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Eyvind Skáldaspillir's silver –

refining and standards in pre-monetary economies
in the light of finds from Sigtuna and Gotland

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It is said that in the first half of the 10th century, when the court poet of King Hakon the Good, Eyvind Finnsson Skáldaspillir, had composed a poem to the honour of the Icelanders, it was decided to reward him by making him a cloak-pin.

"Eyvindr orti drápu um alla Íslendinga, en þeir launuðu svá, at hverr bóndi gaf honum skattpening. Sá stóð þrjá penninga silfrs vegna ok hvítr í skor. En er silfrit kom fram á alþingi, þá réðu menn þat af at fá smíða til at skíra silfrit. Síðan var görr af feldardálkr, en þar af var greitt smíðarkaupit. Þá stóð dálkrinn fimm tigu marka. Hann sendu þeir Eyvindi, en Eyvindr lét höggva í sundr dálkinn ok keypti sér bú með." (*Heimskringla*: Sagan af Haraldi konungi gráfeld:18. Aðalbjarnarson 1941–1979:221f).

"Eyvind composed a poem about the people of Iceland, for which they rewarded him by each bonde giving him three silver pennies, of full weight and white in the fracture. And when the silver was brought together at the General Thing, the people resolved to have it purified, and made into a shoulder-pin, and after the workmanship of the silver was paid, the shoulder-pin weighed some fifty

marks. This they sent to Eyvind; but Eyvind had the shoulder-pin broken into pieces and with the silver he bought a farmstead for himself." (Foote 1961:125f)

In other translations *keypti sér bú með* is variously translated as "bought cattle with it" or "obliged to...buy food for his household". The phrase "...at hverr bóndi gaf honum skattpening. Sá stóð þrjá penninga silfrs vegna" has also been translated as "each bonde [farmer] offered a scatt penny of pure silver equal to three weighed pennies" which is supposed to be a reference to imported debased Anglo-Saxon pennies, of which three were equal to one penny of fine silver (Dasent 1861:405).

James Graham-Campbell (2007:216) and Gareth Williams (2007:182) draw attention to this episode from *Heimskringla*, as it sheds light on several different aspects of the handling of silver. In different situations the very same silver is treated as counted coins when collected as tax; as jewellery and a status gift; and finally as weighed hack silver in a market situation. The story illustrates how different systems of exchange were adopted for different purposes, and how old and new traditions could

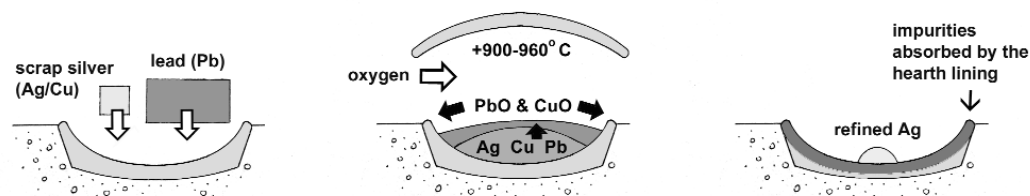


Fig. 1. Cupellation of silver: 1) recycled silver is molten together with an excess of lead in a hearth lined with a bone ash material. 2) Oxygen is blown over the molten metal. 3) The hearth material absorbs the oxidised lead (litharge) and other impurities. Drawing by the author. – *Kupellering av silver: 1) Silver för återbruk smälts samman med ett överskott av bly. 2) Syre blåses över den smälta metallen. 3) De oxiderade föroreningarna absorberas av hårdväggen.*

be interchanged in a way that probably was a reality for 10th century Scandinavia. In addition to this, the story reflects a clear awareness among the Scandinavians of the value and different grades of silver. There are, as both Graham-Campbell and Williams show, aspects of value measured by weight, and of fineness of quality tested by pecking or carving as indicated by the quality criterion “white in the fracture” (*hvítr í skor*). There is also the small but important verb *skíra* – to purify, to cleanse, to baptise (Vifgusson 1874:550). This word refers to the process of refining the silver to maximal purity and was performed before transforming it into the gift for Eyvind. Clearly, accumulated metal went through a full refining process before reuse. Even though the story was recorded some 300 years after the event, this alleged information about Viking customs is of great interest, as several finds of early silver refining waste have recently come to light in Scandinavia. The refining of noble metals has long been associated to minting, but the Eyvind story may also help us to place these finds in the context of the management of silver in pre-monetary Scandinavian bullion economies.

Refining silver

Silver was refined by cupellation (*fig. 1*). This technique first appeared c. 3000 BC in connection with silver mining. The technology became widespread and was used on a



Fig. 2. Hearth material (litharge cakes) from silver refining hearths is heavy, due to a high lead content, grainy and sometimes contains tiny bone fragments, grey with a green zone close to the surface and slightly bowl-shaped in section. 12th century litharge material from Trädgårdsmästaren, Sigtuna (find no 5952). Photo by the author. – *Hårdmaterial från silvveraffinering är påtagligt tungt p.g.a ett högt blyinnehåll, grått och kornigt med ibland synliga smärre benfragment, lätt skålformat i profil och med en grönaktig zon närmast ytan.*

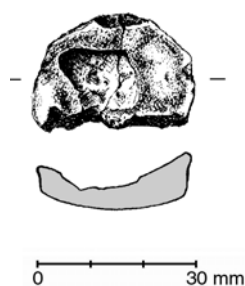


Fig. 3. A fragment of a small scorifier from the workshop area near the Birka town rampart, probably from the 10th century (find no 1071). Drawing by the author. – *Fragment av en liten skärvel från verkstäderna vid Birkas stadsvall, troligen 900-tal.*

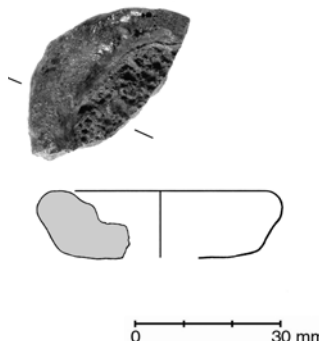


Fig. 4. A scorifier fragment, Sigtuna, late 10th century, Trädgårdsmästaren, Sigtuna (find no 10532). Drawing by the author. – *Skärvelfragment, sent 900-tal. Sigtuna.*

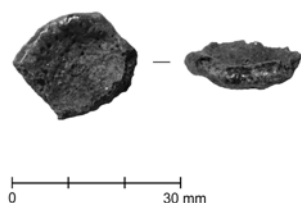


Fig. 5. A small scorifier with gold droplets, early 11th century, Urmakaren, Sigtuna (find no 5195). Photo by the author. – *Liten skärvel med gulddroppar, tidigt 1000-tal. Kv Urmakaren, Sigtuna.*

large scale, as for example in the antique silver mines of Larium, Attica, a few thousand years later (cf. Conophagos 1980). The basic principle of cupellation in the mining process is melting argentiferous lead in a hearth lined with a porous material of bone ash and clay (fig. 2). Oxygen is blown over the melted alloy whereupon the lead is transformed into molten lead oxide, *litharge*, that also absorbs oxidised copper and other metal oxides. The molten oxide is then skimmed off or absorbed by the porous hearth material. The silver, which doesn't react with oxygen, stays in a metallic state and is thus refined to a concentration of up to 99%. Nils Björkenstam (1989:149ff) offers a good description, in Swedish, of the process as used in the 17th century silver mines of Piteå in northern Sweden.

The same technology was used to refine recycled silver. In this process lead is added to the silver in question (cf. Rehren & Kraus

1999). In these cases the aim is to drive out the copper and other alloying metals, in order to obtain silver of maximal and known silver content. During the first millennium AD the method was further developed into a technique for testing or assaying noble metal content in smaller samples. This could be considered man's first invention of a method of analytical chemistry. The technique came to be linked with the use of precious metals in mining, goldsmithing, as symbols of value and objects for payment and to test the silver content in copper and lead in market situations before fixing the price (Martinon-Torres, pers. comm.). Fire assay is performed as a process of two steps, wherein the sample is melted together with an excess of lead in a small ceramic vessel, a *scorifier* (figs. 3–5), and the molten alloy is then cupelled in a vessel, *cupel* (fig. 6), made from absorbent bone ash. The sample is weighed before the

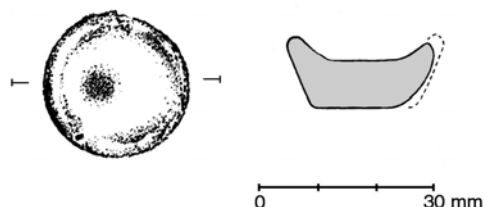


Fig. 6. A small cupel, probably made from bone ash. Probably 10th century. Stray find from Birka (find no SHM 8985:14). Drawing by the author. – *Litet kapell, troligen av benaska. Lös-fynd från Birka.*

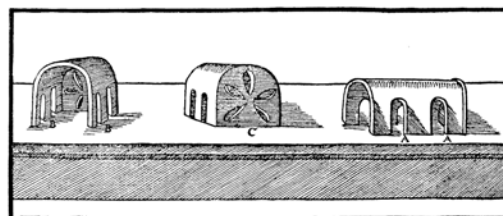


Fig. 7. A muffle for covering the test hearth, according to Agricola 1556 (after Hoover & Hoover 1950). – *Ett valv att täcka testhärden med vid silvertestning enligt Agricola 1556.*

test, as is the silver remaining afterwards, and the difference reveals the purity of the tested silver. Renaissance test furnaces were easily put together by using a portable muffle (fig. 7), creating a space free from charcoal for maximal oxidation, and also for directing the toxic lead fumes away from the assayer. A similar solution was probably used in early medieval Scandinavia, but so far no traces have been identified of these kinds of objects. Scorifiers and cupels are generally found in medieval and Renaissance mints (cf. Wadsten 1979; McLees 1996) and they also seem to have been the alchemists' favourite vessels in their arsenal of containers used for different chemical and metallurgical processes (cf. Martinon-Torres & Rehren 2005).

Finds of cupellation waste and some SEM/EDS analyses

Let us now return to Eyvind Skáldaspillir and examine the treatment of the silver collected in his honour. There are some Scandinavian archaeological finds of cupellation waste, in the shape of hearth lining or *litharge cakes*. The earliest is from a workshop of the 7th century AD at Dagstorp, Scania (Kresten et al 2000). After this, there

is nothing until the early 11th century finds from King Olof Skötkonung's mint on the Urmakaren site in Sigtuna and the Humlegården site in the same town. The next find dates from the mid-11th century, and comes from a silver workshop at Fröjel, Gotland (Söderberg & Gustafsson 2006; Gustafsson & Söderberg 2007). Rich finds of cupellation waste have occurred in late 12th century contexts associated with minting and exclusive jewellery production on the Trädgårdsmästaren site at Sigtuna (Kresten & Larsson 1996; Söderberg & Gustafsson 2007). Apart from these there is an exclusive group of finds that deserves mention: ceramic vessels with no obvious admixture of bone ash, from building group 3 at Helgö. These vessels are rectangular, up to 100x150 mm in size, and flat with low brims. The size seems suitable for refining smaller amounts of silver, and analyses show high contents of lead, tin and zinc (Lamm 2008:200ff). A fragment of similar ceramic material was discovered during excavation of the Urmakaren site in Sigtuna (find no 2903, recorded as a crucible).

The traces of cupellation that were found in the late Viking silver workshop in Fröjel can be considered as concrete and illumi-



Fig. 8. Mould fragments from the silver workshop in Fröjel, representing Stenberger's type 3 arm-ring, find no 16889 (above) and an animal head arm-ring, find no 23675 (below). Photo and sketches by the author.
 – *Gjutformsfragment från verkstaden i Fröjel, representerande Stenbergers armbygel typ 3 och en djurhuvudarmring.*

nating illustrations of the Eyvind story, even though the find is about hundred years younger than the depicted event. The find indicates that silver refining was the first stage in the casting of Gotlandic silver arm-rings and penannular brooches. This activity is roughly dated to the mid-11th century by ^{14}C samples (lab. no. Ua-18941) and by finds of mould fragments for 10th–11th century arm-rings of type 3 (cf. Stenberger 1958:110) together with the less common late 11th–12th century arm-rings with animal heads (fig. 8). The fact that the silver was refined before producing these pieces, shows an ambition to produce objects of optimal or perhaps even pre-defined silver content, and that the goldsmiths in the

workshop had the competence to fulfil this ambition. Obviously the Gotlanders were well acquainted with the phenomenon of silver content and considered this an important quality when handling precious metals, just as did the people and craftsmen in the story about Eyvind.

The cupellation material and casting waste from the Fröjel workshop have been analysed by Malgorzata Wojnar Johansson at the Archaeological Research Laboratory of Stockholm University (Wojnar Johansson 2005a, b). The original surfaces of the samples were examined with Energy Dispersive X-ray Spectroscopy (EDS) on the SEM. A few representative results are shown in table 1, where the values of phosphorus (P) and calcium (Ca) indicate high contents of bone material, together with clay that is mainly represented by the presence of Al, Si, Mg, Mn and Fe. The presence of lead (Pb) mainly represents the lead used in the refining process while Cu, Zn and Sn represent alloying metals that were separated from the bullion during refining. Ni, As, Sb, Pt, Au and Hg probably represent trace elements originating from the original silver ores.

These latter elements may contain information concerning the original source of the silver that was handled in the workshop. In particular, the percentages of arsenic (As), platinum (Pt), gold (Au) and mercury (Hg) may indicate an origin in the rich silver veins of Rammelsberg, Sachsen, that were opened in the late 10th century. Rammelsberg silver came to be of great importance not just for the German mint activity that had expanded dramatically by the end of this century, but also for the north European silver supply in general. German silver reached the British mints in the form of re-

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	Na	Mg	Al	Si	P	Cl	K	Ca	Mn	Fe	Ni	Cu	Zn	As	Ag	Sn	Sb	Pt	Au	Hg	Pb
<i>Fröjel inside</i>	2.86	-	4.43	9.46	10.31	-	-	30.72	-	2.55	-	9.38	-	-	1.68	-	0.30	2.23	2.48	-	23.61
<i>Fröjel outside</i>	1.37	0.46	4.02	8.15	22.66	-	0.88	27.74	1.62	-	-	1.23	-	2.04	-	-	-	1.54	1.58	2.25	24.46
<i>Sigtuna inside</i>	-	-	6.73	11.60	19.00	-	2.30	11.81	1.66	4.44	2.48	5.55	0.49	0.91	0.75	0.51	0.84	2.49	0.01	2.86	25.57
<i>Sigtuna outside</i>	1.91	0.63	2.49	10.34	22.68	4.13	1.27	14.06	0.68	1.54	1.02	7.33	0.30	0.36	2.40	-	-	1.30	0.08	2.44	25.03

Table 1. Values in atomic per cent from analyses (SEM-EDS) of cupellation hearth material (litharge cakes) from 11th century Fröjel (find no 20218) and from 12th century Trädgårdsmästaren in Sigtuna (find no 5952). Analyses were made on the inside surfaces, facing the molten bullion, and the outsides of the fragments. By Wojnar-Johansson 2005. – *Värden i atomprocent från analyser av härdmaterial från silverkupellation från 1000-talets Fröjel och från 1100-talets Sigtuna.*

	Na	Mg	Al	Si	P	Cl	K	Ca	Mn	Fe	Ni	Cu	Zn	As	Ag	Sn	Sb	Pt	Au	Hg	Pb
<i>Crucible 25413</i>	-	2.98	18.67	50.86	3.12	-	3.96	10.83	0.72	2.07	-	1.62	0.90	0.73	1.93	-	-	0.55	-	0.47	0.59
<i>Crucible 25413</i>	-	1.45	9.82	24.81	6.35	-	1.30	12.16	0.99	5.81	-	28.08	4.38	-	2.65	0.38	-	0.55	-	0.86	1.23
<i>Mould 23672</i>	2.03	1.43	15.77	66.70	-	-	2.08	3.29	0.72	4.79	0.16	0.86	-	0.52	1.43	0.26	-	0.27	-	-	0.18
<i>Mould 23672</i>	-	5.19	19.71	53.34	1.67	-	4.83	3.64	-	3.79	1.30	2.74	2.43	-	-	-	-	0.07	-	0.73	0.56
<i>Mould 23675</i>	-	4.85	17.91	58.71	1.67	-	3.28	3.69	0.02	4.84	-	1.03	0.59	0.97	0.01	0.89	-	-	0.61	0.34	0.56
<i>Mould 23675</i>	0.62	4.59	23.82	57.76	0.50	-	5.07	1.57	0.31	3.32	0.47	0.96	0.30	0.09	-	-	-	-	0.45	-	0.16

Table 2. Values in atomic per cent from analyses (SEM-EDS) of a crucible, find no 25423, and two mould fragments, all from Fröjel. Find no 23675 represents the mould for casting animal head arm-rings shown in fig 8. Traces of As, Pt, Au and Hg indicate the use of silver similar to that refined in the workshop and raised levels of P and Ca in the crucible may indicate an admixture of bone ash to the crucible clay. Go Fröjel 2000, Bottarve 1:19. Analyses by Wojnar-Johansson 2005. – *Värden i atomprocent från analyser av degel och gjutformar. Spårmetaller antyder användning av likartat silver som kupellerats i verkstaden.*

cycled German coins which served as the raw material for Anglo-Saxon coins (Spufford 1988:74ff, 88ff). This new silver source also had an impact on the supply of silver on Gotland, and compensated for the decline in the import of Islamic silver that had occurred by the mid-10th century. Approximately 40,000 German coins have been found on the island, imported between 990 and 1040. The combination of high contents of gold and platinum in the refining waste from Fröjel, may possibly point towards an origin in Rammelsberg (cf. Kraume & Hatz 1961:19; Hårdh 1976:110). The high zinc contents in the analyses of the crucibles and the moulds, could point to-

wards the use of German coin silver mixed with silver of different origins, or German silver that had been re-alloyed in England. Zinc just occurs as traces in German coins while Anglo-Saxon coin silver was usually alloyed with brass, containing zinc (Hårdh 1976:118).

Also worth mentioning are similar combinations of trace metals, shown in analyses of sandstone moulds for silver ingots from a late 10th or early 11th century house at Humlegården in Sigtuna (Söderberg 2008:103). There are also slight similarities in samples of refining waste from a minting context related to the 12th century king Knut Eriksson, in Trädgårdsmästaren in the

same town (table 1; cf. Söderberg & Gustafsson 2007).

It must be emphasised, however, that these analyses only show the element content of metal oxides detected in small spot checks on the surfaces of the samples, and not the metallic content of the original alloys. As a result, no conclusions can be drawn concerning proportions of alloys. Another important point is the possibility that imported silver of different ages and origins was mixed and processed together in the workshop. Thus, no unambiguous conclusions about the origin of the silver (or different “silvers”) can be drawn from these analyses, and the figures quoted in tables 1 and 2 should be understood as guide lines, rather than as indisputable truths.

It would appear that the knowledge of cupellation was common among Viking silversmiths and goldsmiths, just as seems to have been the case in Provincial Roman cities early in the first millennium (cf. Rehren & Kraus 1999). Furthermore, it seems fair to assume this technology was important in contexts where silver served as a means of exchange, as that concerns the *fineness* of silver. As will be shown in what follows, the Scandinavians seem to have been concerned at an early stage with this concept. The jewellery identified as being produced in the Fröjel workshop are of types that may all be tied to customs of payment or the accumulation of economic wealth. The phenomena of Viking neck- and arm-rings often corresponding to specific units of weight, and in many cases were bundled together in silver hoards according to units of weight, are well known and give strength to the hypothesis that these were produced as means of payment or accumulators of value (cf. Lundström

1973; Hårdh 1996:58ff, 137ff; Gustin 2004:138; Kilger 2008: 286ff).

Small-scale chemical assaying and two inherited problems of interpretation

The second aspect of cupellation, the analytical process of *fire assay*, is represented in Scandinavia from the late Iron Age by scorifiers from the workshop site at Helgö (cf. Lamm 2008:191ff) and from the hill fort of Gåseborg (Kangur 2004). At these sites the scorifiers show signs of processing gold and *electrum*, a gold/silver-alloy. Helgö and Gåseborg were centres in the Migration Period, which means that the skill in handling a rather advanced analytical instrument had already been well established when large imports of Islamic silver were introduced in the Viking Period. As gold was always a rare and highly valued metal, and thus usually handled in small volumes, we might conclude that the gold scorifiers were used in metal analysis as well as being the goldsmith’s cupellation vessels for refinement of smaller amounts of gold to be used in his production. Silver was usually handled in larger volumes and we might, accordingly, consider that the silver scorifiers were mainly used as assaying vessels. This is confirmed to some extent by their usual find contexts.

Finds of bone ash cupels from the Viking Period are rare, but ceramic scorifiers are relatively common. Perhaps this finds explanation in the early 12th century treatise of Theophilus, where he describes a simplified method executed solely in a ceramic vessel whereby the molten litharge was skimmed off by hand during the process (Hawthorne & Smith 1979:96f). Nevertheless, bone ash cupels were probably used in the period, and Theophilus does describe

them in another chapter concerning gold refining. Raised levels of calcium indicate bone ash layers on scorifiers in Kaupang, Norway, as early as the 9th century (Pedersen 2010:198) and together with a stray find from Birka (*fig. 6*), this suggests an earlier use of fully developed cupels than usually expected; the problem being that archaeologists have not been able to identify them so far. This is further confirmed by finds of bone ash material identified as cupels from a smithy and a goldsmith's workshop in Viborg Sønder, Jylland, dated to 1018–1030 (Jouttijärvi & Andersen 2005:359). That workshop was tied to activities connected to King Cnut the Great, under whose rule Viborg became one of several mints. Another contemporary find of bone ash material, from the mint of King Olof in Sigtuna, is too fragmented to determine with certainty whether we are dealing with sherds of cupels or the lining of larger refining hearths (find nos 1547 and 1743; recorded as crucibles).

Scorifiers have until recently been usually described in Scandinavian archaeology as “heating trays” or “soldering trays”, and so too in the excavation records of the Sigtuna mint where they are recorded as soldering trays and sometimes as crucibles. Despite this, we can without reasonable doubt determine that most of them were used as trays in fire assay. This is confirmed by analyses of early 10th century finds from York (Bayley 1992:748ff), Viborg Sønder (Krongaard Kristensen 1990:344) as well as Birka and Sigtuna (Bayley 1979; Söderberg 2004 & 2008) where lead, silver and copper have been detected. This gives cause for a reassessment of “heating trays”, in keeping with an interpretation as *assaying trays* made by Kristina Lamm already in

the late 1960s (1969:116f; Lamm 2008: 195ff). This confusion has been accentuated by the mistaken interpretation of scorifiers at Fyrkat in Denmark in the 1970s, which by reference to earlier identifications of similar finds, were labelled soldering trays (Roesdahl 1977:51ff). This mis-identification has had a great impact on the interpretation of South Scandinavian finds ever since.

According to analyses made by Birgitta Hulthén, the scorifiers from Fyrkat had been exposed to temperatures of 800–900° C from above and 500–600° C from below. 800–900° C is sufficient for melting silver and lead together. For instance, 925/1000 sterling silver, containing 7.5 % copper, melts within this range. Higher temperatures are demanded for full assay above the melting points of lithargic lead oxide (950°) and fine silver (960°). This may provide some valuable information about the Fyrkat scorifiers, as it may be an indirect indication that the process was finished in cupels made from bone ash that were never found or identified by the archaeologists. If this is the case, the Fyrkat finds may suggest a fully developed fire-assaying process by the end of the 10th century, and this may indirectly support an early dating for the undated stray cupel from Birka.

The lower heat markings registered for the undersides of the Fyrkat scorifiers might be explained if they stood on a slightly cooler surface while that heat was primarily directed towards the molten alloy uppermost in the trays, as is the case in assaying. This makes sense, since temperature levels in high-temperature charcoal furnaces tend to be rather more local than one might expect,

sometimes giving surprising variance between different locations in the same fire.

The glazed upper surfaces of the trays from Fyrkat contained large quantities of lead, and the metallic droplets contained silver with a certain content of copper, both characteristic signs of cupellation. Lead, on the other hand, is not used in solder and moreover, analysis of 65 silver ornaments from Birka suggests that the Viking goldsmiths usually preferred a chemical solder (different copper compounds) when dealing with delicate filigree and granulation jewellery, rather than a metallic solder (different alloys). A chemical solder was probably more suitable for the purpose and does not contain any other metals but copper (Duczko 1985).

Results from commissioned soldering experiments by Birgitta Hulthén have been submitted when interpreting scorifiers as soldering trays. These experiments showed temperature levels of c. 300° C at the top of the trays (Hulthén 1995:23). When soldering small joints with a blowpipe, temperature levels are extremely local and hardly affect surfaces beyond a centimetre from the point of heat, and Hulthén's results seem to harmonise well with this. This also means that soldering by this method could never create the dramatic vitrification we usually see on the upper sides of the Viking Period scorifiers, even if the silversmith used a fluxing agent when soldering. These scorifiers usually show signs of being affected from temperatures of up to 1000° C. Accordingly, this means that there are great numbers of finds that have been interpreted as "soldering trays" on the basis of very weak indications. There are, though, a smaller group of low-fired ceramic trays of similar size that could derive from soldering

(Hultén 2006:41), and to provide more solid ground for further research, all earlier finds would need to be re-examined.

Another interpretative problem is provided by the custom in British archaeology of using the term "cupel" for all early medieval scorifiers since it has been presumed that bone ash cupels were not used in the early Middle Ages. It has been suggested that the early medieval vessels used for fire assay may just as well be described as cupels, no matter the material (cf. Bayley 1992:749; Lamm 2008:191). The surprisingly early finds of bone ash cupels from Viborg Sønderød, and the one from Birka that may date to the 10th century, tell a different story and show that we should rather employ modern terminology that clearly separates cupels from scorifiers even when dealing with early finds.

Scorifiers as indicators of high-status sites and minting contexts

There are examples of ceramic scorifiers from 9th and 10th century Kaupang in Norway (Pedersen 2010:194), Hedeby (Drescher 1981:182), Staraja Ladoga, Gnezdovo and Novgorod (Eniosova & Mitoyan 2005:328), in 9th century finds from the Black Earth at Birka (Bayley 1979; Jakobsen Holback, personal communication) and at workshops close to the Birka town rampart (Söderberg 2004). There also are the previously mentioned 10th century finds from Fyrkat in Denmark and those from the 11th-century workshop in Viborg Sønderød. We find them at Brough of Birsay, Orkney (Curle 1982:42) and in Dublin, Lincoln and York, and as far as can be seen, almost everywhere that Scandinavians were active in the Viking Period. Obviously, the testing of silver was an important metallurgical

process, but was it primarily tied to the goldsmiths' production of jewellery or used in connection with exchange and the circulation of goods? Or both? The common size of the scorifiers – usually within the range of 40 to 70 mm in diameter – suggests a use for testing samples rather than for refining bulk silver. As the silver must be molten together with a considerable surplus of lead, these small vessels would hardly be suitable for refining silver sufficient for an object. However they do seem suitable for the analysis of small samples of silver.

As with the early 10th-century finds from 16–22 Coppergate in York, which may be connected with mints of Æthelstan, “King of All England” (Bayley 1992: 799ff), scorifiers are generally found in minting contexts throughout history; all the way up to the 17th century Royal Mint at Helgeandsholmen in Stockholm (cf. Wadsten 1979). In a mint, the refiner purified incoming bullion before alloying it with copper or copper alloys into a legal percentage. The scorifiers and cupels were important tools for controlling silver content before sending the metal to the moneyers. Accordingly, it seems tempting to tie the scorifiers and the cupels in the Viborg Sønder sø smithy to the mint of Cnut the Great, especially since bone ash cupels seem to be an exclusive technological speciality at this time and indicative of an activity of high social dignity. Finds of scorifiers may also be worth mentioning in connection with discussions concerning whether the Danish 10th century circular forts – the *trelleborgar* – hosted the production of late *Nordic coins* (cf. von Heijne 2004:80f). Normally scorifiers are found occasionally and in small numbers, but 160 fragments were collected in the circular fort of Fyrkat and this is a re-

markably dense find. The fort of Trelleborg in Zealand, Denmark, also produced finds of this type as well as the fort of Borgeby in Scania; those at the latter being interpreted as soldering trays (Brorsson 1998).

Refining, assaying, minting and weight manufacture in 11th Century Sigtuna

The excavation in 1990 of the early 11th-century mint of King Olof on the Urmakaren site in Sigtuna (Malmer et al. 1991; Malmer 2010), revealed significant numbers of scorifier fragments, most of them found in waste deposits in the mint (*fig. 9*). There are slight indications that during the minting periods of Olof and his son Anund Jakob (c. 995–1030/35) the use of scorifiers was very firmly tied to the mint. According to the few finds related to this minting phase in the nearby Trädgårdsmästaren site, scorifiers may have been infrequently used in activities in “downtown” Sigtuna during this period. It is not until the decades after the subsidence of the Sigtuna mint in the 1030's that the practice of assaying seems to flourish in workshops on the common town plots in the Trädgårdsmästaren site (Söderberg & Gustafsson 2007). This becomes comprehensible if we consider that the right to assay precious metals was probably reserved for the staff of the mint and regarded as a regal right, and that the court lost control over the administration of precious metals after the decline of the mint.

Cross-comparisons with the results of other Sigtuna excavations must be made, though, before establishing this as more than a supposition, and we must await the publication of important reports before this can be done. Nevertheless, since jewellers



Fig. 9. The medieval town plot on the Urmakaren site and the early 11th century mint. The distribution of scorifiers in layer 4, mainly concentrated to the mint's waste deposits, where also six discarded weights and two die impressions in lead of King Olof's "long cross" coins were found. Distribution map superimposed on original plan by Ros 2009. – *Stadsgården i Kv Urmakaren. Spridningen av skärvlar är tätast i avfallsdepåerna inne i mynthuset där även sex vikter och två stampavtryck på bly av Olofs "long cross"-mynt påträffades.*

do not show up in Trädgårdsmästaren until the mid 11th century, in the shape of production of dress accessories and exclusive bridle-fittings, it seems fair to suggest that most of the metal craft and manufacture of prestigious jewellery was closely tied to the court during the reigns of Kings Olof and Anund Jakob. This impression correlates well with southern Scandinavia, where the old tradition of mass-manufacture of copper-alloy brooches for widespread distribution had declined by the second half of the 10th century, after the collapse of the system of central trading centres for long-distant trade. This breakdown was followed by a stronger focus on the manufacture of high-

quality precious metal jewellery tied to the elite and the Danish Jelling court (Callmer 1995:60f, 67). When jewellery production appears at all in late 10th and early 11th-century Sigtuna it shows up in the shape of delicate high-status craftsmanship, as in the find of a die for the production of brooches and a delicate gold pendant on the Tryckaren site, not far from the mint and close to the supposed location of the king's manor (Tesch 2007:96). The die suggests local manufacture on the site and both objects are of the south Scandinavian *Hiddenese* style. Finds such as these are generally considered as exclusive goldsmithing products for courts closely connected to

Danish traditions and to Danish politics, and indeed the manufacture of Hiddensee jewellery is in evidence at the forts of Trelleborg and Borgeby (Jansson 1991:279ff; Svanberg 1998:116ff). These links between Sigtuna and Denmark may be further strengthened by a soapstone mould with a carved image of Christ found when digging in Sigtuna's Stora Gatan (main street) not far from the Tryckaren site. The carving is in many ways strikingly similar to the image of Christ on King Harold Bluetooth's runestone at Jelling (Floderus 1928:103f). At the Urmakaren site, the presence of goldsmiths is indicated both before as well as during the minting phase (cf. fig. 5).

An exclusive town plot on the Humlegården site in Sigtuna, dated to c. 990–1010 (Ljung & Wikström 2008:88f), has produced a few scorifiers as well as stone moulds for silver ingots. Furthermore, cupellation waste of litharge-soaked bone ash was found in layers belonging to the subsequent building phase in the adjacent plot, which together with the finds from Urmakaren make up one of the two finds from Sigtuna that can be stratigraphically tied to the 11th century. The activities on the site were of an exclusive nature, probably connected to King Olof's court, which is indicated by the fact that a blacksmith's workshop here manufactured weights simultaneously with the extensive manufacture of weights at the mint on the Urmakaren site. The two workshops probably formed parts of one and the same production project. It is hard to tell if the weights were produced primarily for use in the town or for external distribution, but it seems fair to consider hinterland distribution while the amount of weights produced during what was a very

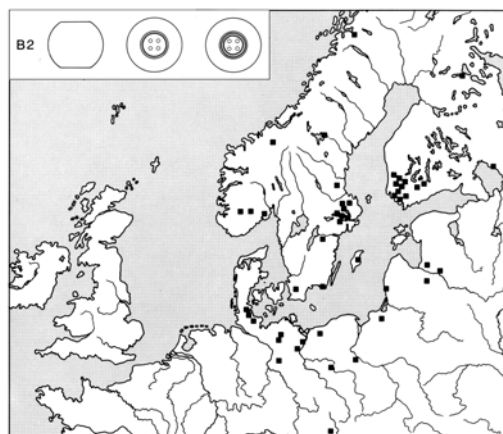


Fig. 10. The distribution of finds of type B2 weights, probably introduced by the beginning of the 11th century. The distribution of type B1 (middle) is similar. After Steuer 1984. – *Fynd-distribution vikter av Steuers typ B2, antagen introducerad vid inträdet till 1000-talet.*

short period of production probably can be counted in their thousands. These finds are extremely important keys to further understanding weight production in the Baltic area in the late Viking Period. Clearly, their manufacture was undertaken as major and administered projects.

In this context, maps correlating the find spots of truncated iron weights in the Baltic region (Steuer 1984:286f), may shed light on questions of their distribution. Steuer's type B1 (middle type), considered to have first appeared at the end of the 10th century, and type B2, at the beginning of the 11th century, both show their densest concentrations in the Mälaren area and southern Finland (fig. 10). If we study these maps in the light of the large finds of manufacturing waste from Sigtuna, it seems fair to suggest that the town was one of the more important producers of iron weights in the Baltic region at this time. Despite the massive minting project in the beginning of the century, the silver weight-based economy lingered on

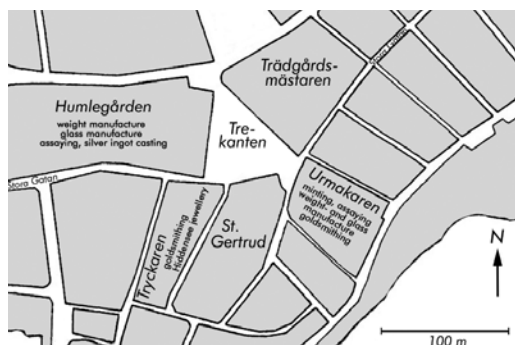


Fig. 11. Central Sigtuna and the different sites (modern housing blocks) mentioned in the paper. Finds of craftworking from the late 10th and early 11th centuries. The supposed site of the king's manor is in the northern part of the St. Gertrud block. – *Centrala Sigtuna och de kvarter som nämns i texten. Förmodad plats för den tidiga kungsgården är den norra delen av kv. St Gertrud.*

and was an important concern for central control. The Sigtuna mint represented a transitional stage between old and new systems of exchange. Perhaps the mint was not even intended to introduce a fully developed monetary economy in the strict sense, since the court was obviously aware of the need to perpetuate the old custom of payment by weighed silver (cf. Kilger in press).

The type of workshop that existed at Humlegården is difficult to ascertain in detail, but both there and at the Urmakaren mint the manufacture of weights was confined to an extremely short period – perhaps even weeks, judging from the very distinct and well-defined waste deposits and the Humlegården site showed one single, massive primary deposit of manufacturing waste. Accordingly, the workshop can hardly have been built primarily as a “weight smithy” since its activities probably lasted for at least a decade. Perhaps it might even have been a second mint working simultaneously with that in Urmakaren, although

there are no obvious mint-related finds from the site, such as dies or die impressions, to support such a suggestion. There are contemporary English examples of the simultaneous running of several mints within the same town, such as in late 11th-century Winchester where different moneyers independently administered the mints by commission from the king, with personal responsibility for obtaining, storing and refining the bullion (Biddle 1976: 398ff). At that time Winchester had old minting traditions that are in no way comparable to the conditions in King Olof's Sigtuna but the phenomenon should be noted, not least since English moneyers possibly were personally present and active in Sigtuna. The mint may very well have been decentralised and spread over several workshops, similar to that obvious for the manufacture of weights. Probably the production of weights and coins went hand in hand, making a decentralised “landscape of royal workshops” in the areas surrounding the St Gertrud block (fig. 11), the presumed location of the king's manor. Accordingly, it becomes rather one-dimensional to speak of the workshop in the Urmakaren site as *the* mint. Judging from the finds, rhetorically speaking, the mint building could just as well have been a moneyer's own smithy for the manufacturing of dies and weights, storing and assaying of bullion and goldsmithing. It would make the subject a lot more intriguing to consider the Urmakaren mint as *one of several* workshops involved in a larger context, including minting and the production of goods connected with exchange and prestige for the court.

In this context it is worth mentioning the manufacture of high-lead content glass (perhaps too with English reference accord-

ing to crucible types and chemical composition of the glass) that took place in the Humlegården smithy by the beginning of the 11th century – a prestigious production obviously performed by itinerant craftsmen returning to the site several times and building a new furnace for each visit (Söderberg 2008). The glass melting crucibles from Humlegården show similar designs to contemporary finds from Lincoln and Gloucester. As in Sigtuna, there is a slight tendency in Lincoln for a contextual connection between the production of means of payment, silver processing and glassmaking. The major part of the glassmaking finds from there were excavated at Flaxengate, which is also the site of most of the silver refining waste and an 11th century coin die (cf. Bayley 2008a:23, 27ff & 2008b). Traces of glass manufacture, including crucibles sherds (find nos 1825 & 1842, recorded as pottery), are also present among the finds from the excavations of the Urmakaren site in Sigtuna.

The finds of refining material of bone ash from the Urmakaren mint are extremely sparse, well below 30 grams, and thus we should probably exclude that bullion was processed here. This may also be confirmed by the sparse finds of crucibles from the mint. Metal was not melted here to any larger extent. It may be that the few fragments represent rather the use of bone ash cupels for assaying. Accordingly, we must search elsewhere for sites where the bullion may have been prepared and perhaps the moneyers took care of this in workshops of their own, as they may have been personally responsible for the treatment of the bullion as was the case for their contemporary English colleagues. Perhaps the Humlegården town plot could be a candidate in this matter, with

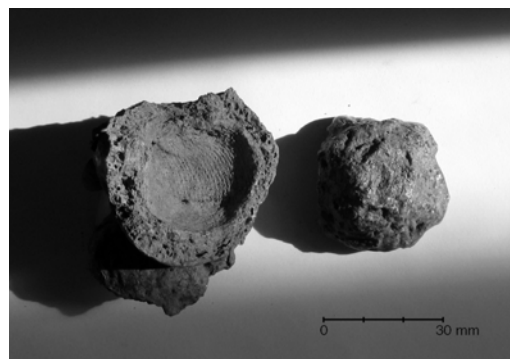


Fig. 12. Fragments of melting bowls, i.e. ceramic shells in which copper alloy coatings were brazed onto truncated spherical weights. Late 10th–early 11th century. Sigtuna, kv Humlegården 2006 (find no 2438). Photo by the author.
– *Fragment av smältkylor, keramiska skal i vilka ytskikt av kopparlegering löts fast på sfäriska järnvikter. Kv Humlegården, Sigtuna.*

its evidence for weight manufacture, glass manufacture and casting of silver ingots. The possible presence of a South Scandinavian royal goldsmith on the Tryckaren site is of great interest in this context, too, as is the partly excavated Trekanten site close to the king's manor (fig. 11). Excavations in Trekanten in the 1920's revealed 11th-century bronze workshop finds (Floderus 1928; Arbman & Floderus 2005) and waste from weight manufacture that could be primary depositions. A few scorifiers were found as well as a large litharge/bone ash fragment (find no 1069f; 165 grams), that unfortunately is an undated find collected from the excavation dump. Despite this, the site remains highly interesting and there may still be unknown workshops belonging to royal contexts buried in the neighbourhood.

The production of weights in the Sigtuna workshops is indicated by large volumes of *melting bowls* (*Schmelzkugeln*) – ceramic remains of brazing packages in which thin copper alloy coatings were brazed onto

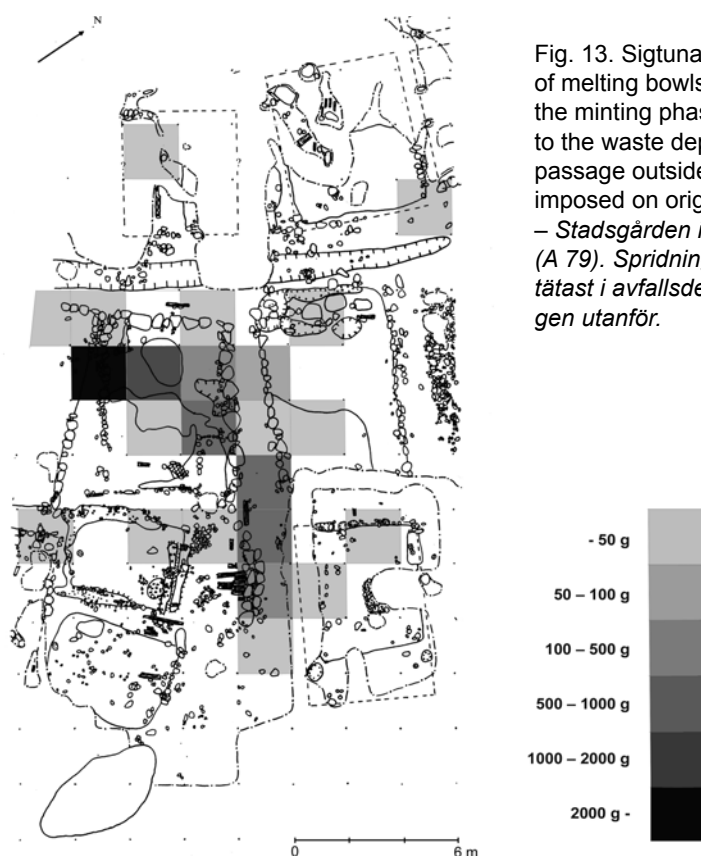


Fig. 13. Sigtuna, Urmakaren site. Distribution of melting bowls in layer 4; mainly representing the minting phase. Densest occurrence located to the waste deposits in the mint and in the passage outside. Distribution map superimposed on original plan by Ros 2009.

– *Stadsgården i Kv Urmakaren med mynthuset (A 79). Spridning av smältkylor. Spridningen är tätast i avfallsdepåer i mynthuset och i passagen utanför.*

the iron weights (fig. 12). The fragments are recorded in the Urmakaren site records as *Schmelzkugeln* and crucibles and several papers refer to “*hundreds of crucibles found in the mint*”. It must be stressed that these are not crucibles at all, but the remains of packaging material from a brazing process. As mentioned above, the occurrence of crucibles for melting metal was surprisingly low on the site, just 200 grams in the layers connected with the mint and its following phases, while there were 9000 grams of melting bowls, roughly equivalent to the manufacture of c. 300–400 weights. So far, waste of this sort from the manufacture of c. 1000 weights have been found at different sites in the town, and even more probably

lie still buried in unexcavated soil. Accordingly, the early 11th century production of weights in Sigtuna was remarkably large. On the Urmakaren site, the main finds derive from the waste deposits in the mint (fig. 13), where several discarded weights were also found (fig. 14).

The control of weight and silver content and some aspects of trade security

One scorifier doesn't make a mint. Not even 160 scorifier fragments would make one. On the other hand it seems far-fetched to imagine a mint without the occurrence of scorifiers and cupellation waste, since these processes are associated with contexts

wherein control of the the degree of fineness of precious metals is essential. Nevertheless we must remember the small group of shallow low-fired vessels mentioned earlier that could have been used for soldering, and that a goldsmith may have been cupelling smaller amounts of precious metal to obtain a particular purity, such as in the manufacture of metallic solder. Still, it is hard to ignore the occurrence of scorifiers and cupels in contexts allied to gauging value, to the exchange of goods and to minting. The link between the analysis of silver and various methods of payment has, for obvious reasons, been central throughout history and this circumstance has served as a springboard for the following hypothetical discussion.

Scorifiers appear as part of the analytical equipment in mints, but they also appear in contexts associated with the metalworkers' craft and with trade in pre-monetary contexts, such as the 8th–10th century trading port of Birka. In these cases interpretation of function can be problematic, as the finds usually appear in contexts where jewellery making and the operation of payment may both have taken place. Nevertheless it is important to remember that the use of unminted silver as a mean of exchange indicates that silver was managed not just according to weight, but also according to its purity in a very conscious way.

Viking weights and balance scales are well known to archaeology, as is their potential to measure to levels of very fine accuracy (cf. Herschend 1989:190). The other pillar stone for a metallic means of payment, the means to control the purity of precious metals, has so far been noted mainly as ocular inspection by means of mechanical markings, such as *peck marks* and *carv-*

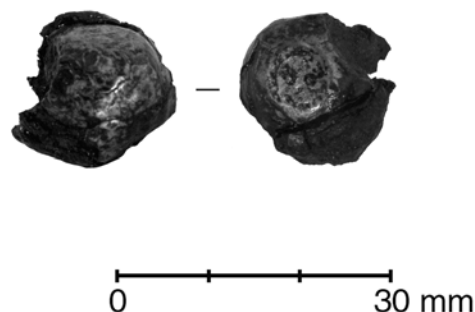


Fig. 14. A badly corroded truncated iron weight of Steuer's type B1 (middle), from the mint's waste deposits (find no 4009). A single beaded circle surrounds the weight markings on the flat end. Photo by the author. – *Korroderad sfärisk järnvikt av Steuers typ B1, mellanvariant, från avfallslagren i mynthuset i Kv Urmarkaren, Sigtuna.*

ings on coins (cf. Kilger 2006) and a few finds of touchstones – “*lydian stones*” – at ports of trade (cf. Van Es & Verwers 1980:167f; Moore & Oddy 1985). The scorifier was probably also a part of this “pillar stone”, supporting the practical use of silver bullion as a means of exchange in the Viking Period.

Ingrid Gustin (2004) emphasises the importance of creating trust and a sense of security in trade during the Viking Period. In this era, market trade was probably considered as problematic and associated with the risk of being swindled; trade between strangers at an open market was not protected by the norms that regulated exchange between counterparts within one's own group. Accordingly, there was a need for rules, common norms and procedures and even designs that signalled reliability and security. The use of normative weights may have been one of many important components for creating security and trust in this matter.

In this context, it is important to stress the possibility of a monopolisation of weight manufacture in Sigtuna (Gustin 1997; Söderberg 2008:122f), as well as similar indications at a 10th century workshop site near the Birka town rampart, excavated in 1987–1996 (Holmquist Olausson 1993; Holmquist Olausson & Fennö Muyingo 1995; Söderberg & Holmquist Olausson 1996), where 1374 grams of melting bowls were found, mainly recorded as crucibles. The find spot was interpreted as a *bronze foundry* in the excavation report, but should rather be considered a waste pit belonging to a smithy. The site with its several house terraces was, before the workshop phase, settled with long houses and is interpreted as a high status settlement (Holmquist Olausson 1993:90ff) and it seems likely that the site's connection with the upper levels of society was still intact during the workshop phase in the 10th century (Hed Jakobsson 2003:197ff). This may be confirmed by the production of high status jewellery as indicated by a find of a mould for a disc brooch (Holmquist Olausson 1993:105), glass bead making and weight manufacture, a combination that suggests a close kinskip to the royal workshops in early Sigtuna. The manufacture of weights was a late event at the site, probably dating to the middle or later part of the 10th century, to judge from the fact that the waste pit appeared immediately under the topsoil and that the melting bowls came from the upper level of the pit-fill.

The manufacture of weights in Birka may have been an administered project similar to what we see in King Olof's Sigtuna half a century later. Monopolising and standardising the production of means of payment – in this case in the shape of normative

weights – may have been one of several ways of securing the market peace that was a basic condition for maintaining a trading site, and one of several different ways of emphasising the the local ruler's protection. The early medieval arrangement of producing weights according to standards drawn up by the court, goes back at least to the 8th century royal decrees of the Frankish empire, stating that exact and identical weights should be used in each town and monastery (Gustin 2004:180). This may be the tradition from which the late Viking Scandinavian petty kingdoms sought their models, and the power over measurement and weighing may very well have been considered a regal matter in the 10th and 11th centuries. Thus, weight control may have been at least as important as the novelty of minting, once the king had founded Sigtuna by the end of the 10th century.

Viking balances had the potential for strong accuracy and this was also the case with fire assay. Accordingly, the Viking Scandinavians possessed the necessary tools for performing accurate testing of precious metals. An important ritual of trust may have been to visit an assayer when dealing with larger transactions or assignment and, as the payee, to show a willingness to undergo a spot test of the silver to be assigned. As the assaying procedure is somewhat complicated and takes a little while to perform, it is unlikely to have been used in smaller transactions, but the larger the amount of silver about to change ownership, the larger the risk, and accordingly, the stronger the need for procedures for creating confidence; procedures that were well-known and trusted by both parties to the assignment, even if strangers from different parts of the known world. Perhaps the

will itself to undergo the ritual might have served as proof of the paying party's honesty. Christoph Kilger places the custom of ocular testing by pecking into a similar context of creating confidence, and emphasises the test was a symbolic social act – “*the practice of carving was understood as signing a contract, irrespective of the silver content*” (Kilger 2006:464). The important part of the assay may have been the ritual itself and the agreement between the two parties, therefore it was not necessary to test every single piece of silver within a transaction.

Ocular testing techniques were the everyday methods used by craftsmen, merchants and the common man. The touchstone, used for testing gold content by examining the colour left by the metal after scratching the stone, was probably a tool reserved for goldsmiths (cf. Moore & Oddy 1985). The peckmarks and carvings we find on coins reveal silver testing associated with transactions, where judgement was made according to consistency under the edge of the knife and the colour of the uncorroded metal. The hardness and colour of silver alloys change with the increase in content of base metals. Pecking also leads the eye under the surface of the coin, thus showing the real nature of the silver by revealing possible surface enriching, whereby the silver content of the surface has been deliberately enhanced in order to hide the use of debased silver (Hydman 2009, personal communication). Moreover, fine silver has the following property: if pecked, fired red hot and cooled down, the peckmark will still be metallic white because of the silver's reluctance to react with oxygen, while debased silver will turn black from the same treatment. This phenomenon could have been taken advantage of as a testing method

when checking objects of fine silver and this quality is probably what the Heimskringla refers to in Evvind's story as “white in the fracture” (*hvítr í skor*). It would hardly have been used when handling coins since they were never struck from unalloyed silver.

There is another aspect to the necessity of showing “white in the fracture”. Fine silver shows the whitest tint of any metal in a cut, with a slightly warm and noble hue. Increased debasement turns the alloy colder and bluer in hue, which is already clearly visible at the alloying ratio of sterling silver; 925/1000. To an eye well acquainted with silver these differences are easily detected by a simple ocular test. In early medieval Scandinavian sources, fine silver was called *skírt silfr* or *brennt silfr* – refined or burnt silver (Vifgysson 1874:528; Naumann 1987:377). These terms obviously refer back to the purification process in fire that the metal had undergone – cupellation. Debased silver was known as *bleikr silfr*; pale silver (Naumann 1987:377), or *blá-silfr* and *grá-silfr*; blue silver and grey silver respectively (Vifgysson 1874:528), where the expression blue silver obviously refers to the blue hue in the fracture of alloyed silver. Thus, the terminology concerning pure silver relates directly to the refining process. The silver is actively purified – i.e. treated in a refining process that common people were acquainted with. The different terms for debased silver, on the other hand, relate to colours and hues and thus obviously relate to experiences from ocular testing methods. Thus, while we see obvious terminological hints of chemical refining being well known in early medieval Scandinavia, we don't see similar linguistic signs of chemical testing. The common testing

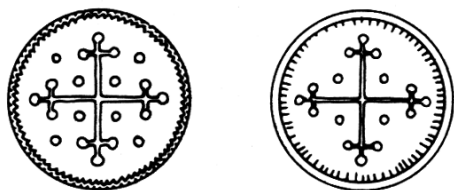


Fig. 15. A late Nordic coin with crosses presumably inspired by Continental and Byzantine coins. Harold Bluetooth (?), late 10th century. After Lagerqvist & Nathorst-Böös 1981.
– *Nordiskt mynt, halvbrakteat, sent 900-tal.*

method was pecking and other ocular methods. Fire assay, with scorifiers and cupels, may have been an exclusive technology tied to specific contexts and professions. Even if archaeology comes across the vessels that were used in this process, it doesn't show any impact on medieval Scandinavian colloquial language in the way that the refining process does.

Chemical testing may, accordingly, not have been a part of common everyday silver exchange but enjoyed an exclusivity that perhaps was tied to larger transactions with silver between parties of a higher social level. It is likely that the ability to consult an assayer who borrowed his technology from the continental mints, made a significant symbolic impression in 9th, 10th and 11th century Scandinavia. The process must also have appeared rather magical to the spectator in a way that may have strengthened its symbolic value. It is certainly a dramatic experience to watch purified silver appear in the molten oxide, when the rather dirty-looking litharge surface opens up and a shiny mirror-like silver surface appears at the end of the process. It is almost as if silver is created out of primordial soup. The Swedish terms "*blickar*" and "*blicksilver*"

(cf. German "*Blicksilber*") – whereby the metal suddenly opens its eye and "looks up" are traditional professional terms for the finishing phase of the cupellation process, and this convincingly emphasises the depth of its visual impact. Perhaps this is also one of the reasons why the process later came to be an important part of the Renaissance alchemist practice, as it truly could be considered an illustration of ideas of transformation from low to high, from impure to noble.

If fire assay was an exclusive method connected with upper social levels, it is once again worth stressing that the production waste from the Birka town rampart workshops also contained a few scorifier fragments. Obviously, assayers had been present in this workshop context where weights were mass-produced under the presumed control of the local king. This is just another example of the production of means of payment going hand in hand with knowledge in assaying. The different disciplines also have in common that they require well-educated artisans – craftsmen with specialised mathematical knowledge including the understanding of the phenomenon of fractions, as well as weight-smiths who would have needed insight into the phenomenon of density. These metalworkers were probably specialists possessing knowledge akin to the skills needed by the staff in the Continental mints of the period.

Late Viking Gotlandic exchange of silver under the influence of monetary ideas

It's easy to consider pre-monetary systems of exchange as "primitive" in the worst sense of the term – uncontrolled and resting upon a low cognitive level. The refinement

of Viking weighing technology already shows what a mistake this would be. Moreover, the customs of refining and assaying precious metals show that the pre-monetary exchange systems in Scandinavia were already resting upon two of the three corner stones of the monetary ideal; the concepts of weight and purity. Only the third foundation stone was missing – the standardised unit with an implied additive value and carrying the king's image to assure its qualities, which would later make weighing and assaying superfluous at the circulation level. The introduction of the penny was not at all dependent primarily on knowledge, but on organisation, decision-making, and on a political power to bear and defend the project itself (cf. Williams 2007). Thus there were several transitional episodes between gift and display economies, bullion or hack-silver economies and the monetary systems present in the Viking world. One such episode was evident in the increasing volume of fragmented silver in South Scandinavian hoards during the 10th century (cf. Hårdh 1996:84ff). The fragmentation is explained as a sign of an increasing use of silver as a weighed means of payment, which is also illuminated by the story of Eyvind Skáldaspillir, who hacked his cloak pin into smaller pieces in order to buy merchandise.

A hint of an ambition to actually provide Gotlandic silver with a third foundation stone, after weight and purity, may be represented in the symbols on the reverse of late Viking arm-rings. Sometimes there are different constellations of punched crosses and rings, often reminiscent of symbols familiar from late Nordic coins (fig. 15) as well as from the Anglo Saxon *long cross* and *helmet* pennies (cf. Thunmark 1974:28ff; Malmer et al. 1991:15ff). The



Fig. 16. The reverse of an Æthelred penny of the "long cross" type, 997–1003. From the Hultungs coin hoard, Bunge parish, Gotland (f46.2). Photo by Dan Carlsson. – *Frånsida av Æthelredmynt av long cross-typ, 997–1003.*



Fig. 17. The reverse of an Æthelred penny of the "helmet" type, 1003–1009. From the Hultungs coin hoard, Bunge parish, Gotland (f20.2). Photo by Dan Carlsson. – *Frånsida av Æthelredmynt av helmet-typ, 1003–1009.*

symbols shown in figures 15–17 seem to correspond well to the symbols on Gotlandic arm-rings (figs. 18 & 19) where they are considered as a "symbol type C" by Thunmark-Nylén (Thunmark 1974:28). The type-C symbol seems to be closely associated with Stenberger's type 3 arm-ring (cf. Stenberger 1958:110), a type that was cast in the silver workshop in Fröjel (cf. fig. 8). The symbols may have been punched after casting, and it seems reasonable to suggest that this happened as a result of some sort of administrative control. The symbol depicted in figure 19, a square with curved sides and groups of rings or dots at each corner, could have originated from the symbol that is included in the reverse cross of the English *helmet* pennies introduced by Æthelred II in 1003 (fig. 17). The type was also struck under King Olof in Sigtuna from c.1005, while the *long cross* types were struck by Æthelred II from 997 and by Olof in Sigtuna shortly thereafter (Malmer et al. 1991:16, Malmer 2010:52ff).



Fig. 18. A punched symbol on the reverse of an arm-ring of type 3, reminiscent of crosses on Nordic coins and contemporary European pennies. Kyrkljuves, Vänge parish, Gotland (find no SHM 7259) Photo by Yliali Asp, SHM. – *Punsad markering på insidan av armbygel av typ Ab 3.*



Fig. 19. A punched symbol on the reverse of an arm-ring of type 3, similar to the symbol on the reverse of Æthelred's "helmet" pennies. From Lilla Rone, Lye parish, Gotland (find no SHM 8315). Photo by the author. – *Punsad markering på insidan av armbygel av typ Ab 3, snarlik symbolen på frånsidan av Ethelreds helmet-mynt.*

This custom has a history, judging from Hiberno-Norse arm-rings of the late 9th and early 10th centuries. Kilger associates these symbols with the crosses on contemporary coins such as Anglo-Saxon pennies or even Merovingian *tremisses* that are supposed to have set the weight standards for these arm-rings (Kilger 2008:286). The phenomenon is also reminiscent of the use of Islamic coin symbols on Scandinavian weights in the mid-Viking Period, including the Arabian word *bakh* (meaning choice, first-class, first-rate) (Sperber 1996:96ff). The trustworthiness of coins was in this way transferred to the weights (Kilger 2008:307ff). There is also a late Viking weight with a cross symbol that is obviously influenced by the crosses of late Nordic coins (Lagerqvist & Nathorst-Böös 1981) and a similar symbol is engraved on a copper case for a set of scales from Uppland (now in the Kalmar County Museum; KLM 2694). There seem to have been certain traditions of providing credibility by the transferred use of coin symbols in this way; in this re-

spect it may be relevant to ask what was the primary significance of equal-armed crosses to the common man in late Viking Scandinavia – Christianity or, possibly in addition, security and trustworthiness in exchange?

Lena Thunmark-Nylén discusses the phenomenon and rejects the idea that the symbols relate to geographic locations of the production sites, as the distribution pattern for arm-rings with identical obverse decorations shows that these products were usually not distributed as widely as were the arm-rings with identical reverse symbols. Common symbols punched on the reverse must have been used in several different workshops on the island. However, she does not deny a possibility that the symbols may be tied to silver purity (Thunmark 1974:31f). There are not yet any series of analyses available to confirm whether these symbols concern silver quality, site of origin or master of the workshop site, but the custom of punching symbols in this way does remind us of modern hallmarking. It is

also worthwhile mentioning that the symbols sorted under Thunmark-Nylén's type C, obviously influenced by the reverse symbols of coins, began to show up simultaneously with the introduction of the Æthelred pennies in fig. 16 and 17 around 1000 AD (cf. Thunmark 1974:30). Thus, the custom of marking the silver in this way may imply a certain wish to adapt the administration of Gotlandic exchange silver to the contemporary attempts to introduce coin economies on the Scandinavian mainland. A traditional "primitive" system of exchange seems to meet an advanced administrative approach at a turning point between old and new in Scandinavian customs of exchange

Perhaps this should not be considered as unexpected – the fact that silver bullion was refined before casting the arm-rings, as was done in the Fröjel workshop, may by itself be a strong hint of an administrative approach towards silver. If cupellation wasn't just connected to an ambition to be able to distribute silver of the highest possible purity, but was also aimed at a slightly higher level by the desire to actually reach stipulated standards, this would perhaps suggest a further approach towards the routines of contemporary mints. English mints had a long-standing tradition of keeping standards, as well as of periodic recoinages. We find these ingredients in King Alfred's coinage in the late 9th century (Blackburn 1995:106f). As mentioned, there are also obvious material traces of quality testing from early 10th century York in the shape of cupellation- and assaying waste – litharge cakes and scorifiers – tied to King Æthelstan's minting. In 973, King Edgar's reform enforced a standard coinage over the kingdom. The production was decentralised to several regional mints, but operated under

central control (Jonsson 1994:194ff). In the mints of Winchester and in Worcester the moneyers were independent entrepreneurs working under laws strictly stipulating weight and silver content, and a continuous purity control of the bullion was a central part of the production line (cf. Biddle 1976:398ff; Symons 2006:546ff). Later, in the 13th century, the mint in Venice, Italy, reached high levels in the formalized handling of noble metals. The bullion was kept under continuous quality control by the mint's staff, and all refining in the city had to be executed by the state refinery or by the mint, even for the precious metal used by the Venetian goldsmiths (cf. Stahl 2000:289; 326ff).

Eleventh century society on Gotland could hardly be compared to that of England, and even less to a Venetian organisation two centuries later, but it seems likely that the punched symbols on the arm-rings – to be considered more as ornamented ingots than as jewellery – hint at something happening to the organisation of exchange. A somehow official approval of purity and weight, confirmed by a symbol, may suggest the presence of an authority with certain ambitions for centralisation.

Hence strength and security

The silversmiths of Gotland did not execute their work at random. The custom of refining the bullion in combination with punching symbols on the reverse of their products, possibly suggests a wish to formalise their production under the influence of customs associated with minting in England and Germany as well as on the Scandinavian mainland by the beginning of the 11th century.

The knowledge of weighing, refining and assaying implies the ability to maintain proportional alloy standards. Can the idea of standards have been an integral part of the production and use of silver objects in the Viking Period? The average silver content in southern Swedish neck- and arm-rings of the 10th and 11th centuries, as analysed by Hårdh (1976: 114ff, 120ff), all show high percentages of silver. The work of Hårdh may reflect different “standards” relating to different categories of objects, where analysed neck- and arm rings – the classic “primitive money” groups – show average Ag-percentages of 90,6 and 92,6 %. This hits close to the percentages in pre-mid 10th century Islamic coins as well as to western European coins of the early 11th century. Analyses of four 10th century arm-rings from Birka show similar if slightly higher percentages, c. 93–96 % (Arrhenius et al. 1973:154ff). These figures seem to reflect different silver standards for exchange purposes, while the average percentages in status objects such as filigree jewellery generally lie between averages of 96,8 and 97,7 % and even up to 99±1,0 % as the highest content. This may probably have been considered as fine silver – “*skírt*” or “*brennt*” silver – and perhaps this was considered a common standard for fine jewellery when the reward for Eyvind Skáldaspillir was manufactured.

It is obvious that Islamic silver was not re-alloyed in Scandinavia before casting it into objects. Islamic coins, and objects made from re-melted Islamic coins, are generally alloyed with pure copper and contain very sparse zinc percentages. This can be studied in the Scandinavian 10th century jewellery from Birka (Arrhenius et al. 1973:156f) and in the analyses made by

Hårdh, where the neck- and arm-rings generally show zinc contents below 0.5% and the filigree jewellery mainly shows no zinc content at all (Hårdh 1976:120ff). Pure copper was not used to alloy silver in Scandinavia and England in the Viking Period; instead copper/zinc-alloys were used for this purpose (Hårdh 1976:117).

The custom of debasing coins to secure profit for the king by a successive reduction of the silver content in each new edition without altering its weight and nominal value, did not make its appearance in Scandinavia until the late 11th century. In the mid-11th century Norwegian coinage of King Harold Hardrade, roughly contemporary with the workshop in Fröjel, the practice seems to have been in full swing. This seems to be supported, along with modern analyses (Elfvér 2007), by the Icelandic saga *Morkinskinna*, which relates that the king’s guardian, Halldór Snorrason, preferred payment in fine silver rather than in King Harald’s coins which he knew contained a very high content of copper (cf. Williams 2007:178).

The coins of early 11th century Sigtuna hold a fair silver content and do not show signs of debasement. They show an average content of 89,7 % for the first decades of minting (10 analyses), close to the results of analyses of 16 German Otto-Adelheid coins struck in Goslar (Malmer 2010:44) and slightly below the contents of the early 10th century Islamic and late 10th century Anglo-Saxon coins. Furthermore, the average percentage in the analysed Sigtuna pennies shows a slight tendency to correspond closer to the silver content in the neck-rings rather than to the arm-rings analysed by Hårdh, which perhaps suggests an adjustment to traditional neck-ring standards – or

simply that they were struck directly from imported coin bullion of German origin.

Minting was in itself an innovation for the Scandinavians, and it seems likely that this was performed not just under the influence of western European coinage but also with regard to traditional Scandinavian approaches to silver. Thus deliberate debasement was perhaps out of the question in the early Sigtuna coinage since it may have challenged traditional codes of honesty and honour. This, together with the simultaneous royal maintenance of the weight economy, may make the Sigtuna coinage rather a transitional stage than part of a fully developed monetary economy (cf. Kilger *in press*). The differences between the Danish and Swedish systems of exchange in the 11th century, may in some respects be illustrated by Steuer's distribution maps for the B1 (middle) and B2 weight types. The weights are hardly represented at all in Danish soil except in the Hedeby area and sparsely in Scania and Blekinge (*cf. fig. 10*). In terms of monetisation, Danish minting of Sven Forkbeard and Cnut the Great was far more developed than the Svealand/Sigtuna minting ever became since the use of weights remained deeply integrated with Svealand's exchange customs.

The formalized handling of silver that we experience from 11th century Gotland may in some respects also be considered a transitional stage on the way to monetisation. The refining of bullion, the adjusting of weight and the application of punched "hallmarks" inspired by the monetary sphere that most Gotlander's were probably well acquainted with, may have lent a symbolic assurance of security and reliability at the exchange level. The responsibility for ensuring weight and silver quality may in

this way have been transferred from the distribution level and back to the producer, who confirmed it by punching symbols before releasing the arm-rings into circulation.

Conclusions

There seem to be a few discernible Viking silver standards, one or two "currency standards" for arm- and neck-rings that fairly closely follow foreign coin standards, and a standard for fine jewellery with the quality of fine silver. We do not know for certain if silver was routinely refined before being cast into objects for exchange, or if the finds from the Fröjel workshop uniquely reflect current trends belonging to the mid-11th century. This was an era when the large inflow of silver to Scandinavia was ebbing and when obtainable bullion may have been of poor quality, which could explain the need for refining before use in order to obtain a traditional currency standard.

From the available sources, we might carefully draw the following conclusions: silver used for fine jewellery was refined in order to maintain its high purity, while arm- and neck-rings were possibly cast directly from imported coins without pre-treatment – except during periods when the quality of the imported silver was less reliable and refining would have been necessary. We cannot yet tell if the late 10th and early 11th century moneyers of Sigtuna refined their bullion on a regular basis or if they simply struck the coins directly from delivered bullion, but we do know that they controlled its quality by fire assay.

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Sammanfattning

Eyvind Skáldaspillirs silver – raffinering och standard i förmonetära ekonomier i ljuset av fynd från Sigtuna och Gotland

Kupellationsprocessen har en lång historia. Den bör ha uppfunnits i Mellanöstern runt 3000 f Kr och används vid extrahering av silver ur silverhaltiga blymalmer. Senare har processen även använts vid raffinering av legerat silver för återbruk, samt utvecklats till en analytisk process som används för test av silverkoncentrationen i silverprover alltifrån medeltida myntning till modern ädelmetallhantering och även av alkemister under renässansen. Blybemängt hårdmaterial av benaska från silverraffinering dyker upp i Sverige redan i vendeltid i en vid en stormannagård i Dagstorp i Skåne. Senare finner vi fynd i det tidiga 1000-talets myntning under kung Olof Skötkonung i Sigtuna och i en verkstad från 1000-talets mitt i Fröjel socken på Gotland, som producerade silverarmbyglar av specifikt gotländska typer.

Förmodligen har även kemiska testmetoder för ädelmetaller använts tidigt. Keramiska skärvarlar är representerade redan i folkvandringstid på verkstadsplatsen i Helgös husgrupp 3. Senare har de en tendens att dyka upp i vikingatida högstatussammanhang under 800-, 900- och 1000-talen, som i Birka, Kaupang, Hedeby, Staraja Ladoga, Gnezdovo, Novgorod, Sigtuna, Dublin, York, i Fyrkat och Viborg Søndersø. På ett fåtal platser, i Birka och 1000-talets Viborg Søndersø, har även hittats tidiga exempel på s.k. kapell, små kärl av benaska som använts tillsammans med de keramiska skärvarlarna vid ädelmetallanalys.

Det tidiga 900-talets York och 1000-talets Sigtuna och Viborg Søndersø var myntorter och det verkar rimligt att anta att användningen av tekniken på dessa platser intimt hängt samman med myntningen. I början av 1000-talet, under

den period då Kung Olof myntade i Sigtuna, påträffas fynden framförallt i mynthuset. Det är rimligt att anta att även förmonetär närvaro av skärvarlar, dvs före Sigtunamyntningen, varit kopplad till testmetoder för betalningsmedel. Det finns en nära koppling mellan kupellation, silvertestning och betalningsmedel genom historien. En annan koppling mellan fynd av skärvarlar och betalningsmedel visas av verkstäder vid Birkas stadsvall där även storskalig produktion av vikter ägde rum, en typ av produktion som senare också ägde rum i kung Olofs mynthus i kv Urmakaren och i en smedja i kv Humlegården i Sigtuna. Vid handel och silveröverlåtelser föreslås i artikeln att testmetoder genom kupellation kan ha förekommit som en tillitsskapande rutin knuten till större transaktioner på högre nivåer i samhället, ett komplement till gängse okulära testmetoder.

Myntekonomin tog god tid på sig att slå rot i Svealand och på Gotland. Ändå finns tidigt tecken på monetära influenser av vilka omsorgen av silverhalten var en. Av fynden från Fröjel att döma lade 1000-talets gotlänningar möda på att raffinera silver inför tillverkning av armbyglar som fungerade som värdeackumulatorer. Tillsammans med noggrannheten i vikingatida vikt-mätning kan metoden även ha gett skandinaverna verktyg att upprätthålla fasta metallstandarder, något som i någon mån bekräftas av tillgängliga silveranalyser som grovt förefaller kunna särskilja tre skilda legeringsgrupper – armringar, halsringar och filigranarbeten. Andra tecken på hög omsorg om silverkvalitet återfinns som språkliga avtryck. Medeltidssvenskan skiljer *skirt silfr* eller *brennt silfr* – raffinerat eller bränt silver, dvs finsilver, från *bleikr silfr*; blekt silver, *blá-silfr* och *grá-silfr*; blått och grått eller legerat silver. Av intresse är att termerna för finsilvret refererar direkt till kupellationsprocessen, medan termerna för legerat silver hellre refererar till okulära erfarenheter och således till

vardagliga testmetoder som pecking, dvs att hacka märken i silvret med kniv för att komma åt att studera silvrets färg i rena okorroderade ytor, något som för ett vant öga kan berätta mycket om silvrets renhet.

Ett annat tecken på inflytande från myntekonomi är förekomsten av gotländska armbyglar med punsade symboler på insidorna, som påminner om symboler på fransidorna hos samtida engelska och kontinentala mynt samt hos de sena nordiska halvbrakteaterna från 900-talet. Det förefaller rimligt att anta att dessa symboler markerar en kontrollrutin i verkstäderna som anslutit till någon form av administrativt system kopplat till distributionen – en kontroll av vikt eller silverkoncentration eller kanske både och. En eventuell auktoriserad kontroll ses här som en trygghetsskapande rutin för att säkra marknadsfrid och tillit till värdebärarna och denna kontroll kan ha bekräftats genom symboler lånade från mynt som gotlänningen givetvis var väl förtrogen med.

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