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ANALYSIS OF THE NOTCHES OF ANCIENT SERRATED DENARS*

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A number of serrated silver denars of the Roman Republic and a Greek bronze coin were investigated, paying special attention to the notches, in order to reveal their production technique. Particular interest was devoted to three contemporary forgeries of serrated denars, because the official pure silver issues were also available for inspection. Several microbeam analytical techniques were applied, such as scanning electron microscopy (SEM), electron probe micro-analysis (EPMA) and secondary ion mass spectrometry (SIMS). The surfaces of the notches, which show traces of the tools used, were investigated by SEM. In the case of the forged coins, the thickness of the silver layer (inside the notches as well as on the surface of the coin) was determined by SEM and SIMS. The main components of the surfaces were similar in both cases as measured by EPMA. Combining the results, it is possible to reconstruct the steps in the production of the serrated denars. The investigations also permit a review of different opinions about the purpose of the notches.

KEYWORDS: ROMAN COINS, SILVER, FORGERIES, SEM, EPMA, SIMS

INTRODUCTION

Soon after the introduction of the Roman silver denar (from ~211 BC onwards), a specially shaped coin was produced that exhibited serrated edges (from ~209 BC). This remained a common practice until ~78 BC. However, neither the manufacturing process nor the purpose of the notches have so far been clarified. Different opinions exist and are the subject of lively discussions. Irregular spacings between the notches, as well as varying contours and depths of the notches, provide evidence of handicraft. Due to the coin being mass-produced, the manufacturing process of the notches had to be rapidly realizable. For clarification of these issues, contemporary forgeries of the serrati are of special interest. As shown in previous work (Kraft *et al*. 2004), the forged serrati were manufactured by foil silvering a base metal core, creating a silver layer of ~100 μm in thickness, a typical value for this technique (Moesta and Franke 1995). The surfaces of the notches have not been scrutinized. Bahrfeldt (1904) even suggested the absence of any silver coating. Otherwise, the skills required to forge serrated edges would have increased markedly. The aim of this analysis is to clarify the manufacturing process of the serrati and to discuss the probable purpose of the notches.

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Figure 1 *Six of the investigated coins (for details, see text). The diameter of the coins is ~2 cm.*

MATERIALS AND METHODS

The investigated samples were as follows:
(1) C. Mamilius Limetanus denarius serratus, about 82 BC, Roman pure silver coin, for reasons of comparison;
(2) C. Mamilius Limetanus denarius serratus, about 82 BC, forged;
(3) C. Sulpicius Galba denarius serratus, about 106 BC, forged;
(4) C. Poblicius denarius serratus, about 80 BC, forged;
(5) Antiochos VI Dionysos, serrated, genuine bronze, about 145 BC;
(6) Q. Antonius Balbus denarius serratus, about 83 BC, pure silver coin.

In what follows, the samples will be referred to as 'coin 1' and so on, according to the list given above. Figure 1 shows the obverses of coins 1–6.

For the investigation of the surface morphologies, the high-resolution Philips FEG-XL30 SEM was used. The system is equipped with a backscattered electron detection system (BSE) that permits a display of the atomic number contrasts of the investigated areas. By tilting the sample, it is possible to change the angle of examination, allowing a direct view into several notches simultaneously. The images were measured with accelerating voltages in the range 10–30 kV.

In addition to SEM and EPMA (both non-destructive electron beam methods), an ion beam technique was applied (SIMS). This mass spectrometric method allows the acquisition of depth profiles, which show element intensities versus measurement time and depth. For this purpose, coin 2 had to be fragmented, to make the faces of the notches accessible for the investigations.

SIMS was applied to survey the thickness of the silver layer in the notches of coin 2. For this purpose, a Cameca ims 5f instrument (Cameca, Paris, France) was used. The depth profiling was performed with oxygen primary ions (O_2^+) and an accelerating voltage of 8 kV for detecting positive secondary ions. The crater dimensions were $(300\ \mu m)^2$, and for the measurement the inner area of 60 μm diameter was used. The crater depth was determined using a profilometer (Dektak IIa).

The metal components of the surfaces (obverses) of coins 1 and 2, as well as of the silver faces in the notches, were quantified by EPMA. After the SIMS measurement, element distribution images of a notch fragment of coin 2 were recorded in the vicinity of the SIMS crater to ensure that the copper core was reached. The EPMA equipment used was a Camebax SX 50 (Cameca, Paris, France) with four wavelength-dispersive X-ray spectrometers (WDX). The measurements were performed at a 20 kV accelerating voltage and a beam current of 40 nA.

RESULTS

The investigations by SEM provided evidence that the notches of contemporary forged serrati also have a silver coating. The backscatter electron micrograph of Figure 2 indicates, due to

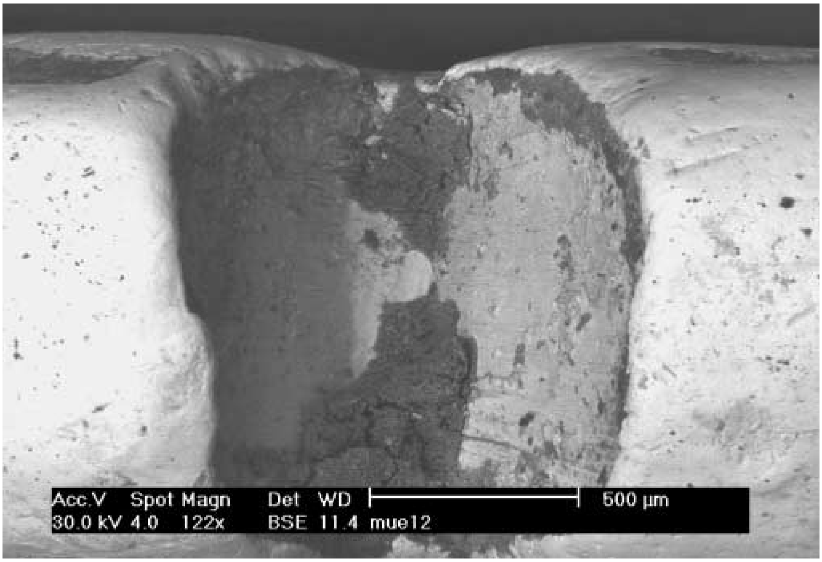

Figure 2 *A backscatter electron micrograph, generated by SEM, of a notch area of coin 3.*

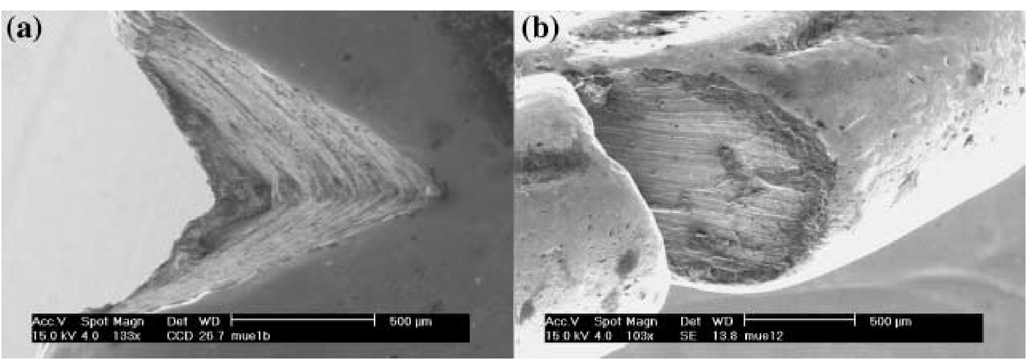

Figure 3 *SE micrographs by SEM: (a) coin 1, pure silver coin; (b) coin 3, forged.*

the nearly identical brightness values on the obverse and the surface of the notches, that these areas have no differences in atomic number; slight variations of intensities can be attributed to geometric effects. Comparing the notches of forged and pure silver coins, it is obvious that they exhibit the same characteristic appearance. The remaining traces of processing are oriented vertically into the notches (Fig. 3). Another characteristic of all notches is an overlap of silver into the notches (Figs 2 and 3).

Several fragments of coin 2 were generated by sawing (Fig. 4 (a)) to enable further investigation of the notches. The silver layers in the notches were considerably thinner than 100 µm (Fig. 4 (b)), as found on the obverse sides. The depth profile measured by SIMS (Fig. 5) suggests that the thickness of the silver layer is ~5 µm. The intensities of surface contaminants such as sodium or carbon decrease after ablating the outer surface area. However, it should be

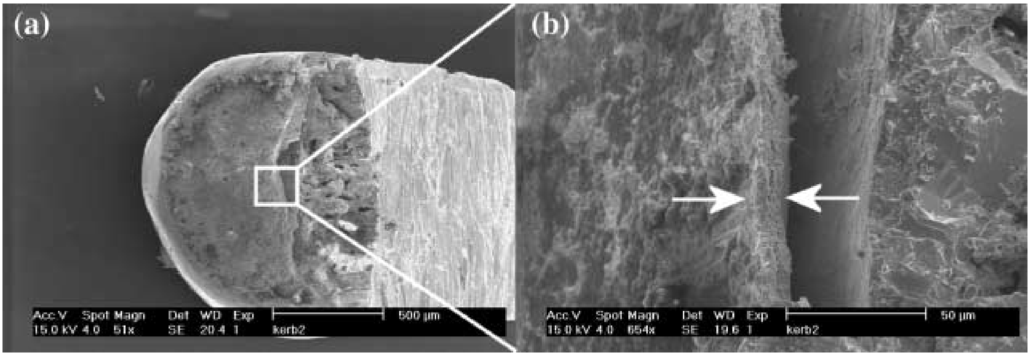

Figure 4 *BSE micrographs by SEM: (a) a fragment of coin 2; (b) the silver layer in the notch.*

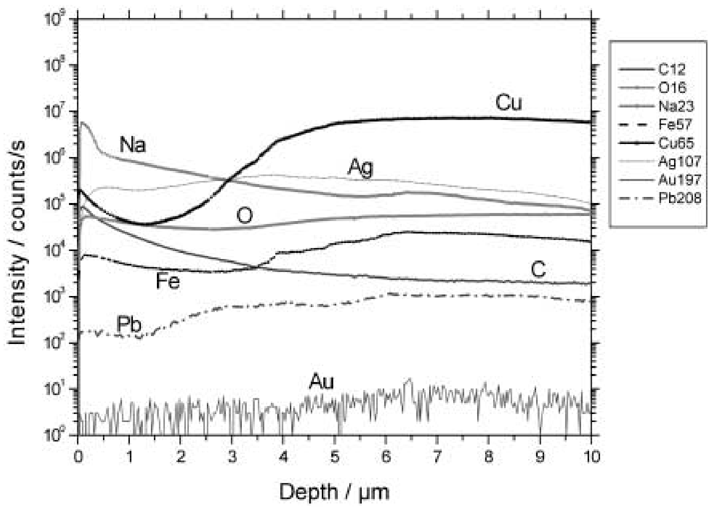

Figure 5 *A depth profile through the silver layer of coin 2: primary ions O_2^+, 8 kV, 220 nA, crater (300 μm)^2.*

noted that the intensity of an element signal does not only depend on the concentration, but is also influenced by the presence of other elements. Thus, the intensity of the copper signal decreases at first due to higher amounts of the mentioned contaminants on the outer surface. Upon reaching the copper core, the intensity of copper increases by about two orders of magnitude. The EPMA images (Figs 6 (a)–(c)) show explicitly the lateral distribution of silver, copper and oxygen in this order. The higher intensities of the copper distribution image inside the SIMS crater demonstrate that the copper core was reached after the SIMS measurement. Figure 6 (d) is a backscatter electron micrograph showing the atomic number contrasts of the silver layer and the copper core.

Table 1 shows the results of the EPMA/WDX measurements of the surfaces (obverses) of coins 1 and 2 and the quantitative composition of the silver face in a notch of coin 2. The compositions of the silver surfaces show no significant differences.

The silver cover of coin 3 is damaged in several places, both on the obverse and in the notches, which allow thickness measurements. The one area of damage on the obverse was

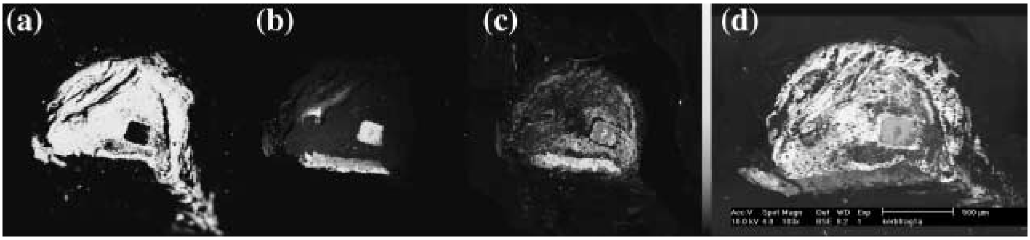

Figure 6 *A notch of coin 2 after SIMS measurement (square crater), (a)–(c) Element distribution images of silver (a), copper (b) and oxygen (c) by EPMA/WDX: 20 kV, 40 nA. (d) A backscatter electron micrograph by SEM: 10 kV, magnification ×103.*

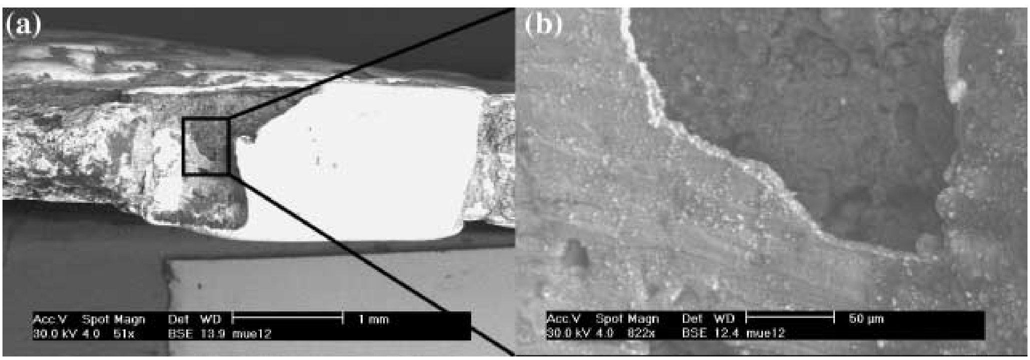

Figure 7 *BSE micrographs of coin 3 by SEM: (a) the damaged edge of a notch; (b) a defect with a sharp tear-off.*

~80 µm deep (Kraft *et al.* 2004). The thickness of the silver layer in the notches was accessible due to a sharp tear-off (Fig. 7) and an area that showed a crack (Fig. 8). In both cases, the layers were about 5–10 µm thick.

DISCUSSION

Contrary to the suggestion by Bahrfeldt (1904), the notches of contemporary forgeries of serrated denars have a silver covering. Therefore the question arose as to whether different silvering techniques had been used for the obverses and the notches. The same characteristic appearance of the notches of forged and pure silver coins proves that the same technique was applied in their production. The vertical direction of the processing traces indicates that the notches cannot have been produced by filing or sawing but, rather, by striking—otherwise, horizontal working marks would have remained. Besides, all of the serrated denars exhibit an overlapping of silver from the obverses into the notches, which provides evidence that the notches were manufactured before the embossing procedure. Prior to this last working step from the blank to the final coin, the blank was heated to just below the melting point so that it became ductile (to be able to fill the stamp details adequately). Due to the pressure that was applied during embossing, the silver overlaps into the notches.

As the composition of the silver layer in the notches of forged coins shows no significant difference compared to that of the obverses, it is assumed that no separate plating technique,

Table 1 *Concentrations (wt%) of selected components of the pure (top) and the plated (middle) C. Mamilius Limetanus denarius serratus on the obverses and in the plated notches (bottom), measured by EPMA/WDX: the arithmetic mean and the standard deviation are tabulated for n = 10 measurements, x ± 1 s.d.; –, below the significance level*

	Ag	*Cu*	*Si*	*Pb*	*Fe*	*Sn*	*Au*	*Hg*	*As*
Silver obverse of coin 1	98.2 ± 0.8	0.3 ± 0.1	0.16 ± 0.1	0.8 ± 0.8	–	–	0.4 ± 0.2	0.27 ± 0.2	0.12 ± 0.08
Silver layer, obverse of coin 2	94.2 ± 3.3	3.0 ± 0.5	0.3 ± 0.2	1.7 ± 1.3	0.04 ± 0.02	0.04 ± 0.05	0.5 ± 0.13	0.3 ± 0.2	0.12 ± 0.1
Silver layer in the notch of coin 2	91.99 ± 0.89	4.77 ± 0.58	1.22 ± 0.72	1.34 ± 0.42	0.013 ± 0.01	0.09 ± 0.04	0.43 ± 0.16	0.02 ± 0.01	0.11 ± 0.05

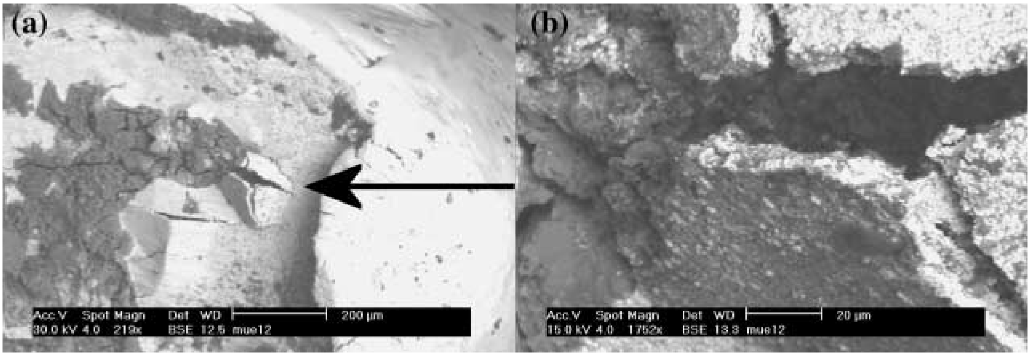

Figure 8 *BSE micrographs of coin 3 by SEM: (a) a crack of the silver layer in a notch; (b) a detail of the damaged silver layer.*

such as amalgam silvering, was applied to the notches, as otherwise there should be significant residues of mercury (Reiff *et al*. 2001). The blanks of contemporary forgeries were obviously prepared by foil silvering a copper core, followed by striking the notches with a punch. In this way, the silver gets drawn into the notches, becoming thin (~5–10 µm). This means a decrease in thickness to about 10% of the original value. However, the copper core remains covered and invisible to an observer.

Two opinions exist about the purpose of the notches. One proposition, due to Bahrfeldt (1904) and Crawford (1974), was that the serrated edges should improve the aesthetic appearance of the coins. Since the spacings between the notches, as well as their contours and depths (Fig. 1), show a great variance, this seems rather unlikely. Inspection of the notches of several serrated denars gives the impression of hasty handiwork. As mentioned before, fabrication of the notches had to be done very quickly since the coin was mass-produced. The use of serrated edges to improve the aesthetic appearance is known from ancient times. In this case, the notches or dents, respectively, were prepared with the production of the blank, to be given equal shapes, as can be seen on the Greek bronze coin (Fig. 1, coin 5). The dents appear irregular on the upper part of the coin, because during embossing the stamp did not hit the blank in the centre.

It seems more likely that serrating the denars should have prevented forgery or predacious trimming, given the presumption that in such a case the base metal core would have become visible. The first appearance of the serrati in ~209 BC, only two years after the introduction of the denar, indicates that forgery might have become a more urgent problem. The production of notches by handicraft all round the coins was an attempt to avert the increasing release of forgeries, as proposed by Humphrey and Sutherland (2003).

Crawford (1974) claimed that the aim of the notches could not have been to protect against forgery, because serrated and non-serrated denars were produced at the same time. Thus, had they wanted to avoid additional notch work, the forgers could have resorted to forging non-serrated denars. But this argument seems short-sighted: the additional work was worthwhile, as the serrated coins were considered to be safe and were accepted as a medium of exchange without suspicion.

Over the years, it became apparent that serrating the coins did not have the desired effect. This may be the reason why serrated denars were only produced for about 130 years (until ~78 BC).

CONCLUSIONS

Combining the results, the manufacturing process of the serrated denars can be regarded as having been clarified. The blanks of contemporary forgeries were prepared by foil silvering of a copper core. The production steps that followed were identical for both forgeries and official coins. The notches were manufactured using adequate tools (a punch); in the case of silvered blanks, the silver was drawn into the notches. Separate silvering of the notches was not necessary. Thereafter, the blanks were heated to improve their formability. The last working step from the blank to the coin was the embossing procedure. Due to the pressure applied, the silver overlaps into the notches.

Combining the described indications, it seems probable that the serration of the denar was an attempt to prevent forgery.

REFERENCES

Bahrfeldt, M., 1904, Antike Münztechnik, *Berliner Münzblätter, Neue Folgen*, **XXV**, 433–48.

Crawford, M. H., 1974, *Roman Republican coinage II*, Cambridge, UK: Cambridge University Press.

Humphrey, C., and Sutherland, V., 2003, *Coin*, Encyclopaedia Britannica, Ultimate Reference Suite DVD, Encyclopaedia Britannica Inc., Chicago.

Kraft, G., Flege, S., Reiff, F., and Ortner, H. M., 2004, Investigation of contemporary forgeries of ancient silver coins, *Microchimica Acta*, **145**, 87–90.

Moesta, H., and Franke, P. R., 1995, *Antike Metallurgie und Münzprägung*, Birkhäuser Verlag, Basel.

Reiff, F., Bartels, M., Gastel, M., and Ortner, H. M., 2001, Investigation of contemporary gilded forgeries of ancient coins, *Fresenius Journal of Analytical Chemistry*, **371**, 1146.