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## The alloy content of folles and imitations from the Woodeaton hoard

Recent years have seen increasing interest on the part of numismatists in determining as accurately as possible the alloy content of ancient and medieval coins. The development of non-destructive methods of analysis and in particular x-ray fluoresence has enabled researchers to examine fairly large numbers of coins relatively quickly and graph the results obtained. Up to now most of the actual analyses have been performed by scientists but during the past two years in Oxford four numismatists have been trained to use the x-ray fluorescence equipment at the research laboratory in archaeology, which has meant that a considerable range of projects have been undertaken, the results of which in some cases are already in print<sup>1</sup>.

The numismatist analysing groups of coins by x-ray fluoresence soon becomes acquainted with the advantages and pitfalls of the technique and it is not necessary here to discuss the practical problems of segregation, surface enrichment, or matrix effects all of which have been critically assessed previously<sup>2</sup>. Nor is there any real need to compare the advantages and disadvantages of conventional wet analysis techniques with those of x-ray fluorescence<sup>3</sup>. Although there is no doubt that individual results obtained by wet analysis are undoubtedly more accurate for the coin as a whole than those obtained by superficial analysis, the information derived from the latter can nonetheless be useful since by examining and comparing the alloy content of a large number of coins one can have a broad view of the parameters within which various alloy components could fluctuate.

Few superficial analyses exist for the argentiferous bronze coinage produced by Constantine in the years A.D. 330-341 although there is a relatively substantial body of full chemical analyses by L.H. Cope<sup>4</sup>. In this present study approximately

<sup>&</sup>lt;sup>1</sup> For example: D.R. WALKER *The Metrology of the Roman Silver Coinage*, Pt. I, Augustus to Domitian, British Archaeological Reports Supplementary Series, Vol. 5, 1976, and Pt. 2, Nerva to Commodus, *ibid.*, Vol. 22, 1977.

<sup>&</sup>lt;sup>2</sup> J. CONDAMIN and M. PICON, Changes Suffered by Coins in the Course of Time and the Influence of these on the Results of Different Methods of Analysis, — in Methods of Chemical and Metallurgical Investigation of Ancient Coinage (RNS Special Publication, 8), 1972; pp. 49 ff. and F. SCHWEIZER, Analysis of Ancient Coins Using a Point Source Linear X-ray Spectrometer: A Critical Review, ibid., pp. 153 ff.

<sup>&</sup>lt;sup>3</sup> L.H. COPE, Archaeometry, 1973, pp. 221 ff.; Num. Chron., 1967, pp. 109 ff.

<sup>&</sup>lt;sup>4</sup> L. H. COPE, The Metallurgical Development of the Roman Imperial Coinage During the First Five Centuries A.D. (unpub. PhD thesis of the Council for National Academic Awards, March 1974, pp. 226 ff. (forthcoming as an RNS special publication.) Cope's analyses have been of inestimable value since they provided a reliable set of data against which the x-ray analyses could be compared and assessed. J. N. BARRANDON, J. P. CALLU and C. BRENOT however have published analyses of

350 coins have been analysed all of which came from the Woodeaton Hoard of folles found in Oxfordshire<sup>5</sup>. The original hoard contained more than 1500 coins largely of Western provenance, and has never been fully published<sup>6</sup>. Most of the coins can be dated to A.D. 330-341 with well over 50% falling in the years 330-335. In addition to the genuine pieces there were approximately 100 ancient imitations readily recognizable by their small size, blundered legends or clumsy execution<sup>8</sup>.

The argentiferous bronze coinage of A.D. 330 which had been debased several times after 306 and once reformed, consisted of a single denomination weighing c. 2.5 gm. with approximately one percent silver in its alloy which L.H. Cope identifies as a Roman Standard of three scrupula per libra (theoretically 1.04%) There were three standard reverse types: GLORIA EXERCITVS, Wolf and Twins, and Victory on Prow. In 335 this coinage was again altered and the weight was reduced to 1.5 gm<sup>9</sup>.

The purpose of this study was to discover whether by non-destructively analysing a large number of coins of the same provenance which had been produced by several mints and restricted to a fairly brief span of time, one could distinguish: 1) differences in alloy content of coins from different mints; 2) significant changes in the alloy content between 330-341; and 3) differences between the alloy content of ancient imitations in the Woodeaton Hoard and that of genuine coins. The coins were analysed by the isoprobe using an americium source which is especially useful when measuring coins of a high copper content and very low silver.

The predominant alloy components of folles of the early fourth century are copper, lead, tin and silver but frequently there are traces of gold, nickel, cobalt, iron, arsenic, antimony and zinc as well 10. The major ingredient was copper with proportions of silver and tin which ranged on average between just below 1% to about 4%. The lead content, however, was much more variable particularly in coins from the Western mints as Cope has demonstrated for the years 313-328. Between the years 313-318 for example, the percentage of lead in folles from Trier, Lyons, and Arles ranged from 3% to 14% although it appears to have stabilized

Constantinian coins A.D. 31240 in *Archaeometry*, 19, 1977, pp. 173 ff. not available to me when writing this paper.

- <sup>5</sup> A brief report of the hoard was published by Milne in JRS in 1931, pp. 108 ff. A complete catalogue and discussion of the hoard's contents is forthcoming in the *Num. Chron.*, 1978.
- <sup>6</sup> It is interesting to compare the chronological distribution of the coins from Western mints with that for the Appleford Hoard (RBN 1977) since the latter has very few coins of 330-335 with the bulk of the hoard falling both earlier and later.
  - <sup>7</sup> The actual figure is c. 76%.
  - <sup>8</sup> The Appleford Hoard also contained a small but significant proportion of ancient imitations.
- <sup>9</sup> For the weights and finenesses see fig. 6. Cope has identified a slight rise in fineness to a standard of 4 scrupula per libra (theoretically 1.35%).
- of Chemical and Metallurgical Investigation of Ancient Coinage (RNS Special Pub. no. 8), 1972, pp. 34 ff.
  - 11 Ibid.

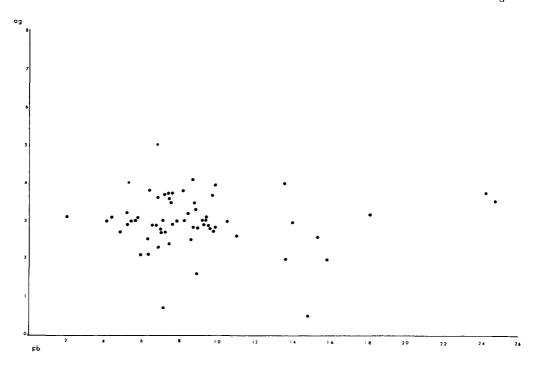


Fig. 1. Trier 330-335. Lead Content.

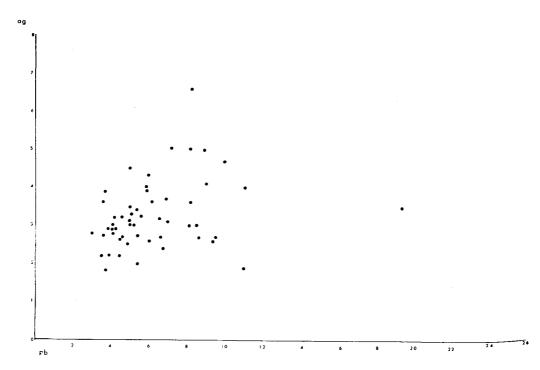


Fig. 2. Lyons 330-335. Lead Content.

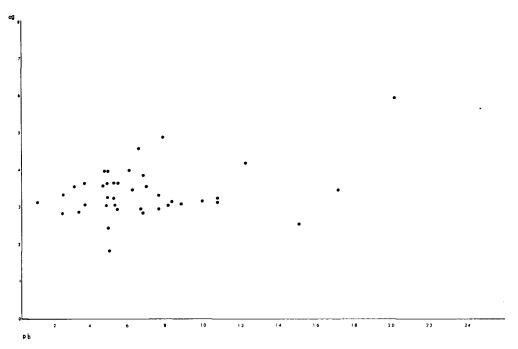


Fig. 3. Arles 330-335. Lead Content.

after the reform of c. 317 until 330 at about  $3^{1}/_{2}$ - $4^{1}/_{2}\%^{12}$ . After 330 the amount of lead used in the alloy at Western mints again increased, and in particular at Trier <sup>13</sup>. A comparison of the lead contents of folles from the Woodeaton Hoard of 330-335 from the mints of Trier, Lyons, and Arles (Figs. 1-3) using graphs constructed from the ratio figures, demonstrates that all three mints had a significant number of coins with a relatively high lead content. Folles from Trier seem to have had a higher lead content with a majority of coins falling between ratio values 6 and 10 than those of Lyons and Arles whose ratio values peak between 4 and 8. Trier and Arles also had a more scattered distribution than Lyons with more coins between 10 and 20 on the ratio scale.

After 335 the lead content of folles seems to have increased even more at both Trier and Lyons. Trier again shows a more dispersed distribution than Lyons with much higher ratio figures at the top end of the scale<sup>14</sup>. (Figs. 4-5) Cope has not yet published the lead content of more than a few folles of 335-341 from Western mints although one contained 19.62% lead; and three coins belonging to the following period, one of which was from Trier had lead contents of  $15^{1}/_{2}\%$  and  $17^{1}/_{2}\%$  and so it seems very likely that the practice of alloying copper with

<sup>12</sup> Ibid

<sup>&</sup>lt;sup>13</sup> L.H. COPE, The Mettallurgical Development of the Roman Imperial Coinage, p. 226.

<sup>&</sup>lt;sup>14</sup> The very high values are to be regarded with some distrust since they undoubtedly reflect segregation effects.



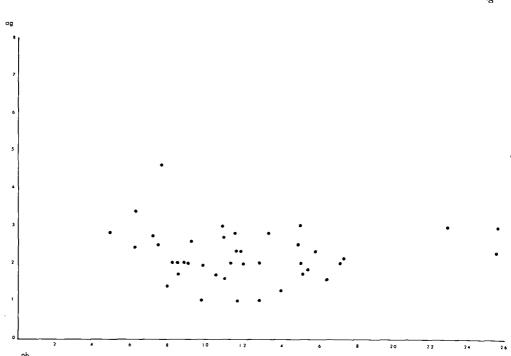


Fig. 4. Trier 335-341. Lead Content.

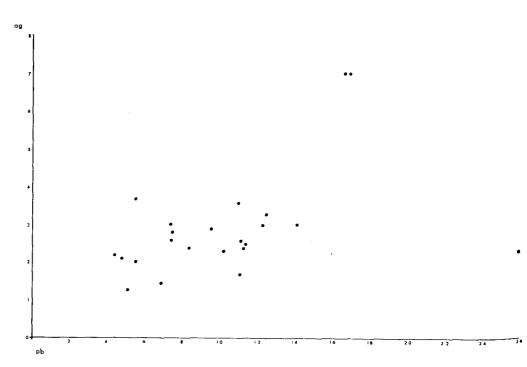


Fig. 5. Lyons 335-341. Lead Content.

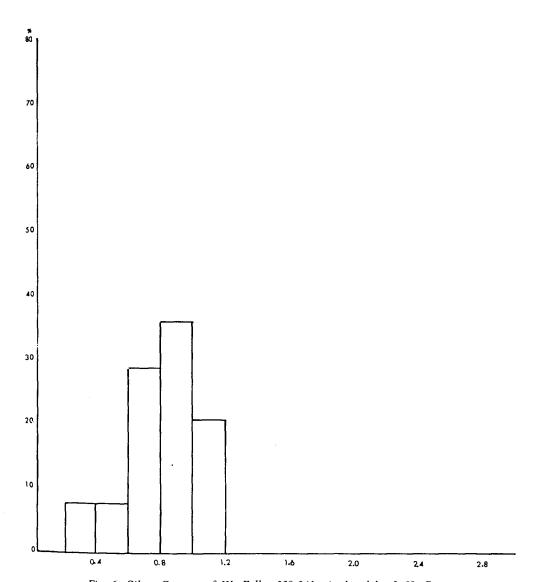


Fig. 6. Silver Content of W. Folles 330-341. Analysed by L.H. Cope.

substantial quantities of lead again became common in the West in the 330s and after 15.

The problems of determining the actual percentage of lead in an alloy content of this sort are enormous owing to segregation and subcutaneous corrosion effects and for these reasons it was decided not to try and convert the lead ratios into

<sup>&</sup>lt;sup>15</sup> COPE, *ibid.* p. 226; *Bulletin of the Historical Metallurgy Group*, Vol. 1, no. 9, 1967, pp. 1 ff. Ref. W 5. Interestingly this piece had no silver in its alloy which leads one to wonder if it was in fact genuine.

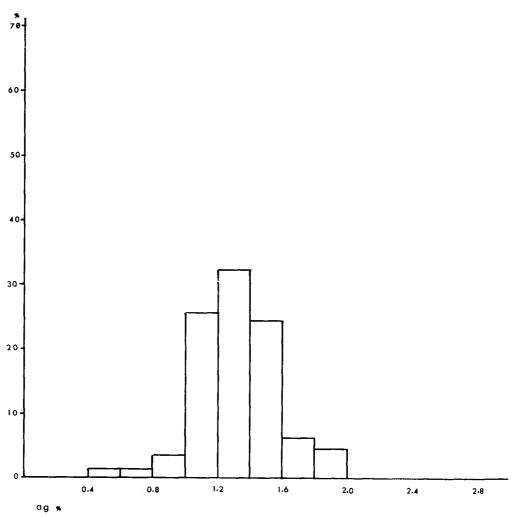


Fig. 7. Trier 330-335. Silver Content.

percentages <sup>16</sup>. There is no doubt, however, that in the West lead was a significant alloy component in the coinage of the 330s and that the amount used was on the increase between 330-341.

16 Some notion of the variability of lead readings can be seen from a comparison of three results of the same coin half of which had previously been analysed by L.H. Cope and found to have a lead content of 9.2%. See *The Metallurgical Analysis of Roman Imperial Silver and Aes Coinage*, pp. 36-7 coin no. 36. The ratio readings I obtained were 1.1, 2.3 and 4.6 respectively. Unfortunately the readings from this coin and a number of others of known composition lent to me by Cope were too variable to permit the construction of a straight line graph. It may be worth noting however that lead contents known to be in excess of 12% had ratio readings of 6.5 and 7.9 respectively which is certainly compatible with the lead ratio figures from Trier, Lyons and Arles in the Woodeaton Hoard. Similar problems exist for silver contents although they are less severe. A comparison of the XRF readings with Copes results yields the following answers: Cope NMW 40 (0.9% Ag): 1.2%; NMW 39 1.37% Ag: 1.7%; NMW 38 1.73% Ag: 2.0%.

TABLE A. TIN CONTENT OF FOLLES 330-335.

SN %	TRIER		LYONS		ARLES		ROME		AQUILEIA		SISCIA	
	No.	%	No.	%	No.	<u>%</u>	No.	%	No.	%	No.	%
0.1-0.4	1	1.6	3	5.7	_	_	_					
0.5-0.9	2	3.2	3	5.7	1	2.4	1	4.5	-		3	18.7
1.0-1.4	2	3.2	25	47.2	8	20.0	3	13.6			5	31.2
1.5-1.9	17	27.0	10	18.9	6	15.0	3	13.6			5	31.2
2.0-2.4	10	15.9	5	9.4	13	32.5	1	4.5	1	14.2	2	12.5
2.5-2.9	19	30.1	3	5.7	5	12.5	8	36.4	1	14.2	1	6.2
3.0-3.4	7	11.1	1	1.9	2	5.0	3	13.6		_		
3.5-3.9	1	1.6	2	3.7	3	7.5	1	4.5		_		_
4.0-4.4	3	4.8		_					1	14.2		
4.5-4.9	_	_		_	1	2.4	1	4.5	1	14.2	_	_
5.0-5.4	1	1.6			_	_		_	_			
5.4-5.9		_	_	_			1	4.5	-			
6.0-6.4	_	_	_		_	_	_		2	28.6		
6.5-6.9	_		1	1.9					1	14.2		
7.0-7.4	_	_	_	_	_	_	_					_
7.5-7.9	_	_	_			_			_		_	
8.0-8.4		_		_			_		_		_	_
8.5-9.0										_	_	
9.0-9.4	-				1	2.4				_		

The tin content of the argentiferous bronze coinage of the earlier fourth century also varied from series to series but much less dramatically than the lead. The early folles contained on average between 2% and 5% tin and this proportion was maintained in the alloy content at the Western mints until 330 except at London where it was dropped briefly c.  $322^{17}$ . The one analysis by Cope recording the tin content of a follis of Trier datable to 330-335 is 2.41% which is compatible with the results obtained from the Woodeaton hoard which ranged from 0.4% to 5.5% but were concentrated between  $1^{1}/_{2}\%$  and 3% for Trier, and 1% to  $2^{1}/_{2}\%$  for Lyons and Arles  $1^{18}$ . Coins minted at Rome had a distribution very like Trier ( $1^{1}/_{2}\%$ - $3^{1}/_{2}\%$ ) while Siscia coins were more like Lyons or Arles (Table A). Between 335-341 the tin content of folles from Trier, Lyons, and Arles was concentrated between  $1^{1}/_{2}-3\%$  (Table B). Despite minor mint differences these figures suggest that the tin content of Western folles from 330-341 was regulated at a level between  $1^{1}/_{2}-3\%$ . There are exceptions, for example a number of coins had more than 5% tin, but these do not form a significant part of the total.

Fortunately as a result of L.H. Cope's work we now have a reasonable number of full chemical analyses of coins from W. mints datable to 330-335<sup>19</sup>. By

<sup>&</sup>lt;sup>17</sup> COPE, *ibid.*, pp. 40-1.

<sup>&</sup>lt;sup>18</sup> COPE, The Metallurgical Development of the Roman Imperial Coinage, pp. 226.

<sup>&</sup>lt;sup>19</sup> *Ibid.*, pp. 226 ff. Dr. Cope has also generously allowed me to see the results of a further group of analyses he has undertaken of argentiferous bronze coins of 330-341 and I have included them in the graph illustrating the silver content of the folles of this period which he has analysed.

graphing the silver percentage of all folles he analysed from Trier, Arles, and Lyons for 330-335, it is clear that the peak falls between 0.8-1.0% silver and 85% of the coins fall between 0.6-1.2% (Fig. 6). Coins from Trier, Lyons, and Arles from the same period in the Woodeaton Hoard present a somewhat different pattern (Figs. 7-9). All seem to have a higher silver content than the coins analysed by Cope but it should be noted that the figures do not reflect totals corrected to include the tin and lead contents since the latter was so difficult to quantify in the x-ray fluoresence analysis. Thus in individual cases the silver % could be as much as 20% too high. Nonetheless the figures are still of interest since they demonstrate that coins of Trier had a slightly lower peak (1.2%) and tighter distribution than Lyons and Arles (1.4%). Arles has a slightly narrower distribution than Lyons and both Arles and Lyons had more coins of a higher silver content than Trier did.

After 335 there appears to have been a drop in the silver content at the Western mints or at least a slightly less well-maintained standard to judge from the Woodeaton Hoard (Figs. 10-11). The silver content of Trier coins is concentrated between 0.8-1.0% while that of Lyons falls between 1.0-1.2%. These results are compatible with the range recorded by Cope which varied from 0.5-1.66% at Trier and 0.56-1.41% at Lyons with the lower percentages predominating <sup>20</sup>.

TARLE	R	TIN	CONTENT	ΩF	FOLLES	335_341

	TR	IER	LY	ONS	ARLES		
Sn %	No.	%	No.	%	No.	%	
0.1-0.4		_					
0.5-0.9	1	2.4	_				
1.0-1.4	5	12.2	1	4.8	2	20.0	
1.5-1.9	12	29.3	14	66.6	4	40.0	
2.0-2.4	11	26.8	4	19.0	3	30.0	
2.5-2.9	2	4.9		_			
3.0-3.4	2	4.9	1	4.8	1	10.0	
3.5-3.9	4	9.7	1	4.8	_	_	
4.0-4.4	_				_		
4.5-4.9	1	2.4	_	_	_	_	
5.0-5.4	_						
5.5-5.9			_	_	_	_	
6.0-6.4						_	
6.5-6.9	1	2.4		_	_		
7.0-7.4	_					_	
7.5-7.9			_	_			
8.0-8.4	2	4.9		-			

<sup>&</sup>lt;sup>20</sup> Ibid., Cope's results suggest an increase in silver content from 335-7 and an apparent drop thereafter at the Western mints which is supported by these analyses. Barrandon et al., Archaeometry, 1977, p. 177 publish results which do not seem to show a decline after 337 in the silver standard in the West.

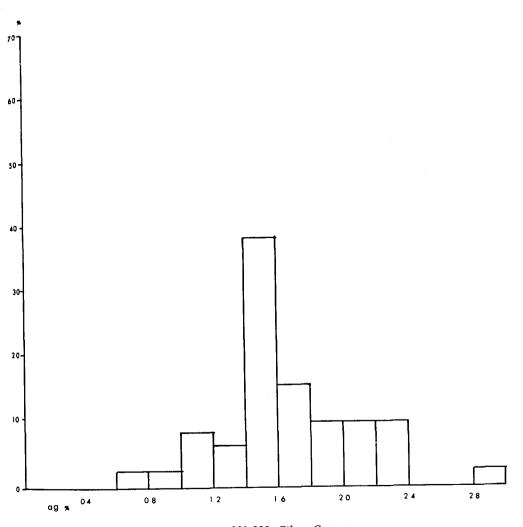


Fig. 8. Lyons 330-335. Silver Content.

It is worth noting that although fourth century folles are known to have been silver coated any surface silvering that the Woodeaton coins may have had originally has long since disappeared. Although the somewhat higher silver figures obtained from the x-ray analyses could be due in part to surface enrichment, the fact that the silver figures have not been corrected either for tin (1-3%) or for lead, which was likely to range from 4-13% probably provides up to 15% of the difference between the Woodeaton figures and those obtained by Cope. What is significant is that both the silver and lead content of folles minted between A.D. 330-341 show a difference between mints among coins produced in the West, an increase of lead, and a slight decline in silver after 337.

Most of the ancient imitations are readily distinguished from official issues on the basis of their aberrant style and smaller size. However, some obviously

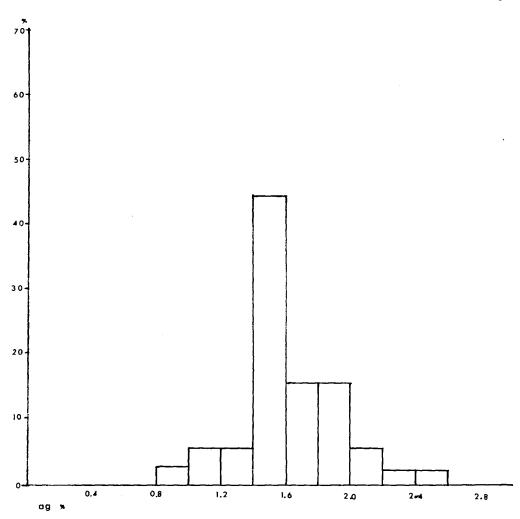


Fig. 9. Arles 330-335. Silver Content.

were good enough to be hoarded and in a period when genuine pieces were often carelessly struck it is not surprising that some of the copies passed a casual inspection  $^{21}$ . In weight they are compatible with the standard in use after 335 (i.e. c.  $1^{1}/_{2}$  gm.) although the types are often copies of pieces produced on the 2.5 gm. standard which prevailed from 330-335.

It is in their alloy content that the imitations diverge most sharply from the official issues. Without exception the Woodeaton copies had extremely low silver

<sup>&</sup>lt;sup>21</sup> There is evidence earlier in the century that bronze coinage circulated in bags worth 12,500 denarii. To the extent that money was passed back and forth in sacks and not subjected to a very careful examination each time a bag changed hands, it would have been relatively easy for forgeries to be included with genuine coins. See J.-P. CALLU, *La politique monétaire*, p. 363 who summarizes the relevant evidence substantiating the circulation of coins in bags.

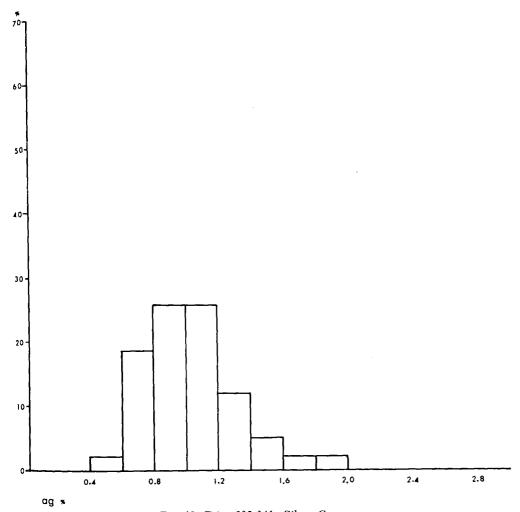


Fig. 10. Trier 335-341. Silver Content.

contents which ranged on average between 0.0-0.4% (Fig. 12). Normally their tin content was equally low, c. 82% of the imitations had a tin content between 0.0-1.4% and 60% had 1% tin or less (Table C). There is no doubt whatever that the alloy content of the imitations differed significantly from that of genuine pieces and that the more valuable alloy components, i.e. silver and tin are the ones which have been left out of the imitations. Not surprisingly the imitations have extremely high lead contents. Over 40% had lead ratios between 9 and 13. It seems likely that lead was added as a cheap method of giving the coins weight.

What is less certain is whether some of the immitations were made from official coins which had been melted down and their silver and tin extracted. This practice was banned later in the century as we know from a law in the Theodosian Code which could suggest that the abuse existed earlier in the century as well<sup>22</sup>.

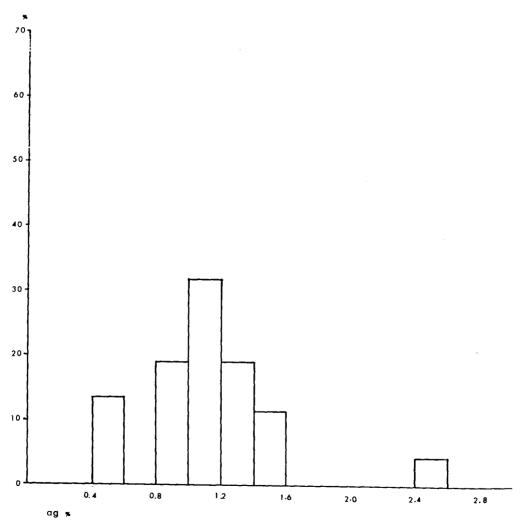


Fig. 11. Lyons 335-341. Silver Content.

In conclusion: The analyses of folles of A.D. 330-341 from the Woodeaton Hoard show: 1) minor but significant alloy differences between the mints of Trier, Lyons and Arles; 2) indications of either a declining silver standard at these mints, or perhaps one which was less well-maintained than it was at the Eastern mints<sup>23</sup>, and 3) a clear distinction on the basis of alloy content between official issues and contemporary imitations since the latter have virtually no silver or tin in their composition and a high proportion of lead.

It remains to consider briefly why the Western mints were unable to maintain the silver content of the follis in a period when the Eastern mints apparently were

<sup>&</sup>lt;sup>22</sup> C TH 9 21, 6 (A.D. 349): Comperimus nonullos flaturarios maiorinam pecuniam non minos criminose quam crebre separato argento ab aere purgare....

<sup>&</sup>lt;sup>23</sup> Barrandon, et al., op. cit., p. 184 where the pattern becomes clear after 335.

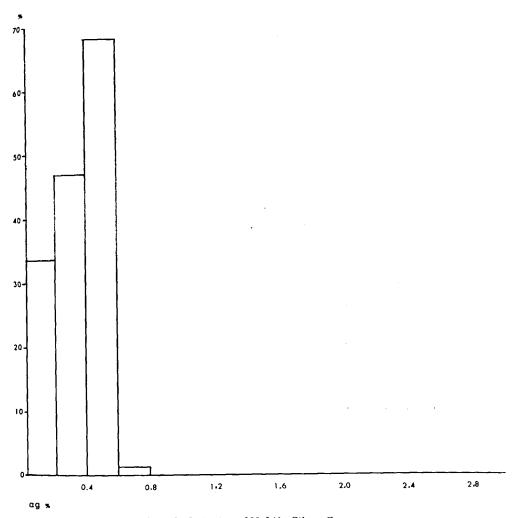


Fig. 12. Imitations 330-341. Silver Content.

not experiencing the same difficulty. Two possible solutions can be suggested although neither is particularly satisfactory. It is conceivable that supplies of silver at the Western mints were insufficient for the Gallic mints to maintain the official silver level. It should be noted however that one of the few established sources of fourth century silver was in Britain where it was mined in the Mendips and in theory at least this silver should have been accessible to the Gallic mints<sup>24</sup>. Alternatively there may have been abuse on the part of mint officials which

<sup>&</sup>lt;sup>24</sup> Unfortunately we do not know whether silver and gold were supplied to mints directly from the central government or on a more local basis. If gold and silver first went to the central administrative bureau and was then handed back to regional mints, delays in receiving supplies would be understandable.

TABLE C. TIN CONTENT OF IMITATIONS 330-341.

Sn %	No.	%
0.0-0.4	34	41.4
0.5-0.9	17	20.7
1.0-1.4	16	19.5
1.5-1.9	4	4.9
2.0-2.4	3	3.6
2.5-2,9	3	3.6
3.0-3.4	2	2.4
3.5-3.9	2	2.4
4.0-4.4		
4.5-4.9	1	1.2

led to a decline in the silver content and an increase of lead<sup>25</sup>. The way in which the alloy content of the Western folles was regulated however suggests that its vicissitudes in the 330s were the result of policy since one would have expected the alloy content of the coinage to fluctuate much more if mint workers were abusing the system. It is to be hoped that further analyses determining the limits within which the alloy content of folles from central and Eastern mints was allowed to vary may shed some light on this problem.

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<sup>&</sup>lt;sup>25</sup> C Th 9, 21, 2 (A.D. 321) states that some imperial minters were secretly and criminally engaged in the coinage of counterfeit money although which coins they were counterfeiting is not specified. Producing counterfeits at an imperial mint, however, and modifying the alloy content of the bronze coinage are not the same offence.