METALLURGICAL ANALYSES OF LATE THIRD-CENTURY ROMAN IMPERIAL COINAGES

(A report to the British Academy, November 1977)

INTRODUCTION

1. In June 1976 the Research Fund Committee of the British Academy made an award of £300 towards the author's research into the chemical composition of late third-century AD Roman coins, whereby it was intended to determine, in particular, the silver fineness standards and alloying patterns which were adopted in a period which involved a veritable spate of monetary problems and consequent changes in minting policies both in the legitimate empire and in the territories controlled by the successful Gallic and British usurpers.

2. There was no shortage of suitable disposable material for this study - most of which was donated by the various Museums and persons listed in Appendix I. But the available coins were of such irregular chronological pattern and mint distribution that they had to be carefully selected (on the basis of the maximum potential numismatic worth of the expected results) prior to the detailed preparation of a limited number of pieces for a full metallurgical analysis within the limits of the budget.

3. Enquiries amongst commercial analysts brought an offer from Johnson Matthey Chemicals Ltd to perform as many as thirty full coin analyses for the sum of £300. This was promised at basic cost to the Company provided that the metal samples would be fully prepared for the analysts, and that the work could be spread over a period so as to take up the slack which would arise from time to time within the routine laboratory work-load. Although this has involved waiting for just over a year for the final results it has enabled the most economical use to be made of the funds available whilst maintaining the highest scientific standards (at two-fifths of the normal commercial cost).

4. Further points in favour of the choice of Johnson Matthey Chemicals Ltd, of Enfield, as the analysts, were their familiarity with both modern copper and precious metal assays and that they had already obtained satisfactory experience in analysing ancient coins of a similar metallurgical type by performing several hundred analyses for Dr P Tyler. That study, however, concerned the Gallienic coins minted during a narrow period in the middle of the third century, and just prior to the coin issues of the present series; but for Dr Tyler the results were unnecessarily reduced in their potential accuracy by the corroded condition of many of the samples submitted and by the limitations which he (as a cautious non-scientist) arbitrarily imposed upon the analysts.

5. In this present work the full potential accuracy of the approved analytical techniques has been achieved by the provision of assured

solid alloy samples to the analysts, free from either superficial or penetrating corrosion products. To this end all the coins were first fractured and examined metallographically, to determine the depth of any corrosion and to facilitate the planning of the complete removal of corrosion products, surface contaminants, and surface enrichments of silver, which would otherwise have affected the acquisition of true analyses of the original coin materials.

6. In those cases where traces of corrosion penetration ran too deep for complete mechanical removal by filing, the superficially cleaned samples were finally fusion-reduced (either by gas-torch or in vacuo) to provide complete metal samples weighing in the region of one gram - which were adequate for reasonably representative results of each original coin as a whole. In the case of the four vacuum-fused samples the inevitably volatilised lead and zinc were condensed on cool surfaces in a closed system and were determined separately by the author and later added to the known weight of the appropriate button sample - thus allowing total metal recoveries of well in excess of 99% for each complete analysis.

7. In every case, approximately one half of each coin sample, in its original condition, has been preserved for posterity and to provide a small sample for the neutron activation analysis of the minor impurities arsenic and antimony which could not be determined on the principal sample.

8. The work which was possible with the British Academy Award is now completed; and this is a summary report pending the open publication of these and some available supplementary results in the numismatic literature. As was the case with the results obtained with previous Awards, a copy is also being forwarded to the Department of Coins and Medals in the British Museum so that the analyses will become immediately available to both national and overseas visiting scholars concerned with the numismatic problems of the enigmatic Roman coinage of the late third century AD.

THE COINS

9. The thirty selected coins comprised radiate pieces minted in the period between the closing months of the reign of Gallienus (in AD 268) and the time of their final issue - as post-reform tetrarchic pieces (in AD 305-307), together with Alexandrian tetradrachms of broadly the same period but carefully spanning the final decline of the tetradrachm as a silver denomination. These were chosen, in regnal order of issue, as follows:-

Emperor	Radiate coins from various mints	Tetradrachms of the mint of Alexandria
Marius	1	-
Gallienus	2	-
Aurelian and Severina	3	2
Tacitus	3	1
Probus	6	3
Numerian	1	1
Diocletian	-	1
Carausius and Allectus	4	-
Constantius Caesar	1	-
Maximinus Daza	1	-
	22	8

10. At a first glance the chronological and regnal distributions of the selected pieces may look uneven; but they do represent a deliberate choice, covering a range of mints issuing coins at suspected periods of critical change in monetary policies - some of which had been adumbrated by the author's exploratory analyses. The results now fully justify the somewhat arbitrary selection which had to be made in the circumstances. The coin analyses are listed in the Appendices IIa and IIb, in chronological order of issue of the radiates, and the tetradrachms, respectively. Their numismatic implications are discussed below. Generally, they confirm and then extend some initial exploratory studies; and it is now evident that both the major alloying constituents and impurities reveal mint characteristics which were hitherto unknown, except for indications from other periods. These reveal the preference for comparatively local supplies of copper rather than the provision of copper or basic alloy from any central source; for example, the coins of eastern mintage are found to be rather richer in their nickel impurity levels than western coins; and, similarly, the impurity zinc is to be found at only just detectable levels in western coins but in much larger proportions in coins which were minted in the east and made with copper originating in Asia Minor and Egypt. Furthermore, the Alexandrian tetradrachms comprise a series which have distinctive nickel and zinc proportions despite wide variations in their other alloying constituents.

THE NUMISMATIC IMPLICATIONS OF THE RESULTS

11. The brevity of the reign of Marius, within the year AD 268, provides a sharp chronological landmark for the fineness of the Gallic coinage which has suffered severe debasement under his predecessor, Postumus. P Le Gentilhomme records the only previously known assays (of four coins of Marius) ranging between the narrow limits of 5.0 and 5.8% silver for issues from the mints of Cologne and Trier. This seemingly odd proportion of silver (equivalent to between 14 and 16-scrupula per Roman libra in the finished coins) is higher than the 12-scrupula standard to which the final issue of Postumus is known to have descended; and so this matter has necessitated further investigation. The coin included here corresponds with one of those assayed for Le Gentilhomme (Elmer 640) and it is found to have a closely comparable fineness (5.18 to 5.31% Ag). But the full analysis reveals that the alloy is substantially leaded; and this provides a metallurgical explanation for

the silver being enriched above that of the true 12-scrupula norm (4.17%) by virtue of the ready oxidation of some of the lead in the alloying and re-melting sequences of coin manufacture. In its other metallurgical features the coin is typical of the almost tin-free copper-silver alloys of the coinage of Postumus, and therefore of the Gallic category to which it rightly belongs.

12. The two radiate coins of Gallienus were closely contemporaneous with those of Marius, but they are both from the mint of Siscia - for which P Le Gentilhomme recorded a fineness reduction (to as low as 3.3% silver) in the course of the PROVID AUG issue (RIC 580). Dr Tyler's assays have revealed only the higher (earlier) standards introduced with various similar coin types which bear, unfortunately, the same numismatic reference number despite their reverse inscription differences. The two new analyses (Items 2 and 3) show basic alloy features consistent with the metallurgical characteristics of Tyler's selected Siscian pieces; but the silver assays (3.6 and 5.61% Ag) now confirm P Le Gentilhomme's lower recorded fineness, and reveal that the Siscian debasements did, indeed, descend to the same low level as that reached at the mint of Rome with the final 'animal' series of issues for Gallienus. The new results help us, therefore, to refute Tyler's hypothesis that quite different contemporaneous fineness standards were in use at the eastern and western mints during the sole reign of Gallienus. Although the standards suggested were based on similar (yet more statistically voluminous) results to those of the present work it is clear that Dr Tyler's conclusions were drawn with no evidence at all at the really critical point of issue and, furthermore, they were correlated with an obsolete system of coin dating. The proper evidence combined with improvements in the chronology of the coinage suggested by other numismatists, now shows that Tyler's results really conform to a different and much more numismatically reasonable interpretation than he proposed.

13. Aurelian's coinage reform was manifest in two stages at the imperial mints; and the improvements in fineness of the argentiferous bronzes can be correlated also with small dimensional changes in the die diameter. There is some uncertainty, however, concerning the separation of these issues at the mints which did not use, immediately, the XX.I mark pertaining to the second and major reform in AD 274, or did not control die diameter with the same precision. Furthermore, there have been no parallels established, hitherto, for the proto-reform and the full reform at Alexandria - where the full reform of the tetradrachm fineness appears to have taken place perhaps a year later than at Rome. For these reasons both Aurelianic antoniniani and tetradrachms are included in the series studied, the tetradrachms having the advantage that they can be dated accurately with at least the certainty of having been minted within the Egyptian regnal year clearly marked on the coins.

14. The Aurelianic antoninianus from the mint of Milan (Item 6) is almost exactly of the full reformed fineness standard and die dimension, although it lacks the XX.I mark. Thus it can now be dated and placed amongst the full reform issues - in confirmation of another Milanese piece of different type (RIC 150) which was too rare for other than a non-destructive analysis by neutron activation. These two coins now establish that the Aurelianic full reform was completed before the closure of the mint of Milan in AD 274. The full analysis of this

latest piece confirms that it is genuine, since it possesses the compositional characteristics of other known Milanese coins of the period.

15. The other Aurelianic antoniniani (Items 4 and 5), also bearing the simple officina marks of Milan and Cyzicus (without XX.I) are, however, of the larger diameter of the proto-reform coinage; and they are found to contain the lower proportions of silver which equate with the 8-scrupula per libra standard previously identified by the author for the proto-reform coinage in general.

16. The two tetradrachms of Aurelian's year 'Z' at Alexandria (Items 23 and 24) span the final period of issue which may not have extended much longer than August to October, AD 275, and consequently they provide evidence for the highest fineness having been reached at Alexandria more than a year after the full reform of the antoninianus at Rome and the other western mints. The standard appears to be one of 8 scrupula per libra (compared with 10 scrupula at Rome), and this peak was reached only after a standard of 6 scrupula per libra had operated even early into the 'Z' year.

17. The three antoniniani of the short reign of Tacitus (Items 7 to 9) represent western, central, and eastern mintages, with their distinctive alloy and impurity characteristics; but a tetradrachm(Item 25) shows a sudden return to the Aurelianic 6-scrupula standard. The Lugdenese antoninianus contains so little tin that it is not a bronze but an argentiferous copper; and this feature applies to the Lugdenese coin of Probus (Item 15) minted between one and seven years later. The Roman mint issue (Item 9) is an almost perfect coinage bronze - containing no excess tin and very little lead. The Cyzicene piece (Item 8) is at an intermediate alloy composition, but with the higher nickel and zinc impurity levels to be expected. The most remarkable feature of these coins is, however, that the silver in two of them is well above the average for the XX.I coinage of any date. In the case of the western coins this could be explained as being due to the enrichment which follows the re-melting and re-minting of coins collected into the Treasury, especially if no further base metal were added to compensate for the oxidation losses of normal minting operations. But in the case of the Cyzicene antoninianus, the high level of 8.932% silver is completely inexplicable, for the coin closely resembles its contemporaneous antoniniani which have only one half of its silver content. The author has encountered a similar high-fineness piece (of Aurelian) - in another study - which is also inexplicable at present, for there is no other evidence for the existence of a higher silver denomination than the antoninianus, possessing similar appearance and dimensions, in this period.

18. The imperial coinage of Probus (Items 10 to 15) is well represented by issues from mints lying between Lyons and Antioch, and these all bear the expected fineness of approximately 4½% silver - despite the widely different alloy and impurity levels which are typical of the different characteristics of the basic coppers which were perhaps supplied from the nearest local source to each mint. The western habit of using no tin at this time, in contrast with the eastern tendency to make argentiferous coinage bronzes containing about 2½% tin, is now apparent; and this is of considerable significance to the mint-attribution of unmarked or damaged coins whose analyses may be made in future for this purpose.

19. The isolated coin for Numerian, from the mint of Ticinum (Item 16) is remarkably similar in all its metallurgical characteristics to the ones minted up to eight years earlier for Probus. Indeed, with only one exception (Item 8) the composition of the coinage of the decade AD 274 to 284 shows a remarkable stability and control of minting policy with respect to fineness, together with a freedom for local flexibility in metallurgical preference and practice based on individual mint tradition. This is characteristically Roman in concept and is to be encountered again with the coinage of the many different mints used in the early fourth century.

20. The coins of Carausius (Items 17 to 20) typify, metallurgically, the independence of spirit with which he usurped and established a separate British Empire. Not only are the coinage alloys distinctive in possessing a fineness of less than one-half of that of the products of the legitimate imperial mints, but the high purity of the British copper used in their manufacture imparts compositional characteristics which are now revealed as being much superior to any of the alloys of the imperial coinage.

21. It is also remarkable that, despite the abundant supply of tin available in the British Isles (which was later exploited to excess in the Gallic coinages produced in the empire after the re-conquest) the British coinage alloys of AD 286-296 contain much less tin than even the low-tin eastern imperial coinage.

22. Certain unmarked pieces minted for Carausius have been attributed by R A G Carson to a northern Gallic mint - most probably Boulogne. Their negligible silver content - in comparison with the positive (although low) silver content of the British marked pieces - at first adumbrated a different place of origin; but a full analysis (of Item 20) now confirms this beyond doubt. The nickel impurity content is certainly conventionally western, but it is associated with a much higher than usual zinc proportion which points to the basic copper alloy being non-British. Consequently the coin was almost certainly minted in the alternative north-Gallic territory then controlled by Carausius, with the garrison city of present-day Boulogne as the strongest possibility for the location of the mint.

23. Radiate coins resembling the antoniniani of AD 274 to 294 were minted at most of the already established mints when Diocletian and Maximian completed their major coinage reform of AD 294 - but not at any of the newly-created mints. In obverse design and in module they bear close similarities to the pre-reform antoniniani; but their fundamental difference is that they contain virtually no silver above what may be regarded as impurity level. The full analysis of a Cyzicene piece of AD 295/9 (Item 21) reveals a greater economy also in the use of tin in the alloy: together these features are indicative of a major change from an argentiferous bronze to a cheaper impure copper for this reformed coinage in general. The rather later issue from Alexandria (Item 22) shows the same basic low quality copper - although the proportions of impurities present show differences between the two mints, as might be expected when their local sources of base metal are not identical.

24. The tetradrachm analyses are valuable in that they now establish

the precise Egyptian year (September 277 to August 278) in which the suspected dramatic debasement by the Emperor Probus began; and this was completed in the following two years when the tetradrachm alloy became little more than a leaded bronze. These consequent alloy trends, no doubt designed to cheapen the cost of the coinage metal with substantial additions of lead, followed this ultimate establishment of the tetradrachm as a purely token coinage containing no intrinsic worth of silver. The event is, however, without parallel in the imperial coinage of Probus, and must have had serious repercussions on any artificially maintained exchange rate between the antoninianus and the tetradrachm.

25. It was their total lack of added silver which enabled the tetradrachms to continue in issue, without apparent change, for a few years after Diocletian's reform which had necessitated the ultimate in the debasement of the antoninianus. Items 27 to 30 reveal the excess to which lead was added to the tetradrachms whose other alloying and impurity constituents remained fairly conventional - except for an increase in the proportions of tin in the alloy, perhaps to compensate for the lack of silver with the lesser whitening influence of tin. The resultant leaded bronze tetradrachms of AD 278 to 290 are palpably poorer in overall metallurgical quality than the earlier mintages; and they are generally found to be very deeply corroded - the corrosion having made deep inroads via the inter-connected anodic lead-rich microstructural phase. It was the visible extent of this corrosion which necessitated pre-analysis fusion-reduction so as to obtain enough sound metal for a proper analysis.

CONCLUSION

26. The objectives of the present study have been fully realised, and new metallic composition data of the highest analytical accuracy and reliability have been obtained for hitherto enigmatic coinages. The results now provide numismatists and historians with positive criteria for their interpretations of the economic history and legislation of the times, some of which are initiated and developed in the discussion. Furthermore, they set standards of scientific technique which can be repeated should this type of work be extended in the future, and provide fundamental criteria against which comparisons can always be made.

Lawrence H Cope
Culcheth, 3 November 1977

APPENDIX I

THE DONORS OF THE THIRTY COINS ANALYSED

Coin Code Prefix	Donor
A	Ashmolean Museum, Oxford
AHB	A H Baldwin & Son Ltd, London
AJHG	A J H Gunstone Esq
B	City of Birmingham Museum & Art Gallery
BM	The British Museum
Ca	Carlisle Museum
Ex	Exeter Museum
LHC	The author
NMW	National Museum of Wales
SL	Schweizerisches Landesmuseum, Zürich

APPENDIX IIa CHEMICAL ANALYSES OF RADIATE IMPERIAL COINS AD 268-307

Item	Code No.	Emperor	Date of Issue	Mint	RIC No.	Chemical Composition - Weight Per Cent									Total
						Copper	Tin	Silver	Lead	Iron	Nickel	Cobalt	Zinc	Gold	
1	BM. 421	Marius	268	Gaul	19	87.32	0.192	5.129	4.935	0.471	0.030	0.001	0.008	0.048	98.134
2	AHB. 38	Gallienus	268	Siscia	580	93.03	0.381	5.397	0.583	0.024	0.033	0.004	0.039	0.030	99.521
3	BM. 491	"	268	"	580	95.11	0.115	3.620	0.409	0.015	0.054	0.001	0.058	0.020	99.402
4	Ex. 2	"	272/4	Milan	129	88.41	3.566	2.986	3.574	0.011	0.033	0.001	0.018	0.029	98.628
5	AHB. 40	"	"	Cyzicus	348	88.86	3.948	2.671	2.244	0.011	0.044	0.004	0.032	0.021	97.835
6	Ex. 3	Aurelian	275	Milan	120	88.79	4.876	3.391	1.410	0.009	0.047	0.001	0.015	0.003	98.542
7	Ca. 72	Tacitus	275/6	Lyons	30	93.11	0.061	5.198	0.434	0.028	0.020	<0.001	0.006	0.022	98.879
8	Ex. 4	"	275/6	Cyzicus	cf 206	88.63	1.137	8.932	0.183	0.008	0.039	0.004	0.029	0.034	98.996
9	AJHG.19	"	275/6	Rome	92	91.09	2.778	4.447	0.545	0.008	0.031	0.001	0.022	0.011	98.933
10	AJHG.20	Probus	276-282	Rome	202	91.35	1.616	4.683	0.450	0.037	0.044	0.004	0.025	0.031	98.240
11	SL. 17	"	276-282	Ticinum	517	92.57	0.048	4.887	1.543	0.062	0.032	0.002	0.008	0.035	99.187
12	Ca. 59	"	276-282	"	351	95.02	0.006	3.723	0.638	0.084	0.042	0.002	0.088	0.028	99.631
13	AHB. 41	"	276-282	Siscia	732	92.70	1.081	4.373	1.079	0.089	0.039	0.003	0.014	0.021	99.399
14	Ex. 5	"	276-282	Antioch	925	89.58	2.454	4.400	1.774	0.016	0.061	0.011	0.103	0.005	98.404
15	Ex. 6	"	276-282	Lyons	35	93.48	0.036	4.566	0.169	0.017	0.023	<0.001	0.007	0.015	98.313
16	AJHG.13	Numerian	284	Ticinum	446	94.09	0.085	4.323	0.277	0.017	0.041	<0.001	0.012	0.023	98.868
17	NMW50	Carausius	286/7	London		95.91	0.146	2.171	1.118	0.017	0.025	0.002	0.013	0.019	99.421
18	LHC.14	"	286/7	"	287	96.40	0.077	1.460	1.206	0.042	0.021	0.003	0.014	0.011	99.234
19	Ca. 60	"	288/9	"	101	92.81	1.876	2.589	1.458	0.014	0.028	0.002	0.005	0.023	98.805
20	Ca. 61	"	286/90	Boulogne	895	96.57	0.836	0.079	1.140	0.015	0.027	0.002	0.117	0.002	98.788
21	LHC.39	Constantius	295/9	Cyzicus	vi 19a	90.74	1.666	0.276	3.894	0.070	0.078	0.046	0.115	0.001	96.886
22	Ex. 12	Max Daza	305/7	Alexandria	vi 60b or 85	96.85	0.021	0.195	1.569	0.018	0.039	<0.001	0.007	0.003	98.702

APPENDIX IIb CHEMICAL ANALYSES OF ALEXANDRIAN TETRADRACHMS

23	A. 29	Severina	Aug/Oct 275	Year Z	Milne 4469	90.06	2.110	2.562	4.455	0.014	0.047	0.005	0.123	0.013	99.389
24	BM. 481	Aurelian	"	Year Z	BMC 2345	89.68	2.406	2.382	4.960	0.030	0.048	0.004	0.098	0.007	99.615
25	B. 177	Tacitus	early 276	Year A	Milne 4493/5	91.67	1.256	1.798	3.522	0.013	0.029	0.002	1.317	0.012	99.619
26	AHB. 14	Probus	278/9	Year Δ	Milne 4574	90.55	2.431	1.517	3.713	0.006	0.045	0.003	0.093	0.002	97.861
27	BM. 482	"	279/80	Year E	BMC 2429	78.84	3.744	0.564	15.719	0.009	0.043	0.005	0.148	0.005	99.077
28	BM. 483	"	281/2	Year Z	BMC 2431	80.38	5.162	0.149	12.977	0.013	0.044	0.006	0.348	0.003	99.082
29	A. 25	Numerian	283/4	Year β	Milne 4719	80.86	6.018	0.256	11.506	0.015	0.038	0.007	0.366	0.004	99.070
30	AHB. 13	Diocletian	290/1	Year Z	Milne 4946	72.77	3.896	0.102	22.254	0.011	0.043	0.005	0.101	0.003	99.185

