NEUTRON ACTIVATION ANALYSIS OF SILVER IN SOME LATE ROMAN COPPER COINS

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INTRODUCTION

To understand the late Roman copper coinage it is necessary to know if it did, as so often supposed, contain some proportion of silver. 122 coins, representing the main issues of the fourth century, and including some counterfeits of fourth-century coins, were chosen for analysis by neutron activation. 24 "radiates", both genuine and counterfeit, of the third century, preceded by a "double *denarius*" of Caracalla, were also examined.[1]

TECHNICAL REPORT

The technique has been described in Archaeometry Vol. I (pp. 6 ff.), and in studies of coinage it has been used to compare trace elements in Greek silver, and to determine the silver content of Diocletianic billon coins (Archaeometry Vols. 1–3, 4). The coins in question here were irradiated, together with "standards" of pure silver foil, with neutrons in the BEPO reactor at Harwell, at the rate of 12×11^{11} neutrons/sq. cm./second. This produced, in those containing silver, the isotope Ag^{110m}, decaying to Ag^{110} with gamma emission of half life 253 days. After the lapse of a month, during which the radiation from other isotopes (especially Cu^{64}) declined to small proportions, the remaining gamma-ray activity was examined with a scintillation spectrometer.

Pulses caused by the gamma rays from the silver present were recorded at those energy levels where gamma-ray emission from silver is especially strong: 0.67 MeV and 0.89 MeV. These readings were then compared with those from the standards. It was deemed that the distance of the samples from the crystal was sufficient to eliminate differences in geometry between the coins and the standards.

Certain coins had a full gamma-ray spectrum taken, and the profile of this indicated whether other elements were significantly contributing to the total gamma radiation. Time precluded the possibility of doing this with every coin, but all were recorded not only at the "peaks" of intensity for silver, but at the neighbouring "valleys." If this ratio was much higher in the coins than in the standards, this was taken as an indication of interfering elements, and a closer search for possible contributing isotopes was made.

In fact, antimony (Sb^{124}), whose maximum near the 0.67 MeV peak occasionally caused confused readings, seemed to be the only source of significant interference. It was very marked in the case of only one coin (No. 58), which was later found by wet analysis to have no silver, but to have about 0.35% antimony. This coin was also unusual in being composed mainly of tin.

The best test of results is to take readings again after a lapse of time, to confirm that the element contributing the radiation is decaying at the appropriate rate

[1] The work was carried out in Leeds in 1961-2 by courtesy of the Metallurgy Department in the Houldsworth School of Applied Science. Thanks are due to Dr. R. Shuttleworth and Dr. R. B. McLellan, who gave me help and lent me facilities, and to Mr. H. A. Foner, who carried out a chemical analysis of six coins. Dr. J. P. C. Kent gave me numismatic advice, and my husband gave me valuable criticism.

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Six coins were later analysed by chemical methods, and the results confirmed the slight overestimation of the silver that had been expected from the gamma-ray analysis. Ten coins were examined again after having their whole surface area filed away, to see if they could give any support to the idea that later Roman coppers had their small quantities of silver concentrated mainly at, or near, the surface. Very little variation in counts was observed after filing, and they might be either slightly above or below those obtained before filing. The experiment threw no light on the possibility of silver coating, which has now been confirmed by other methods,[2] but it indicated the uniform distribution of silver throughout the body of the coins.[3]

For coins with silver content of more than 0.5% the analysis proved its worth. Though in some groups a wide range of silver values was apparent, this is historically plausible. On occasion the results seemed to show distinctions between coins from different mints, or of different denominations, always allowing for the small size of the sample (Figs. 1, 3, 4).

Coins which were recorded with less than 0.5% silver, on the other hand, posed a problem. There was always an emission of energy on the silver peaks. Certain coins which, in spite of this, were found to lack the characteristic silver spectrum, were concluded to be devoid of silver (e.g., Nos. 77, 85). In two other examples the methods of wet analysis indicated absence or mere trace, though the neutron activation technique had indicated considerably more (Nos. 58, 84).

In a surprising number of the remaining coins registering less than 0.5% silver, however, typical silver curves were found to be present, although the proportions are, in all probability, even lower than this method suggests. The question then arises whether amounts of from 0.1% to 0.4% silver could possibly have been added as a matter of policy. While, chemically, such quantities are significant, it seems more likely that they were there as a residue from old and re-used coin metal, which the state now considered unprofitable to separate. When no single denomination of coin was put out bearing, as a rule, 1% or more of silver, we may conclude that the state had abandoned its policy of a "silvered" copper coinage.

[2] E. S. Hedges and Dudley A. Robins, Numismatic Chronicle 1963.

[3] The coins so treated were nos. 7, 13, 25, 42, 54, 59, 82, 106, 111 and third-century radiate no. 9. The count rate reduction or increase after the removal of some 25 per cent. of the mass ranged from 0.6–9.08 per cent. per gm.

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TABLE I

References are (for coins of 306–324) to J. P. C. Kent, The Pattern of Bronze Coinage under Constantine I, Numismatic Chronicle 1957: (for coins up to 346) P. V. Hill and J. P. C. Kent, Late Roman Bronze Coinage Part I, 1960; and (for coins up to 408) R. A. G. Carson and J. P. C. Kent, Late Roman Bronze Coinage Part II, 1960. The marks of *officinae* other than primary are shown in brackets.

	MINT	REFERENCE	% SILVER
Group I (297-311)			
1	London	11	2.3
2	London	11	2.2
3	London	36	1.7
4	Trier	B | ⌐	
5	Trier	B | *	2.0[a]
6	Trier	101	1.8
7	Alexandria	S | EP / ALE	3.4
8	Alexandria	X | CE / ALE	1.6
9	Alexandria	C / ALE	0.4
Group II (317–330)			
10	Trier	209	2.5
11	Trier	212	2.1
12	Trier	212	2.0
13	Lyons	300	2.5
14	Lyons	315	1.3
15	Lyons	318	2.0[b]
16	Rome	516	2.4
17	Siscia	835	2.7
18	Thessalonica	TSEIII	3.2
Group III (330–341)			
19	Trier	51 (S)	1.2
20	Trier	58	1.1
21	Trier	TRP (Constans)	1.2
22	Lyons	195	1.1
23	Lyons	184	1.2
24	Lyons	200	1.3
25	Antioch	1360/9 (T)	1.4
26	Antioch	1380	1.8
27	Antioch	1363 (B)	1.8
Group III (341–346)			
28	Trier	139	0.6[c]
29	Trier	140	0.8
30	Trier	148	0.8
31	Trier	142a	1.1
32	Trier	148 (S)	0.6
33	Trier	138 (S)	1.0
34	Arles	457	0.9
35	Siscia	793	1.1
36	Siscia	793	1.2
Group IV (346–353)			
37	Trier	41	3.5
38	Trier	41 (S)	3.2
39	Trier	42	2.7
40	Rome	593 (E)	1.8
41	Rome	606 (S)	2.9
42	Rome	612 (S)	2.7
43	Thessalonica	1636	1.5
44	Thessalonica	1636 (E)	1.6
45	Constantinople	2012 (S)	1.2[d]
46	Constantinople	2026 (⌐)	1.2
47	Constantinople	2018	1.1
48	Cyzicus	2474	1.7
49	Alexandria	2837 (⌐)	1.3
50	Alexandria	2837 (P)	1.4
51	Alexandria	2837 (⌐)	1.3
52	Siscia	1124	0.3
53	mint unknown	type 1	0.5
54	mint unknown	type 1	0.4
55	mint unknown	type 2	0.5
56	mint unknown	type 1	0.4

MINT

Group IV (350–353) usu
57 Trier
58 Trier
59 Trier
60 Amiens
61 Amiens
62 Amiens
63 Lyons
64 Lyons
65 Rome

Group IV (353–363)
66 Lyons
67 Lyons
68 Arles
69 Arles
70 Arles
71 Rome
72 Rome
73 Rome
74 Rome
75 Constantinople
76 mint unknown

Group V (364–375)
77 Lyons
78 Arles
79 Arles
80 Arles
81 Rome
82 Rome
83 Siscia
84 Siscia
85 Siscia

Group VI (383–392)
86 Arles
87 Rome
88 Constantinople
89 Constantinople
90 Siscia
91 Antioch
92 Antioch
93 Alexandria
94 Alexandria
95 Cyzicus
96 mint unknown
97 mint unknown
98 mint unknown

Group VII (388–408)
99 Lyons
100 Rome
101 Constantinople
102 Constantinople
103 Antioch
104 Antioch
105 mint unknown
106 mint unknown
107 mint unknown
108 mint unknown
109 mint unknown

Chemical analy

MINT		REFERENCE	% SILVER
Group IV (350–353)	usurping emperors		
57 Trier		55 (S)	2.0
58 Trier		56 (S)	0.2[e]
59 Trier		62	0.5
60 Amiens		2	1.9
61 Amiens		9	1.4
62 Amiens		6	1.0
63 Lyons		239	0.6
64 Lyons		217	2.3
65 Rome		650	2.3
Group IV (353–363)			
66 Lyons		//PLG	1.2
67 Lyons		//SLG	1.2
68 Arles		457 (S)	1.3
69 Arles		455 (S)	1.4
70 Arles		455 (T)	1.1
71 Rome		680/2	0.8
72 Rome		695	0.4
73 Rome		695	0.4
74 Rome		695	0.4
75 Constantinople		2056	2.9
76 mint unknown		—	0.8
Group V (364–375)			
77 Lyons		322	0.0
78 Arles		477/8	0.4
79 Arles		525/6	0.3
80 Arles		528	0.2
81 Rome		723	0.2
82 Rome		724	0.2
83 Siscia		1278	0.1
84 Siscia		1445	0.1[f]
85 Siscia		1271/2 (B)	0.0
Group VI (383–392)			
86 Arles		553 (S)	0.4
87 Rome		782	0.3
88 Constantinople		2159	0.4
89 Constantinople		2147	0.5
90 Siscia		1514	0.0
91 Antioch		2727 (S)	0.5
92 Antioch		2751 (B)	0.5
93 Alexandria		2897 (B)	0.2
94 Alexandria		2897	0.2
95 Cyzicus		2566 (D)	0.2
96 mint unknown		as 2552	0.2
97 mint unknown		as 2552	0.6
98 mint unknown		as 2549	0.6
Group VII (388–408)			
99 Lyons		391/4	0.2
100 Rome		as 797	0.3
101 Constantinople		2186	0.2
102 Constantinople		2192	0.1
103 Antioch		2783	0.2
104 Antioch		2792	0.2
105 mint unknown		as 2188	0.3
106 mint unknown		as 2404	0.2
107 mint unknown		—	0.3
108 mint unknown		as 1092	0.2
109 mint unknown		as 391/6	0.1

Chemical analyses: a, 1.9; b, 1.9; c, 0.4; d, 1.3; e, 0.0; f, trace.

Counterfeits

	PROTOTYPE	EMPEROR	% SILVER
110	VICTORIAE LAETAE PRINC PERP	Constantine I	1.8
111	CONSTANTINOPOLIS		0.2
112	URBS ROMA		0.4
113	URBS ROMA		0.2
114	URBS ROMA		0.1
115	GLORIA EXERCITUS (2 standards)	Constantinc I	0.2
116	GLORIA EXERCITUS (2 standards)		0.3
117	FEL TEMP REPARATIO (SLG) (galley-victory)	Constans	0.7
118	FEL TEMP REPARATIO (fallen horseman type 3)	Constantius II	1.2
119	FEL TEMP REPARATIO (fallen horseman type 3)		0.8
120	FEL TEMP REPARATIO (fallen horseman type 3)		0.9
121	FEL TEMP REPARATIO (fallen horseman type 3)		0.0
122	FEL TEMP REPARATIO (fallen horseman type 3)		0.9

	TYPE	EMPEROR	% SILVER
	Third-century "radiates"		
1	*denarius*	Caracalla	39.2
2	SALUS AUGG	Valerian I	17.1
3	MARTI PACIFERO	Gallienus	4.9
4	ORIENS AUG	Aurelian	4.0
5	VICTORIA AUG	Probus	3.7
6	IOVI CONSERVATORI AUGG	Diocletian	1.3
7	VOT XX	Maximianus	0.0
8	PAX AUG	Tetricus I	2.1
9	PIETAS AUGUSTORUM	Tetricus II	1.5
10	PAX AUG	Victorinus	3.1
11	(altar)	Divus Claudius	0.0
12	(PAX)	Carausius	0.2
13	. . . TIA AUG	Allectus	2.0
	Counterfeit "radiates"		
14	PAX	Victorinus	0.1
15	VIRTUS	Victorinus	0.2
16		Divus Claudius	0.2
17		Divus Claudius	0.2
18	PAX	Tetricus I	0.7
19	VIRTUS	Tetricus I	0.5
20	HILARITAS	Tetricus I	0.2
21	COMES	Tetricus I	0.8
22	(diameter 11 mm.)	—	2.1
23	(diameter 10 mm.)	—	0.4
24	(diameter 10 mm.)	—	1.1
25	(diameter 9 mm.)	—	0.3

Group I	
1, 2, 4–7	GENIC
3	SOLI I
8	PROVI
9	CONC
Group II	
10–12, 14	BEAT/
13	VIRTU
15	SARM
16	PROVI
17	VOT X
18	VOT X
Group III (330–341)	
19, 20, 22–4	URBS
21	GLOR
26–7	GLOR
25	CONS
Group III (341–346)	
28–36	VICTO
Group IV (346–353)	
37–9, 41–2	FEL T
40, 47	FEL T
43–5, 48	FEL T
46, 49–51	FEL T
52–6	FEL T
Group IV (350–353)—u	
57, 60	GLOR
58, 61–2, 64–5	VICTO
59, 63	SALU
Group IV (353–363)	
66–71	FEL T
75	SECU
72–4	VOT
76	VOT
Group V (364–375)	
77–8, 80, 82–4	SECU
79, 81, 85	GLOI
Group VI (383–392)	
86, 90	REPA
87	VICT
88	VOT
89, 91–2, 98	GLOI
93–4	SALU
95	VIRT
96–7	VOT
Group VII (388–408)	
101, 103, 105	GLO
100, 102, 106–7	SALU
104	VIRT
108–9	VICT

TABLE II

Group I	
1, 2, 4–7	GENIO POP[ULI] ROM[ANI]
3	SOLI INVICTO COMITI
8	PROVIDENTIA DEORUM
9	CONCORDIA MILITUM
Group II	
10–12, 14	BEATA TRANQUILLITAS
13	VIRTUS EXERCIT
15	SARMATIA DEVICTA
16	PROVIDENTIAE AUGG
17	VOT X CAESARUM NOSTRORUM
18	VOT XX
Group III (330–341)	
19, 20, 22–4	URBS ROMA
21	GLORIA EXERCITUS (2 standards)
26–7	GLORIA EXERCITUS (1 standard)
25	CONSTANTINOPOLIS
Group III (341–346)	
28–36	VICTORIAE DD AUGGQ NN
Group IV (346–353)	
37–9, 41–2	FEL TEMP REPARATIO (galley)
40, 47	FEL TEMP REPARATIO (emp and 2 captives)
43–5, 48	FEL TEMP REPARATIO (hut)
46, 49–51	FEL TEMP REPARATIO (fallen horseman)
52–6	FEL TEMP REPARATIO (phoenix)
Group IV (350–353)—usurping emperors	
57, 60	GLORIA ROMANORUM
58, 61–2, 64–5	VICTORIAE DD NN AUG[G]ET CAE[S]
59, 63	SALUS DD NN AUG ET CAES
Group IV (353–363)	
66–71	FEL TEMP REPARATIO (fallen horseman)
75	SECURITAS REIPUB
72–4	VOT X MULT XX
76	VOT V MULT X
Group V (364–375)	
77–8, 80, 82–4	SECURITAS REIPUBLICAE
79, 81, 85	GLORIA ROMANORUM
Group VI (383–392)	
86, 90	REPARATIO REIPUB
87	VICTORIAE AUGGG
88	VOT X MULT XX
89, 91–2, 98	GLORIA ROMANORUM
93–4	SALUS REIPUBLICAE
95	VIRTUS EXERCITI
96–7	VOT XX MULT XXX
Group VII (388–408)	
101, 103, 105	GLORIA ROMANORUM
100, 102, 106–7	SALUS REIPUBLICAE
104	VIRTUS EXERCITI
108–9	VICTORIA AUGGG

HISTORICAL COMMENTARY

The results confirm the presence of small amounts of silver in most issues up to 364. After that date, the majority of coins were shown to have such inconsiderable quantities of silver that it seems unlikely that the state now offered these as "silvered" or billon coins.[4] By this time there were apparently ample supplies for a real silver coinage, and it may be that the mints decided against extracting such small residual amounts of silver from the copper coins.

Up to 364, the results suggest, small coins, when they were minted concurrently with large ones, were not intended to bear silver. We see this in the "half follis" of Constantius (No. 9), again in the "phoenix" coins of 346–350, and possibly also in the small pieces of Julian and Jovian (Nos. 72–4, 76).

As well as the important decision of 364, the results show the decline of silver in coins between 330 and 346; the promising return to values up to 3½% in the new, large coins of the reform of 346, and the abrupt decline only a few years later, when coins again began to reduce noticeably in size (Fig. 1). One sample of Julian suggests that he, again, in his large pieces, tried to return to the silver values of the earlier coinage reforms (No. 75).

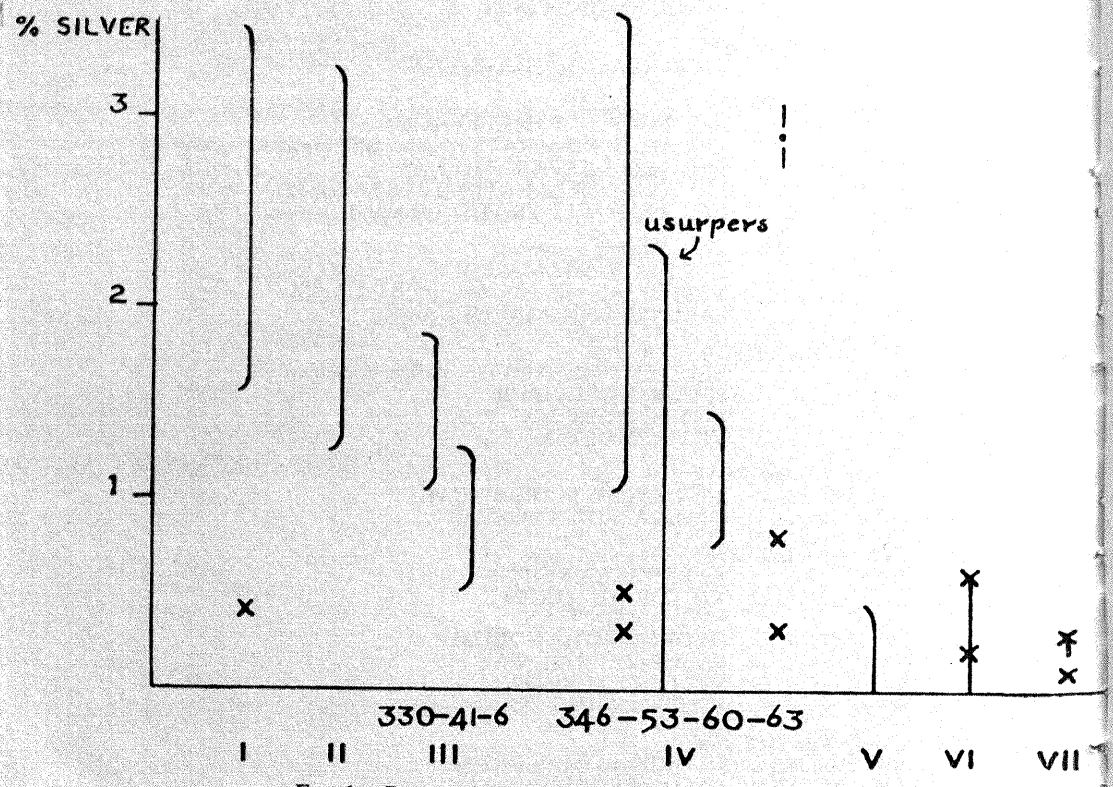

FIG. 1. Range of silver in different coin groups.
(x = small coins)

[4] Six *asses* and *sestertii* from Claudius I to Gallienus which were also analysed indicated amounts of silver from 0.1 to 0.3 per cent., but there was no question of such coins ever having been intentionally silvered. The figures for silver may be due to accidental traces in the ore, perhaps exaggerated by background radiation.

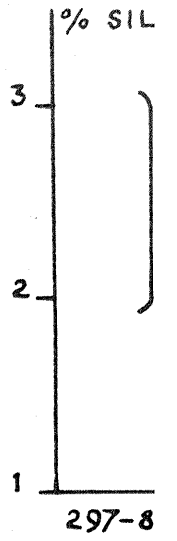

FIG. 2. Range of

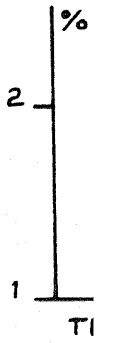

FIG. 3. Range of si

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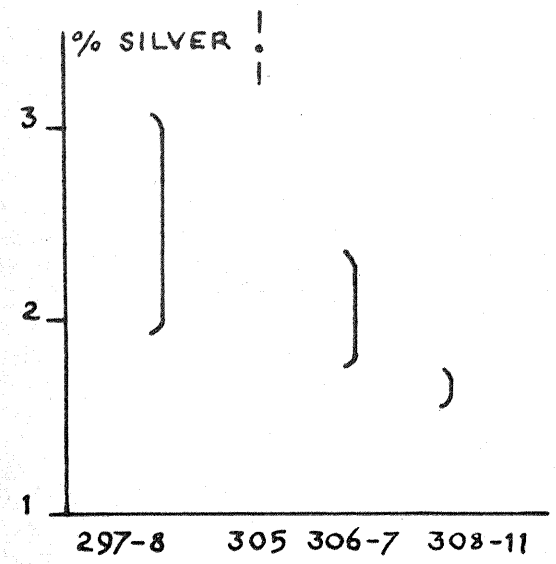

FIG. 2. Range of silver in large coins of Group I (297-311).

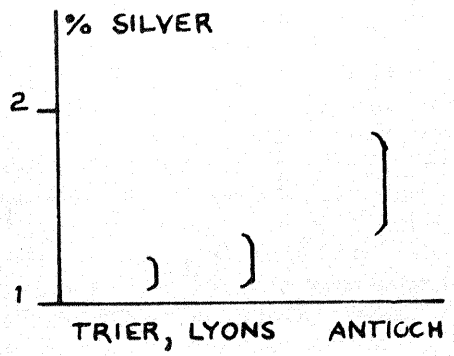

FIG. 3. Range of silver at different mints in Group III (330-341).

The total sample is so small that points of detail suggested may later be invalidated by a larger sampling. There may have been different policies at different mints. Antioch in 330–341 is noticeable for higher values than two western mints (Fig. 3), and the coins of Constantinople in 346–350 seem to anticipate the lower values of 352–356 in western mints (Fig. 4). The Amiens coins of the usurpers, Magnentius and Decentius, have values corresponding to the coins of legitimate emperors at this time; but three coins from other mints have unexpectedly high silver, whilst their group as a whole has an untidily wide range. The counterfeit coins usually have considerably less silver than the coins they were imitating—naturally so, since part of the profit must have been in using coin metal from

which the silver had been extracted. This is not the case, however, with four out of the five of the "FEL TEMP with fallen horseman" copies; but the rarity in Britain of their prototype, and the frequency with which they were overstruck on older, genuine coins, have demonstrated that considerable profit lay in producing the type itself, without necessarily depriving it of silver.

The results of this analysis fall in with the figures given for silver in various earlier analyses of late copper coins.[5] Recently, the systematic study of Diocletian's billon coins was begun by Sutherland and Harold, whose analyses of 40 "folles" of 294–6 showed that they contained at first between 3.3% and 5.6% of silver, but rapidly declined to between 1.8% and 4.4%. If we suppose that the deterioration continued, these figures are not inconsistent with 2–3% in 297–8, an even higher figure in 305, 1.8–2.3% in 306–7, and 1.6–1.7% in 308–11 (Fig. 2). The "half-follis" (No. 9), like ten similar coins examined by Harold, is unlikely to have contained a deliberate addition of silver.

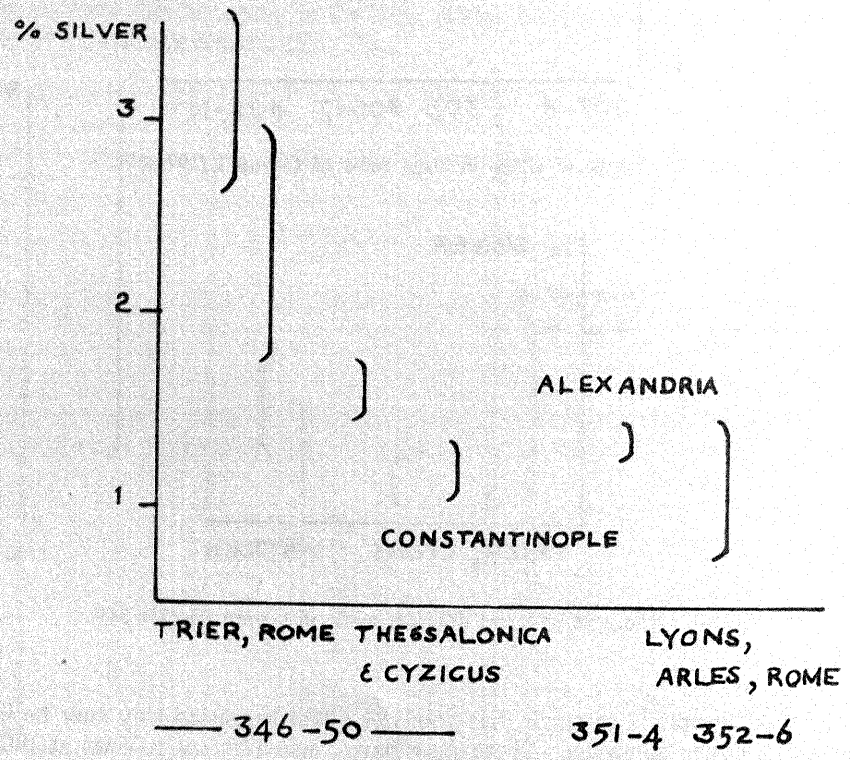

Fig. 4. Range of silver at different mints in large coins of Group IV (346-356)

The motive in adding such insignificant amounts of precious metal to the copper coins was the belief that the silver enriched their value. The later imperial gold, and many of the silver coins were little more than stamped pieces of bullion

[5] J. Hammer, Der Feingehalt der griechischen und römischen Münzen, Zeitschrift für Numismatik, XXVI, 1908; J. Maurice, Numismatique Constantinienne, III, 1912, xxx ff.

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[6] A. H. M. Jones, Inflation under the
1952–3.

and the same notion that a coin should be worth its precise metal equivalent was applied to the copper coinage. The ratio of silver to copper may not have deviated much from 1: 100 throughout the fourth century, so that even 1% of silver was well worth adding. The silver, in any case, arrived in the base coinage as much through tradition as theory. Since in 301 prices were still reckoned in *denarii*, the "follis" of Diocletian must be regarded as a multiple of this unit, and therefore in line of descent from that silver coin. But during the third century the *denarius* had been ousted by the double *denarius*, first issued, much debased, by Caracalla. By the 270's this was virtually the only coin, either of silver or copper, in production, and its silver had fallen to 5% or often less. If not regarded exactly as a silver coin, the silver in it was supposed to uphold its value, and there is now firm evidence that in the fourth century pains were still taken to make coins look like silver.[2]

Yet even had it been possible for such small quantities of silver to tie the copper coinage to the precious metals, all the results now available show that the silver content was permitted to vary widely in some issues, and the state no doubt published the highest values as the "official" ones. The copper coinage was in fact, then, a token coinage, and external influences operated upon it to cause a disastrous inflation.[6] The steadily falling size of the basic coin up to 346, and its depreciating metal value, reflect this inflation, which caught up the state in its toils, no less than the private citizen, so that coins on the old standard could no longer be afforded. Remedies were sought in 346, and perhaps again in 361, by giving them once again more generous proportions of silver. Not striking at the roots of the inflation, these attempts proved vain. Finally from 364 all attempts to peg the base coins to the precious metals were abandoned.

Further analyses are needed for the picture to become comprehensive, and accurate in detail. Its implications for archaeology are far-reaching. At the worst crises of inflation, more coins would have been needed to carry out transactions, whilst for lasting savings coins with more silver would have been selected, at least until the time when real silver pieces were available. This, even in the present state of knowledge of the composition of the base coins, goes far to explain the incidence of the main fourth-century issues on Romano-British sites, and the characteristic composition of many hoards. The probable silver content of a coin provides a better clue to its actual worth than size or weight alone. This can now be used to compare hoards of different dates, not simply by how many coins they contain, but in terms of their comparative purchasing power.

[6] A. H. M. Jones, Inflation under the Roman Empire, Economic History Review (2) V, 1952–3.