Gold, Silver and Bronze
Analysis of Three Fragments of Technical Ceramic from Elsfleth-Hogenkamp, Germany

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Keywords

Archaeometallurgy, Barbaricum, Coastal Settlement, Goldsmith, Lower Saxony, Precious Metals, Refractory Ceramics.

Abstract

Two crucible fragments were found during recent excavations in levels dated to the Roman imperial period in Elsfleth-Hogenkamp, a site interpreted to be a beach market located at the junction of the Hunte and Weser Rivers with water access to the North Sea. The crucible fragments were discovered in cultural layers dated to the 2nd-3rd centuries AD in an excavation trench placed near the concentration of metalworking debris, copper-alloy objects and casting waste found during terestrial metal-detecting surveys. Near this concentration in southwest part of the site, a fragment of technical ceramic with copper-alloy corrosion products was found as a surface find. These three pieces of technical ceramic were investigated by optical and scanning electron microscopy and compared with five pottery sherds of local manufacture. Evidence of the casting of gold, silver, bronze and copper was found as well as the importation of high quality technical ceramic. This study focuses on the material and technical aspects of the metallurgical ceramics and the results raise further questions on the meaning and organization of metalworking at the site.

Introduction

Direct evidence for copper metallurgy in northern Germany before the Middle Ages is rare, and the evidence for working of gold and silver is even rarer. In the Roman imperial period, when discussing the parts of Germany free from Roman control, a handful of settlements have crucibles that attest to the casting of copper alloys (overview Schuster, 2006, pp.132-145). The greatest evidence for copper metallurgy comes from an excavation in Westphalia, Warburg-Dasenburg, where ca. 475 thick-walled crucible fragments were found in contexts dating to the 1st century AD (Günther, 1990, pp.56-58). Also in Westphalia, three crucible fragments are known from Soest-Ardey, which are interpreted as evidence for copper-based metallurgy. The crucibles are very similar to the contemporary settlement of Warburg-Daseburg. No traces of metal or slag could be seen on the interior of the crucibles (Pfeffer, 2012, p.71). In the northern lowlands, Feddersen Wierde was a settlement that existed in the late pre-Roman Iron Age and ended at the start of the Migration period (Schuster and Rijk, 2001, p.40). At Feddersen Wierde crucibles (64 complete/fragments) were found; there is no evidence of precious metals being worked there (Schuster, 2006, pp.132-133). Also at Ahrensboek, in Mecklenburg Germany, a fragmented crucible was found dating to the early Roman Iron Age and is thought to associated with copper-based metallurgy (Saalow and Wehner, 2008, pp.44). Concerning gold-based metallurgy, in none of the settlements in Germany of the Roman period studied by Baumeister (2004, p.42) or Gralfs (1994, p.144) is there direct evidence for the casting of gold. One mention of a crucible with gold droplets can be found from an excavation of an Roman imperial period settlement in Bochum-Harpen, however this crucible was found in secondary fill and lacks a secure and datable context (Brandt, 1997, pp.117-119).

The archaeological site of Elsfleth-Hogenkamp is located in northern Germany at the confluence of the Hunte and Weser Rivers. The nature of the settlement is not entirely known, but due to the significant amount of non-ferrous metal objects discovered by metal detecting (< 700), many dated to the Roman imperial period, and its advantageous geographic position at the juncture of two rivers with water access to the North Sea, discussions of the settlement have centered on its potential importance in regional and long distance trade (Mückenberger, 2013, pp.200-203). Important in this discussion is the question of metalworking at the settlement. The metal detecting surveys of the last decades have shown that there is a concentration of non-ferrous metal finds in the southwest part of the site in an area of about 50 m radius (Mückenberger, 2013, p.198), and in this area Roman coins, complete and fragmented Roman copper-alloy objects, scrap gold, silver and copper alloys were found, but also there is evidence of casting, such as casting sprues and amorphous droplets of metal. Since scrap metal is easily transported and may have been traded by weight, it cannot be excluded that metal scrap, regardless of form, may be a trade good rather than true evidence of on-site metalworking. No crucibles, melting hearths or features directly connected to non-ferrous metalworking have been identified in the past; recent excavations and re-examination of metallurgical waste are beginning to change the picture.

Technical Ceramic and Archaeological Context

In the framework of the first series of excavations begun in 2016, five small test trenches were made. Trench 3, with a size of 4.5 m^2, was placed near to the shore of an ancient tidal channel in the southwest part of the site. Here there is a high concentration of surface finds of Roman coins and casting waste, and it is suggested that these remains reflect a metallurgical workshop specialized in the recycling of copper alloys (Mückenberger, 2013, p.198).

Under a ca. 40 cm thick plow zone layer, a total of four cultural layers were identified down to a total depth of 1.20 m, where sterile soil was finally reached. The ceramics and metal objects show a stratigraphic sequence from the pre-Roman through the Roman Iron Age followed by the Migration period and Early Middle Ages. In the oldest cultural layer dated to the pre-Roman Iron Age, twenty post holes were found whose size argues against a direct relationship to a residential structure; possibly these reflect the remains of a fence or similar structure. In the layer directly above this, the two crucible fragments (Fd. Nr. 410 and 3342) were found (Layer 4d) and were associated predominately with ceramics that date to the 2nd and 3rd centuries AD, examples being sherds of a narrow-mouthed pot and a funnel-shaped bowl, but additionally, there were a few sherds of vessels that have a long production period that reaches into the 5th century AD, for example from a decorated dish-shaped vessel. Other important finds from this level are three crossbow brooches that date to the early Roman imperial period. Furthermore, fragmented copper-alloy scrap and casting waste were found as well as slag associated with ferrous metallurgy.

A fragment of slagged ceramic with green corrosion products was found during a terrestrial metal detecting survey undertaken in 2008 (Mückenberger, 2013, p.179). This dark bloated ceramic is now interpreted as having clear ties to copper-based metallurgy. Its find location was recorded to be about 10 meters to the northwest of the highest concentration of Roman copper-alloy coins and casting debris (compare Mückenberger, 2013, pp.83, 166), and thus is likely to be associated with metallurgical activities carried out there.

As the first technical ceramic finds identified from the settlement, the three fragments were sampled for optical and scanning electron microscopy to better understand the metallurgy of Elsfleth-Hogenkamp in the Roman imperial period and to explore the broader organization and meaning of non-ferrous metallurgy in this region in the first half of the 1st millennium AD.

Analytical Methods

The fragments were sawn, mounted in epoxy resin, and polished. Additionally, for comparison purposes, thin-sections of five common domestic pottery sherds were prepared to obtain detailed data about the tempering materials and the mineralogical composition (see Struckmeyer in Folkers, et al., in press). Optical microscopy was carried out with a polarized light microscope and a Keyence digital microscope. Scanning electron microscopy (SEM) was performed with a Zeiss Gemini with energy dispersive X-ray spectroscopy (EDS) capabilities (Thermo UltraDry Silicon Drift X-ray Detector). The polished samples were analyzed under low vacuum conditions (30-50 Pascal) with a energy of 20kV and a working distance of 14-16.4 mm. The EDS software uses

Table 1. Semi-quantitative SEM-EDS analyses of the NIST-612 glass standard. Results in weight percent, normalized to 100 percent and oxides were determined stoichiometrically.

	Na_2O	Al_2O_3	SiO_2	CaO
612 Standard Measured (1)	14.0	2.1	72.5	11.5
612 Standard Measured (2)	14.0	1.9	72.4	11.7
612 Standard Measured (3)	14.0	2.1	72.5	11.4
612 Standard Measured (4)	13.9	2.1	72.5	11.6
612 Standard Certified	14	2	72	12

Table 2. Semi-quantitative SEM-EDS analyses of the technical ceramics and five pieces of common pottery from the site. In weight percent, normalized to 100 %, and oxides were determined stoichiometrically. The "-" means below the detection limit, < 0.5 wt. %.

		(n)	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	Fe_2O_3
Cr. 410	Ceramic (Bulk)	5	0.7	0.8	7.8	84.6	0.5	2.6	1.2	3.0
Cr. 410	Slag (Bulk)	3	4.9	2.9	6.4	58.5	0.6	6.5	16.0	3.7
Cr. 3342	Ceramic (Bulk)	4	0.9	1.0	18.7	73.0	-	3.0	0.9	2.2
Cr. 3342	Ceramic, Int. Layer (Bulk)	5	1.5	0.9	10.9	80.2	-	2.9	0.7	2.6
Hearth 1032	Ceramic (Bulk)	4	0.6	1.7	10.3	72.3	3.0	2.9	2.9	6.4
Hearth 1032	Ceramic, Vitreous (Bulk)	4	0.4	2.0	10.3	74.3	1.2	3.5	3.1	5.3
Sherd 11	Ceramic (Bulk)	3	0.8	0.9	16.2	66.4	4.3	3.2	1.9	6.3
Sherd 9	Ceramic (Bulk)	4	1.2	1.5	13.2	68.0	4.5	2.7	1.9	6.7
Sherd 2	Ceramic (Bulk)	4	1.2	1.6	19.1	63.0	2.3	3.3	4.3	5.2
Sherd 13	Ceramic (Bulk)	4	1.1	1.3	18.5	64.4	2.5	3.4	1.9	6.8
Sherd 15	Ceramic (Bulk)	4	1.1	1.1	17.1	62.2	5.8	2.8	2.3	7.6

a fitted standard calibration. The NIST SRM 612 glass standard was measured before the analyses (Table 1). The EDS was used to obtain semi-quantitative bulk compositions of the ceramic, metal inclusions, phases and minerals. The bulk ceramic and glassy slag compositions were acquired by analyzing areas of 1-2 mm² of representative ceramic fabric (or glass matrix) and avoided large non-plastic and metallic inclusions (Table 2). The SEM-EDS analyses are all normalized to 100 weight percent. Oxygen was measured as a control, but the results represent oxygen determined stoichiometrically.

Figure 1: Section of open-faced crucible Fd. Nr. 410 with red glassy slag on the interior associated with dark vitrification of the ceramic. The ceramic is thoroughly burned and has a homogeneous texture (Keyence digital microscope image).

Results and Discussion
Macroscopic and Microscopic Investigation

Crucible Fd. Nr. 410 (Elsf. 4, 2016)

Macroscopic description: The fragment was identified as a crucible fragment because of its roughly uniform wall thickness of 9 mm and that it was thoroughly fired and exhibits vitrification and red glass on one surface (Figure 1). The red glass and highest vitrification of the ceramic is interior surface, which is slightly concave. The ceramic is made of a coarse, but homogeneous clay that was oxidized to deep red color which becomes darker as the level of vitrification increases. The glass layer on the interior is up to 1 mm thick, and no metal prills could be detected by eye.

Microscopic description: Under the microscope, the ceramic shows that it is filled with silt to very fine sand sized quartz inclusions and lesser amounts of feldspar and mica, which are almost consistently under 100 µm. There is a clear gradient from exterior to interior in the level of vitrification. The typical structure of the ceramic

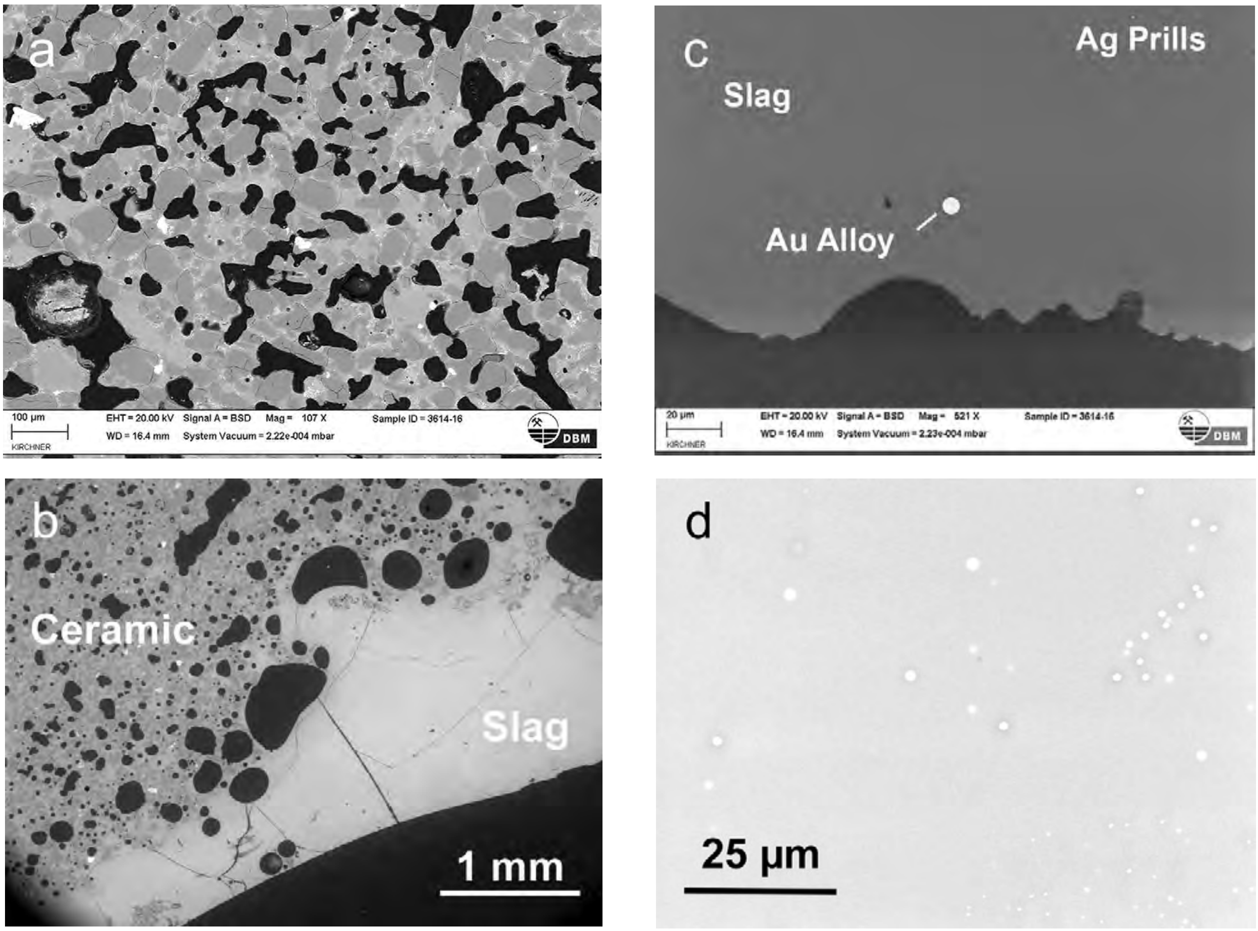

Figure 2: Crucible Fd. Nr. 410 SEM-backscatter images. a) Crucible ceramic microstructure. Silt to fine sand-sized quartz, feldspars and micas held together by a network of glass. b) Vitreous slag and crucible ceramic. c) Gold alloy prill in glassy slag and region with µm to sub-µm-sized silver prills. d) Silver prills in slag.

can be described as fine quartz inclusions held together by a network of glass left from the melting of the clay minerals (Figure 2a). The interior is increasingly vitrified which merges with a layer of intensely red glass (Figure 2b). The composition of the glass layer has increased amounts of lime, soda and potash compared to the crucible ceramic and this indicates that the glass formed by the fluxing of wood ash with the ceramic (Table 2). In the glass layer abundant metallic prills could be found, but they tend to be very small (< 20 µm). The largest prills are near the surface of the glass and are gold-silver-copper alloys (Figure 2c). Deeper in the glass the prills are smaller and are silver (Figure 2d). Unlike in other instances of crucibles with red glass on the interior (example Bayley 2009), no crystals of cuprite or copper prills were detected, and thus it appears that the ruby red color of the glass may be due to the presence of colloidal silver and gold.

Interpretation: The object is interpreted as being a fragment of an open-faced crucible for the melting of precious metals. The deep red color of the ceramic is due to firing with oxidizing conditions. The melting of gold and silver with plenty of oxygen may have been intentional in order to oxidize and remove a small portion of the base metals or other impurities, a process similar to scorification (Bayley and Rehren, 2007, p.53). The glass formation on the interior of the crucible was produced during the high temperature reaction of wood ash and the crucible ceramic; the nature of the glass is not similar to Viking period open-faced crucibles for precious metals from Hedeby and numerous other early medieval sites, which commonly contain a lead-rich glass on the interior (Merkel, 2016, pp.216-220); however, archaeological examples are known in which other fluxes were used for cleaning gold (Bayley, Dungworth and Paynter, 2015, pp.53-55).

Concerning the crucible ceramic itself, its fire resistance relies on its high content of quartz because the clay itself is not very refractory. Since it appears to be an open-faced crucible with heat applied from above, the thermal requirements of the ceramic are much less than closed crucible forms where the heat must travel through the wall thickness (Bayley and Rehren, 2007, p.43).

Figure 3: Section of crucible Fd. Nr. 3342 showing the two layered structure of the crucible and repair layer on the interior.

Crucible Fd. Nr. 3342 (Elsf. 4, 2016)

Macroscopic description: The crucible wall fragment is 9 mm thick and appears to be part of a cylindrical crucible form with a rounded base (Figure 3). The crucible ceramic is made from a white-firing refractory clay. The interior of the crucible is coated with a 1 mm thick layer of a less refractory clay that has undergone intense vitrification. The outer surface of the crucible is glazed bright red and a flake of magnetite (magnetic) could be found adhering to the exterior, possibly a flake from the iron tongs used to hold the crucible.

Microscopic description: The interior surface of the crucible was first examined by SEM-EDS. Crusts of silver corrosion products containing sulfur, chlorine, iodine and bromine were found. Once bisected (Figure 4a), silver corrosion products and a small number of metallic silver prills were exposed (ca. 20-50 µm). Six prills had roughly 95 wt. % silver with 5 wt. % copper and a seventh prill was about half silver, half copper and an eighth prill was two-thirds bronze and one third silver. Although these latter prills may be an indication of mixing or the use of debased alloys, the fact that there is almost no corrosion products of copper on the interior surface or in the porosity of the ceramic points to the casting of high quality silver, at least for the last use of the crucible.

The interior of the crucible appears to have been coated with a 1 mm thick layer made from a less refractory material. This interior lining is glassy with large rounded porosity and abundant quartz inclusions (Figure 4b). The layer applied to the inside of the crucible is bloated and frothy while the crucible ceramic is dense. The interior layer consists of a bubbly glass dotted by silt to sand-sized quartz grains (< 500 µm) and round pores. Sand may have been added as temper. The crucible ceramic itself is light reactive under the cross-polarizer indicating that ceramic is not fully vitrified. The white-firing crucible ceramic has rounded to subrounded quartz inclusions that are typically under 200 µm. The bulk SEM-EDS analyses (Table 2) show the elemental difference between the crucible and the interior layer: the crucible is made of ceramic that is high in alumina and low in iron, and the higher silica contents of the interior layer reflects the abundant quartz inclusions and the lesser amount of clay.

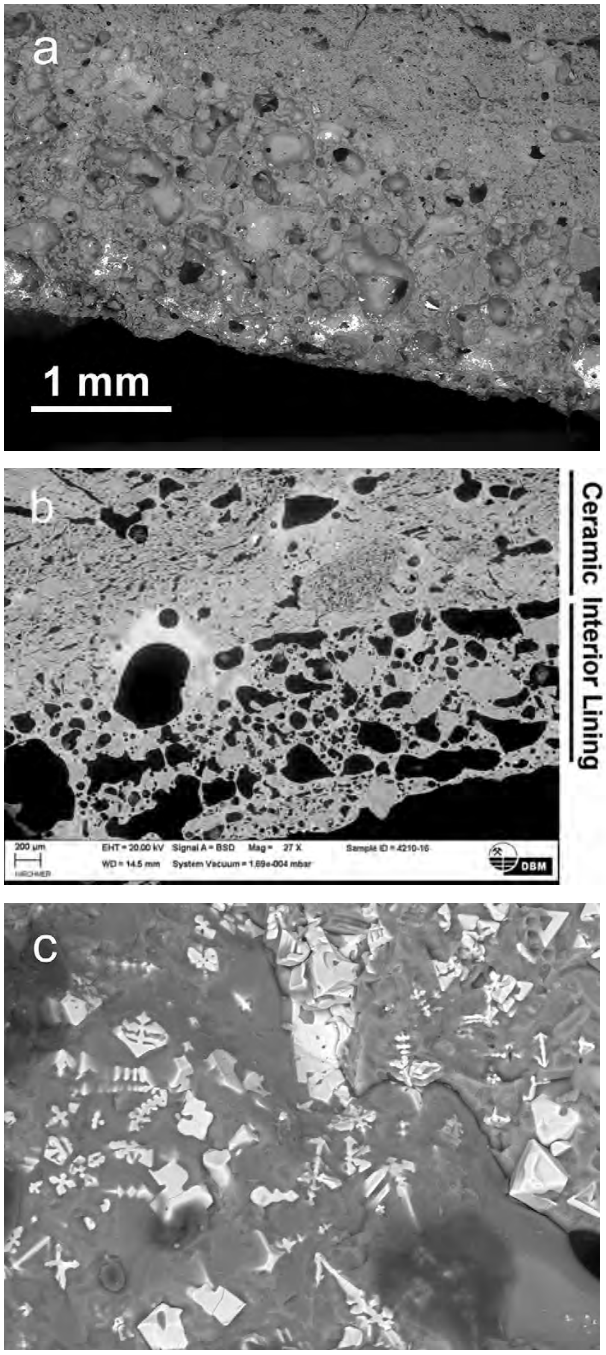

Figure 4: Crucible Fd. Nr. 3342 SEM-backscatter images. a) Section showing the frothy vitrified repair layer and the denser crucible ceramic. The white areas are silver corrosion products and metallic silver in the crucible ceramic pores. b) Mounted and polished section showing the repair layer and the crucible ceramic. c) Magnetite crystals in the glass on the crucible exterior. No scale.

Figure 5: Section of hearth fragment Fd. Nr. 1032. The section reveals bronze casting waste and copper prills and frothy vitrified ceramic and glassy slag.

The outer glass was analyzed by SEM-EDS and showed increases in lime and potash and thus reflects fluxing by wood ash. A region on the exterior of the crucible was magnetic and magnetite dendrites could be found in the outer glass (Figure 4c), again probably a reaction with the iron tongs used to manipulate the crucible.

Interpretation: Being an externally heated crucible, the high alumina and low iron oxide and alkali contents are important for the stability of the crucible ceramic at casting temperatures (Freestone, 1989, p.159). The ceramic is lower in iron oxide and lime than the hearth fragment and the five pottery sherds and is clearly of non-local origin. The quality of the crucible ceramic is similar to one type of imported crucible refractory from Viking-age Hedeby (Merkel, 2016, p.213). The purpose of the applied layer that coats the interior of the crucible was to extend the use-life probably after a crack resulted in the loss of metal, or otherwise preemptively to prevent a loss of metal from occurring. The repair coating shows that the imported crucible ceramic was available in restricted quantities and was valued by the metallurgist.

Hearth Fragment Fd. Nr. 1032 (after Mückenberger, 2013)

Macroscopic Description: This ca. 5 x 3 x 3 cm piece of frothy bloated dark ceramic material appeared to have a two layered structure with green copper corrosion products. The corrosion products and the density of the object gave the impression that there may be metal inside. Upon sectioning, the two layered structure was confirmed and inclusions of copper alloy droplets could be found (Figure 5). These droplets range in color from reddish copper to paler copper-alloys. The ceramic is dark and frothy with a reddish-yellowish glassy surface between the layers. The largest metal inclusions are between the layers and appear to have coalesced upon the glassy surface.

Microscopic Description: There is a strong gradient from partially melted ceramic to fully vitrified glass. The less vitrified ceramic is made of a silty and coarse ceramic (Figure 6a) that consists of rounded to subrounded quartz, feldspars and mica usually under 100 µm in size. There are regions of glass and a layer of glass bisects the sample. This glassy region is bordered by metal inclusions that conform to its shape. There is evidence that the metal reacted with the glass at high temperature causing the formation of several metal oxide phases in the glass (Figure 6b). Glassy areas can contain tin oxide crystals, zinc silicates, bronze and copper prills and calcium silicates similar to diopside. The largest metal inclusions are tin bronze with ca. 8 percent tin and less than 2 percent lead. The microstructure of the bronze is not homogeneous and consists primarily of an alpha phase and between the alpha grains there is an alpha-delta infill with higher tin contents (Figure 6c). Droplets of unalloyed copper up to 2 mm in size could also be found. The copper has been exposed to oxygen during melting and upon crystallization, cuprite formed as a separate

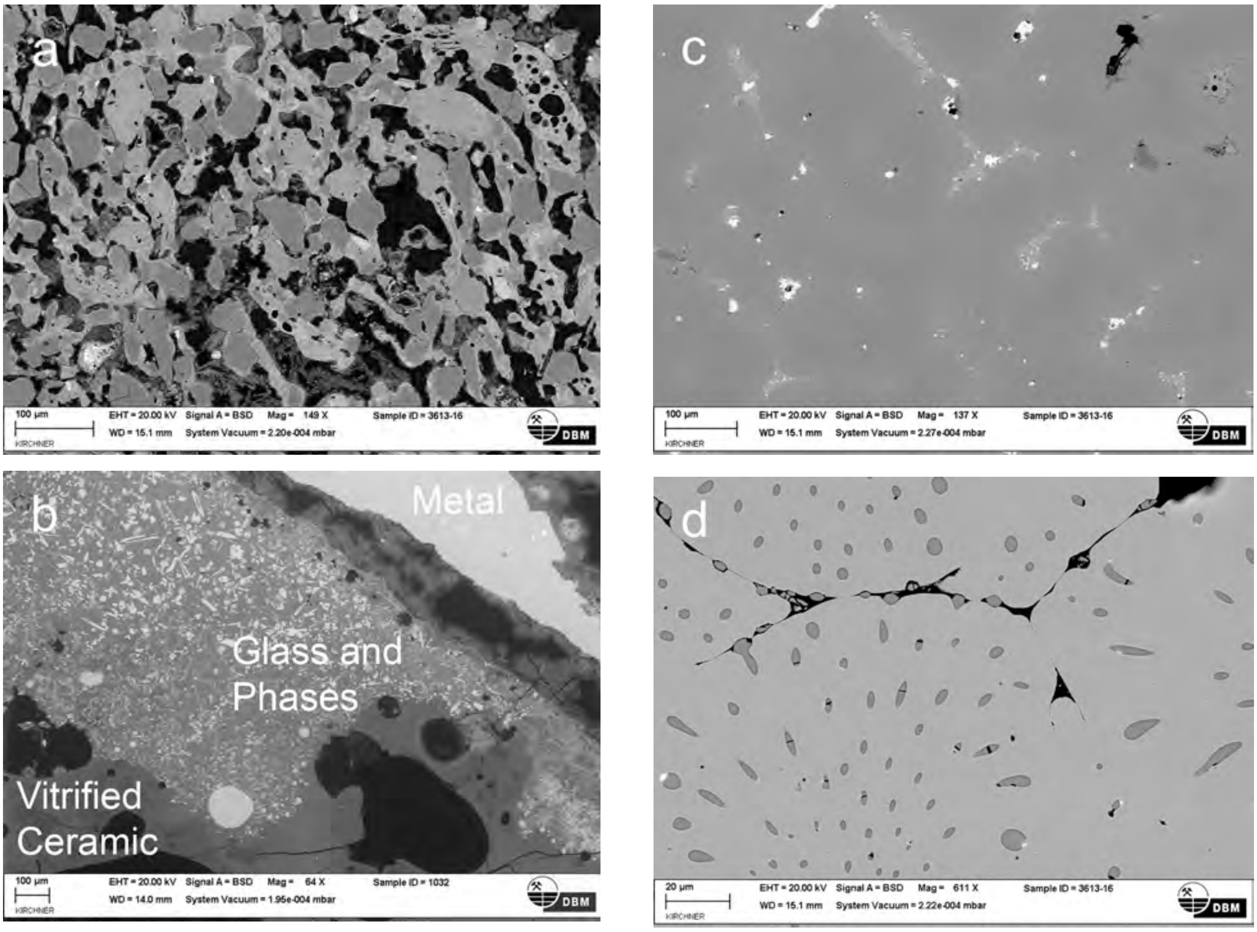

Figure 6: Hearth fragment Fd. Nr. 1032 SEM-backscatter images. a) Microstructure of the technical ceramic with abundant silt to fine sand-sized quartz, feldspars and micas held together by a network of glass. b) Glassy layer between ceramic and bronze metal. The tin oxide phases in the glassy layer show that there was a high temperature interaction with the bronze. c) Microstructure of bronze spill. Lead (white) is found at the grain boundaries along with regions of high tin (alpha+delta). d) Prill of copper with cuprite eutectic showing that the copper was in a liquid state.

eutectic phase (Figure 6d). Above the metal, there is a region of corrosion products of tin and copper followed by another layer of fired clay, again with a vitrification gradient with least vitrification near the glass and metal layer and increases outwards from this surface.

Interpretation: This frothy melted ceramic with a two layered structure with glass and metal in between can be interpreted as a fragment of a melting hearth that was relined with clay after it became vitrified. The gradient of the vitrifications shows that the glassy layer with the droplets of metal was at one time the bottom of a melting hearth that was exposed to elevated temperatures. The metal represents copper and bronze spills or crucible leaks and afterwards this metal was not recovered but instead the hearth was cleaned of ash and charcoal and a new layer of clay was added. The fact that such a large bronze droplet of several tens of grams was not recovered from the bottom of the hearth fits together with the general profligacy of copper-alloy scrap metal in the part of the site.

Raw Materials for Technical Ceramics

There are clear differences in the various raw materials used for the technical ceramics and the pottery. For the technical ceramics, three types of ceramic materials were used. The dish-shaped crucible made of extremely silty body is not particularly refractory but sufficed for its use as an open-faced crucible heated from above. Morphologically and compositionally, a similar material appears to have been used to coat the inside of crucible Fd. Nr. 3342. These appear to be locally acquired refractories. The hearth fragment is like these silty ceramics, but is notably coarser, richer in iron and therefore less refractory and was not likely specially selected.

The local produced technical ceramics do not appear to be same as the locally produced domestic pottery. The five sherds chosen for comparison were selected to represent the range of locally available clays, all of which can be described as being rich in silt. Under the microscope, Sherd 2, dated to the pre-Roman Iron Age, was made of a medium-coarse clay with a very large quantity of silt.

There are also many particles of mica and remains of plant material in the clay. Two sherds of the late Roman imperial period were made of a coarse clay, which contains very high amounts of silt and mica (Sherds 9 and 15). Occasionally, sand grains, accessory minerals as well as organic remains can be detected in the thin-sections. Furthermore, this clay can clearly be distinguished from the other analysed raw materials in the occurrence of diatoms. The other two potsherds of the Roman period were made of a sorted, fine clay with a large quantity of silt and mica (Sherds 11 and 13). As a natural component of this clay the thin-sections show significant amounts of very small plant remains. All of the five sherds analysed were tempered with crushed granite. The two sherds made of a fine-grained clay body were additionally tempered with sand (Sherds 11 and 13). In one case the addition of grog could also be proven (Sherd 15).

The microscopy and SEM-EDS bulk compositions of the five potsherds, more specifically the higher alumina to silica ratios and the higher iron contents, seems to indicate that the bodies used for pottery ceramics had a higher proportion of clay than the dish-shaped crucible (Fd. Nr. 410) and the repair layer in crucible Fd. Nr. 3342. The higher clay content in the pottery body may have been needed for the plasticity requirements of vessel production, whereas the bodies used for the open crucible and repair layer are lower in clay and higher in silt and fine sand, which makes for bodies that are neither very plastic nor sturdy, but because of the higher proportion of silica, it is more refractory than the potting bodies. It therefore appears that there was a conscious selection of locally available refractory materials by the metallurgist for crucibles.

The white-firing ceramic used for the cylindrical crucible is of non-local origin. Sources of white-firing refractory clay are not common and tend to be geologically associated with the *in-situ* weathering of acidic igneous intrusive rock or coal beds of the Carboniferous Period and thus the nearest sources of such clays to Elsfleth would be the Central European Mittelgebirge, a notable example being the Westerwald region of western Germany (Worrall, 1986, pp. 55-72).

From the archaeological evidence, not only did the metalworker(s) of Elsfleth-Hogenkamp have access to imported gold, silver and copper-based metals; crucible refractory, either as pre-made crucibles or clay, was brought to the settlement from a distant source. It is clear that the white-firing refractory was prized and not easily accessible, as it was repaired to extend its use-life. Although it cannot be proven at the state of present research, it is perhaps most rational to assume that the white-firing crucible material was imported rather than being brought to the settlement from its source by a migrant metalworking craftsperson.

Concerning the broader supply of raw materials for the metallurgy at Elsfleth, there are two levels to consider. The supply of metals to the site may be tied primarily to economic processes, i.e. use for exchange purposes, and part of this may have formed the basis of a recycling industry producing new objects. The importation of refractory ceramic is of an entirely different character: it was brought to the site for a particular purpose for a very specialized user. The metal supply is the most obvious prerequisite for metal recycling, but the supply of imported refractory materials reveals an underlying level of organization that has received little attention in the past. Whereas the non-ferrous metals could come from all over the Roman World and beyond and could have passed through numerous hands along the way, the imported refractory is a consumable product made and traded for a highly specialized market. Non-ferrous metalworkers were the solitary consumers of this material. This means that the non-ferrous metalworker(s) at Elsfleth was (were) connected to this long distance movement of refractory ceramic and that non-ferrous metallurgy at Elsfleth had such a significant status that specialized products like this were made available.

Metals and Metalworking at Elsfleth

Though this study is small and preliminary, some inferences can be made on the metalworking at Elsfleth. Until now the interpretation of the scrap metal concentration in the southwest part of the site was that this was the workshop debris for the reworking of copper-based metals with very few precious metal finds. The only two crucible fragments, however, reflect the melting of precious metals rather than copper alloys. This brings up a point that has been discussed by Unn Pedersen (2016, pp.191-192): the non-ferrous metal scrap found in workshops does not necessarily reflect the focus the metallurgy, but may be strongly influenced by the relative value of metals. A different picture is developed when technical ceramics are investigated. In the case of Viking-age Kaupang there is a great disparity between the metal finds and the traces of metals in/on the crucibles. The relative proportion of crucibles containing gold and silver is significantly higher than that found as scrap metal and casting waste, which is in turn much higher in copper alloys.

Thus, the discussion of recycling at Elsfleth is beginning to develop a more polymetallic character, which includes both base metals and precious metals. Although slag from ferrous metallurgy was also found in the layers along with the crucible fragments, it is currently unclear whether both ferrous and non-ferrous metallurgy were practiced in the same workshop or if they were simply practiced in close proximity and not necessarily at the same time or by the same individuals. Evidence for polytechnical metalworkers can be found at Warburg-Daseburg (Günther, 1990), and, at a small number of Roman Iron Age sites in southern Scandinavia, the combination of ferrous and non-ferrous metallurgy and even the working of precious metals has been recorded and the combination does not seem to be unusual (Axboe, 2012). Further excavations may reveal more evidence for the degree of metallurgical specialization at Elsfleth.

Conclusions

The study of three fragments of technical ceramic from Elsfleth attests to the melting of gold, silver, bronze and copper and has yielded new information about the selection and movement of refractory materials for metallurgical purposes. Concrete evidence for the melting and casting of gold and silver in Germanic settlements east of the Rhine/Limes is indeed rare: the finding of firm evidence of a goldsmith at Elsfleth increases the status of the settlement. However, many questions still remain concerning the function of the settlement in the Roman Iron Age and the role the metalworking industry played.

Concerning the metalworkers themselves, the gold-silver smith that worked at Elsfleth appear to have had specific knowledge of the local raw materials because silty silica-rich ceramic bodies were used for metallurgical refractories, which are dissimilar to the ceramic bodies used for the domestic pottery. Furthermore, the import of special refractories over long distances adds a layer of complexity to the organization of non-ferrous metallurgy at the site.

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Appendix

Some notes on phosphorus contents

There are major differences in the phosphate contents of the various ceramics. Phosphate contents can be extremely variable in archaeological ceramics. Contents above 0.5 wt. % are rare in soils, so the enrichment of phosphates above this amount in ceramics is thought to be from contamination from the burial environment (Freestone, Meeks and Middleton, 1985, p.161). Phosphate contents are highest in the pottery sherds and clay-bearing accretions on crucible Fd. Nr. 410, however, they are very low in the crucible ceramics. The analysis of the hearth fragment shows that in the more vitreous areas there is less phosphate while in the non-vitreous areas there is an enrichment of phosphate. The up-take of phosphate in the ceramics appears to be related to the amount of vitrification. The two crucible fragments are highly vitrified and the closed porosity and glassy texture may have prevented the accumulation of phosphates in the ceramic body (see Freestone, Meeks and Middleton, 1985, p.165).

On Monazite

All ceramics / loam of presumably local origin (Fd. Nr. 410 both in crucible ceramic and adhering clay-bearing accretions, the interior ceramic lining of Fd. Nr. 3342, hearth fragment Fd. Nr. 1032, and pottery sherd 09, they were not sought in the other pottery sherds), inclusions the phosphate mineral monazite were found. The inclusions tend to be smaller than 20 µm in size but can be up to 100 µm. They tend to be dominated by cerium with lesser lanthanum. The ratios of La : Ce vary from about 1 : 3.2 to 1 : 4.2. Occasionally thorium was detected, but was always in less quantites than lanthanum. In one example in the hearth fragment (Fd. Nr. 1032), a monazite rich in yttrium was found. Monazites are associated with granitic igneous rocks (Buxeda I Garrigós, Ontiveros and Kilikoglou 2003, pp.11-14), and the presence of silt-sized micas and feldspars identified in most of the ceramics and clay-bearing accretions helps to confirm the granitic origin of the material. None were identified in the white-firing crucible ceramic (Fd. Nr. 3342).

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