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Investigation of Contemporary Forgeries of Ancient Silver Coins

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Abstract. Four ancient Roman silver coins from about 200 BC to 200 AD, mainly contemporary forgeries, were investigated in order to deduce the methods and materials used in the production of the forged coins. Special attention was devoted to a Denar from the Roman Republic, a C. Mamilius Limetanus denarius serratus (approx. 82 BC), because an original coin (pure silver) as well as a forgery were available. These coins both show serrated edges, i.e. notches all around with irregular spacing. A combination of microbeam analytical techniques was applied: Scanning Electron Microscopy (SEM), Electron Probe Micro Analysis (EPMA) and Secondary Ion Mass Spectrometry (SIMS). Some of the counterfeits consist of a base metal core plated with silver. The serrated Denar exhibits a plating layer with a thickness of approx. 100 μm as determined by SEM and SIMS. This is an indication for foil silvering, as well as the apparent overlapping of the outer layer in one particular area.

Key words: Ancient coins; forgeries; SEM; EPMA; SIMS.

The first coins in history appeared approximately 700 BC in Asia Minor, soon to be followed by first forgeries fabricated by plating a base core (blank) with a layer of noble metal [1]. Thus a forger was able to produce a larger amount of apparently genuine coins with a mass near to the noble metal, which promised high profits.

Because of the silver Denar being the most common Roman coin, many forgeries of this coin are known and a number of different methods was applied for their fabrication. One approach was the plating of the base metal core with pure silver or a silvery alloy. A very durable overlay could be obtained by using a silver foil to enfold a copper core, followed by heating above 780 °C. In the contact area between core and foil a chemical compound with eutectic composition developed. Thus using a solder was not obligatory to attach silver to copper, but may also have been common practice [1–3]. A second method was to apply silver amalgam onto the core followed by expelling the mercury by heating to above 357 °C (the boiling point of mercury) [2]. Depending on heating time and temperature, residues of mercury should be detectable to give evidence of this technique. The required technical skills of forgers increased during the republican period when coins often exhibited serrated edges. Neither the manufacturing process of the notches has been clarified so far nor their plating technique. The aim of this investigation is the clarification of the forging techniques used.

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Fig. 1. (a) C. Mamilius Limetanus denarius serratus (coin 2), the black line indicates the cutting direction. (b) C. Sulpicius Galba denarius serratus (coin 3)

Experimental

The investigated samples were:

1. C. Mamilius Limetanus denarius serratus, about 82 BC, pure Roman 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. Septimius Severus denarius, between 193–211 AD, forged.

The samples will be referred to as coin 1 etc. in the following according to the list given above. Figure 1 shows the obverses of coins 2 and 3.

Apart from two non-destructive methods (SEM, EPMA) a sample consuming mass spectrometric technique was also used (SIMS). This was justifiable because coin 2 was fragmented to study the plating thickness in detail.

A high resolution SEM Philips FEG-XL30 was used for the investigation of the surface morphology and the polished cut faces of coin 2. The system is equipped with a detection system for backscattered electrons (BSE) which allows to show atomic number contrasts. In addition an energy-dispersive X-ray detection system (Si-detector EDAX TM DX4) with thin window served to identify the unique components. Furthermore it is possible to change the angle of examination by tilting the sample. The images were measured with an accelerating voltage of 20 kV; measurements of the energy-dispersive spectra were performed with 25 kV to obtain high X-ray yields.

The metal components of the surfaces of the coins 1, 2 and 4 were quantified by EPMA. Element distribution images of a fragment of coin 2 were recorded as well. 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 20 kV accelerating voltage and a beam current of 40 nA.

SIMS was applied to survey the thickness of the silver layer of coin 2. For this purpose a Cameca ims 5f (Cameca, Paris, France) was used. The depth profiling was performed with oxygen primary ions (O_2^+) and an accelerating voltage of 8 kV.

Results and Discussion

During investigation by SEM the qualitative composition of the surfaces was accessible via EDX. The surface of coin 1 mainly consists of silver and shows low concentrations of other elements like chlorine or silicon, the latter ones being constituents of the patina. The surface of coin 2 appears optically brighter and does not seem to have a patina. The EDX shows silver and copper as the main components, the copper content being lower than the silver one.

Table 1 shows the results of the EPMA/WDX measurements of the coins 1, 2 and 4. The surface of coin 1 mostly consists of silver and smaller quantities of copper, lead and gold. In contrast, the silver wrapping of coin 2 contains less silver but more copper, and the other components such as lead show a larger quantity than in coin 1. The higher copper content of the wrapping in the outer layer of coin 2 in comparison to coin 1 should not be seen as indication for a forgery because higher copper contents are also known in pure silver coins [4]. The low content of mercury however gives evidence that coin 2 has not been produced

Table 1. Concentrations (wt.%) of metallic components of coin 1, 2 and 4, measured via EPMA/WDX, standard deviation $\bar{x} \pm 1s$, n = 10 measurements

Coin	Ag	Cu	Si	Pb	Fe	Sn	Au	Hg	As
1	98.2 ± 0.8	0.3 ± 0.1	0.1 ± 0.2	0.8 ± 1.0	0.0 ± 0.1	0.0 ± 0.0	0.4 ± 0.2	0.1 ± 0.2	0.1 ± 0.1
2	94.2 ± 3.3	3.0 ± 0.5	0.3 ± 0.2	1.7 ± 1.3	0.02 ± 0.02	0.04 ± 0.05	0.5 ± 0.13	0.14 ± 0.24	0.12 ± 0.1
4	0.16 ± 0.16	19.9 ± 6.6	2.8 ± 1.0	24.9 ± 4.9	0.34 ± 0.18	49.7 ± 4.7	0.02 ± 0.02	0.0 ± 0.0	2.1 ± 0.4

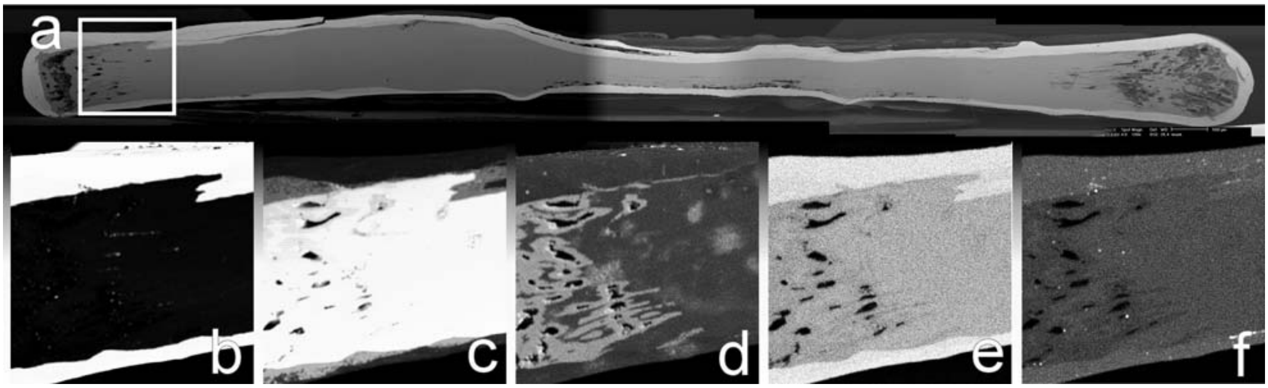

Fig. 2. (a) Backscatter-electron image (20 kV) of the sectioned C. Mamilius Limetanus denarius serratus (coin 2), magnification factor 100, the white square indicates the location of EPMA measurements. (b–f) Element distribution images of silver (b), copper (c), oxygen (d), gold (e), and iron (f) by EPMA/WDX, 20 kV, 40 nA

by an amalgam silvering method [5]. For further investigations coin 2 was fragmented by sawing, Fig. 1a shows the cutting direction. The fragments were used to obtain SEM micrographs of the polished cut. The diameter of coin 2 amounts to approx. 2 cm. Figure 2a shows a BSE image. It provides evidence of a varying thickness of the silver layer between 70–150 μm on the top resp. bottom and about 250–300 μm at the outside margin. The thicker silver plating at the fringes is possibly an effect of the high pressure occuring at the embossing procedure, which is the last production step transforming the blank into a coin. A silver plating of approx. 100 μm as found here, is a typical indication of foil silvering which is often described in the respective literature [1, 2, 6]. Another indication of this technique was found: one area shows a triple overlapping of the foil, probably folded by the forger to finalize the fabrication of the blank (Fig. 2a). The EPMA images (Fig. 2b–f) show explicitly the lateral distribution of silver, copper, oxygen, gold, and iron in this order. The lateral distribution of the elements is homogenous, except the one of iron in the outer layer and the one of oxygen showing enrichment around some holes at the outer

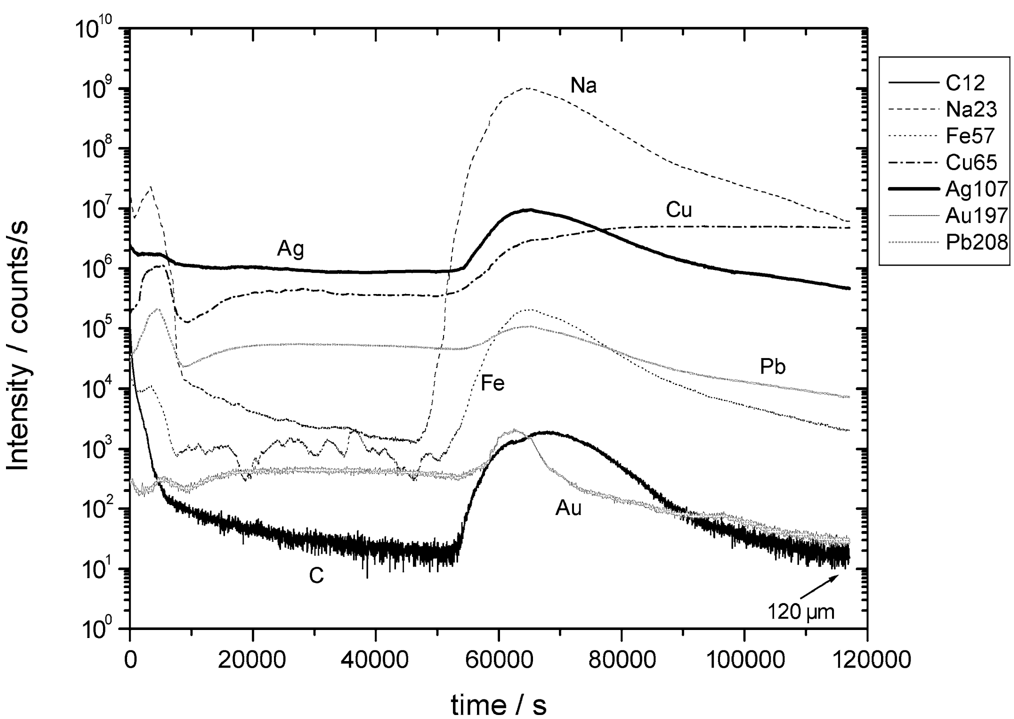

Fig. 3. SIMS depth profile of the silver layer of coin 2. Primary ions: O_2^+, 8 kV, crater size 300 μm, 220 nA

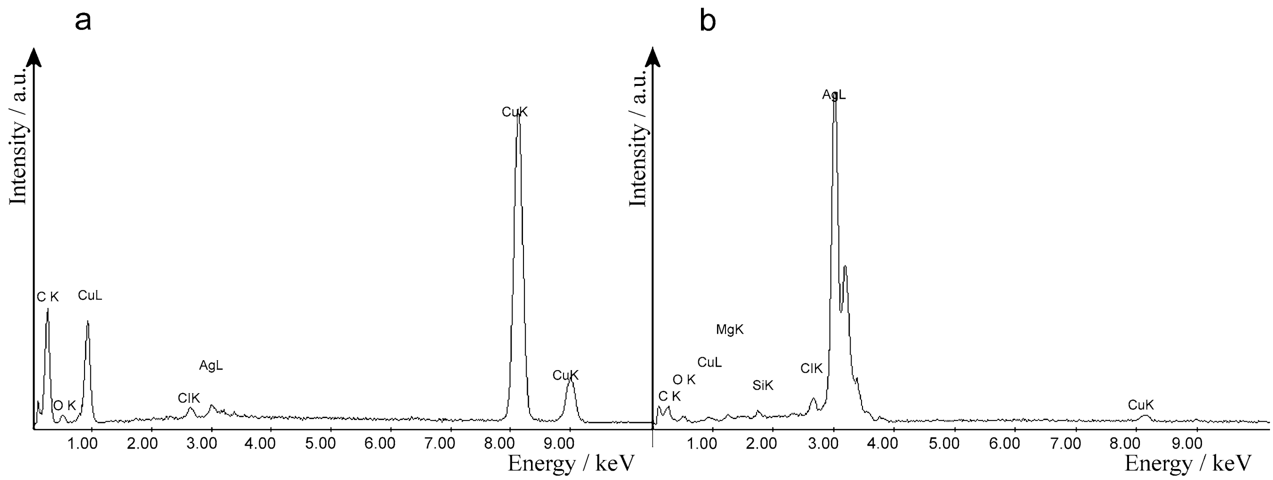

Fig. 4. EDX spectra (25 kV) of the C. Sulpicius Galba denarius serratus (coin 3): (a) Core, (b) silver surface

sides of the copper core which are probably a result of oxidation.

The depth profile measured by SIMS (Fig. 3) shows an enrichment of contaminations such as sodium and carbon at the surface, followed by a silver layer containing copper, lead, gold and iron. The latter one exhibits unsteady intensities, which is a characteristic sign of an inhomogenous lateral distribution as found also by EPMA. Passing a highly contaminated interface, the copper core is reached after about 70 µm. The increase of the intensity of the metallic elements in the interface is not necessarily due to a higher concentration, but can be related to changes of the sputter rate and the ionization probability. The measured thickness of the silver layer endorses the former value obtained by SEM, even though lying at the lower end of the scale. The mass spectra of the silver layers within and outside of the notches show differences in the Ag/Cu-ratio. Whether this is an indication of another plating technique will be the subject of further investigations.

Coin 3 possesses notches like the coins 1 and 2. It also exhibits a silver surface. Figure 4b shows the respective EDX spectrum. The coin exhibits several damages. These areas admit a view on the core which consists mainly of copper (Fig. 4a). Positioning the coin vertically in the microscope, one area even allowed to measure the thickness of the silver plating, by looking towards the edge. The silver layer was about 75 to 80 µm thick.

The surface of coin 4 does not contain much silver but great amounts of tin, lead and copper (Table 1). This coin is obviously a copper core wearing a formerly silver-coloured cover consisting of tin and lead which became dark due to oxidation.

Conclusions

The low mercury contents of the C. Mamilius Limetanus denarius serratus (coin 2) and the C. Sulpicius Galba denarius serratus (coin 3) give evidence that the counterfeits have not been produced by an amalgam silvering method. They have been manufactured by foil silvering; in addition to the thickness of the silver platings of approx. 100 µm, as measured by SEM and SIMS, especially the area of coin 2 with the overlapping foil proves the application of this technique. Whether the same plating technique was used for the serrated edges will be the subject of further investigations.

The Septimius Severus denarius (coin 4) is obviously a copper core with a cover consisting of tin and lead which appeared silvery before it became dark due to oxidation.

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