A catalogue of bone-ash cupels dating from AD 1500–1537 found in the Mint in the Archbishop's Palace, Trondheim, during archaeological excavations in 1991–1995

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Abstract

During the archaeological excavations in the Archbishop's Palace in Trondheim in 1991–1995, three successive mints dating from about AD 1500–1537 were uncovered. A high number of bone-ash cupels used for assaying precious metals were found. The assemblage, which is now stored in the NTNU University Museum, Trondheim, represents one of the largest collections of late medieval bone-ash cupels found in a European excavation to date. The catalogue comprises a brief presentation of the use of bone-ash cupels in medieval times and individual descriptions of 186 uncovered cupels and fragments of cupels. The cupels were made in moulds but no such moulds have been found. The upper, outer rim diameter of each cupel has been measured and the results show that the cupels in the assemblage may be grouped into five size classes: 25, 30, 35, 40, and 45 mm. The majority have a rim diameter of 35 mm (54%).

Introduction

During the archaeological excavations of the Archbishop's Palace in 1991–1995, three successive mint complexes, one above the other, were uncovered (McLees, 1994; Saunders, 2001; Nordeide, 2003; Lohne et al., 2010). The mints date from the period of the last three archbishops, from about AD 1500–1537. Among metalworking debris there was a high number of used bone-ash cupels. Together in the archaeological excavation records, 174 cupels or fragments of cupels of various sizes have earlier been reported (Saunders, 2001, p. 27). In the catalogue presented in this paper the number of cupels is increased to 186 cupels, due to identification of cupels previously recorded as crucibles. Both the cupels and fragments of cupels are systematically described, albeit not in very much detail. The main purpose of the catalogue is to give a qualitative overview of the size, shape and condition of each cupel or fragment.

Background

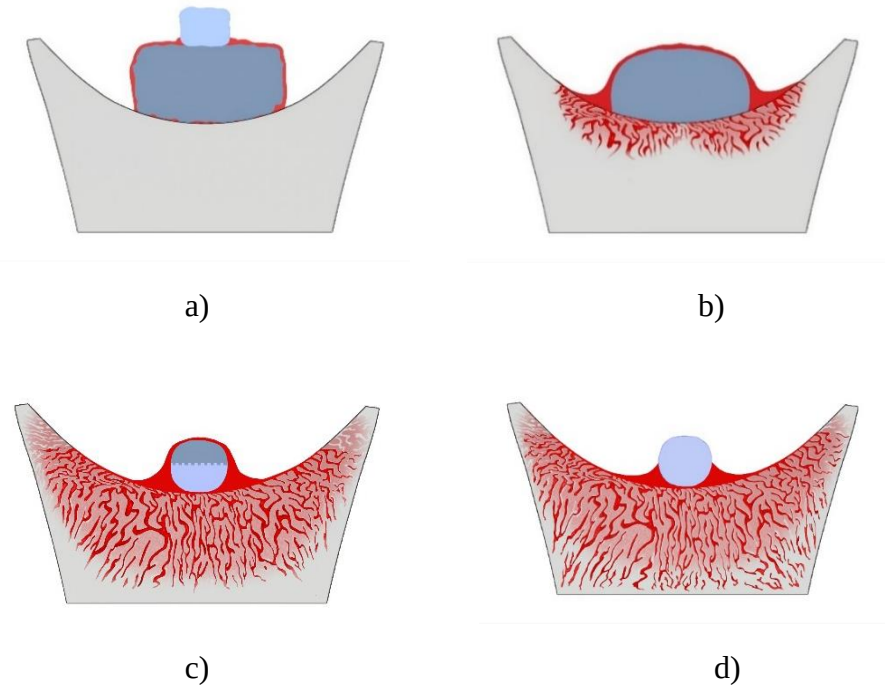
Several treatises from the 16th century describe the manufacture of cupels and the cupellation process, including those by Biringuccio (1966 [1540]), Agricola (1950 [1556]), and Ercker

(1951 [1574]). According to the aforementioned authors, good cupels were made using ground and washed ash that is moistened with a binder, such as strong beer, packed into a mould, and beaten with a mallet to make a shallow bowl on top of the compacted body. The top surface was then faced with a finely ground bone-ash, which was beaten onto the surface, so it adhered evenly. Bone-ash from calves' heads was recommended as the best material for the purpose. However, the authors also informed that in the 16th century the materials selected, and assayers' practices varied.

Many publications deal with archaeologically excavated cupels from various places dating from the 16th century and earlier, including Oberstockstall, Austria (c.100 cupels) and Castle of Pymont, France (c.20 cupels) (Martinón-Torres et al., 2009), Legge's Mount, the Tower of London (14 cupels) (White, 2010), and Porto, Portugal (171 cupels) (Hsu and Martinón-Torres, 2019). The main investigations described in the aforementioned publications concerned the material used in the manufacture of the cupels and their microstructure. Except for four cupels (White, 2010), all investigations were of used cupels. Although only a small fraction of the excavated cupels have been investigated, the main material used is reported as bone-ash, mainly pure bone-ash or in some cases mixed in with some other material, accounting for up to 10% in cupels from Pymont and 30% in cupels from Oberstockstall. In cupels from Porto, wood ash might have been mixed in with the bone-ash.

The use of bone-ash cupels

In medieval times, bone-ash cupels were the main equipment used when assaying precious alloys, such as measuring the silver content of coins. However, the process of cupellation can be traced back as far as the Early Bronze Age (Kohlmeyer, 1994). The four main steps in the cupellation process are shown in Fig. 1 (for details, see Lohne et al., 2021, this volume; Lohne and Ulseth, 2021, this volume).



a) b)

c) d)

Figure 1. a) A small piece of metal of unknown composition (pale blue) is placed on a pre-heated bone-ash cupel (grey) together with about ten times as much lead (dark blue) and then the cupel is placed in a hot furnace. On the lead surface, solid lead oxide is shown as red; b) During heating, lead melts and the metal of unknown composition is dissolved in the melt. At a temperature just below 900°C lead oxide melts, dissolves impurities (not silver) and is soaked into the cupel by capillary action. Some lead oxide evaporates. c) More and more lead transforms into lead oxide by reacting with oxygen above the melting lead button and is soaked into the cupel. Consequently, the concentration of silver in the molten pool increases. When the concentration reaches c.90%, solid silver starts to precipitate in a dendritic shape. Dendrites grow, impinge on other dendrites, and are transformed into grains (pale blue). d) All lead has oxidized, and the silver has solidified into a bead of almost pure silver. When all the lead oxide has been soaked into the cupel, the process is complete. After the cupel and its contents have cooled, the bead is removed. The ratio between the weight of the bead and the original metal of unknown composition gives the fraction of precious metal (assuming that the bead is pure silver, that no silver has been soaked into the cupel, that the bead has been cleaned and/or brushed properly, and that the lead did not contain any silver at the start of the process).

Results and discussion

Some typical bone-ash cupels from the excavations in the Archbishop's Palace are shown in Figs. 2–4. It is clear that the cupels were made in moulds. The diameter of the upper outer rim of each cupel is listed in Table 1. The results of examinations of the assemblage revealed that the cupels may be grouped into five size classes according to their rim diameters: 25 mm, 30 mm, 35 mm, 40 mm, and 45 mm. The upper rim diameter in each class may vary ± 1 mm. The majority of cupels had a rim diameter of 35 mm (54%). Although there must have been moulds for making cupels in least five different sizes, no such moulds were found during the excavations.

Many of the cupels that lack part of their base are ball shaped. A total of 154 (83%) ball-shaped cupels were found and measured. For all cupels with a base or part of their base surviving, the heights of the cupels were measured too.

Figure 2. An original silver bead seen at the bottom of cupel N124867. Diameter of bead: 0.7 mm. Photograph: Åge Hojem, NTNU University Museum.

Figure 3. Four bone-ash cupels viewed from two angels. From left to right, they have an outer rim diameter of 30 mm (N125123), 35 mm (N122514), 40 mm (N124858), and 45 mm (N124857), respectively. Note the depression at the bottom of the largest cupels, N124857 and N124858. Photograph: Åge Hojem, NTNU University Museum.

A fine-grained surface layer, called facing, has been registered. With the exception of one or two cupels, all cupels have a fine-grained facing layer, which made it easier for all silver to be collected in one bead through cupellation. Erker (1951 (1574) p. 31) underlines the importance to have a good cupel facing. At flaws in the surface layer silver may be lost (Ulseth et al., 2015).

Some cupels with an upper rim diameter of 40 mm or 45 mm have a depressed area at the bottom – 15 out of 27 (56%) and 8 out of 17 (47%), respectively. Such depressions have been seen also on cupels from Pymont (Martinón-Torres et al., 2009). The depressed area might have facilitated the process of collecting all silver into one bead. One question that arose during this compilation of the catalogue, was whether there might be an identifiable chronological development from cupels without a depression to cupels with a depression. However, archaeological data do not support this theory: of the 22 cupels with a rim diameter

of 40 mm and 14 cupels with a rim diameter of 45 mm, which could be placed within a time frame corresponding to their use, cupels either with or without a depression were equally distributed. In total, 61% (22 of 36 cupels), with an almost 50:50 division based on the presence or absence of a depression or not, were found in a levelling layer relating to a fire of 1532, which devastated the eastern and southern parts of Archbishop's Palace, including the second workshop. The fire was caused by the troops of the Protestant king, Frederik I (1523-1533), who attacked the palace in retribution for the archbishop's support to the deposed Catholic king, Christian II (1513-1523).

Figure 4. Cross-section of cupel N124860. Upper rim diameter 35 mm, height 23 mm. Note the fine-grained surface layer (i.e. the facing) at the bottom of the bowl and the two dark areas at the bottom of the cupel where lead oxide has filled both cavities between the bone-ash particles and the canals in the bone-ash, in contrast to just in the canals in the bone-ash particles higher up. Photograph: Åge Hojem, NTNU University Museum.

Bone-ash cupels are brittle. However, in the parts of used cupels that are 'impregnated' with molten lead oxide during the cupellation process, the bone-ash particles are strengthened and 'glued' together. As a consequence, these parts might survive handling during excavations, whereas excavated cupels might lack parts that were not impregnated (Fig. 5) and might have a ball-shaped bottom and lack parts of their upper rim. Bone-ash in cupels that have not been impregnated by molten lead oxide might have been reused by assayers (Lohne et al., 2021, this volume).

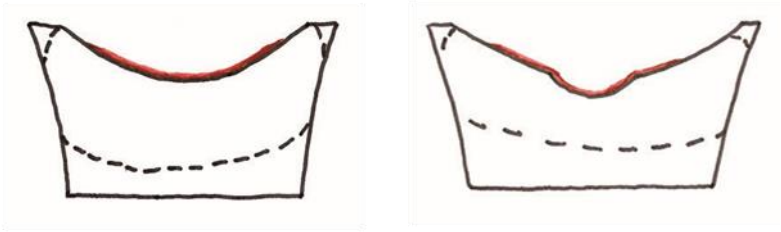


Figure 5. Sketches of two cupels with an upper rim diameter of 35 mm (left) and 40 mm (right), the latter with a depression at the bottom. The dashed lines indicate where many cupels are broken (the majority of them ball-shaped cupels). Red lines illustrate the facing. (Reproduced from Ulseth et al., 2015, p. 270)

Two cupels were cut in two halves and then metallographic specimens were prepared and investigated using a scanning electron microscope (SEM) equipped with energy dispersive x-ray spectrometer (EDS), for chemical analyses. In addition to lead oxide, the dominant elements were calcium (Ca) and phosphorous (P), with low concentrations of magnesium, aluminium and silicon. The results show that the cupels were made mainly from bone-ash, without the addition of clay. Analysis of the ash in the canals in the ash particles show that the ashes were derived from animals (Ulseth et al., 2015).

Earlier, we conducted laboratory experiments on making bone-ash cupels, ranging from calves' sculls to finished cupels with facing, and we tested a silver and a gold alloy with known purity with good results (Lohne et al., 2021, this volume)[1]. From the experiments, we concluded that it is most likely that the cupels excavated from the Archbishop's Palace were produced on the Mint's premises.

Table descriptions and comments

Systematic descriptions of the 186 bone-ash cupels are listed in Table 1. The descriptions are not very detailed. Rather, the catalogue is intended to provide a qualitative overview of the size, shape and condition of the cupels. The weight of the cupels indicates that all of them were used. The cupels have each a specific museum number, prefixed with the letter N (e.g. N115972).

Similar sample presentations are missing at an international level. By presenting the catalogue, we aim to contribute results that might be used when researchers compare manufacturing techniques and use of cupels across Europe and across various time periods.

The number of unearthed cupels presented in different papers from the excavations of the three archbishop's mints at the Archbishop's Palace in Trondheim vary. This is partly because the cupels were found in different areas and in different layers. Our catalogue includes a further 12 cupels to the 174 cupels and cupel fragments presented in earlier publications of the excavations. From our experience, some cupels have been stored in boxes together with crucibles and consequently they have been registered as crucibles rather than as cupels.

[1] See also: Lohne, O. and Ulseth, P., 2016. *Framstilling av beinaskekupeller fra grunnen av og erfaringer med kupellering*. Notat. 15 pages in Norwegian.

However, in some boxes containing cupels also contain small crucibles, which have been registered and counted as cupels. Furthermore, it remains unclear whether some of the fragments we have identified as belonging together were perceived during the excavations as separate entities or parts of the same object. Therefore, there may still be some unidentified or wrongly identified cupels stored among other objects from the excavations.

In addition, it should be noted that of the 17 objects registered as N124864, one includes the note 'Plastic bag (921043)'. The reason for the object being stored with the rest of the objects under the same number, but separately in a plastic bag with another number, is unknown.

Table 1. A description of the 186 cupels/fragments of cupels

References

Agricola, G., 1950 [1556]. *De Re Metallica,* Transl. H.C. Hoover and L.H. Hoover. Dover Publications, New York.

Biringuccio, V., 1966 [1540]. *The Pirotechnia: The Classic Sixteenth-Century Treatise on Metals and Metallurgy,* Transl. C.S. Smith and M.T. Gnudi. Dover Publications, New York.

Ercker, L., 1951 [1574]. *Treatise on Ores and Assaying,* Transl. A.G. Sisco and C.S. Smith. University of Chicago Press, Chicago.

Hsu Y.-T. and Martinón-Torres, M., "Fire assay and cupellation at the late medieval Porto Mint, Portugal: a technological study", *Journal of Archaeological Science: Reports*, 24, 2019, p. 496-506.

Kohlkmeyer, K**.,** 1994. Zur frühen Geschichte von Blei und Silber. In: Wartke, R. (ed.), *Handwerk und Technologie im Alten Orient,* pp. 41–48. Mainz.

Lohne, O. and Ulseth, P., 2021. A metallurgical investigation of the formation of silver beads during cupellation of a 925 ‰ silver alloy [This volume].

Lohne, O., Risvaag, J.A., Ulseth, P., Lohne, J., 2010. *The Mint in the Nidaros Archbishop's Palace: Coin Production under Archbishop Gaute Ivarsson (1475–1510*), Transactions of the Royal Norwegian Society of Sciences and Letters 2010:1. Trondheim.

Lohne, O., Ulseth, P. and Risvaag, J.A., 2021. From calves' sculls to finished bone-ash cupels and testing of precious metals: An investigation of the cupellation practised in the Mint in the Archbishop's Palace in Trondheim in medieval times [This volume].

McLees, C. 1994. The late medieval mint workshops at the Archbishop's Palace, Trondheim, *Antiquity*, 68, p. 264–274.

Martinón-Torres, M., Rehren, T., Thomas, N., and Mongiatti, N., 2009. Identifying materials, recipes and choices: Some suggestions for the study of archaeological cupels. In: Guimlia-Maire, A. (ed.), *Proceedings of the 2nd International Conference Archaeometallurgy in Europe*, 17–21 June 2007, Aquileia, Italy, pp. 435–445. Ass. Italiana di Metallurgia, Milan.

Nordeide, S.W., 2003. *Erkebispegården i Trondheim: Beste tomta i by'n*. PhD thesis, University of Oslo, Oslo.

Saunders, T., 2001. *The Archbishop's Palace: A Social Analysis of the Power Centre in the Late Medieval Period – Money, Warfare and Charity. Utgravingene i Erkebispegården i Trondheim.* NIKU Temahefte 18. NIKU, Trondheim.

Ulseth, P., Lohne, O., Risvaag, J.A., Lohne, J. and Ervik, T., 2015. Late medieval bone-ash cupels from the archbishop's mint in Trondheim, *Fornvännen* 4, pp. 26–279.

White, H., 2010. *Legge's Mount, The Tower of London, London: Scientific Examination of the Cupels.* Technology report. Research Department Report Series, no. 57-2010. Archaeological Science, English Heritage, Portsmouth.