Silver plating technology of the late 3rd century Roman coinage

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ABSTRACT: The discovery in 1998 of a late third century AD coin hoard at Rogiet (Monmouthshire) provided the opportunity for a technical study of the plating of the later Roman silver coinage which carried a very thin silver wash over a copper core. Optical metallography and scanning electron microscopy were carried out on taper sections on eight coins. Their plating was rarely thicker than 1-2μm and often too thin to be visible in cross section. There was no eutectic layer or diffusion zone at the interface between plating and core. The plating penetrated into cracks and crevices of the copper. It was not connected to the small amounts of silver phase within the copper core. From a comparison of these results with replication specimens it was concluded that the plating was applied in the form of a silvering paste, possibly based on silver chloride. Hot-dipping into molten silver chloride proved to be impractical in the replication experiments and was ruled out. No mercury was detected on any of the coins with EDX analysis in the electron microscope.

Introduction

Manufacturing techniques of plated Roman silver coins have been the subject of technical studies since the 1930s (Darmstaedter 1929, Campbell 1933). More recently a number of authors discussed Roman coin plating techniques on the basis of metallographic and scanning electron microscopic evidence (Cope 1972, Kalsch and Zwicker 1986, La Niece 1993a, Zwicker *et al* 1993, Anheuser and Northover 1994, Anheuser 1998). Most of these papers focused on republican and early imperial denarii, periods in which the genuine coinage maintained a consistently high silver standard. Plated imitations were normally coated with thick silver foil strong enough to withstand considerable wear and convincingly emulate the look of solid silver. In the later Roman empire the silver standard of the Roman coinage declined sharply and during the mid 3rd century AD reached a point when even official issues were merely copper coins which carried a token silver coating so thin that it would have worn off rapidly in exposed areas of the surface and could certainly not long have been mistaken for genuine solid silver. These 3rd-century radiates were mass produced in very large numbers (millions). Their plating technique was first discussed in detail by Cope (1972, 275) who postulated a silver surface enrichment technique related to the cupellation process which required lead as an additional constituent, or alternatively hot-dipping into molten silver chloride, although he did not present any metallurgical evidence for the use of either option. Whilst our knowledge of Roman republican and early imperial coin plating techniques is detailed and appears well founded, the later Roman issues have so far been neglected. Unlike the investigation of the earlier Roman plated coins, no technical studies using modern analytical equipment have been carried out even 30 years after Cope's work, and it is the aim of this study to contribute to filling this gap[1].

The discovery in September 1998 of a large coin hoard in the village of Rogiet (near Caldicot, Monmouthshire) (Besly 2001) offered an opportunity for a technical study of the plating technique of the later Roman silver coinage. This unique hoard, now kept in the National Museum and Gallery of Wales, Cardiff, consisted of more than 3,750 Roman coins of the late 3rd century covering a period of 40 years and the issues of 22 emperors from a number of different mints. It was ideally suited to provide the necessary material for investigation.

Figure 1: Coins from the Rogiet hoard examined in this study; left image: obverse, right image: reverse.

This paper aims to re-assess Cope's theories in the light of new evidence available from the investigation of coins from the Rogiet hoard, using modern analytical techniques.

Materials and methods

Eight coins from the Rogiet hoard were investigated metallographically (Fig 1 and Table 1). All coins carried substantial remains of a thin silver plating worn off in areas of high relief. They were typical representatives of the Roman late-3rd-century silver coinage.

A tangential taper section of the plating was prepared on each of the coins by grinding and polishing the edge until the uncorroded core was reached. The necessary interference with the coins was minimal (Fig 2). Surfaces and polished sections were investigated using optical microscopy and a CamScan Maxim 2040 scanning electron microscope equipped with a Link ISIS energy-dispersive X-ray analyser (EDX) and a MicroSpec wavelength-dispersive analyser (WDX) at the School of History and Archaeology, Cardiff University.

Results

The silver plating on the coins was very thin with a typical thickness of 1–2µm or less. In nearly all instances it was difficult to detect the silver layer in cross-section even though it was readily recognizable on the surface of the coins. Figure 3 shows the plating in one of the few examples where it was clearly visible in cross-section. The plating was not connected with the small amount of silver phase present in the copper core. On the surface the microscopic appearance of the plating was discontinuous and patchy (Figs 2 and 4). On coin 6 the taper section touched a deep crack in the coin which was covered with silver on the inside (Fig 5). No signs of heating, such as the formation of silver-copper eutectic or a diffusion zone at the interface between core and plating, were observed. No mercury was found with EDX analysis in the silver on any of the coins (detection

Table 1: Coins from the Rogiet hoard, investigated in this study.

No	Emperor	Date	Mint	Type	Weight (g)	Accession No.
1	Aurelian	270-275	Milan	RIC 150	3.31	99.31 H/427
2			Ticinum	RIC 152	3.96	99.31 H/449
3	Tacitus	275-276	Lyon	RIC 61	3.79	99.31 H/704
4	Probus	276-282	Lyon	RIC 17	4.87	99.31 H
5			Lyon	RIC 104	4.61	99.31 H
6			Rome	RIC 673	4.49	99.31 H
7			Ticinum	RIC 332	4.50	99.31 H
8	Diocletian	284-305	Lyon	RIC 28	4.55	99.31 H

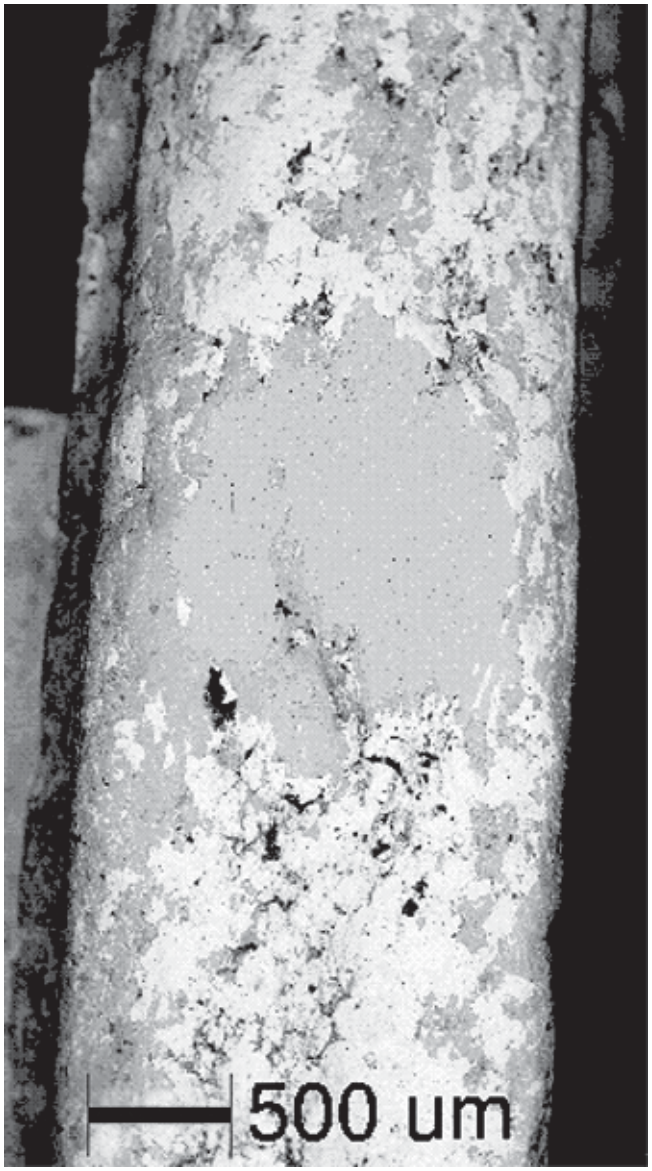

Figure 2: Edge of coin No. 7, showing tangential polished area (centre) and plating (pale areas above and below). SEM backscattered electron image.

limit approx 0.1%), suggesting they were not silvered with mercury, as previous work has shown the residual mercury content is normally at least several percent (Anheuser 1999).

The compositions of coins 6 and 7 were analysed using WDX. The results (Table 2) were in close agreement with published results from other coins of the same type (Cope *et al* 1997).

Discussion

The thinness of late 3rd century Roman coin silvering contrasts with the much thicker plating on republican and early imperial issues which were normally

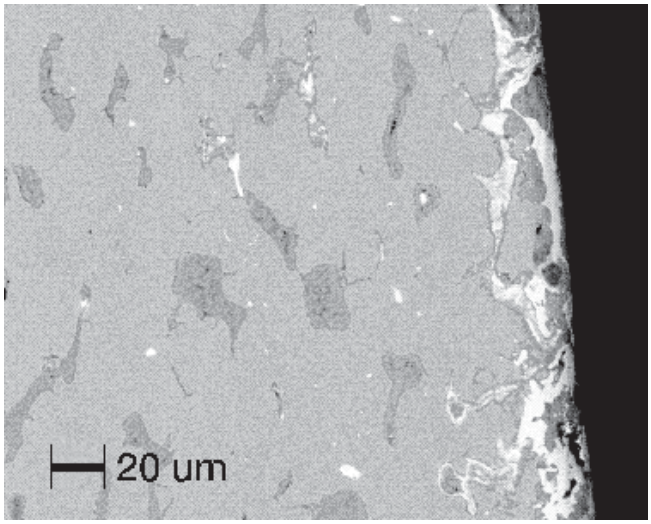

Figure 3: Coin No. 6; tangential polished section showing silver plating (white) at the right edge. SEM backscattered electron image.

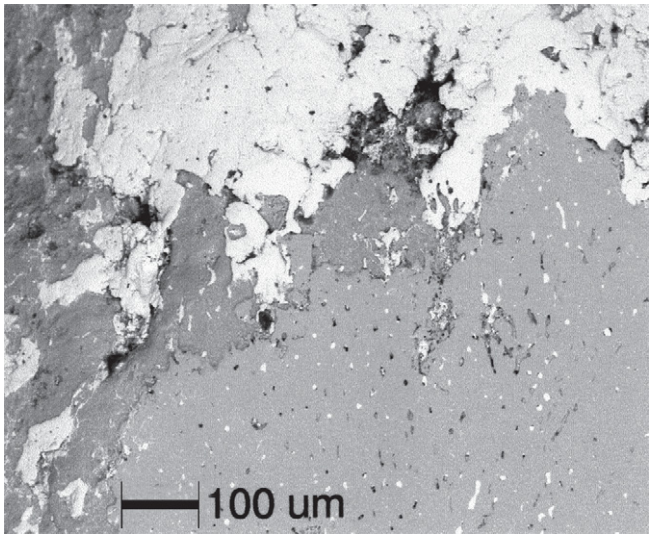

Figure 4: Coin No. 7; tangential polished section with silver plating (white) on the edge of the coin. SEM backscattered electron image.

manufactured by wrapping individual copper blanks in silver foil followed by fusing above 800°C. Such foil silvering produced a continuous high quality plating which could be up to several tenths of a mm thick (Fig 6). For the much thinner coatings of the later Roman coinage, Cope (1972, 275) suggested two different methods as the most likely. The first is based on the segregation of lead from copper alloys and is related to the cupellation process for the purification of silver. Cope assumed that by cold hammering and annealing of a leaded argentiferous copper blank, molten lead together with the silver would have migrated to the surface where the lead was oxidized and removed in a

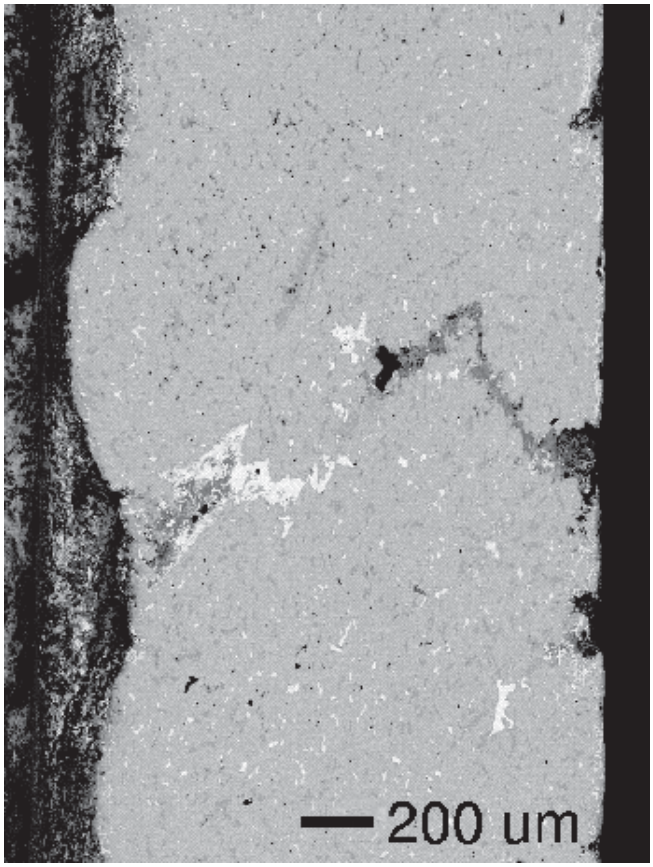

Figure 5: Coin 6; tangential polished section with a crack coated with silver inside. SEM backscattered electron image.

pickling bath. The coins investigated for this study contained too little lead and silver for the method to be feasible, and the metallographic investigation did not show any lead enrichment near the surface, or a lead

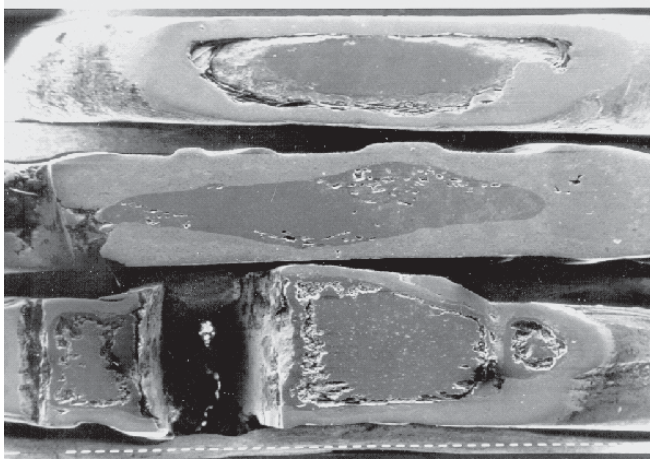

Figure 6: Tangential polished sections of three Roman plated denarii of 1st century BC/AD, showing silver foils (pale grey) fused around copper cores. Top to bottom: Petillius Capitolinus (Crawford 487/2), Vespasian (RIC 10), Q. Ant. Bulbus (Crawford 364/1c). All Ashmolean Museum, Oxford. SEM secondary electron image. One small scale bar (bottom) equals 0.1mm.

Table 2: Compositions of the two coins analysed by WDX (wt%).

Element	Coin No.6: Probus, Rome	Coin No.7: Probus, Ticinum
Cu	94.8	93.7
Ag	2.5	3.9
Sn	1.3	nd
Zn	0.08	0.05
Pb	tr	0.20
Fe	nd	0.21
Co	nd	nd
Ni	tr	tr
As	0.05	tr
Sb	nd	nd
Bi	nd	tr
Au	nd	nd
S	nd	nd
Total:	98.7	98.1

Analytical conditions: WDX, 20kV, 20nA. Cu, Zn, Fe, Co, Ni, S: Kα; Ag, Sn, As, Sb: Lα; Au, Pb, Bi: Mα. Total counting time 60s per element. Each figure is the average of 3 analyses of small (4.8 x 6μm) areas of the copper phase. nd: below detection limit (approx 0.02wt%), tr: trace near detection limit.

concentration gradient towards the exterior which would necessarily have remained in place after such an operation. The coins investigated here contained hardly any lead, and only very little silver. The cupellation technique can therefore be discounted. Cope himself accepted that this technique would not have worked for the highly debased alloys from the Western mints.

As a second option Cope suggested the dipping of copper blanks into molten silver chloride (mp 455°C). This should have led to the deposition of a thin silver layer on the copper by electrochemical replacement. However, replication experiments by the authors of this paper demonstrated the impracticality of this procedure. On acid-cleaned copper sheet dipped into molten silver chloride, silver immediately precipitated as a thick, dark and porous deposit, not as a thin layer. The assumption that quick dipping of a piece of copper into molten silver chloride would create a thin coherent coating that resembled a silver surface is unrealistic. This is in addition to the practical difficulties associated with hot-dipping in mass production. Heating pieces of copper together with solid silver chloride in a crucible to a temperature above the melting point of the silver salt followed by removing the copper from the liquid salt (a procedure potentially suitable for mass production) produced equally poor results, with thick and porous

silver deposits. Such a process would also have been inefficient in its use of silver.

The evidence from the present study suggested that the 3rd-century radiates were certainly plated (as opposed to being depletion-silvered), and that this plating process was carried out below the temperatures required for the formation of the eutectic phase (mp 780°C), or indeed for any significant diffusion at the silver-copper interface (400–500°C). It used a silvering agent able to penetrate into cracks and cavities. The extreme thinness of the plating, its appearance and the absence of mercury, clearly indicated some form of electrochemical replacement silvering. This could have been carried out by bringing clean copper blanks into contact with silver salts or their aqueous solution.

It is usually assumed that silver salts (as opposed to metallic silver) only became available with the post-medieval introduction of nitric acid. Not by coincidence did recipes for silver chloride-based silvering pastes start to appear in numbers in the 17th century (La Niece 1993b, Anheuser 1997). However, Lechtman (1979) demonstrated experimentally that a silvering paste could equally well be obtained from silver and commonly available corrosive salts (sodium chloride, potassium nitrate and alum). The fact alone that a technology *could* have been used at an early date provides no indication, let alone proof, that it *was* actually practised, but it is difficult to see how these Roman coins could have been plated by any other technique. A silver chloride paste would be the most likely agent for Roman electrochemical replacement plating. Because of the ubiquitous presence of chlorides in natural salt deposits it would have hardly been possible (and indeed unnecessary) to obtain pure soluble silver nitrate which could be applied in solution.

To investigate the feasibility and properties of silvering with a silver chloride paste, replication experiments with modern copper-plated pennies were carried out. With a finely ground paste of silver chloride mixed with a few drops of 5% hydrochloric acid excellent results were obtained (Fig 7). After a few minutes in contact with the paste the copper coins carried a silver plating which adhered firmly to the substrate. After washing and polishing the surface with cotton wool the coins displayed a convincing likeness to solid silver. Thorough cleaning of the copper surface in an acid bath was essential for the success of the plating.

The appearance of the replication plating closely resembled the Roman originals also on a microscopic

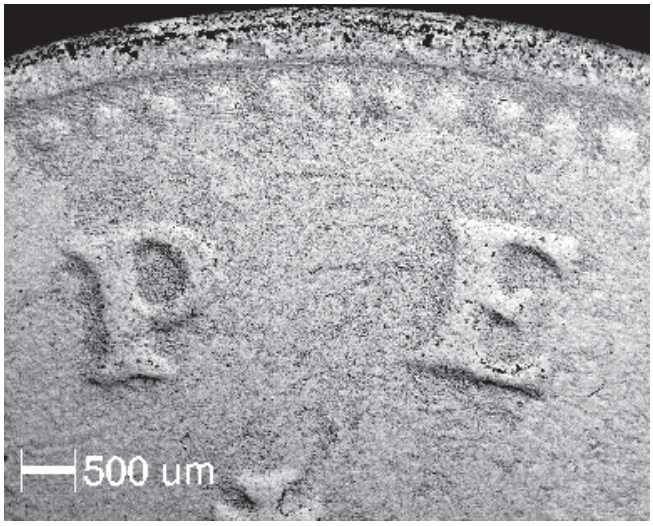

Figure 7: Surface of a modern penny coin plated using silver chloride paste. SEM backscattered electron image.

scale and in cross section (*cf* Figs 4 and 8). Because the steel core of the replication coins was coated with a dense electroplated copper layer (thickness approx 30μm) there were no cracks or grain boundaries which could be penetrated by the silver plating (Fig 9). This was different from the dendritic structure of the cast Roman coin blanks into which the silver paste entered (Figs 3 and 5).

Whilst these replication experiments were carried out on struck coins it is more likely that the Roman originals would have been plated before striking. Even though the plating was sufficently thin for the struck design of

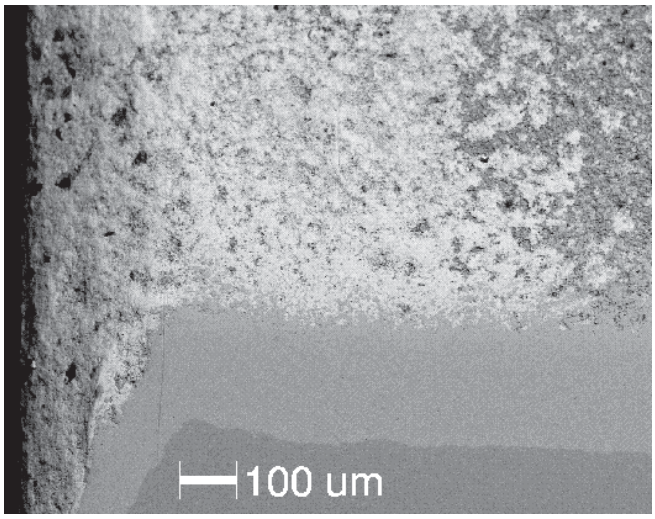

Figure 8: Tangential polished section (bottom) and plating on the edge of a modern penny coin. The coin consists of a steel core (dark grey) electroplated with a copper layer (light grey), with an extra layer of silver (white) plated on top using silver chloride paste. SEM backscattered electron image.

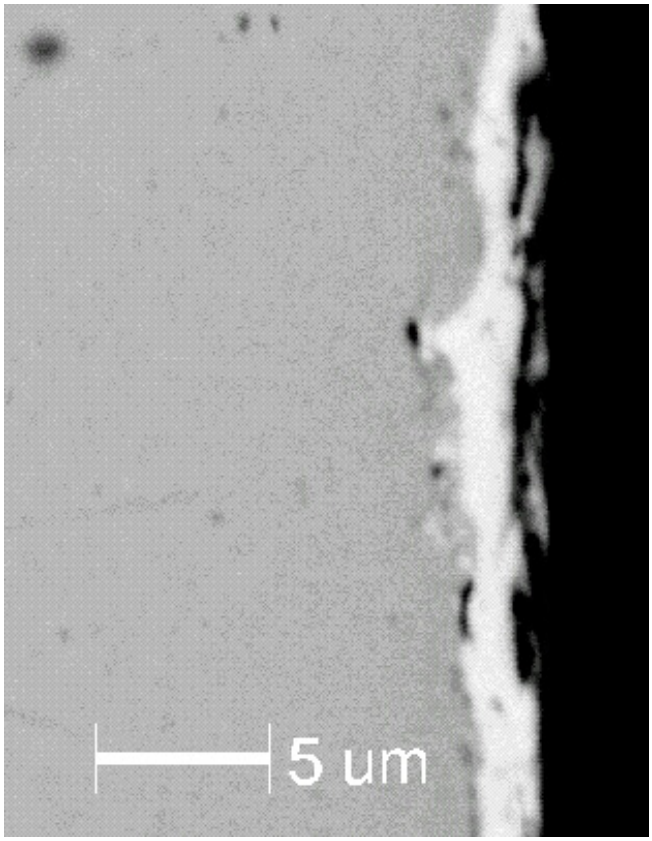

Figure 9: Tangential polished section with silver plating (white) on a modern penny coin plated using silver chloride paste. SEM backscattered electron image.

the pennies not to be obscured, the silver coating was more homogeneous on a microscopic scale in smooth areas without design. The silver chloride tended to fill crevices along edges in the struck design where the thickness of the silver deposit was slightly increased (Fig 7)This was different from the original coins where depressions in the struck relief were not filled with an increased thickness of silver plating.

Any discussion of late-3rd-century Roman coin silvering must take into account the enormous numbers of plated coins produced in this period, which ran into millions. This rules out any plating technique which required spending any significant amount of time on the handling and plating of individual coins. Coin striking was carried out at great speed and the supply of blanks must have matched this. Electrochemical replacement plating and the subsequent washing and polishing could be conveniently carried out in large barrels. Obviously extensive wear resistance of the silver finish was not asked for. All that was required was a notional silver wash on the surface which clearly must have worn off before long. This is fundamentally different from the thick individually-applied foil silvering of Roman republican and early imperial denarii.

Conclusions

The metallographic investigation of the silver plating on mass-produced Roman 3rd-century radiates showed that the silvering was carried out cold with a paste or liquid which penetrated into cracks and recesses. Replication experiments proved that a macro- and microscopically identical plating could be produced by electrochemical replacement silvering with a silver chloride paste. Hot dipping into molten silver chloride which was previously postulated as a likely plating technique for these coins must be discounted. It is probable that the copper coin blanks were plated before striking.

Acknowledgment

The authors would like to thank Edward Besly (National Museum and Gallery of Wales, Cardiff) for making coins from the Rogiet hoard available for this study.

Note

1. Late Roman coin-plating techniques are also the subject of currently ongoing research for a PhD by Constantina Vlachou at Bradford University.

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