

Metallurgic ceramics as a key to Viking Age workshop organisation

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Metallurgic ceramics form a common group of Iron Age/Early Medieval workshop finds. These highly specialized refractory ceramics carry a lot of information; telling us not just about the blacksmiths' and goldsmiths' skills in handling ceramic materials, but also about production and workshop organisation. This paper mainly deals with the question of *heating trays*, interpreted as vessels used in fire assay, or the refining and analysis of silver. A general connection between assaying and means of payment is briefly discussed, and a hypothesis is put forward that the presence of heating trays may provide information on Viking control over the means of payment and trade, in the same way as the presence of weights and weighing does. The Viking weight economy was dependent on methods for weighing the silver used for payment and methods for checking its purity. Analyses of heating trays from 9th–10th century Birka and of trays from the 10th–11th century mint in Sigtuna are made and an experimentally produced heating tray is analysed for comparison purposes.

Keywords: Viking Period, Birka, Sigtuna, heating trays, archaeometallurgy, experimental archaeology

Metallurgic ceramics has been a twin brother of metallurgy since its very beginning and a basic condition for any metallurgic development at all. No metallurgy could have emerged in man's early history without a knowledge of refractory materials for use in furnaces, crucibles and moulds.

When excavating Iron Age and Early Medieval workshop sites, ceramic materials of this type are common finds. They are generally easy to spot, but sometimes easily lost among finds of slag and vitrified clay. They tell us about the metalworkers' skill in making specialized ceramics and about various metallurgical processes, such as the assaying process that will be discussed in this paper. Metallurgic ceramics are specially designed materials of various mixes that will stand up to the specific demands of each process.

A beneficial fact as far as the archaeologist is concerned is that ceramic tools were generally discarded after use, so that unlike the actual manufactured products, they are still present when the sites are excavated. A knowledge of the different kinds of refractory vessels

can be used to deduce what has been going on in a workshop. The products will have long since disappeared, but the ceramics are still present for use in interpreting the sites.

Classic examples of this are the use of mould fragments to determine which objects were produced and the deduction of which alloys were used through analyses of metal residues in crucibles. There is still more that could be told, however, as there are probably several types of ceramic vessels that have not yet been identified. Examples of these are the recently identified melting bowls and the *heating trays*, interpreted in this paper as vessels for use in silver refining.

The identification of ceramic tools and the processes of which they were a part can be of help for the further interpretation of workshops – telling us not only about production but also about workshop organisation. There would have been metallurgical processes that were conducted in workshops at higher levels but not at lower levels, of course, which is why different types of vessels can be expected in some contexts but not in others.

Workshop organisation

In order to connect workshops and metalworking processes to particular social contexts, we need hypothetical models for classifying the workshops themselves. A classification of Scandinavian Vendel (Merovingian) and Viking Period casting workshops was made by K. R. Hedegaard (1992):

- 1) Administered urban casting – a Viking Period/Medieval activity connected with permanent workshops manufacturing products for sale.
- 2) Merchants' and raw material casting – casting of simple products such as ingots and weights. A mobile activity.
- 3) Professional super-regional casting – intensive seasonal production by mobile professional craftsmen at permanent workshop sites and intended for sale at periodic markets.
- 4) Court casting – possibly permanent workshops within the chieftains' administrative centres, with highly appreciated artisans engaged virtually as bondsmen. Production was concentrated on unique high status objects and characterised by high degrees of skills and a variety of techniques.
- 5) Socially determined casting – a monopoly activity governed by norms and traditions at peripheral inland sites. This was characterised by rigidity, little experimentation, rudimentary workshops and long intervals between periods of activity.
- 6) Domestic household casting – simple types of jewellery and repairs such as riveting and soldering. A non-professional level. (Hedegaard 1992, author's translation)

The model is hypothetical and can be further modified and refined. The idea of weights being a "simple" product seems slightly disturbing, considering the precision required in these objects and their use in advanced contexts of measurement and trade. The suggestion that the merchant himself cast his weights can also be discussed. The accuracy of the Viking copper alloy weights points to well-equipped workshops possessing considerable know-how (Sperber 1996:61). Weight manufacture could perhaps be considered an authorized activity, placing it at level 4, at least in the late Viking Period as explained below.

Melting bowls and weight manufacturing

Excavation of King Olof's mint in Urmakaren 1 in Sigtuna in 1990 showed beyond doubt the position of this workshop in the above hypothetical classification. Two die impressions on lead were found, showing that



Figure 1. A melting bowl fragment from the Sigtuna mint (after Söderberg 1996).

this was the mint of King Olof Skötkonung and the workshop where the first minting in Sweden took place around 995 AD and for a few decades thereafter (Malmer et al. 1991).

The common Swedish means of payment in the Viking Period was silver measured by weight. In a monetary economy the silver concentration and weight of the coin are guaranteed by the king or by state authorities. The Viking pre-monetary weight economy, however, required tools along with the raw silver itself, in order to decide its value. Scales and weights were closely connected with the means of payment, and we could schematically consider scales, weights and the silver itself to be highly dependent on each other in this context.

The excavation of the Sigtuna mint revealed that a vast production of brazed spherical ironweights was kept up parallel to the minting operations. This was

demonstrated by finds of melting bowls – fragments of closed spherical ceramic packages in which the thin copper alloy coatings were brazed onto the iron weights (Söderberg & Holmquist Olausson 1997) (Fig. 1). This “clay-package brazing” method was described in the early 12th century by Theophilus (Hawthorne & Smith 1979:186–187), and has been discussed in the light of modern research by the Norwegian archaeologist Sigmund Jakobsen (1991:29), by Torbjörn Jakobsson Holback (1999) in connection with the manufacture of Viking Age padlocks, and later by Ny Björn Gustafsson (2003). This was obviously a common soldering method – used for various purposes – in the Scandinavian Iron Age and the Middle Ages, as related ceramic waste seems to be commonly found at workshop sites and in Early Medieval towns.

Melting bowls deriving from weight manufacture, similar to the Sigtuna finds, have so far been identified in 9th–10th-century Birka (Söderberg 1996, Söderberg & Holmquist Olausson 1997) and at the Viking town of Hedeby (Drescher 1983:183–184). These ceramic bowls are neither crucibles nor moulds in the usual sense, but should be described as a packaging material having no other purpose than to keep the brazing process free of oxygen.

How should we understand the presence of these melting bowls in King Olof’s mint? Ingrid Gustin (1997) interprets them as a possible proof of the weight system being kept under royal control, and proof that King Olof kept control over the old system of payment in Sigtuna while trying to introduce a monetary system (Gustin 1997:175).

Heating trays

Heating trays are present in Scandinavian workshop finds from Migration Period up to the 13th century AD, and have been identified as trays for use when soldering small jewellery details such as granules and filigree work or as vessels for refining and testing silver. So far no comprehensive Scandinavian study has been made of their use and what their presence tells us about the contexts in which they are found.

These trays are most commonly round, shallow vessels 30–70 mm wide and 5–15 mm high at the edges, usually with a heavily vitrified upper surface and a base surface fired at lower temperatures and not affected by fluxing agents. The ceramic material has generally been reduced, but it can sometimes show oxidised areas. The vitrified surface may be black over grey to green, often with red spots. There is usually a more or

less distinctive depression at the centre of the surface.

Early Swedish finds descend from the large chieftains’ barrows of Högom, dating from the Migration Period (Hulthén 1995; Ramqvist 1990), and from Helgö, of a similar date. The Helgö trays show a wide range of shapes (Kristina Lamm pers. comm.), either deriving from one and the same process or else reflecting different metallurgical processes. The round, shallow type is represented, however, as is a considerable larger rectangular type. The Högom trays are of the common small, disc-shaped type.

Heating trays from the Viking Period have been found at several sites around Scandinavia and the Baltic, e.g. at Hedeby in Germany (Drescher 1983:182–183), at Ribe (Brinch Madsen 1984), Fyrkat (Roesdahl 1977:51–56) and Viborg (Krongaard Kristensen 1990:343–345) in Denmark and at Birka in Sweden (Bayley 1979, Söderberg 1996). They are also represented at Anglo-Scandinavian sites such as York (Bayley 1992) and Hiberno-Scandinavian Dublin.

The trays are well represented among Medieval workshop finds from sites excavated in the town of Sigtuna, including King Olof’s mint and among 13th century finds connected with minting through the discovery of coin-die impressions on lead (Jonsson 1996, Tesch 1996).

Accordingly, we are talking about a metallurgical process – or set of processes – that left very similar ceramic traces behind for at least 800 years.

Cupellation and assaying

As mentioned above, the heating trays have been interpreted as soldering trays (Hulthén 1995:22–23), although another interpretation is that they are generally derived from the refining or testing of debased silver (Drescher 1983:182–183; Bayley 1992:749–751 & 1997:110–111).

Fire assay is a very old quantitative method of silver analysis, originally deriving from the process of cupellation, a chemical method for extracting silver from argentiferous lead ores that dates back several thousand years, in the last step of which the metal is melted in a furnace lined with lime or bone ash (Pernicka et al. 1998). As air is blown over the melted lead/silver alloy, the lead will oxidise and transform into liquid lead oxide (litharge) which will become absorbed into the porous walls of the furnace, while the silver will remain in a refined metallic state. The same technique can be used when refining silver for recycling.

On a smaller scale, the method can be used to test the purity of samples of silver. In the first step a sample is

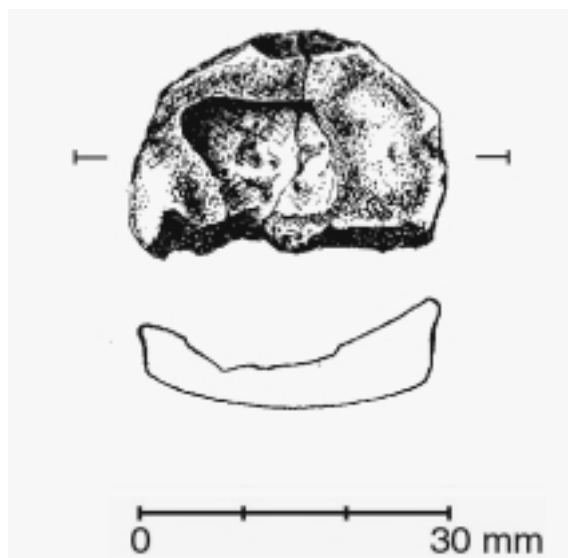


Figure 2. Fragment of the heating tray from the Birka town rampart analysed here (after Söderberg 1996).

melted together with lead in a ceramic vessel, a *scorifier*. In step two cupellation is carried out in a bone ash vessel, a *cupel*, where lead and other impurities – including copper – will be absorbed. The difference in weight between the sample and the purified silver provides information on the silver concentration of the sample.

The cupellation technique was used for refining silver in the Roman Empire (Rehren & Kraus 1999). Alchemists are thought to have developed the fire assay method for testing purposes during the later Middle Ages and the Renaissance (Rehren 1997:13), but its history during the earlier Middle Ages is still virtually unknown.

The interpretation of the Helgö trays as cupellation vessels was put forward by Wilhelm Holmqvist (Holmqvist & Granath 1969:116), and research into cupellation and assaying has been intensified in recent years by Justine Bayley, Kerstin Eckstein and Thilo Rehren. The work of Bayley, to a large extent concentrating on finds from Anglo-Scandinavian York (Bayley 1992), has confirmed Holmqvist's interpretation.

The Birka tray

One purpose of this paper is to report on analyses of fragmented trays from Birka and Sigtuna. The Birka tray is one of three fragments found in the 9th–10th century AD workshops close to the Birka town rampart (Holmqvist Olausson 1993; Holmqvist Olausson & Fennö Muyingo 1995; Tengnér 1995; Söderberg & Holmqvist Olausson 1996).



Figure 3. One of four experimental trays made by the author. The silver/lead alloy has solidified in the tray, showing its position in the central depression eroded by the lead. Width 63 mm. Photo: Anders Söderberg.

A cross-section of the Birka fragment (Fig. 2) shows a dark-grey ceramic material, rather coarse and fragile. The glassy surface is dark green to black and heavily vitrified, and there is a distinctive depression in it, containing a few small droplets of metal (approx. 0.2–0.5 mm) trapped in the material. The droplets have been analysed earlier as being silver with a slight admixture of copper (Söderberg 1996). A few more small droplets of metal are embedded under the dark surface. The ceramic ware shows a high degree of vitrification. The material towards the upper surface is almost completely glazed. The material towards the base shows early signs of vitrification as quartz grains beginning to fuse and gas bubbles between them. The sample analysed here was taken from the periphery of the central depression in the upper surface of the tray and represents a cross-section through the tray.

The Sigtuna tray

The Sigtuna tray analysed here is a sample from among the 22 fragments found in King Olof's mint (early 11th century AD). The Sigtuna trays are slightly larger than the Birka tray; c. 50–70 mm in diameter; but the ceramic material seem very similar. The cross-section shows a dark grey, rather coarse material, vitrified and with gas bubbles towards the base. The surface is matt grey with no visible metal droplets. A slight depression is visible in the top surface. The sample for analysis was taken from the area of the depression, and represents a cross-section of the tray.

Table 1. Energy Dispersive X-ray Spectroscopy (EDS) analyses of heating trays from the Birka town rampart, the Sigtuna mint and a similar, experimentally produced fragment. All figures in atom %. The analyses were performed by Kjell Jansson at the Division of Structural Chemistry, Stockholm University.

Sample	Si	Al	Ca	Fe	Ag	Cu	Pb
1 Birka, metal beneath upper surface	49.68	15.57	4.72	2.48	14.32	6.02	0.72
2 Birka, glassy spot, close to upper surface	59.18	14.55	3.59	3.93	2.07	10.40	0.94
3 Birka, fracture area	54.61	10.69	3.01	1.56	7.19	17.46	1.96
4 Sigtuna, dense spot beneath upper surface	22.91	18.36	13.32	25.44	1.20	12.38	1.08
5 Sigtuna, glassy spot, close to upper surface	59.84	11.41	11.04	2.66	0.86	2.26	6.56
6 Sigtuna, glassy spot, close to upper surface	61.76	19.71	6.10	3.33	1.47	1.40	0.41
7 Sigtuna, fracture area, close to upper surface	62.46	8.91	6.79	4.20	0.31	4.58	7.00
8 Sigtuna, fracture area, close to upper surface	58.62	20.47	5.36	2.21	0.61	6.92	1.43
9 Sigtuna, fracture area, deeper towards base	96.61	0.93	0.60	1.10	0.00	0.00	0.07
10 Experimental tray, upper surface	50.89	17.05	1.85	2.90	0.17	1.31	15.38
11 Experimental tray, fracture area, towards base	65.67	18.55	0.46	2.33	0.00	0.04	0.05

Table 2. Atomic absorption analyses of the two Viborg heating trays (after Krongaard Kristensen 1990:344).

Sample	Fe	Ag	Cu	Pb
1 VV 51E 2815, Upper face	1.3	0.44	3.3	50.5
2 VV 51E 2815, Base	1.1	0	0	0.7
3 VV 51E 2815, Edge	0.9	0.06	1.2	10.2
4 VV 51E 2805, Upper face	0.9	1.2	3.7	37.0
5 VV 51E 2805, Base	1	0	0	1

Experimental trays

For comparison, analyses were made of a reconstructed ceramic tray used in a simulated "assaying process" carried out in a charcoal hearth blown by bellows (Fig. 3). The material used for making the trays was a postglacial silt from the parish of Håggeby, not far from Sigtuna.

A non-quantified sample of sterling silver (925) was melted together with a non-quantified excess of lead, whereupon hot air was blown over the tray. The process of oxidation of the lead to litharge could be studied until a button of clear metal was visible in a depression that had formed in the tray during the process. The experimentally created trays look very similar to the archaeological specimens, with green/blue/dark red glazed upper surfaces containing depressions and several small solidified droplets of metal trapped in the material. The ceramic material was mainly oxidized in cross-section, and only partly reduced, contrary to the reduced Birka and Sigtuna trays. The sample for analysis was taken from the area of the depression in one of the four trays made in the experiments.

Analyses

Atomic absorption analyses have earlier been made of 1st century AD cupellation hearth linings and crucibles from the Roman Colonia Ulpia Traiana, Xanten, Germany (Rehren & Kraus 1999), and early 11th century AD heating trays from the town of Viborg, Denmark (Krongaard Kristensen 1990), while ICP analyses have been made of a 14th century AD bone ash cupel from the castle of Pymont, France (Rehren & Eckstein 2002). These analyses show comparable proportions of copper and lead in the different vessels.

A series of qualitative XRF analyses of seven heating trays from Birka have been made earlier by Bayley (1979). Four of the trays showed signals of Pb, a strong signal in one case, and all seven showed the presence of Cu and two of them of Ag. A similar pattern was obtained in analyses of trays from the 10th century site of Fyrkat in Denmark (Roesdahl 1977:51–53).

The results of the recent analyses of the Birka and Sigtuna materials are shown in Table 1, with the reservation that they should not be compared directly with the earlier atomic absorption analyses of Danish and continental materials. The EDS analyses were performed on specific micro-spots on the very surface of the material, whereas the atomic absorption method was applied to larger volumes of material. Thus the two methods will not provide directly comparable data. Note also that the percentages in Table 1 are atom %, not weight %.

The analyses in Table 1 nevertheless show a few trends that can be tentatively compared with the earlier analyses. Krongaard Kristensen shows in his analyses of the Viborg heating trays that the percentages of metals are far lower towards the base of the tray, as shown in Table 2. This is to be expected, since ceramic

Table 3. ICP analysis of a bone ash cupel from the castle of Pymont (after Rehren & Eckstein 2002:447).

Sample	CuO	PbO
Bone ash cupel, upper part	1.51 %	66.1 %
Bone ash cupel, lower part	2.83 %	61.1 %

materials show poor absorption qualities (Bayley & Eckstein 1997:111). The silica in the ceramic vitrifies during the heating process, fluxed by the lead, and blocks absorption of the liquid metal oxides. The same tendency is indicated by the analyses in Table 1 – compare the Sigtuna samples 5 and 9 and the experimental samples, 10 and 11. The poor absorption qualities of ceramics can be compared with the more suitable qualities of bone ash. The Pymont cupel shows quite similar percentages of copper and lead towards the base as towards the upper surface (Table 3).

The analyses of the Birka tray provide confusing results for an assaying vessel. The percentages of silver seem high for a vessel used in analytical assay, as the silver would have been carefully collected and weighed after the process. It seems that large amounts of silver remained on the surface after processing, which could indicate a failed assay just as well as a cupellation not performed for analytical purposes – e.g. for refining silver when making solder. As solder requires alloys with known melting points, goldsmiths of the Viking Period could perhaps be expected to have a knowledge of the refining of silver. If this was the case with this tray, it should be described as a recycling tray rather than an assaying tray. This would be somewhat confusing as the minuscule size of it would certainly be suited for the analysis of a small sample of metal. Recycling usually took place on a larger scale, leaving behind litharge cakes of considerable larger sizes, as shown in Anglo-Scandinavian York (Bayley 1992:749), or larger pieces of hearth lining and large crucibles, as in Roman finds (Rehren & Kraus 1999).

The high percentages of Cu in this tray may lead us to make comparisons with those in the hard solder used by jewellers. Furthermore, they may remind us of the interpretation of heating trays as *soldering trays* as used with filigree and granules (Hulthén 1995:22–23). The heavy vitrification of this tray speaks against such an interpretation, however. Measurements obtained in the blow-pipe soldering experiment with charcoal and a piece of jewellery placed on a ceramic tray conducted by Hulthén, showed that the tray was

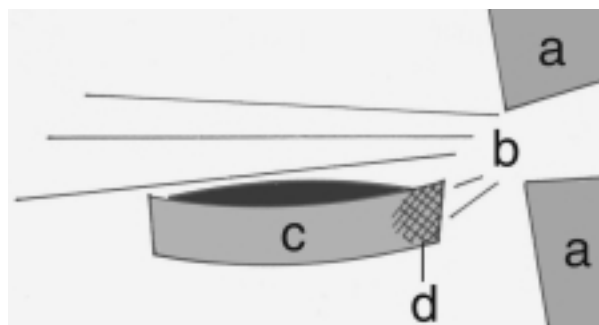


Figure 4. The position of a tray in a hearth, reconstructed from Theophilus' description and from the distribution of vitrified areas on the edges of the Sigtuna trays. a) Tuyere. b) Bellows' draught. c) Heating tray. d) Vitrification on the edge facing the heat. Drawing by Anders Söderberg.

exposed to temperatures of 300°C. This would be far too low for vitrification of the ceramic material. The heavy vitrification of one side of the edge observed with several trays from Sigtuna shows that they were directly exposed to streams of hot bellows' air in goldsmith's hearths, which suggests temperatures of 900–1100°C (Fig. 4). The Birka tray was used in a hearth, and it was certainly not used for soldering with a blow pipe, but possibly for refining heavily debased silver.

It could be that the percentages of lead in this tray are too low for a cupellation vessel at all. Concentrations of lead are detected, but they are not as high as in the Sigtuna tray. Further analyses of this tray, and of other contemporary ones, would be necessary in order to make certain which process and which purpose it actually represents.

The Sigtuna tray shows spots with Cu and fairly moderate Ag content. There are also spots with high, but not exceptionally high, percentages of lead, but not reaching the percentages in the experimental tray. Despite this, its function as an assaying vessel can be confirmed with some certainty by reference to the context of the King Olof mint. Analysis 4 shows a remarkably high percentage of iron, perhaps derived from contamination of the clay material with an iron filing while making the tray. Iron was most certainly frequently used in this workshop, e.g. when making weights, dies for minting and probably for several other purposes.

Assaying in one step, or with scorifiers and cupels?

Modern fire assay is a two-step process in which a silver/lead button is melted in a ceramic scorifier and then cupelled in a bone ash cupel. So far, the earliest

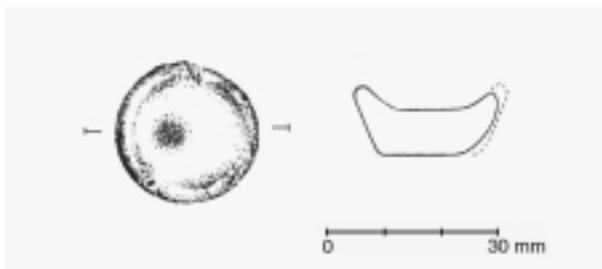


Figure 5. Cupel from Birka, made of a white material with a brownish grey surface colour. Diameter 25 mm, height 11 mm, weight 12 grams. Drawing by Anders Söderberg.

dated European bone ash cupel used for this purpose is from the 14th century castle of Pymont in France (Rehren & Eckstein 2002:446–447).

Our earliest European source describing silver refining vessels is a treatise written by Theophilus in the 12th century (Hawthorne & Smith 1979:96–97). His vessel was an earthenware tray with an upper layer of wood ash. From the author's own experiments it appears that trays made in this way will look very similar to our archaeological heating trays after use. According to Rehren and Eckstein, Theophilus' tray marks a transition from traditional cupellation hearth linings to the analytical ash vessels of the Renaissance (Rehren & Eckstein 2002:446). In chapter 69 he describes the making of bone ash vessels for separating gold from copper and from silver (Hawthorne & Smith 1979:146–147), and these trays show an even closer kinship to modern cupels.

Scandinavian Medieval and Iron Age finds have given us a fairly large material of ceramic heating trays, but so far no bone ash cupels. Does this mean that they represent a simplified or "archaic" one-step process carried out in a ceramic vessel? As mentioned above, ceramic material does not possess the absorbent qualities that we find in lime or bone ash, which may be a problem for achieving proper refinement. Despite this, Theophilus' description of the silver refining tray implies its use in a one-step process. Bayley and Eckstein think that it may be possible to achieve proper refinement in a ceramic vessel, but they still describe the idea as controversial (Bayley & Eckstein 1997:110).

The lack of bone ash cupels accompanying our heating trays from Sigtuna and Birka, could as well be a matter of archaeologists not noticing them during excavations or post-excavation interpretations. Hjalmar Stolpe's finds from the 19th century excavations at Birka include a vessel which is obviously a cupel, prob-

ably made of lime or bone ash (Fig. 5). This was a single find from the fields in the former town area, which had already been heavily disturbed by ploughing, why it is out of context and would be impossible to date. It could even be fairly recent, since refuse from the city of Stockholm was spread over the fields on several islands in Lake Mälaren towards the end of the 19th century (Ambrosiani & Eriksson 1992:14). On the other hand, it may very well encourage a further search for Medieval and Viking Period bone ash cupels.

Other, even older Scandinavian finds are pieces of "slag" from a Vendel Period workshop site at Dagstorp, Scania. Analyses of these have shown the presence of calcium, phosphorus, copper and lead (Kresten et al. 2000:7–8, 12–13, 17–19, 30, 32). The material has been interpreted as bone ash cupellation residue. The workshop finds from Dagstorp are regarded as the outcome of highly skilled, possibly professional activities probably related to the upper levels in society (Kresten et al. 2000:15).

The Scandinavian heating trays – what do they tell us?

So far we have three interpretations to deal with: 1) *assaying trays* (scorifiers or cupels) used for analytical purposes, 2) *refining trays* for the small-scale refining of debased silver; and 3) *soldering plates*. None of these interpretations can yet be completely ruled out in favour of another. Heating trays of several types have been found – from the small circular trays described here, through egg cup-shaped crucibles standing on a "foot" (Lamm 1980:100) to the large rectangular Helgö trays. This range of shapes could as well tell about a range of different metallurgical processes.

We can see that heating trays or test trays were closely connected to minting from the end of the 10th century and onwards (Fig. 6). Several trays were found in King Olof's mint, and 22 fragments (Fig. 7) have been found in a later Sigtuna context together with finds of die impressions on lead, indicating minting under King Erik Eriksson in the first half of the 13th century AD and under King Valdemar or King Magnus Ladulås in the second half of the same century (Jonsson 1996).

The excavation of the early 16th century Norwegian mint in the Archbishop's Palace in Trondheim revealed the foundations of a possible assaying hearth and finds of bone ash cupels (McLees 1996:133). The Royal Mint at Helgeandsholmen in Stockholm, dating from the 1630's (Dahlbäck 1982:313–322), yielded scorifiers and cupels (Wadsten 1979), the ceramic

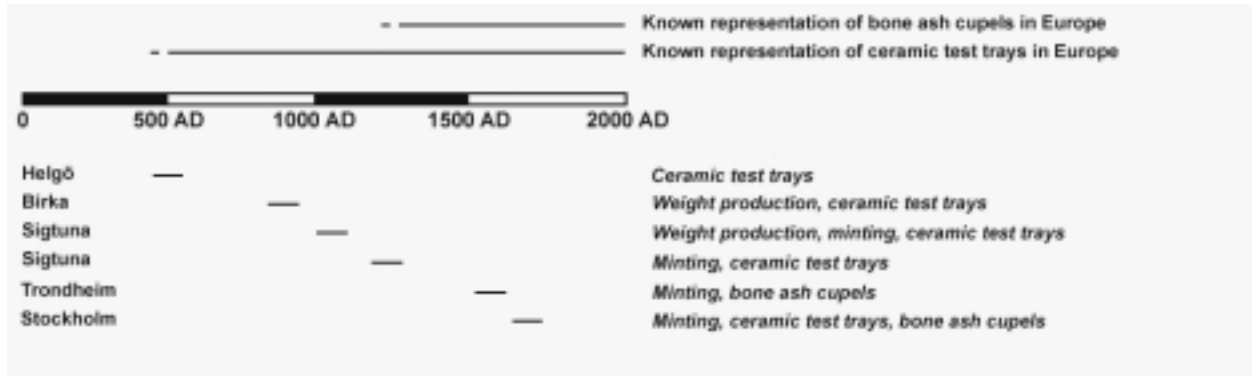


Figure 6. Chronological model of find combinations associated with heating trays – interpreted here as test trays – in a number of Scandinavian workshop and mint contexts.

scorifiers differing from the Birka and Sigtuna heating trays in that they were more regular in shape and had higher brims. Analyses showed high concentrations of lead (Wadsten 1979:172).

What if we go back in time to periods before the Sigtuna mints? Possible test trays have been found in the Viking Period settlement of Birka and at the Migration Period sites of Högom and Helgö, representing periods that were not characterized by minting but by weight economies. What could have been the function of small-scale silver refining or even analytical assaying in these pre-monetary societies? The refining of silver for jewellery production has already been suggested, but would there have been any need for analytical techniques in Iron Age societies?

We have mentioned above the silver itself and scales and weights as interdependent items in the weight economy – even though coins could have been accepted without weighing as a result of the increased inflow of Arabic dirhams during the 10th century (Gustin 1998:82).

Tools for weighing represent only half of the measuring tools needed when dealing with noble metals for currency purposes. The other half, which were just as important, concerned techniques for measuring the concentration of silver in the means of payment (Berg 1980:28). This is the reason why assaying tools are found in mints, but what could the non-monetary Viking Period's workshops have had in common with the Medieval and Renaissance mints?

The answer may be that the workshops where heating trays are found may have been connected with trade and means of payment, and possibly even with economic power. We can see that King Olof in Sigtuna was in charge of weight standards and minting, and we also know that the finds from the workshop close to

the Birka town rampart included not just heating trays but also traces of weight manufacture similar to the melting bowls from the Sigtuna mint. Could the presence of heating trays and waste from weight manufacture point to links between the Viking Period Birka rampart workshop and the Medieval royal mints? If so, this would add another dimension to chieftains' workshops of Viking Scandinavia: they may not only have been workshops for manufacturing high status objects for use in confirming alliances (Arrhenius 1998), but also connected with ambitions for maintaining direct power over trade and the means of payment.

Erik Sperber (1996) assumes that the Viking weight systems of the Baltic region may have been under direct influence from Arabic merchants. According to Heiko Steuer, as quoted by Gustin, power over trade and means of payment in the Baltic region may have been a matter of competition between suggested free merchants' organisations and the chieftains' courts (Gustin 1997:169–170, Steuer 1978; 1984; 1987). Gustin interprets the occurrence of weight manufacture waste in the 11th century Sigtuna royal mint as proof that the king was actively controlling weight standards – or trying to gain control over them in a competition situation similar to that between the court and the merchants in 9th–10th century Hedeby, as suggested by Steuer.

As assaying is a very accurate and highly specialized method, it seems possible that it may have been connected with means of payment even in periods before the late Viking Age/early Medieval Sigtuna mint – if it was used as an analytical method at all in those days. If the method was sufficiently developed in the Viking era, it could even have provided a reliable technique for maintaining uniform silver standards.

If this was so, we still do not know whether use of



Figure 7. Fragment of a heating tray from Professorn 4, Sigtuna. Width approx. 50 mm. Photo Anders Söderberg.

the method was an exclusive branch of knowledge, as it tended to be when assaying and cupellation became closely connected with minting and mining later in history. If traces of assaying activities in general prove to be markers of court workshops as well as market site workshops, this would lend support to Steuer's hypothesis of competing actors.

Theophilus' description speaks in favour of the idea of common use of this technique among craftsmen, as he describes the method strictly as a means of refining metals and not of analysing them. As a result of the analysis performed here, the tray from the Birka town rampart could be interpreted as a tray used by a jeweller for refining silver. This does not completely rule out the possibility of use of cupellation for analytical purposes, of course, as the two activities could have existed simultaneously. We should still bear in mind that the weight economy required methods for testing the concentration of silver in the means of payment – whether by touchstones or by fire assay.

Future research

Further analyses will be made of trays found in other contexts and from other periods in order to ensure comparable element profiles to those expected in assaying vessels. By comparing such data with standard data derived from analyses of recent scorifiers and cupels, it would be possible to tell which of our heating trays may actually have been used for testing or refining silver and which were used for other purposes.

Workshop studies may make it clear whether cupellation was an exclusive skill in the Viking Period

or a more common one, by differentiating tools and metallurgical processes that may have been features of chieftains' or royal contexts from features belonging to common workshops.

The co-occurrence of melting bowls and heating trays *may* be a "regal combination", but this can only be verified by further studies of Scandinavian workshop finds. It may then be possible to proceed further with the hypotheses, reflections and questions introduced in this paper.

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