DANIEL BERGER

COMPOSITION AND DECORATION OF THE SO-CALLED *ZINNFIGURENSTREIFEN* FOUND IN MAGDEBURG, SAXONY-ANHALT, GERMANY

Magdeburg, the capital city of Saxony-Anhalt in Germany, was one of the largest and wealthiest cities in Central Europe during the High and Late Middle Ages. This wealth is predicated on political, religious and social frameworks, but also on beneficial developments in trade and artisanry. For instance, the famous *Magdeburger Gießhütte* (Magdeburg bronze foundry) is believed to have cast monumental bronzes, such as the tomb slabs of the archbishops Friedrich von Wettin and Wichmann von Seeburg in the Magdeburg cathedral or the gate of the cathedral of Novgorod (RUS). Furthermore, many small bronzes from all over Central Europe have been ascribed to this foundry in the last decades (Meyer 1959; Mende 1989).

Although many of their castings survived, it is not handed down in historical sources, nor is there archaeological evidence of where exactly the *Magdeburger Gießhütte* was located (Adam / Stoll / Wilde 1990). By contrast, it is well-known from the city chronicles that the local gold smithies concentrated north of the Magdeburg cathedral at the so-called Regierungsstraße and Goldschmiedebrücke respectively, two of the most important streets of the medieval town (Ditmar-Trauth 2012, 226-228). Besides these, Breiter Weg was the main street running south to north in order to connect the northern trade area and the southern palatinate and cathedral district (**fig. 1**).

In the vicinity of the goldsmithies, the remains of a pewter workshop was documented in 2005 at former Goldschmiedebrücke 7-8 (today Regierungsstraße 6; **fig. 1, 3**), which goes back to the first half of the 13th century. Nearly 500 limestone moulds once served for casting small secular pewter objects such as dress accessories (brooches, buckles, mounts), jewellery (fingerings, beads) or miniature figurines and tableware (Ditmar-Trauth in print). Although made from tin-lead alloys (Berger 2006; Berger in print a), many of these objects certainly imitated counterparts cast in precious metals. The discovery of an autonomous pewter workshop is the earliest known to date, and it is believed that the foundry supplied local as well as (inter)national markets. Thousands of items could have been produced under manufactory-like conditions.

Albeit survivals of the workshop suggest a flourishing pewter craft in medieval Magdeburg, only a couple of pewter items are preserved locally. One such artefact has been described by Ernst Nickel, a German archaeologist, in 1956 that he termed *Zinnfigurenstreifen*, literally »tin figurine stripe« (Nickel 1956). The flat object was found in the backfill of a medieval sewage pit in the old town of Magdeburg (**figs 1, 2; 2**)[1] where an archaeological excavation was carried out at Schwibbogen 9 (today a no longer existing street) in the early 1950s in the course of rebuilding after World War II. The pewter artefact consists of three equal parts with repeating sequences of different figurative motives connected by some kind of soft solder: On a narrow base there is a tree on the left side followed by an eagle struggling with a knight; nearby, an embracing couple and something that looks like a flower are arranged, supplemented by two mounted knights fighting against each other; each sequence is terminated by the silhouette of a castle on the right side of the stripe. This arrangement follows the illustration tradition of the 11th and 12th century AD in Central Europe (Krabath 2009d). The scene depicted in this

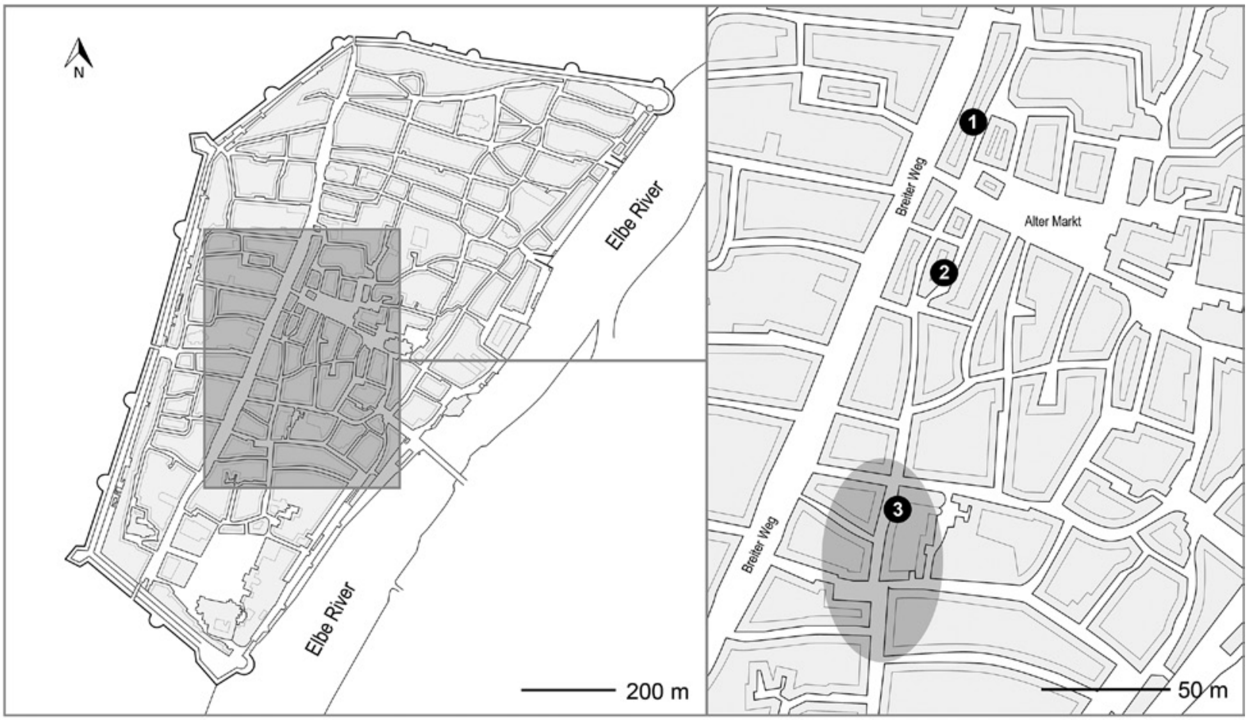

Fig. 1 Location of the find spots of the *Zinnfigurenstreifen* from Breiter Weg 23-26 (no. 1) and Schwibbogen 9 (no. 2) on an old map of Magdeburg from 1829. No. 3 is the finding place of the medieval pewter foundry at Goldschmiedebrücke 7-8 (Regierungsstraße 6) in whose vicinity several goldsmiths and the guild of the goldsmiths are documented along the Goldschmiedebrücke and Regierungsstraße (gray oval). – (Map D. Berger after Robolsky 1829).

Fig. 2 One of three matching parts of the *Zinnfigurenstreifen* from Schwibbogen 9. – (Photos Kulturhistorisches Museum Magdeburg, inv. no. 82:31).

Fig. 3 The *Zinnfigurenstreifen* from Breiter Weg with its damaged second part on the right-hand side. – (Photo D. Berger; collection Landesmuseum für Vorgeschichte Halle, Germany, inv. no. HK 2006:7174).

manner is presumably linked to the courtly love tradition, and some scholars even tried to connect the stripe with the legend of Percival or a tournament held in Magdeburg in 1279 (Nickel 1960; Sachs 1983; Nickel 1997; Puhle 2005, 106 f.). Moreover, the three pieces of the stripe have repeatedly been seen as the major part of a tournament crown or a coronet, but neither the presumed function nor their

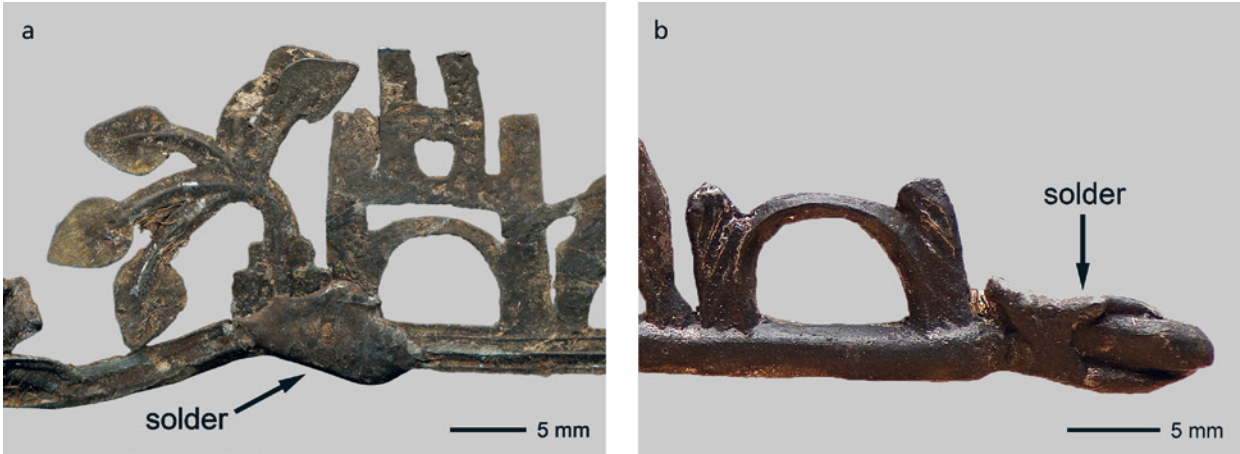

Fig. 4 Detail photographs of the soldered joints at the stripes from (**a**) Breiter Weg and (**b**) Schwibbogen. In **a** bracings on thinner object parts (tree branches) are visible on the reverse face. – (a Photo D. Berger; b Photo Kulturhistorisches Museum Magdeburg).

historical background could yet be clarified with certainty. However, because the elements of the stripe do not seem to have been bent, Krabath (2009d) explicitly rejects the function as a crown. He and others date the »tin figurine stripe« into the early 13th century, whereas Hucker (2006) suggests the end of the 12th century as a possible date due to stylistic and heraldic criteria.

As a surprise, another piece of such a tin stripe was unearthed in Magdeburg in 2005 at a distance of barely 75 m from the other finds. This object was found in a ditch at Breiter Weg and generally shows the same grouping of figurines, even though the largest part cannot be recorded entirely since the stripe is badly damaged and densely folded (**figs 1, 1; 3**). Moreover, the find seems to be broken and incomplete at its left end because some motives are missing (cf. **fig. 2**). Nevertheless, at least two matching pieces are reconstructable, as the soldered joint between the castle and the tree clearly demonstrates (**fig. 4a**). The three parts of the stripe from Schwibbogen 9, which perhaps originally comprised a fourth fitting piece, show soldering at the same position (cf. **fig. 4b**). Therefore and because they are worked flat, it seems plausible that both stripes once belonged to larger items on which they were mounted.

Below is a detailed presentation of the second tin stripe and a report on the hitherto unpublished metallurgical analysis which were carried out on the piece. In addition, the proposed decoration using some kind of surface treatment are also addressed in the study. The functional, stylistic and historical interpretation of the object, however, will be disregarded.

The *Zinnfigurenstreifen* from Breiter Weg

The *Zinnfigurenstreifen* from Breiter Weg in Magdeburg was recovered from a medieval ditch in fall 2005 during archaeological excavation at street numbers 23-26 and is now part of the collection of the Landesmuseum für Vorgeschichte Halle (Saale), Germany (inv. no. HK 2006:7174). The ditch could only be recorded in parts just beneath a road pavement from the 13th century AD, but plenty of fragments of pottery and glass vessels, as well as leather objects were found within the feature (no. 224). Moreover, the ditch contained an exceptional late Romanesque candlestick made from bronze. According to the dendrochronological analysis of a piece of wood and the pottery, the deposition of the finds, including the tin stripe, are dated into the first two quarters of the 13th century AD, which is in agreement with the stripe from Schwibbogen 9. This

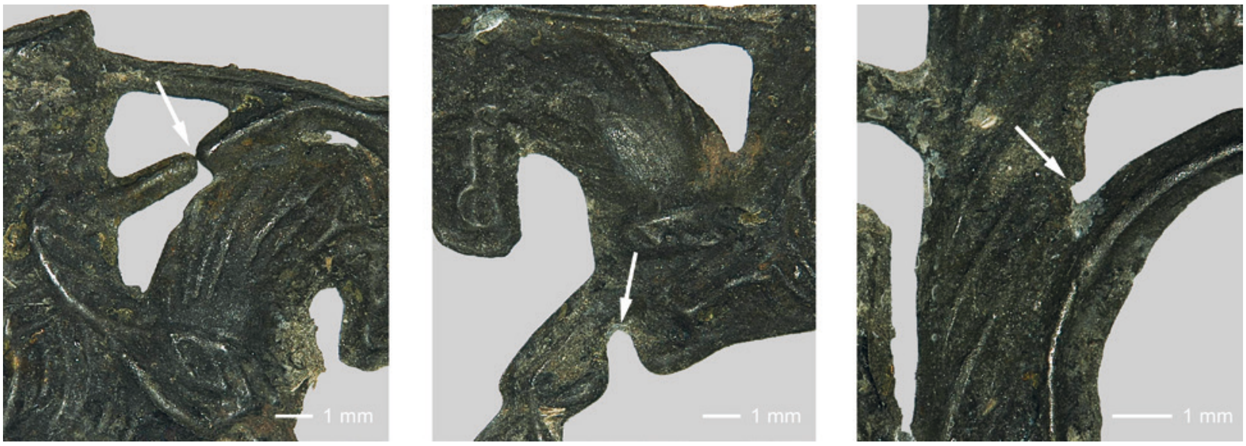

Fig. 5 Casting flaws (voids) at some positions on the stripe from Breiter Weg. – (Photos D. Berger).

is roughly contemporary with the moulds from the pewter workshop at Goldschmiedebrücke (Gildhoff 2006; 2009)[2].

The object under study measures approximately 125 mm in length and 22 mm in height, though its original length was probably about 200 mm. It has a dark brown coloured, rather smooth patina all over its surface that is interspersed by golden spots on some parts of the front and back faces. These golden regions gave reason to believe the object was gilded, and based on this, it was reconstructed as having a great cultural historic value (**fig. 3**; Gildhoff 2006). Irrespective of this controversial embellishment, the base and the detailed decorated figurines are just 0.5 to 1 mm thick, showing that the stripe is a very flat item just like the other tin stripe. Considering the soft tin metal, the object therefore could never have been an independently used commodity like the proposed tournament crown, since there was always danger of damage and distortion. It seems more reasonable that it was fitted onto a stable backing such as a wooden chest or sculpture.

Following the common production method of small medieval pewter objects (Berger 2012), the stripe must have been cast in a bivalve stone mould, which certainly consisted of almost identical pieces. Voids at some locations of the artefact show that the metal did not reach all parts, possibly due to an insufficiently preheated mould material (**fig. 5**). One piece of this mould carried the casting system and the cavity of the base and the figurines (from the tree to the castle) where all details were engraved with subtle tools. These details appear raised on the front face of the final stripe and also on most of other small medieval pewter finds, which is a general characteristic of these kind of objects. Deepened decoration made by chasing or chiselling rarely occur on small pewter pieces and are much more typical for objects made from precious metals or copper-base alloys.

The second piece of the mould presumably showed nothing but faint engravings at those positions where later bracings of sensitive object parts should appear (**fig. 4a**). Apart from this and the obligatory sprue, the back face of the stripe was left plain. Such a practice is also a characteristic for the main part of decorative medieval pewterware (Berger 2012). The mould which was used for casting the stripe surely resembled some stone moulds that were excavated from the above-mentioned high medieval pewter foundry in Magdeburg (**fig. 6**). They served for casting flat stripe-like items which are interpreted as segments for crowns (Brumme 2013).

It is unclear whether the two soldered parts of the stripe derived from a single mould or whether they came from different ones, as is the case for the stripe from Schwibbogen 9. All three parts of the latter show deviations in detail, so they were obviously

Fig. 6 Two limestone moulds from the complex from Goldschmiedebrücke 7-8 (Regierungsstraße 6) in Magdeburg showing concavities for casting flat figurative and floral stripes. – Dimensions upper mould: 161 mm × 66 mm × 23 mm; dimensions lower mould: 183 mm × 72 mm × 20 mm. – (Photo D. Berger; collection Landesmuseum für Vorgeschichte Halle, find nos 202 and 204).

cast in different moulds. This can further be transferred to the Breiter Weg stripe, which shows no direct relationship with the parts of the other stripe. This observation, together with the rather simple execution of the figurines and the utilised base metal are indications that the stripes were mass products for a larger clientele in Magdeburg and probably beyond. In this context, it is worth mentioning that a tin stripe with comparable figurines and scenes, as well as the same manufacturing features was excavated in Lund (Skåne län / S). A relationship between this object and Magdeburg was suggested repeatedly, but due to its earlier dating around 1100, this could not be made plausible until now (Holmberg 1976, 344-355; Krabath 2009a).

Metallurgical and chemical analysis

Tiny samples of the stripe and the solder from Breiter Weg could be extracted with a scalpel for elemental analysis of the metal. Sampling was necessary in this case because the surface is corroded,

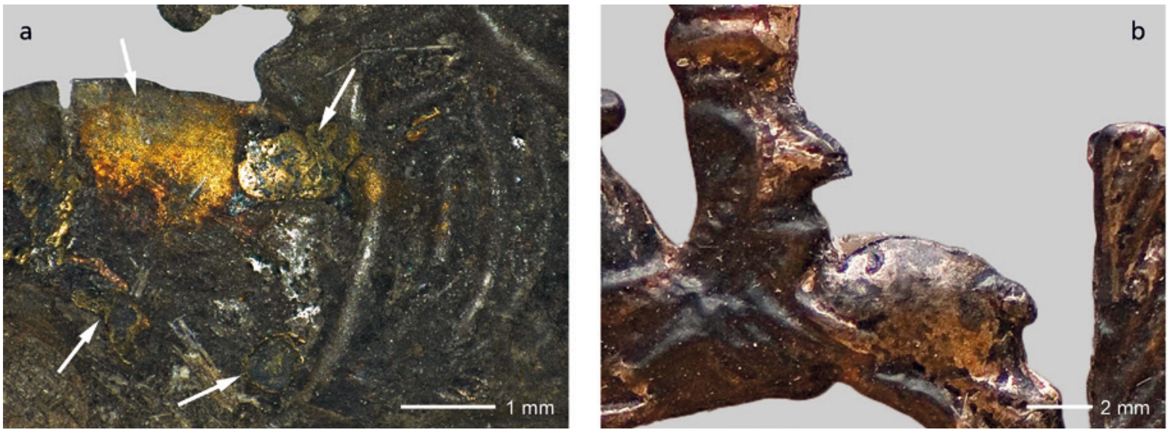

Fig. 7 Supposed gilding (arrows) on the dark coloured surfaces of the stripe from (**a**) Breiter Weg and (**b**) from Schwibbogen 9. On the Breiter Weg stripe the golden spots are sometimes covered with blue-black products. – (a Photo D. Berger; b Photo Kulturhistorisches Museum Magdeburg).

sample no.	object part	position	Al	Si	Fe	Cu	Sn	Pb
MA-092388	stripe, left part	bulk	n. d.	0.25 ± 0.08	0.73 ± 0.23	0.94 ± 0.24	63.3 ± 1.4	34.8 ± 1.1
		α solid solution	n. d.	n. d.	n. d.	n. d.	8.8 ± 3.3	91.2 ± 3.3
		β solid solution	n. d.	n. d.	n. d.	n. d.	95.6 ± 2.6	4.4 ± 2.6
MA-094110	stripe, right part (folded)	bulk	0.42 ± 0.26	0.03 ± 0.08	0.32 ± 0.51	0.63 ± 0.50	62.6 ± 2.8	36.0 ± 1.9
		α solid solution	n. d.	n. d.	n. d.	n. d.	2.6 ± 1.0	97.6 ± 1.0
		β solid solution	n. d.	n. d.	n. d.	n. d.	97.5 ± 8.0	2.5 ± 8.0
MA-092389	solder	bulk	0.22 ± 0.09	0.33 ± 0.32	0.46 ± 0.30	0.76 ± 0.21	61.1 ± 2.3	37.1 ± 1.6
		α solid solution	n. d.	n. d.	n. d.	n. d.	5.8 ± 4.2	94.2 ± 4.2
		β solid solution	n. d.	n. d.	n. d.	n. d.	97.0 ± 3.2	3.0 ± 3.2

Tab. 1 Semi-quantitative results of the chemical analyses of the three metal samples taken from the stripe from the Breiter Weg obtained by SEM-EDX. – Al = aluminium, Si = silicon, Fe = iron, Cu = copper, Sn = tin, Pb = lead, n. d. = element not detected. Values given in wt. %. – (Table D. Berger).

which would result in deviations from the original metal composition due to element enrichment or depletion (Figueiredo / Araujo 2005). The metal shavings were examined optically and also chemically with a scanning electron microscope equipped with an energy dispersive X-ray analyser (SEM-EDX) at the Curt-Engelhorn-Zentrum Archäometrie in Mannheim[3]. In addition, the whole stripe was put into the huge chamber of the SEM in order to check for surface and manufacturing details, especially the assumed gilding of the object (Puhle 2005, 106 f.; Gildhoff 2006). Such a surface decoration was also proposed for the stripe from Schwibbogen 9 (**fig. 7b**; Nickel 1966, 240; Hucker 2006), but this was never clarified by scientific analysis. For a better understanding of the true nature of the observed gold-coloured spots on the front and back face of the stripe from Breiter Weg, X-ray micro diffraction analysis (µXRD) was included in the study, which enables the detection of metals and alloys, as well as crystalline (corrosion) compounds. The µXRD analysis was carried out *in situ* with an X-ray micro diffractometer at the Landeskriminalamt Sachsen-Anhalt in Magdeburg[4].

Results and discussion

Table 1 presents the results of the elemental analyses from the three metal shavings shown in **figures 8a, 9a** and **10a**. Because of the standardless quanti-

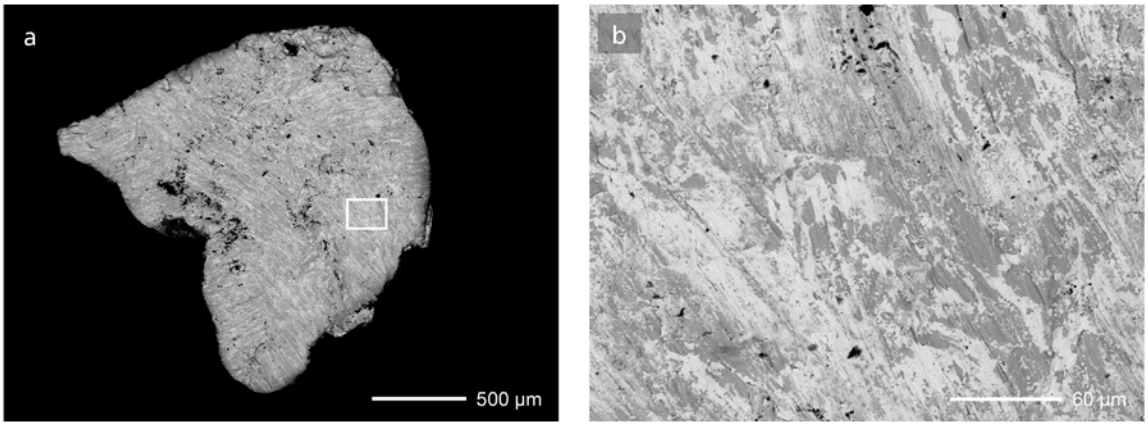

Fig. 8 SEM back scattered image (BSE) of metal sample MA-092388 from the first part of Breiter Weg stripe (**a**) and detailed view thereof (**b**) showing the eutectic structure of the tin-lead alloy. White areas are lead-rich α solid solutions, grey are β crystals. – (Images D. Berger).

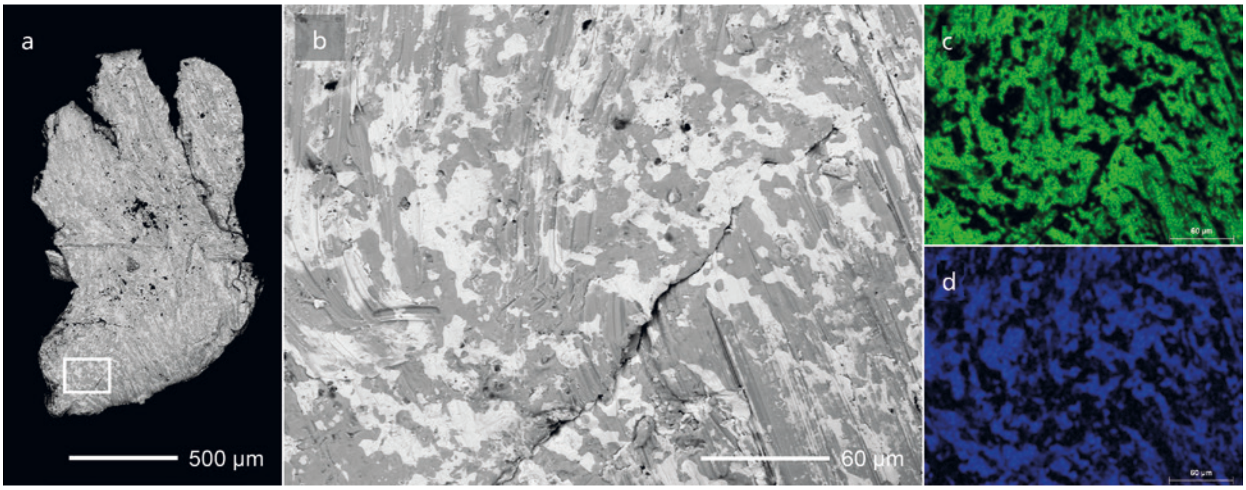

Fig. 9 SEM-BSE images of solder sample MA-092389 (**a, b**) and elemental distribution maps in false colours of (**c**) tin and (**d**) lead. – (Images D. Berger).

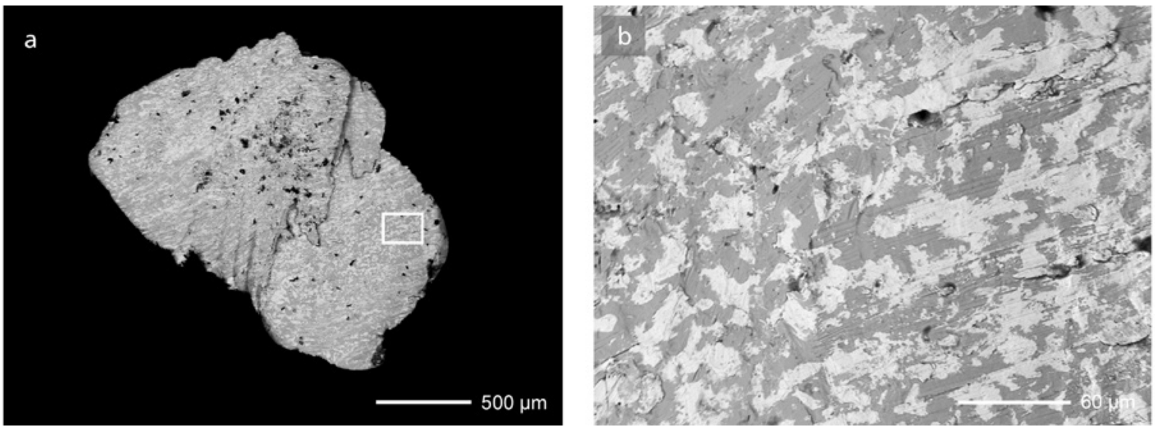

Fig. 10 SEM-BSE images of metal sample MA-094110 from the second part of the stripe and its microstructure. – (Images D. Berger).

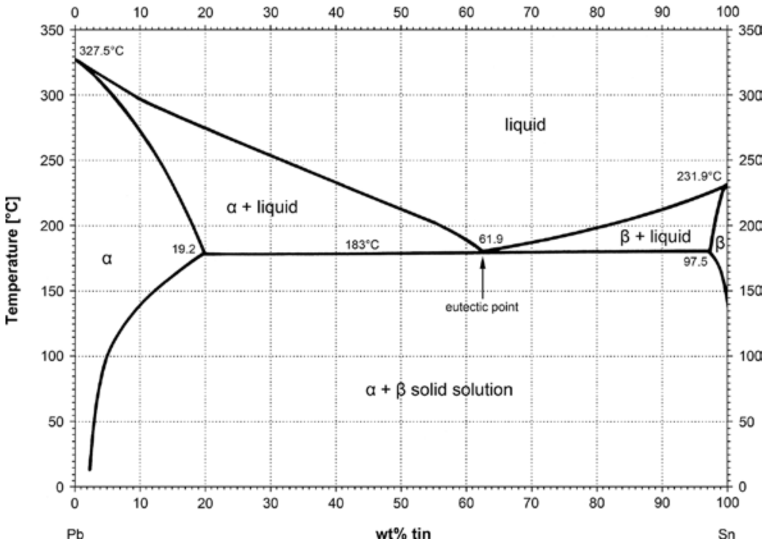

Fig. 11 Binary tin-lead phase diagram under equilibrium conditions. – (After Scott 1991, fig. 209a).

fication with SEM-EDX and the related analytical problems, the data are semi-quantitative but acceptable (Scheller/Salge/Terborg 2010; Bruker 2011). They are means of six area analyses in each case. Considering the standard deviations given after the ± of each value, the metals of the stripe and the solder are almost identical. They contain 61-63 wt.% tin (Sn) and 35-37 wt.% lead (Pb) as major components besides little copper (Cu) and iron (Fe) impurities. This composition is close to the so-called eutectic composition of binary tin-lead alloys (61.9 wt.% Sn, 38.1 wt.% Pb) which is characterised by the lowest possible melting temperature of 183 °C for this system (**fig. 11**; Hedges 1960, 335; Scott 1991, fig. 209a; Chattopadhyay/Srikanth 1994). Moreover, such alloys show a fine microscopic structure of α and β solid solution (i.e. eutectic) which is valid for the present case. **Figures 8b, 9b-d** and **10b** provide back scattered electron images of the samples' microstructures, together with elemental distribution maps demonstrating that lead and tin are localised in the distinct areas. Point analyses, however, prove that β crystals still contain 2-4 wt.% lead whereas lead-rich α crystals contain up to 12 wt.% tin (**tab. 1**). According to the idealised tin-lead phase diagram (i.e. equilibrium conditions; **fig. 11**), the solubility of each element within the other should be small or nearly zero at room temperature, so this observation probably indicates fast cooling after casting due to the use of the supposed insufficiently preheated stone mould. It is possible, however, that some lead and tin might have smeared over the surface during sampling, which could have distorted the results (cf. **fig. 8**). Some lead-free β crystals support this possibility, as do the large confidence intervals (**tab. 1**).

Based on EDX analyses, it was not possible to exactly localise the detected copper (0.7-0.9 wt.%), but due to its poor solubility in lead and better mixing behaviour with tin, it is expected that copper alloyed with the latter, presumably as the η phase (Cu_5Sn_6) of the copper-tin system (Scott 1991, fig. 212; Chattopadhyay/Srikanth 1994). This intermetallic phase often precipitates as tiny needles from the melt (cf. Berger in print a). Unfortunately, one cannot conclude from the composition whether copper is an intentional alloying component of the stripe and the solder or merely a natural impurity, e. g. from the lead ores. In contrast, iron can be regarded as an accidental trace element, since iron compounds are often associated with tin ores, and metallic iron is difficult to remove completely from tin, even up to the present day (Tafel/Wagenmann 1953, 268-272). Iron is in addition a common soil element that is easily introduced into the surface of metals, as is also the case for silicon (Si) and aluminium (Al). The de-

posi-tion	C	O	Na	Mg	Al	Si	P	S	K	Ca	Fe	Cu	Sn	Pb	suggested main phases
1	0.04	1.57	n.d.	n.d.	0.05	0.18	n.d.	33.1	0.24	0.27	27.3	37.2	n.d.	n.d.	chalcopyrite
2	1.58	1.58	n.d.	n.d.	n.d.	n.d.	n.d.	26.4	n.d.	n.d.	24.9	34.0	1.25	10.2	chalcopyrite
3	5.0	8.2	n.d.	0.10	0.06	0.11	n.d.	24.3	n.d.	n.d.	20.4	34.0	7.8	n.d.	chalcopyrite
4	0.13	4.7	n.d.	n.d.	0.07	0.28	0.10	28.3	0.58	0.82	26.5	38.6	n.d.	n.d.	chalcopyrite
5	0.69	0.60	n.d.	n.d.	n.d.	n.d.	n.d.	29.8	0.14	2.09	n.d.	66.2	0.48	n.d.	covellite
6	6.6	10.3	n.d.	n.d.	n.d.	n.d.	n.d.	11.7	n.d.	n.d.	2.39	0.79	6.5	61.7	galena
7	5.5	28.1	0.33	0.17	0.16	0.24	n.d.	17.5	n.d.	2.36	3.2	1.11	33.3	8.0	cassiterite + tin sulphide?
8	1.46	4.4	n.d.	n.d.	0.51	0.32	n.d.	30.5	0.30	n.d.	25.9	33.1	3.6	n.d.	chalcopyrite
9	4.8	17.3	n.d.	n.d.	0.04	0.15	0.33	6.6	n.d.	n.d.	1.09	1.71	21.9	46.0	galena + cassiterite?
10	2.37	5.1	0.04	n.d.	n.d.	n.d.	n.d.	25.5	n.d.	n.d.	18.4	37.5	11.1	n.d.	chalcopyrite + ?
11	1.38	1.70	n.d.	n.d.	n.d.	n.d.	n.d.	30.7	n.d.	0.02	23.0	41.1	2.04	n.d.	chalcopyrite
12	0.65	15.4	n.d.	n.d.	0.01	0.15	n.d.	22.8	0.27	0.25	17.1	43.4	n.d.	n.d.	chalcopyrite
13	1.83	2.95	n.d.	n.d.	n.d.	n.d.	n.d.	28.1	n.d.	n.d.	23.9	32.4	11.8	n.d.	chalcopyrite + tin sulphide?
14	5.3	24.1	n.d.	n.d.	0.02	n.d.	n.d.	n.d.	n.d.	n.d.	1.09	2.17	18.0	49.4	substrate + oxides?
15	n.d.	4.4	0.26	n.d.	0.19	0.12	0.28	28.9	n.d.	n.d.	20.2	36.0	9.8	n.d.	chalcopyrite + tin sulphide?
16	0.05	5.4	n.d.	n.d.	n.d.	0.56	n.d.	27.9	0.91	0.31	15.7	36.4	12.9	n.d.	chalcopyrite + tin sulphide?
17	2.82	23.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.35	2.77	32.7	37.3	substrate + oxides?

Tab. 2 Semi-quantitative results of the chemical analyses on the golden spots and the corrosion layer. – C = carbon, O = oxygen, Na = sodium, Mg = magnesium, Al = aluminium, Si = silicon, P = phosphorous, S = sulphur, K = potassium, Ca = calcium, Fe = iron, Cu = copper, Sn = tin, Pb = lead, n. d. = element not detected. Values given in wt. %. – (Table D. Berger).

tected concentration may therefore – at least partly – derive from contamination or corrosion.

The results of the chemical analyses of the golden shiny spots at the stripe's surface (cf. **fig. 4a**) are summarised in **table 2** and **figure 12**. Judging from the chemical analysis, the spots are rich in copper and iron and contain considerable amounts of sulphur (S). Gold or other precious metals could not be detected and, therefore, the stripe was not gilded as stated elsewhere (Gildhoff 2006). Rather, the golden coloured spots and also large parts of the corrosion layer turned out by µXRD to consist mainly of chalcopyrite ($CuFeS_2$) (**fig. 13**). This sulphidic iron-copper corrosion product is commonly found on archaeological copper-base objects from underwater sites or waterlogged soils where anaerobic conditions prevail (Scott 2002, 227-231). Since there is often confusion with deliberate gilding, it is also referred to as pseudo-gilding (Eggert/Kutzke 2002). Its occurrence on pewter artefacts is also not unusual and sometimes reported (Mitchiner/Skinner 1983; 1984; Duncan/Ganiaris 1987; Spencer 1998, 10; North/Spira 1999, 16f.), even though copper and especially iron are normally only trace elements in tin-lead alloys. The formation of copper-iron sulphides is therefore thought to be connected with iron and copper ions from the soil and sulphur hydrogen which arises from sulphate reducing bacteria (Scott 2002, 227). The sulphides precipitate on the surface of the pewter where other corrosion products can be found (North/MacLeod 1987; Duncan/Ganiaris 1987). On the present artefact, the presence of blue-black cupric sulphide (covellite, CuS) on top of chalcopyrite is suggested by chemical analysis (**fig. 12, point 5**), whereas galena (PbS), the most frequently occurring lead sulphide corrosion product, could be determined diffractometrically and chemically at other positions (**fig. 13; tab. 2**). Additionally, cassiterite (SnO_2) as the main oxidic corrosion product on tin and pewter has clearly been recognised and probably some (hexagonal) berndtite (SnS_2), a rarely occurring tin sulphide. The latter is, however, difficult to verify from the diffraction patterns shown in **figure 13** since some of its diffraction peaks overlap

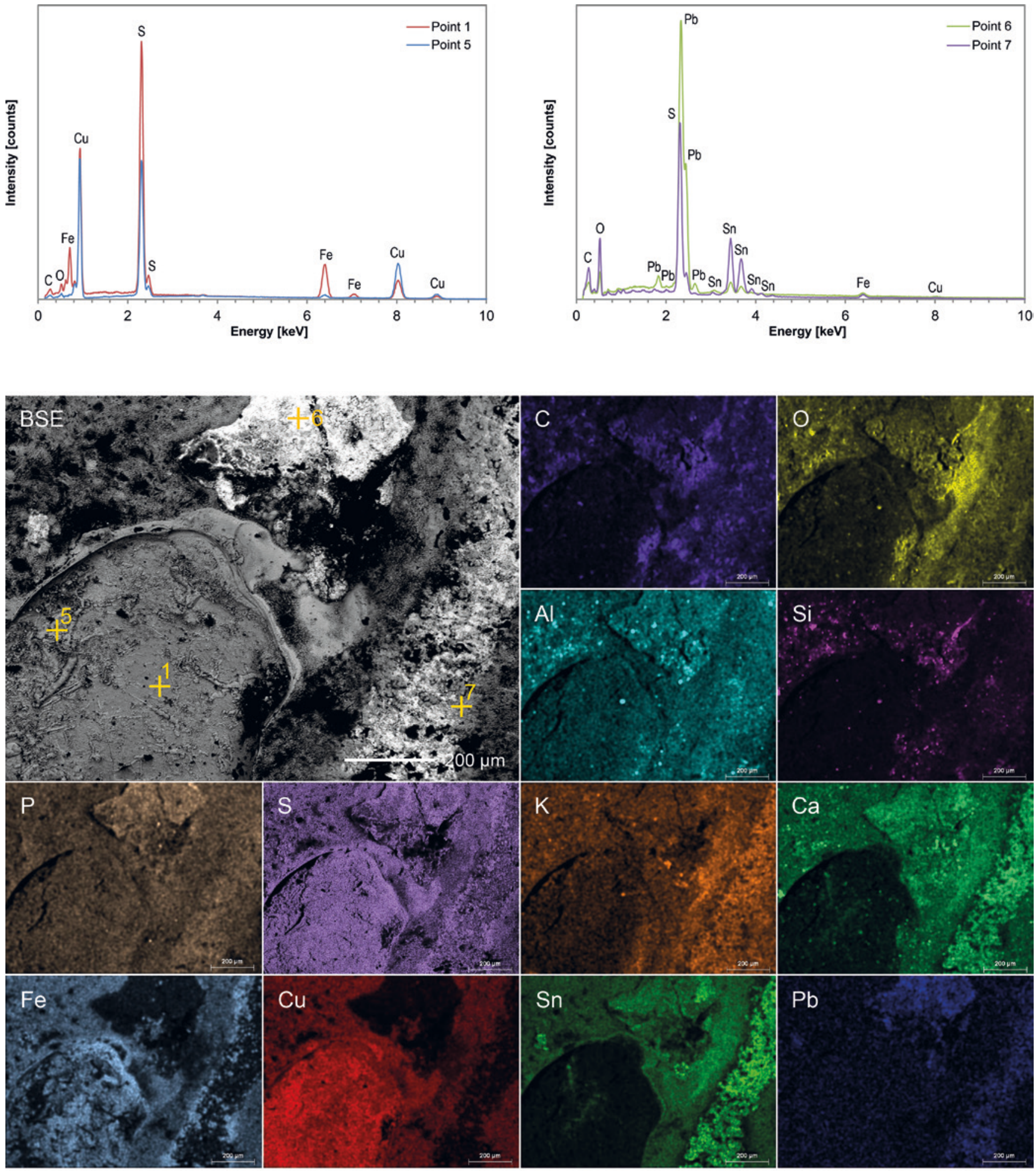

Fig. 12 SEM-BSE image of the corrosion layer and one golden spot covered with blue-black corrosion phases (bottom left) on the Breiter Weg stripe. Also given are X-ray spectra from four spot analyses marked in the BSE image as well as elemental distribution maps in false colours. – C = carbon, O = oxygen, Al = aluminium, Si = silicon, P = phosphorous, S = sulphur, K = potassium, Ca = calcium, Fe = iron, Cu = copper, Sn = tin, Pb = lead. – (Illustration D. Berger).

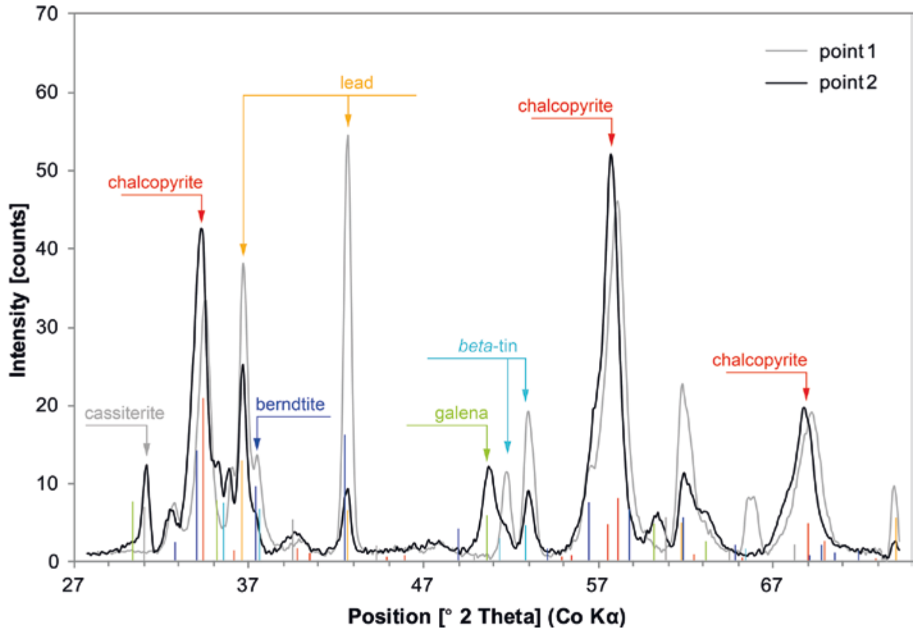

Fig. 13 X-ray diffractograms from two analyses at the surface of the Breiter Weg stripe showing peaks allocable to different corrosion phases, as well as tin and lead from the substrate. – (Illustration D. Berger).

with metallic lead and others are missing. Thus, metallic lead and also tin from the pewter substrate might be identified from the diffractograms. Summing up, the stripe looks back on a complex corrosion history, but compared with pure tin or lead-free pewter, it exhibits a fairly good preservation state with only a thin corrosion layer. This may be explained by reducing (anaerobic) conditions in the ditch on the one hand and with the lead's beneficial effect on tin corrosion resistance on the other, even at higher concentrations (North/MacLeod 1987).

Conclusions

The primary objective of this paper was to disclose the metallurgy and manufacture of the high medieval *Zinnfigurenstreifen* from Breiter Weg in Magdeburg, which was found in 2005. According to the chemical analyses, all three parts of the object were made from the same eutectic tin-lead alloy, nowadays commonly known as soft solder or as pewter. Whether the metal was derived from the same batch is difficult to say, as only semi-quantitative microanalysis of small samples was undertaken. Nevertheless, regarding its composition, the prevalent term *Zinnfigurenstreifen* (tin figurine stripe) now seems no longer appropriate, since the artefact was not made from pure tin. The same conclusion could probably apply to the contemporary stripe from Schwibbogen 9, although this piece was made from another metal batch containing distinctly more tin with only 7.8 wt.% lead[5].

For the stripe from Breiter Weg the craftsman used an alloy with a very low melting point, which he certainly deliberately chose in order to minimise the casting effort and to maximise the profit. The price of lead between AD 1200 and 1400 was only a quarter to a sixth of that of tin (Spencer 1998, 11; Blanchard 2005, 1451-1494 fig. 9, 1; 1525-1539 fig. 11, 1), so many pewterers tried to adulterate tin with as much lead as possible for maximum profit. This is reflected by metal analyses of several pewter items of the 13th and 14th centuries from Germany, Poland or the Netherlands which are high in lead almost throughout, often exhibiting an eutectic composition (**fig. 14a**). Not until the pewter guilds fully controlled and restricted the pewter production by ordinances from the 14th century onwards, the lead content in pewterware decreased, at least in Great Britain (Homer 2001)[6]. By the late Middle Ages and the Early Post-Medieval period the lead content in English pewter had declined considerably,

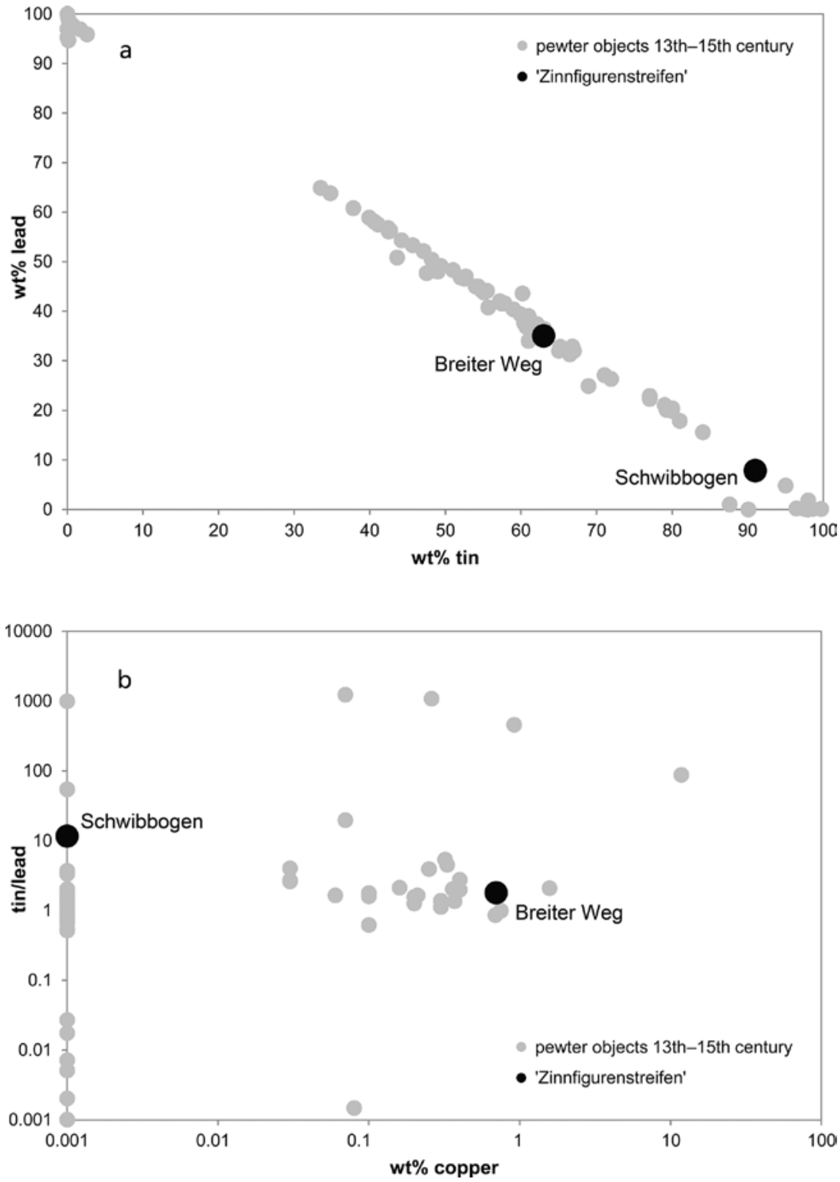

Fig. 14 **a** tin and lead contents of the two pewter stripes from Magdeburg in comparison with the composition of Central European pewter (lead) objects ranging from the 13th to the 15th century. – **b** shows their copper contents; in this diagram 0.001 wt.% is only a fictitious value for plotting the data on logarithmic scale, copper amounts to detection limit in all these cases (data taken from van Beuningen / Koldeweij 1993, 23; Schanz 2011; Berger 2013; Miazga 2014 and from further analyses of the author). – (Illustrations D. Berger).

obviously due to the strict regulations of the pewter guilds (Dungworth / Egan 2005). It is, however, also demonstrated from analyses that especially pilgrim badges retained a high percentage in lead. The majority of these religious souvenirs are still made from eutectic pewter in the 14th to the 16th centuries, which is in opposition to the low or missing lead content, for example in tableware (Brownsword / Pitt 1984; 1990; Mitchiner 1986, 12; Spencer 1998, 10-13; Dungworth / Egan 2005, 323 f.).

It is not clear from previously conducted metallurgical analyses if the development in Germany or Central Europe took the same path. But according to historical sources three types of pewter are known from 14th century onwards: *lautere Zinn* (engl. fine pewter) with only some copper besides tin, *Probezinn* (engl. lay pewter) with up to 17 wt.% lead, *geringe Zinn* (engl. inferior pewter) with equal parts of tin and lead in the worst case (Haedeke 1973, 10). The first two types should have officially prevailed whereas the latter conjecturally played only a minor role. It is very likely that the guild's ordinances were not always obeyed correctly and some fraudulent pewterers tried to circumvent them to their own advantage. To obtain more information about this issue, more metal analyses of German and other continental European pewter are urgently needed.

Turning back to the pewter stripe from the Breiter Weg in Magdeburg, the lead content seems to be characteristically high and absolutely legal for the period of the 12th/13th century AD. No guild control existed at that time (first German guild was Nuremberg 1285). From Theophilus Presbyter, a German monk who had written a treatise of the goldsmith's art around AD 1100, we come to know that two parts of tin (i.e. 66 wt.%) were commonly alloyed with one part of lead (i.e. 33 wt.%) (Brepohl 1987, chapter 89). The resulting (eutectic) solder should be used for joining different metal parts. The same recipe is written down in the early to high medieval manuscript *Mappae Clavicula* which earmarks the solder for a similar function (Smith / Hawthorne 1974, chapter 122-A). Considering that in this time up to mid 13th century diversification in Central European handcraft was not developed to the same degree as in the Late Middle Ages and pewter production was often performed by goldsmiths without guild control, it appears possible that the named recipes represent a typical and widely accepted composition not only for solders, but also for all kinds of pewter objects, such as the investigated stripe. Yet, this hypothesis needs verification by metallurgical analyses, not least because Theophilus also mentions the use of tin alloy with little mercury for production of vessels (Brepohl 1987, 29 and chapter 88). Such an alloy has not been recognised hitherto.

From the metallurgical viewpoint it is not clear at all why the craftsman used the same alloy for the joint and the two separate parts of the stripe. Normally, the melting point of joined metal pieces should be higher than that of the solder; otherwise there was danger of fusion and destabilisation of the object. Of course, the detected low copper content (around 0.7 wt.%) would slightly raise the melting temperature of the stripe's tin-lead alloy (Oettel / Schumann 2011, tabs 6. 17), but since copper is also present in the solder, this effect is put into perspective. Furthermore, it is not even clear if copper was an intentional addition to the pewter by the craftsman: At the current state of research hardly anything is known about deliberate alloying of tin with little copper from the early centuries of the 2nd millennium (until 1300), especially from Central Europe. Both Theophilus and the *Mappae Clavicula* do not report on such practices and also the hitherto available analyses do not substantially corroborate this point (**fig. 14b**). Yet, looking at later periods, copper was sometimes intentionally alloyed to tin-lead and more often to pure tin primarily with the aim to enhance the hardness of the soft metal (Mitchiner / Skinner 1984, 86; Brownsword / Pitt 1990; Spencer 1998, 11; Dungworth / Egan 2005). It would be interesting to know when copper was first introduced into pewter metallurgy, but this once more requires comprehensive metal analyses all over Central Europe and, if necessary, beyond.

Another important result is the observation that the stripe from Breiter Weg was not gilded as formerly postulated. The remains with golden appearance on its surface mainly consist of chalcopyrite that – aside other sulphidic compounds – is merely the result of natural corrosion processes under reducing conditions. Accordingly, the stripe's surface once appeared silvery and not golden, which may also be true for the stripe from Schwibbogen 9, as well as the main part of archaeological pewter objects that possess comparable surface colours (cf. Berger 2012, 52 f.). Considering this point, the pewter stripes from Magdeburg will not have had the social relevance as it was yet believed, although the depicted scenes still hold important historical information. Moreover, both stripes manifest the long tradition of pewter craft and history of mass-produced pewter objects in Magdeburg. They add to a large number of pewter craft remains from all over the old town to which, however, they cannot be linked without problems (Köther 2009; Krabath 2009b; 2009c; Ditmar-Trauth 2012; Ditmar-Trauth in print, fig. 13; Berger in print b). In particular, their relationship to the moulds and the associated high medieval pewter workshop from nearby Goldschmiedebrücke is still not clear, even though lead-rich and apparently eutectic tin-lead alloys were also utilised there (Berger in print a). Desirably, more analytical research on material from Magdeburg, Germany and entire Europe should be carried out in future in order to establish a better understanding of the medieval pewter craft, its development and organisation. Of special interest are for instance the resources of tin that appear as significant requirement for developing specialised tin founders: By the 12th and 13th centuries, new tin resources of the Erzgebirge were opened up, providing cheaper tin than Cornwall and Devon (the major sources until then; Wilsdorf et al. 1988). It could be promising to follow this important change by analysing tin isotope ratios and trace elements that would perhaps allow connection of metals and ores and reconstruction of tin supply.

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Notes

1) An image of the whole stripe from Schwibbogen 9 can be found in Puhle 2005, 106-107 or Krabath 2009d.
2) See also the documentation of the excavation carried out by C. Gildhoff, Landesmuseum für Vorgeschichte, Halle (Saale), Germany; excavation no. 780, D640.
3) For the analyses a scanning electron microscope from Carl Zeiss AG, device type EVO MA25, with energy dispersive X-ray micro spectrometry from Bruker AXS, device type Quantax 400, was used. Parameters and specifications: (SEM) tungsten filament, 20-25 kV, high vacuum (10^{-5} Pa), no carbon coating, SE and BSE detectors, variable operating distance, software: SmartSEM V05.03.05; (EDX) silicon drift detector, 100-250 s measuring time (mapping: 3600 s), standardless quantification, software: Esprit 1.8.2.2167.
4) For the XRD analyses an X-ray micro diffractometer from Bruker AXS, type D8 Discover GADDS, was used. Parameters and specifications: X-ray tube with cobalt anode, 30 kV, 40 mA, graphite monochromator, monocapillary with 300 µm pinhole collimator, 2D-Hi Star-detector, *in situ* analysis, 300 s measuring time, software: X'Pert HighScore Plus, PANalytical BV, PDF 2 database.
5) A metallurgical analysis from the 1950s yielded 91.62 wt.% tin, 7.84 wt.% lead, 0.42 wt.% iron, 0.13 wt.% aluminium and traces of bismuth, cf. Nickel 1956.
6) There are much more analyses on medieval and post-medieval British than on continental European pewter (e.g. Mitchiner/Skinner 1983; 1984; Mitchiner 1986; Brownsword/Pitt 1990; Spencer 1998; Heyworth 2002; Dungworth/Egan 2005; Wang 2005).

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Zusammenfassung / Summary

Zusammensetzung und Verzierung der sogenannten Zinnfigurenstreifen aus Magdeburg

Archäologische und archäometallurgische Untersuchungen der letzten Jahre konnten zeigen, dass Magdeburg im hohen und späten Mittelalter eines der bedeutendsten Zentren für den Zinnguss in Europa war. Anlass zu dieser Aussage geben die Funde hunderter Steingießformen, doch auch einige Weißmetallfunde tragen dazu bei. In diesem Beitrag werden die Ergebnisse der naturwissenschaftlichen und metallurgischen Untersuchung eines dieser Weißmetallobjekte erläutert, um damit seine Metallzusammensetzung und Herstellungsgeschichte zu rekonstruieren. Derartige Betrachtungen wurden besonders im deutschen Raum bislang oft vernachlässigt, sodass nur wenige Erkenntnisse zur Metallurgie mittelalterlicher Weißmetallobjekte existieren.

Composition and decoration of the so-called *Zinnfigurenstreifen* found in Magdeburg

Archaeological and archaeometallurgical investigations in the last years have shown that Magdeburg in Saxony-Anhalt, Germany, was an important centre for pewter casting during the High and Late Middle Ages. This is mainly based on hundreds of stone moulds, but apart from that, some evidence of medieval pewter artefacts has survived. It is the aim of the following paper to examine one of this pewter objects by means of scientific and metallurgical analyses in order to give an understanding of its metallurgical composition, manufacture and decoration. Until now such considerations are rare, especially concerning German medieval pewterware.

Keywords

pewter / tin-lead alloy / metallurgical analysis /
High Middle Ages / medieval Magdeburg /
scanning electron microscopy / archaeometallurgy