]/ wt. %**

No.	Fe	Ni	Cu	Zn	As	Ag	Sn	Sb	Pb
144.436	0,10	0,05	92,67	0,03	0,16	0,20	5,75	0,34	0,56
W92	0,08	0,12	78,01	0,15	0,37	0,89	19,27	0,80	0,20
Ser 2243	0,05	-	other	0,0	0,47	0,33	6,75	0,07	0,12

Crucibles

A convincing proof of casting production comes from fragments of industrial ceramics recognized as crucibles among others basing on defectoscopy images (Figure 2). They confirm the contact of the ceramics with molten metal and penetration of the metal into the porous surface of the crucible walls, and indicated by higher concentrations of metallic elements in the ceramics. In some cases the saturation of the ceramic matrix is visible as a droplet of molten alloy residue in the pores of crucible. Based on the 2D documentation, the three dimensional objects were recreated in computer environment (Figure 3).

Macroscopic images (Figure 4) show droplets of metal surviving on the wall of the crucibles, subjected

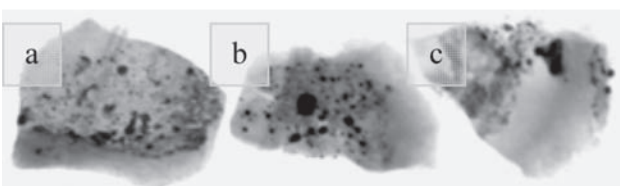

Figure 2 A defectoscope image of the crucible from Chełm: CH1 (a), CH4 (b), CH5 (c)

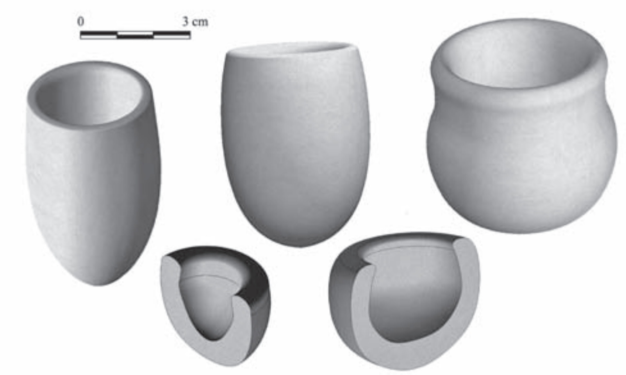

Figure 3 Visualization of the crucible in SolidWorks

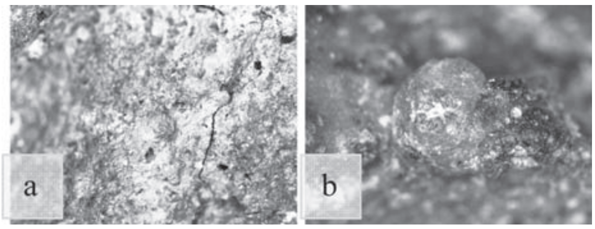

Figure 4 Macroscopic image of the crucible surface with droplets of metal: CH3, 20x (a), CH2, 50x (b)

by chemical composition analyses. Their results are presented in Table 2.

Table 2 **Chemical composition of metal droplets surviving on the surface of crucibles from Chełm/ wt. %**

No.	Fe	Ni	Cu	Zn	As	Ag	Sn	Sb	Pb
CH1	1,33	0,09	52,56	12,94	0,18	1,87	15,43	0,26	15,22
CH2	1,59	0,14	58,12	4,82	0,55	0,14	19,05	0,72	14,73
CH3	1,32	0,09	58,02	3,01	0,74	0,13	20,94	0,76	14,86
CH4	0,22	-	0,28	0,02	-	98,51	0,17	-	0,77
CH5	1,46	0,07	78,35	3,84	0,01	0,08	12,43	0,48	3,27

Research identified the substance melted in the crucibles as copper alloys and silver. Chemical elements (Ag, Cu, Sn, Pb and other) as components of the alloy melted in the crucible diffused into the wall of the crucible, causing a higher concentration of metallic elements in the ceramic matrix. Fragments of pottery with visible traces of metals should be recognized as industrial ceramics (used in casting production). Crucibles have been recorded in many sites in East Europe dating to the period 11^{th} - 13^{th} c. [9-10].

Casting mould

A further trace of casting activity of the workshop in Chełm is a casting mould (or half) of such a mould (No. 94-44-0673) for casting thin circular pieces (Figures 5, 6).

Metal objects

For a fuller picture of the production in Chełm analyses were supplemented by studies of metal artefacts (Table 3) attributable to the activity of the local work-

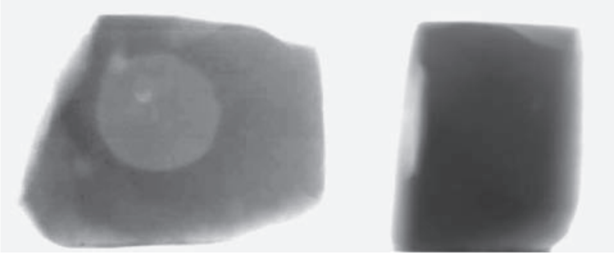

Figure 5 A defectoscope image of the casting mould from Chełm

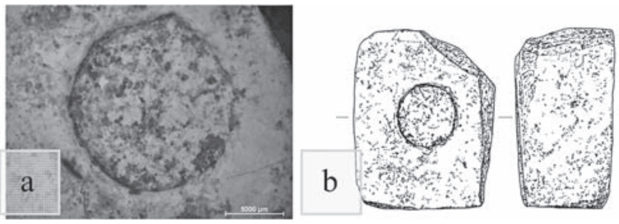

Figure 6 A macroscopic image of the inside of the casting mould (a) and a drawing of the casting mould from Chełm (b)

shops: a finger-ring (99/94), needle (99I), mounts (W21/97 and W22/97), wire (W97/03) and bell (A8441).

Table 3 **Chemical composition of the metal artefacts from Chełm/ wt. %**

No.	Fe	Ni	Cu	Zn	As	Ag	Sn	Sb	Pb
99/94	0,62	0,07	82,76	5,81	0,92	0,07	3,56	0,46	5,34
99I	0,03	0,12	91,18	0,40	0,50	0,14	4,53	0,36	2,62
W21/97	0,58	0,12	58,69	0,68	0,70	0,23	29,20	0,54	9,17
W22/97	0,28	0,09	75,22	0,23	0,16	0,09	16,64	0,33	6,90
W97/03	0,49	0,07	93,04	0,21	0,73	0,08	0,09	0,44	4,20
A8441	0,04	0,12	81,83	1,60	0,31	0,11	14,48	0,22	1,25

The examined artefacts display a variety of chemical profiles. All were made of copper alloy but differ in the content of subsidiary elements of the alloy. The dominant alloy among those investigated are tin-lead bronzes with tin content in the range of 3,56 – 29,02 %. The increased tin content is related to the higher content of lead, at 6,90 – 9,17 %, which in other cases is in the range of 1,25-5,34 %. One of the alloys may be recognized as lead-bronze, Cu-Pb, another, as a multiple-component alloy, Cu-Zn-Sn-Pb. All the alloys contain natural admixtures from ores (Fe, Ni, Ag, As, Sb).

CONCLUSIONS

The discovery at Chełm of artefacts attesting to metalworking activity confirms the presence in that city of a workshop which had specialist tools and a furnace and as the site where non-ferrous metals were worked. Dies used in the manufacture of women's ornaments, crucibles retaining metal residues and the casting mould could have been used within the same workshop. The effect of the production of that local workshop are metal objects: ornaments and mounts.

Techniques used in the workshop included casting and blacksmithing. The alloys used were based on copper, and included mostly tin-lead bronzes as well as silver.

The archaeological finds associated with casting provide insight into the technology of the time. The case analysed here proves that even during the Middle Ages the transfer of technology could be rapid. Within a single generation the Rus'ian Duke Daniil transformed Chełm into a major crafts production centre.

The study of metalworking production in the Polish-Rus'ian borderland has been gaining momentum only since 1989, pursued by international and interdisciplinary research teams. We hope that the cooperation of archaeologists and representatives of technical sciences helps in developing a new, improved understanding of past production in this region of Europe.

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Note: The responsible translator for English language: Anna Kinecka, Terra Nova Office, Wrocław, Poland