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Archaeological Evidence of Medieval Metallurgical Activities in Prague's Clementinum – Production and Processing of Bronze, Brass and Silver

ANNOTATION

The article focuses on documentation of medieval production technologies, especially on the metallurgy of precious and non-ferrous metals or their alloys (silver, bronze and brass). Geochemical analysis was carried out using the EDS-SEM method. Under focus are furnaces and other finds from the Clementinum area near the western edge of Prague's Old Town; reviewed are also the small finds discovered in the vicinity. The local finds of production features (furnaces) or small remains after their destruction (fragments from the walls of the furnaces) and also artefacts belonging to other types of archaeometallurgical finds (lumps and drops of non-ferrous metal alloys, slag, touchstones, technical ceramics, crucible) expand the knowledge of specialized production activities in Prague during the 12th and the 13th century.

SUMMARY

Recent archaeometallurgical finds constantly indicate the existence of specialized workshops producing and processing precious and noble non-ferrous metals in medieval Prague. The analysis of the archaeometallurgical finds' assemblage from the western part of the Old Town of Prague, more precisely from the western part of the Clementinum complex (Křižovnická No. 1040, former Jesuit College) deepened the existing knowledge about these activities from earlier excavations in this part of Prague (Havrda/Zavřel 2008; Havrda/Zavřel 2019).

The excavated area, situated within the Prague early medieval agglomeration, became more intensively settled from the 11th century, when the settlement began to move here from the left bank (Figs. **1**, **2**). The site was at an exposed position within the residential area, being located by the river crossing next to the main route. In the 1230s and 1240s, the unfortified Old Town agglomeration transformed into a highly medieval city. Remains of the production facilitiess supply evidence for activities using fire to a greater extent, including the processing and production of metals. Metallurgy of non-ferrous metals is evidenced by the discovery of the remains of two furnaces. One was found in the eastern part of the Clementinum area (Fig. **3:** V6; **4**), the other in the western part (Fig. **3:** V69; **5**, **6**, 7). Palaeobotanical analysis identified the species of small fragments of wood and charcoal found both in the backfill of the furnace and in its surroundings. Of the wood species, pine prevailed, spruce and fir were less represented (table **2**). Both of these production features disappeared in the second half of the 13th century.

Movable evidence of non-ferrous metals metallurgy included irregular ingots and drops of non-ferrous metal and slag-like lumps (Figs. **16**, **17**, **23**, **26**), fragments of ceramic crucibles, which belonged to cone-shaped smelting crucibles with a circular mouth and a short protrusion for gripping the container with tongs (Fig. **9**). Also fragments of common kitchen pottery with a slag coating (Fig. **15**) were represented, as well as touchstones (Fig. **35**) and also a stone mould for casting small ornaments (Fig. **34**). The assemblage also contains several small artefacts made of non-ferrous metals – metal scrap in the form of a bundle of wires, pagament for secondary smelting (Fig. **29**, **31**, **32**). Geochemical analyses of archaeometallurgical finds proved work with copper, tin, lead, zinc, silver and iron (the samples were examined with an electron microscope with an EDX analyser).

Archaeological excavations have confirmed the importance of crafts dealing with the production and processing of metals. So far, it is not possible to clearly determine which metal (metals or their alloys) was locally produced and processed in the initial stages. Whether it was primarily iron, the production of which was later followed by the metallurgy of copper and its alloys, i.e. tin and lead bronzes and brass, or whether it was done simultaneously. Similarly it is not possible to assess the role and the beginnings of local silver production, confirmed by the analyses of three crucibles from the first half of the 13th century (Fig. **9**). As indicated by the presence of this metal in the weathered copper lump 2010/11-S75, one of the oldest local archaeometallurgical finds from the filling of an 11th century feature, silver processing may be presumed already in the initial stages of the local craft workshop/workshops existence.

In addition to the local production of silver, working with gold can perhaps also be considered. A touchstone with traces of testing gold and brass alloy products – probably imitation of the precious metal – was found near the smelting crucibles (Fig. **35:** D12-11).

Clementinum belongs to one of the two archaeological sites in Prague with the evidence of non-ferrous metal ore – in this case, malachite – in medieval layers or features. This unequivocally proves the metallurgy of the primary raw material in the local metallurgical workplace, at least in some phase of its development. Primary processing of ore raw materials is indicated by the occurrence of heterogeneously composed lumps proving the production of tin bronzes. Their quantity (several tens of pieces) and the highly fluctuating representation of various primary and secondary components (vitreous matrix, tin dioxide, cupric oxide, nodules of metallic copper, lead, tin and tin bronzes with a significantly fluctuating ratio of Cu and Sn and secondary minerals / cuprite, atacamite and anglesit/) suggests that these are not slags, but intermediate products in the production of tin bronzes. The very presence of nodules with high tin contents in similar materials related to bronze production is considered as evidence of the addition of tin or cassiterite during copper alloying and excludes the genesis of these metallurgical products during the recycling of bronze scrap. As mentioned earlier (Havrda/Zavřel 2019, 996*sqq*.), this type of finds from Clementinum best corresponds to materials created during the combined reduction metallurgy of crushed copper ores and tin mixed with charcoal in simple small kilns sunken below ground level, or cementation of copper with material tin-rich (Sn ore or metal scrap with a high tin content). The resulting slag-like semi-finished products with a significant proportion of non-ferrous metal nodules and their alloys of very variable composition were crushed and washed to obtain metal beads for further production process.

From the 9th to the 13th century, Prague was an important centre of iron production and processing (most recently Podliska/Havrda/Zavřel 2021). The situation of the Přemyslid lands in the 12th century with the metallurgical production focused on non-ferrous metals in the proto-urban metropolis of medieval Bohemia, approaches what is also known from German regional centres west of Bohemia, in which the production of non-ferrous metals is usually dated to the 10th and 11th centuries.

The above findings confirm the extraordinary role of metallurgy of non-ferrous metals among the crafts practiced in Prague since the early Middle Ages. Apart from the historic parts of Prague at Malá Strana, Vyšehrad and Nové Město, also the Old Town area becomes significant, which opens up a more comprehensive view of the role and importance of non-ferrous metallurgy in the capital of Bohemia in the initial stages of its history.

Fig. 1. Archaeological evidence of production and processing of non-ferrous metals in Prague's Historic Centre. Malá Strana 10th–11th century, Old and New Towns 11th–13th century. Explanations: **1** – silver metallurgy; **2** – metallurgy of non-ferrous metals and their alloys; **3** – bell maker's workshop (12th–13th century); **4** –fortifications of the 13th century; **5** – Judith's bridge; **6** – ford; **7** – settlement area in the 12th–13th centuries (illustrated by S. Babušková, 2023 from J. Havrda's documentation).

Fig. 2. The Old Town of Prague with the settlement area at the beginning of the 13th century, the production site marked with a circle; today the Clementinum complex No. 190 and 1040.

Fig. 3. Prague 1-Old Town, Clementinum No. 190 and 1040, trenches with evidence of the metallurgy of non-ferrous metals in the 12th–13th centuries. **1** – sporadic archaeometallurgical finds (1–5 pcs); **2** –numerous finds (6–50 pieces); **3** – very numerous finds (over 50 pieces); **4** – production feature (furnaces V6 and V69); **5** – metallurgical workshops (an enormous amount of small archaeometallurgical finds); **6** – sites of ore and metallurgical semi-finished products ('pebble'); **7** – touchstones; **8** – archaeological trenches. Depicted according to field documentation.

Fig. 4. Prague 1-Old Town, Křižovnická No. 1040, Clementinum – eastern part of the main courtyard. The V6 production feature (furnace) sunk into the geological subsoil (**grey**) used by coppersmiths in the 13th century. Legende: **A** – section No. 4; **B** – the groundplan, situation of the section is marked with a **green line** on the groundplan; **C** – photo of the furnace. Exc. NPÚ ÚOP in Prague No. 2001/20, trench III, feature V6.

Fig. 5. Prague 1-Old Town, Křižovnická No. 1040, west wing of the former Jesuit College called Clementinum. Transverse (eastern) section No. A07-R05 of production feature V69 (furnace). Exc. NPÚ ÚOP in Prague No. 2012/35, trench A07. See Fig. **7** and **8** for positioning of sections. Description of the layers: **A07-65** – dark ochre-grey hard cracked sandy loamy clay, in some places traces of non-ferrous metal alloys; bottom of pyrotechnic feature V69 affected by heat; **A07-73** – deep brown homogeneous dusty soil, significant organic content; **A07-74** – greenish red-yellow clay with charcoal, fill of pyrotechnic feature V69; **A07-75** – ochre clayey soil with an admixture of grey dusty soil, occasional fragments of opuka and lumps of red-burnt soil, construction of pyrotechnological feature V69; **A07-76** – red-burnt stiff clayey soil, numerously burnt opuka 6–12 cm, rarely lump of mortar, ferruginous sandstone, belongs to the pyrotechnological feature V69/its older phase(?); **A07-78** – as A07-75, but affected by heat in contrast to it, coloured brown-red, feature V69, **A07-79** – rusty coarse-grained bedded sand,

position within layer A07-76; **A07-84** – dark brownish-grey friable slightly sandy silty soil, tiny mortar grains, random fragments of opuka 0.5–3 cm (description by A. Žďárská).

Fig. 6. Prague 1-Old Town, Křižovnická No. 1040, west wing of the former Jesuit College called Clementinum. Longitudinal (northern) section No. A07-R04 of production feature V69 (furnace). Exc. NPÚ ÚOP in Prague No. 2012/35, trench A07. See Fig. **7** and **8** for positioning of sections.

Fig. 7. Prague 1-Old Town, Křižovnická No. 1040, west wing of the former Jesuit College called Clementinum. Groundplan of production feature V69 (furnace) from the 2nd half of the 13th century. Exc. NPÚ ÚOP in Prague No. 2012/35, trench A07, plan A07-P07.

Fig. 8. Prague 1-Old Town, Křižovnická No. 1040, Clementinum – west wing of the former Jesuit College. Groundplan of the older phase (?) of production feature V69 (furnace). Exc. NPÚ ÚOP in Prague No. 2012/35, trench A07, plan A07-P10.

Figs 9–35: All finds published in this article come from the archaeological excavation in Prague 1-Old Town, Křižovnická No. 1040/I, former Jesuit College called Clementinum. Exc. NPÚ ÚOP in Prague No. 2012/35, only the find on Fig. 16 is from Exc. NPÚ ÚOP in Prague No. 2010/11.

Fig. 9. Fragments of ceramics used in the metallurgy of non-ferrous metals. Finds from the Clementinum area excavated in 2012–2014. Crucible fragments: **1** – 12/35-TT-B04-15-1; **2** – 12/35-TT-B04-15-2; **3** – 12/35-TT-B04-15-3; **4** – 12/35-TT-B04-15-4; **5** – 12/35-TT-B04-15-5; **6** – 12/35-TT-B04-15-6; **7** – 12/35-B05-42a; **8** – 12/35-B05-42b; **9** – 12/35-TT-D11-28; **10** –12/35-TT-D12-25.

Fig. 10. Find 2012/35-B04-15-1 – small silvery grey globule with the locations of analysed points No. 38–41. Tescan Vega 3 electron microscope image, backscattered electron (BSE) mode.

Fig. 11. Find 2012/35-B04-15-2 – a small grey globule with the locations of analysed points No. 44, 45 and surface No. 46. Image of a Tescan Vega 3 electron microscope, BSE mode.

Fig. 12. Find 2012/35-B04-15-2 – detail of lanceolate (arrow-shaped) and feather-like acanthite crystals on the surface of the globule. Tescan Vega 3 electron microscope image, BSE mode.

Fig. 13. Find 2012/35-B04-15-5 – a grey globule surrounded by light blue-green weathering from the inside of a crucible with the locations of analysed points No. 64 and 65.

Fig. 14. Bottom fragment of technological vessel 2012/35-B5-42b-Ke with elongated lump of metal covered with dark green secondary copper minerals.

Fig. 15. Cup-shaped sherd 2012/35-B5-42a-Ke with a slag coating on the inner wall.

Fig. 16. A lump of metal (‘ingot’). Find 2010/11-S75, Exc. NPÚ ÚOP in Prague No. 2010/11.

Fig. 17. Section surfaces of metal lumps 2012/35-B05-44b.

Fig. 18. Part of the surface of the section B05-44-b with predominantly light grey metal (copper with tin admixture), small light inclusions (lead) and dark grey weathering in the gas pores. Tescan Vega 3 electron microscope image, BSE mode.

Fig. 19. Section surfaces of metal lump A07-38, right with polished surface.

Fig. 20. Interface of three differently coloured parts of alloy A07-38; alloys: the dark grey part on the right consists of copper with lead inclusions, the main phase of the light grey middle strip has a composition of bronze with a relatively low proportion of Sn, the left part with a net-like structure is made up of tin bronze of fluctuating composition (85–93 wt.% Cu, 7–16 mass % Sn), there are small abundant lead inclusions. Tescan Vega 3 electron microscope image, BSE mode.

Fig. 21. The slag-like part of the surface of lump A07-38 consisting, in addition to the main alloy of copper and tin, of vitreous slag (dark parts) with SnO_2 crystals, copper weathering (malachite, cuprite) and nodules with significantly fluctuating proportions of tin and copper. Tescan Vega 3 electron microscope image, BSE mode.

Fig. 22. Detail of part of the slag-like part of the sample A7-38 with the locations of the analysed surfaces and points Nos. 30 to 33. Image of the electron microscope Tescan Vega 3, BSE mode.

Fig. 23. Production waste generated when working with non-ferrous metals. Deeply coloured lead-silicon vitreous slag and slag-like lumps are prominently represented. Finds from a layer dated to the 2nd half of the 13th century

(layer A07-11) not far from furnace V69. Trench A07, west wing at Křižovnická Street.

Fig. 24. Polished surface of slag material A07-11.

Fig. 25. Part of the A07-11 slag section with congested white rhombic and needle-shaped stannous oxide crystals (often with central cavities) in a dark grey vitreous matrix and an irregular cluster of tin bronze (bottom left). Tescan Vega 3 electron microscope image, BSE mode.

Fig. 26. Section surfaces of lump B05-44, right with polished surface.

Fig. 27. General image of the thin section sample B05-44 with the marking of significantly different parts: **A** – areas without the presence of non-ferrous metals or their compounds with a predominance of fused light siliceous matter (quartz grains or quartzite?); **B** – the three largest areas with significantly concentrated growths of SnO_2; **C** – small porous parts of the slag mainly with weathered Cu ores – cuprite, atacamite, malachite; **D** – the main mass of the slag with a predominance of the glass component, finely dispersed cuprite, SnO_2 crystals and very abundant microscopic inclusions and small globules of copper, bronze or tin; **E** – marginal heterogeneous parts of slag with cuprite, quartz grains, rarely with mica (?). Tescan Vega 3 electron microscope image, BSE mode.

Fig. 28. Part of slag thin section B05-44 with whitish irregular clusters and congested bands of SnO_2 crystals, also needles of the same oxide and grey globules of copper and bronze in a dark grey amorphous vitreous matrix. Tescan Vega 3 electron microscope image, BSE mode.

Fig. 29. Fragment of copper-coloured metal D12-31.

Fig. 30. Part of the surface of the metal fragment D12-31 with the locations of the analysed faces and points No. 1–6. Tescan Vega 3 electron microscope image, BSE mode.

Fig. 31. Fragment of an artefact made of coiled metal wires 2012/35-D12-157.

Fig. 32. Part of the surface of sample D12-157 composed of metal wires and covered with weathering. Tescan Vega 3 electron microscope image, BSE mode.

Fig. 33. Detail of the surface of one of the wires (D12-157) with the locations of the analysed points and faces No. 1 to 5. Image of the Tescan Vega 3 electron microscope, BSE mode.

Fig. 34. Stone mould – casting mould for the production of small objects from lead and copper alloys (accessories, ornaments, fittings, etc.). Clementinum, Student's Courtyard.

Fig. 35. Touchstones. Clementinum, Student's Courtyard.

Table 1. Prague 1-Staré Město, Clementinum. Range of analysed small finds of non-ferrous metallurgy, revealed during excavations of the NPÚ ÚOP in Prague No. 2010/11 and 2012/35 from trenches located in the western part of the grounds of the former Jesuit College. Samples commented in the text are highlighted in **grey**.

Table 2. Charcoal and wood fractions analysis from the fill of V69 furnace and its surroundings (Kočár/Kočárová 2014, 21 and tab. 4).

Table 3. Results of spherical clusters (globules) analyses from the surface of three smelting crucibles from Clementinum (B04-15-1 in **blue**, B04-15-2 in **green**, B04-15-5 in **yellow**); data in wt % of elements normalized to 100%.

Table 4. Analyses results of samples 2010/11-S50 (No. 1 and 2) and 2010/11-S75 (No. 3 to 5); data in wt % of elements normalized to 100%.

Table 5. Results of analyses of A07-38 slag in the points Nos. 30 to 33; data in wt%, normalized to 100%.

Table 6. Results of analyses of selected bronze globules in A07-11 slag sample; data in wt%, normalized to 100%.

Table 7. Chemical composition of globules of bronze in the thin section of B05-44a sample; data in wt %, normalized to 100%.

Table 8. Results of analyses of the metal fraction D12-31; data in wt %, normalized to 100%.

Table 9. Results of analyses of D12-157 sample; data in wt %, normalized to 100%.

Translation by Linda Foster