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THE ANALYSIS OF CONSTANTINIAN COINS (A.D. 313–40) BY NON-DESTRUCTIVE CALIFORNIUM 252 ACTIVATION ANALYSIS*

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1. INTRODUCTION

Neutron activation analysis has been used for numismatic studies for a number of years: the first work was done by Emeleus (1958) when she determined gold and copper in silver coins. Since then, many analyses have been performed either after irradiation in a nuclear reactor, or with an isotopic neutron source, or with the help of an electrostatic generator (see for example, Kraay (1958, 1959), Thompson (1960), Sutherland (1961), Aitken (1962), Bluyssen (1962), Wyttenbach (1966), Tousset (1968), and Thiele (1972)). In particular, Gordus uses two techniques: analysis with an isotopic source and micro-sampling irradiated in a nuclear reactor (Gordus 1967, 1971, Bacharach 1968). If we exclude the micro-sampling method because the results in our opinion are not always representative of the whole coin composition (particularly in the case of silver plated coins), we can make the following comments about the other activation methods:

1. In most instances irradiations carried out in the high neutron flux of a nuclear reactor induce a residual radioactivity which is not negligible.
2. Although activation with an (α,n) type isotopic neutron source does not present the previous disadvantage, it lacks the sensitivity needed to solve all the numismatic problems.

We think that the use of a ^{252}Cf neutron source is a good compromise between the nuclear reactor and the (α,n) type isotopic neutron source. Using this technique, we studied the composition of Constantinian coins put into circulation during the period A.D. 313–40. Some analytical data for the same period are given by Ravetz (1963), Cope (1968, 1973) and Maurice (1912); and in this study we confirm and complete the initial results given by these three researchers.

* Paper presented at the Symposium on Archaeometry and Archaeological Prospection, Edinburgh, March 1976.

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2. EXPERIMENTAL

Experimental set up

In our laboratory we have four identical ^{252}Cf sources (nuclear data of ^{252}Cf is given in table 1) placed on the arms of a cross, at equal distance from the coin (figure 1). Each source

Table 1 *Nuclear data of californium* 252

Decay mode	α emission 96.9% fission 3.1%
Half-life	α decay 2.73 years fission 85.5 years effective 2.65 years
Neutron emission	2.34×10^9 neutrons s^{-1} mg^{-1}
Average neutron energy	2.35 Mev
Gamma exposure rate	1.6×10^3 mR h^{-1} at 1 m distance per mg

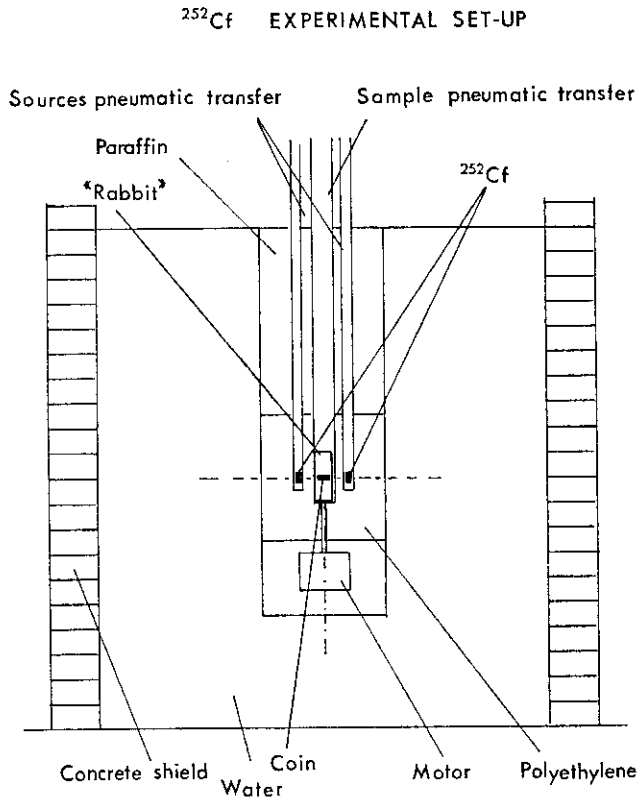

Figure 1

Argentei 313
Maximin D. Licinius Constantin

BN 9503
25.4% *Ag*

BN 9513
24.8% *Ag*

BN 9520
25.8% *Ag*

Plate 1

Nummus 318/319
Licinius *Constantin*

BN 14189
4.6% *Ag*

BN 15078
4.7% *Ag*

Plate 2

Imitation

BN 15045 1.5% *Ag*

Plate 3

facing page 174

emits a flux of 5.2×10^8 neutrons s^{-1} and is contained in a cylinder of diameter 1.2 mm and height 12.5 mm. With such a system we obtain a flux of thermal neutrons which is homogeneous over a volume of 35 cm^3. As a further precaution and to insure an homogeneous irradiation, the coins are rotated at 12 rev min^{-1}.

The coin is placed in the middle of a 'polyethylene rabbit' and a pneumatic system transfers the sample from the irradiation position to the counting position in 4 s. The radioactivity is measured with a germanium (lithium drifted) detector which has a relative efficiency of 20%, a resolution of 2.5 KeV and a peak to Compton ratio of 35, each measured under the usual standard conditions. The detector is connected to a multichannel analyser (4096 channels) which is coupled to a mini-computer PDP 11-05 (16 K). The peripherals of the computer include a cassette, a disc and a printer; this system performs the complete treatment of the gamma spectra automatically.

Standardization

The quantitative analysis of the coins was performed by comparing their silver and copper activity with the silver and copper activity of dummy coins of comparable size irradiated under the same conditions. These dummy coins, of known copper and silver concentrations, are made of thin silver and copper foils. To check the precision and the accuracy of the results obtained by this method, we analysed dummy coins prepared by levitation; table 2

Table 2

	Weight of dummy coins (g)	*True value of silver (1) (%)*	*Silver concentration found by ^{252}Cf activation (1) (%)*	*Difference* a	b (%)
1	2.031	20.14	19.45	−0.69	3
2	1.75	5.906	6.02	+0.11	2
3	3.20	3.488	3.40	−0.088	3
4	2.07	6.19	6.30	+0.11	2
5	2.27	4.89	4.78	−0.11	2
6	3.02	1.03	0.98	−0.05	4.8
		True value of copper	*Copper concentration found by ^{252}Cf activation*		
7	1.75	94.094	94.126	+0.03	0.034
8	3.20	95.512	95.8	+0.29	0.3
9	2.07	93.80	93.45	−0.35	0.4

$a = {}^{252}$Cf activation result − true value.

$b = \dfrac{{}^{252}\text{Cf activation result} - \text{true value}}{\text{true value}} \times 100.$

gives the concentration found by ^{252}Cf activation analysis and we can see that the difference is always less than 5%.

Procedure

The coin, placed in a polyethylene 'rabbit', is transferred to the irradiation position by means of the pneumatic transfer system. For all coins, the irradiation time was 5 min and the counting time 10 min, after 1 min of decay. Figure 2 shows the spectrum obtained;

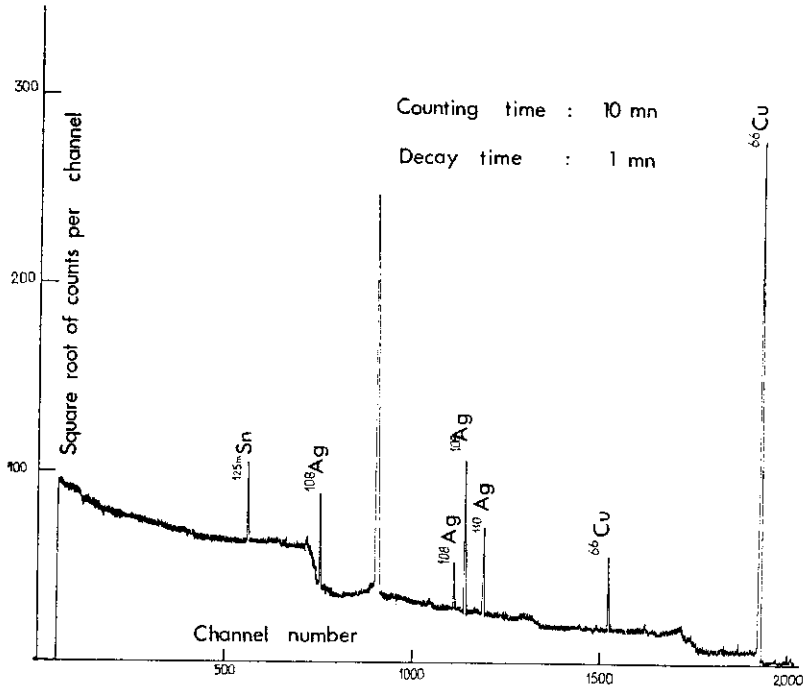

Figure 2

copper, silver and tin are determined simultaneously using copper 66 (half-life 5.1 min), silver 108 (half-life 2.4 min) and tin 125 (half-life 9.7 min) respectively. The gold content can be measured using gold 198 (half-life 2.7 days).

With our experimental conditions and for a 3 g coin, the sensitivity is 0.1% for silver, 0.5% for copper and tin, and 0.05% for gold. A complete analysis takes 15 min.

3. RESULTS

We analysed more than two hundred Constantinian coins from all the different mints of the Roman Empire covering the period A.D. 313–40. Plates 1, 2 and 3 show some specimen coins analysed. The copper and the tin contents are not significant and we only give the silver content (in per cent and mg) which, for each coin analysed, is given in figures 3 and 4; all the analytical data are available from the authors.

4. ANALYTICAL COMMENTS

The only comment concerns a point of method. When comparing the different values given

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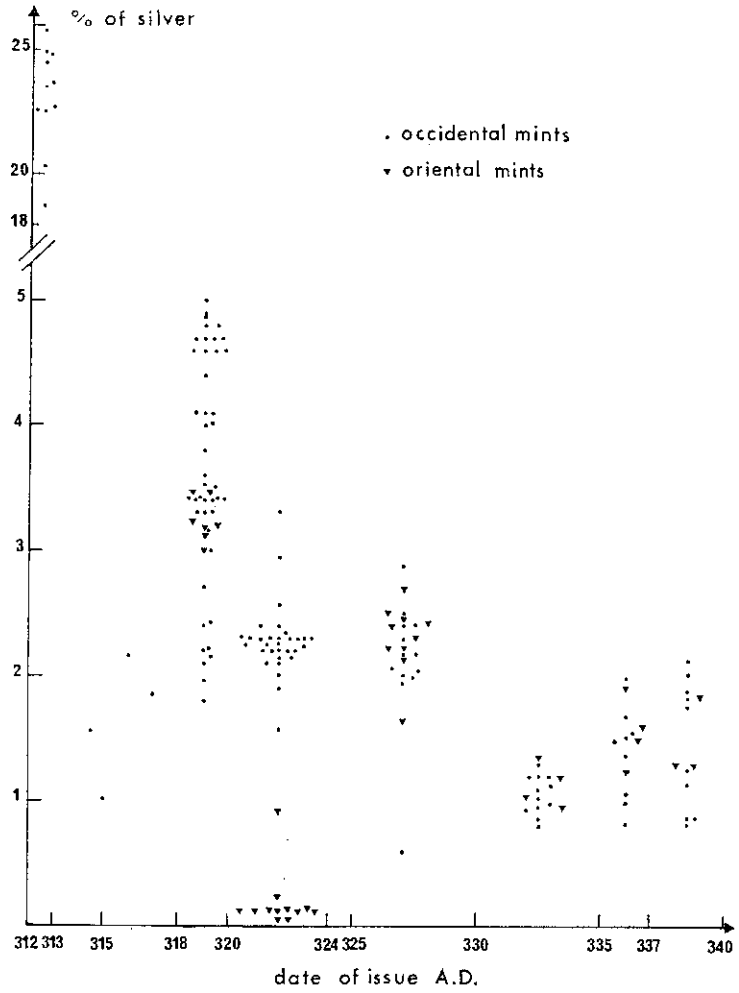


Figure 3

by Cope, Ravetz and ourselves for the different series *Beata Tranquillitas* (from 320) or those of *Vota* in Arles and *Sarmatia Devicta* (before 325) (table 3), it becomes apparent that Cope's data are consistently slightly lower than the others (about 20%). But for the Daza coins, the values given by Cope and ourselves are in a good agreement.

5. NUMISMATIC COMMENTS

A. *The series SOLI INVICTO COMITI in facing quadrigal, IOVI CONSERVATORI AVG emperor borne by an eagle and VICTORIAE LAETAE PRINC PERP*

These series have been the object of a controversy between Sutherland and Bruun. In 1967 (R.I.C. VI (a) 1967) Sutherland, while considering only the types *Soli Invicto Comiti* and

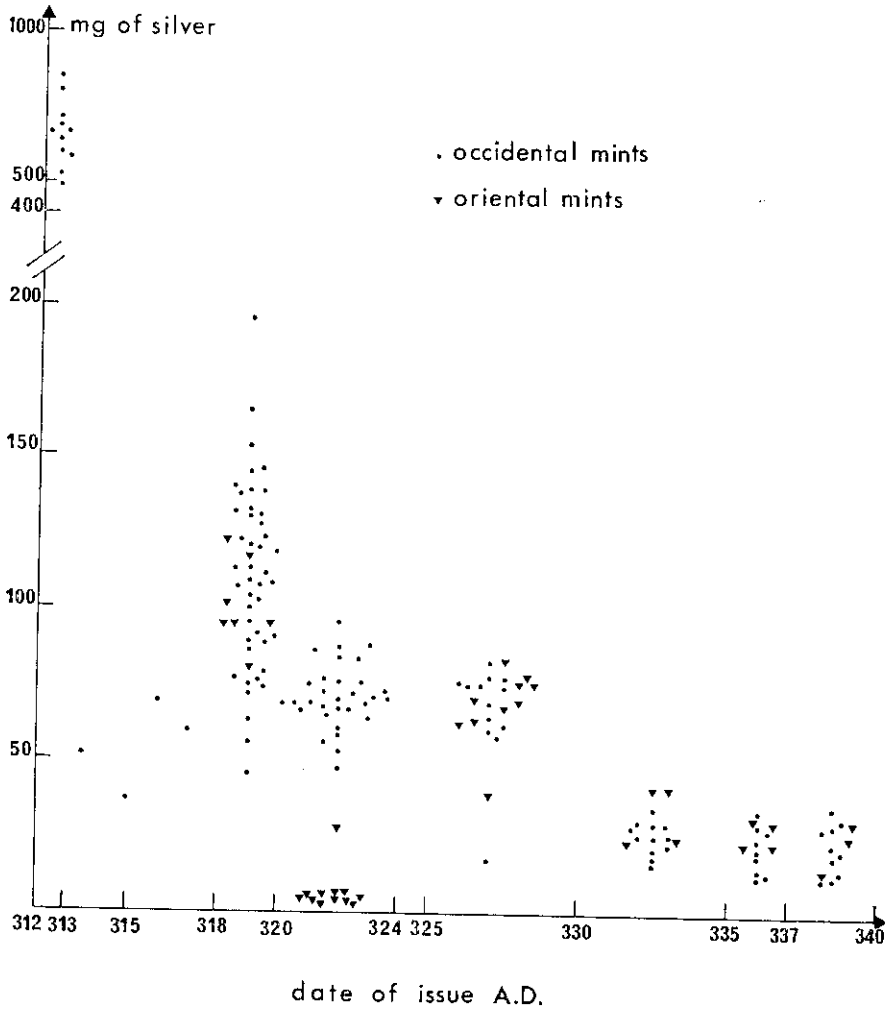


Figure 4

Iovi Conservatori Aug, was of the opinion that they were minted in 'base silver' and estimated their date as being before May 313. In fact, in this issue PTR, the Trier mint associated Licinius with Maximin Daza who disappeared in the spring of that year. However, the British scholar did add a footnote to the effect that his opinion was not shared by the editor of R.I.C. VII, P. Bruun. Bruun (R.I.C. VII (a) 1966) dissociated the reverse side *Soli Invicto Comiti*, engraved with a single officina, from the other two which bear the exergues PTR and STR. Of the three types, the first being of Maximin Daza, remains necessarily placed in 313, while the second and third are given the date of 318–19 at Trier and Ticinium, and 319 at Arles (R.I.C. VII (b) 1966). But however different they may have been in their date, the three species were of an identical nature. In fact, in order to affirm it, Bruun for lack of precise information on the body-matter of the coins relied upon analyses of the surface which showed that there had been a surface content of 65% silver.

Table 3

Mint	*Cope*	*Ravetz*	*Our results*
1. *Beata Tranquillitas or Vota (Arles)*			
London	1.84 ± 0.1*	–	2.23 ± 0.1*
Trier	1.84 ± 0.2*	2.2 ± 0.3*	2.25 ± 0.1*
Lyons	–	1.3†	2.32 ± 0.1*
Arles	1.39†	–	2.25 ± 0.1*
2. *Sarmatia Devicta*			
London	1.67†	–	2.2†
Trier	1.45 ± 0.3*	–	2.3†
Lyons	–	1.95 ± 1*	2.3†
Arles	–	–	2.1 ± 0.3*

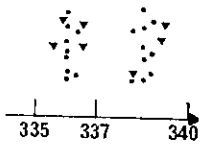
* Mean value and estimation of standard deviation.
† Only one value.

Bruun's conclusion is worth quoting: 'The body alloys of coins appeared to be almost pure copper, and there seemed to be no difference between the Daza coins and, for example, the coin with an obverse of Constantine II and therefore struck after 1 March 317. *A very thin coating of a high percentage silver alloy would thus be compatible with a silver percentage of 1–2 per cent, if the entire coin is considered*' (R.I.C. VII (c) 1966) (Hedges and Robins 1963). According to the author, it was here a question of a conscious effort to improve the coinage. But at the same time, and without appearing in any way contradictory in his eyes, these 'enriched bronzes' were to be integrated each time in the series of current legal currency; in 313 the *Soli Invicto Comiti* were used as half-folles and in 318–19 the *Iovi Conservatori Aug* and the *Victoriae Laetae Princ Perp*, as folles.

Although in Bruun's argument one point is certain—that no coin from Daza was signed STR—is it necessary to follow him in the dissociation that is suggested? A numismatic analysis in depth brings an incontestable reply; keeping the two dates successively exact determines that the dates of the two issues are 313 and the other 318–19.

In 313, three emperors are found on the coins from Trier: Maximin Daza (with SIC), Licinius (with ICA) and Constantine (with VLPP). For all three, the exergue is PTR, which at first sight seems surprising, as Trier at the time had only one officina. But in fact, it is important to translate the letter P as *Percussum* rather than *Prima*. Each one of the obverse corresponds with the nature of the sovereign. Daza adopts the radiated crown of *Sol Invictus* and Licinius holds Jupiter's thunderbolt (R.I.C. VI (b) 1967) in his hand (perhaps to evoke the apotheosis of Galerius who died in May 311). Constantine, wearing a helmet, celebrates his victory over Maxence with the engraving of an obverse whose medallion (dated in 1934 by Alföldi) offers the prototype *Imp. Constantinus PF Aug/Victoriae Laetae Principis Perpetui Vot is PR*. A mention of PR strengthens the idea that this image was created shortly after the affair of the Milvius bridge. However, Bruun dates this medallion at the exergue PTR of 318–19.

What characterizes this first series is its weight, but above all its fineness. Minted to 1/96 before the death of Daza and the opening of the mint at Arles, it is contemporary in the



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Occident with *Nummi* made to 1/72. Thus it shortly precedes the general introduction of a new weight of 3.36 g tried out in this issue of *Festmünzen* in honour of an ephemerary reconciliation.

What is most surprising is the precious metal content of the coins. It is necessary to go far back in time to find equivalent examples. However, in the last ten years some coins of good silver had been distributed; the *Argenteus* and its fractions. These were quickly bought up since only silver coated coins were in circulation and they were in a proportion which had not exceeded 5% for a long time. Now, as shown by Voetter (1921) and later by Sutherland, and as Cope has demonstrated in 1973 for the Daza coin alone, our series have a composition

Table 4 *Analytical results of coins from BN, Paris**

	Date of issue, A.D. 313	
	Silver (%)	*Silver* (*mg*)
1. Maximin Daza: *Soli Invicto Comiti, PTR* (R.I.C. VI 826)		
	25.4	715
	22.7	670
	22.6	580
	20.3	496
2. Licinius I: *Iovi Conservatori Aug. PTR* (R.I.C. VI 825)		
	24.9	805
	24.8	685
	22.5	600
3. Constantin I: *Victoriae Laetae Princ Perp Vot PR, PTR* (R.I.C. VII 208 A)		
	25.8	850
	23.7	645
	23.5	665
	18.7	526

* Nos. 9503, 9502, 9500, 9501, 9511, 9513, 9512, 9520, 9518, 9519 and 15060.

which appears quite exceptional, as in the body of the coins the silver content is around 25% (table 4). At the same time, and simply by the listed percentages, the unofficial nature of the other two examples becomes evident, already apparent from a direct examination:

Constantine I: SOLI INVICTO COMITI, PTR: 3.3%, 95 mg of silver (no. 15022)
VICTORIAE LAETAE PRINC PERP VOT PR, PTR: 6.9%, 209 mg of silver (ex. without no.).

Number 15022 in particular, invoked by one of us as well as by Bastien (1969), ceases to be a useful element for establishing chronology, for it is a hybrid of contemporary counterfeiting. But on the whole, the conclusions then advanced need not be modified and *Victoriae Laetae Princ Perp Vot PR* was indeed minted in 313.

What could have been the value of this restored billon? (The last coin to have about 25% silver is the *Antoninianus* of Valerian–Gallien, issued at Rome in 255–8 (Callu 1969, 1973).)

Table 5

Mint	*Emperor*	*Type*	*Coin ref.*	*Date of issue*	*Silver* (%)	*Silver* (*mg*)	*BN no.*

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Table 5

Mint	Emperor	Type	Coin ref.	Date of issue	Silver (%)	Silver (mg)	BN no.
Trier	Licinius I	*Iovi Conservatori Aug,*	R.I.C. VII, 210	318–19	3.3	109	14190
		STR	R.I.C. VII, 211	318–19	4.6	196	14189
	Constantine I	*Victoriae Laetae Princ*					
		Perp Vot PR STR	R.I.C. VII, 208 A	318–19	3	75	15047
		STR	R.I.C. VII, 209	318–19	4.7	166	15078
		**/STR*	R.I.C. VII, 213	319	4.1	120	15082
Arles	Licinius I	*Iovi Conservatori Aug,*					
		PARL	R.I.C. VII, 196	319	4.8	139	14186
		SARL	R.I.C. VII, 196	319	4.6	139	9510
		TARL	R.I.C. VII, 197	319	4.6	138	14189
	Constantine I	*Victoriae Laetae Princ*					
		*Perp, Vot PR, P*A*	R.I.C. VII, 188	319	4.1	131	Y 367
		PARL	R.I.C. VII, 193	319	4.6	123	15077
		PARL	R.I.C. VII, 193	319	3.3	103	15079
		TARL	R.I.C. VII, 193	319	4.7	130	15070
		PARL	R.I.C. VII, 194	319	4.7	128	15053
		SARL	R.I.C. VII, 195	319	4.7	146	15061
	Constantine II	*Victoriae Laetae Princ Perp*					
		Vot PR QARL	R.I.C. VII, 200	319–20	2.15	74	15819
Ticinum	Licinius I	*Iovi Conservatori Aug,*					
		**/TT*	R.I.C. VII, 89	318–19	1.8	86	H 1510
	Constantine I	*Victoriae Laetae Princ*					
		Perp Vot PR, TT	R.I.C. VII, 82	318–19	4.9	107.5	(Bikić-Do)
		Counterfeited coins					
Trier	Licinius I	*Iovi Conservatori Aug, PTR*			< 0.1	< 2.4	14192
	Constantine I	*Victoriae Laetae Princ Perp*					
		Vot PR, STR			2.5	93	15038
					1.8	45	15040
					1.75	50	1967/144
					1.7	30	15049
					1.5	45	15045
					1.2	37	14428
					< 0.1	< 2	15075

In 301, an *Argenteus* of the same weight, covered at 92.15% was valued at 100 d and, after the compulsory lowering of the *Edictum de Pretiis* to 62.5 d, returned, towards 306–7 (Rea 1974), to approximately the same value of 100 d. In the years 311–12, that is to say during Daza's lifetime, we know that in the Orient the prices were still respected.

However, can the same argument be extended to the case of the Occident? The fixed value of an *Argenteus* at 100 d could be maintained, even if the real quantity of precious metal did not exceed a quarter of the weight (Callu 1975). Our *Festmünzen* would therefore equal 8 *Nummi* of 12.5 d, implying that in 307, due to the lessening of weight, the value of the basic coinage had been lowered from 20 to 12.5 d. (On the contrary, Cope (1973) prefers to suggest a ratio of 1 to 10. He also thinks that the generalization of the 1/96 libra weight-standard is responsible for the cessation of further minting of the *Pseudo-Argenteus*.)

The death of Daza interrupted the experiment, but the public knew that the coins inscribed *Victoriae Laetae Princ Perp* and *Iovi Conservatori Aug* were more valuable than the others. That is why, it seems, these two types were reissued in 318 when, after a systematic demonetization, the authorities relaunched a *Nummus* at 25 d. This was done at Trier in two officinae, at Ticinum in 3, and at Arles in 4, three other mints in the Occident (London, Lyons and Siscia) limiting themselves to the type *Victoriae Laetae Princ Perp* which, in common with Ticinum and Arles, they were adding for the first time. (The absence of *Iovi Conservatori Aug* in no way signifies that these mints began the new fabrication after Trier, Ticinum and Arles. In fact it is to be noted that in Arles the issue PARL, common to both Constantine and Licinius, is preceded by some *Victoriae Laetae Princ Perp* P*A products of a single officine (R.I.C. VII, p. 254, nos. 185–189). In the same way at Ticinum, Licinius accompanies Constantine only from the fifth signature of the *Victoriae Laetae Princ Perp* (*ibid.*, pp. 372–373, nos. 82–89).)

This time, new obverse were added (nos. 209–210) and especially, as can be seen from table 5, the metal had changed. As in 313, the percentage of silver in the counterfeited coins, in this case those of Trier, was again inferior (table 5). It will be noticed that whereas the weight, in relation to the *Nummus* dating from before 318, is scarcely modified, the fineness doubles grosso modo. (We have assumed (*cf.* Callu 1973) that these *Nummi* of 318 were fabricated by melting down larger tetrarchic coinages.) Nevertheless it represents only 1/4 or 1/5 of the billon of 313. In this way, we discover two distinct series, a *Pseudo-Argenteus* of 100 d and a *Nummus* of 25 d which, by their date, number of officinae and fineness have nothing in common in spite of the first appearances.

Cope has foreseen difficulties in establishing a fixed chronology when using Bruun's theories as a point of departure. Although he was the first to determine the fineness of the *Pseudo-Argenteus*, he did not succeed in reconstituting the actual structure of the two series.

B. *The VIRTUS EXERCIT issues*

After the demonetization of 318, the Occident with the exception of Rome, Aquila and Thessalonica, took up the type *Victoriae Laetae Princ Perp, Vot PR.* With the exception of Siscia, the homogeneity of the alloy is obvious in most of the examples which have in general at least 4% silver (figure 5). Three low values are to be noted; two at Ticinum and Siscia (because they date from the beginning of the series *Victoriae Laetae*) and the third at Arles. We are now at the end of the period and immediately before the appearance of the type *Virtus Exercit* (R.I.C. VII (d) 1966).

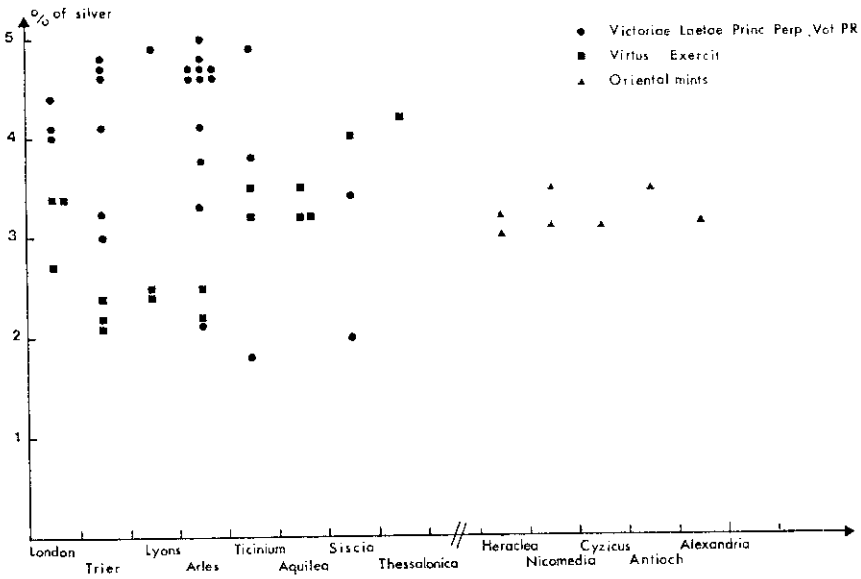

Figure 5

The issues of *Virtus Exercit* do not present us with the same uniformity as the preceding ones in the mints of the Occident from London to Thessalonica. A common denominator is the fall in fineness; whereas elsewhere this becomes stable around 3%, three mints in Gaule: Trier, Lyons and Arles, accentuate this decline to around 2% (figure 5).

A coin with a low percentage of silver (as invoked earlier in the series *Victoriae Laetae* at Arles) forbids us to postulate a chronological shift. It could be supposed that the alloy at Trier and Lyons, Arles was lower, yet it may be that the material melted down represented a greater mixing, or that the issues were more frequent. It would be interesting to pursue the research for Rome and to verify whether, as our three analyses would seem to imply, there were two stages between 318 and 320; the same necessity for complementary information is shown for the *Vota* from Thessalonica in 318–19.

In the Orient, however poor our documentation for the years preceeding 318 (Cope 1968, 1969), it would seem that there also the silver content improved after demonetization without attaining the occidental level (figure 5).

C. *After 320*

The disruption of 320 was at the centre of our paper on the devaluations presented at Rome: Constantine chose the amount of 2% and this lasted for ten years, while Licinius, halving the value of his currency, thereby deprived it almost totally of silver. We can now see how the process had been begun by the *Virtus Exercit* from Trier, Lyons and Arles.

6. CONCLUSION

We have shown that californium 252 is a very attractive neutron source, owing to its favour-

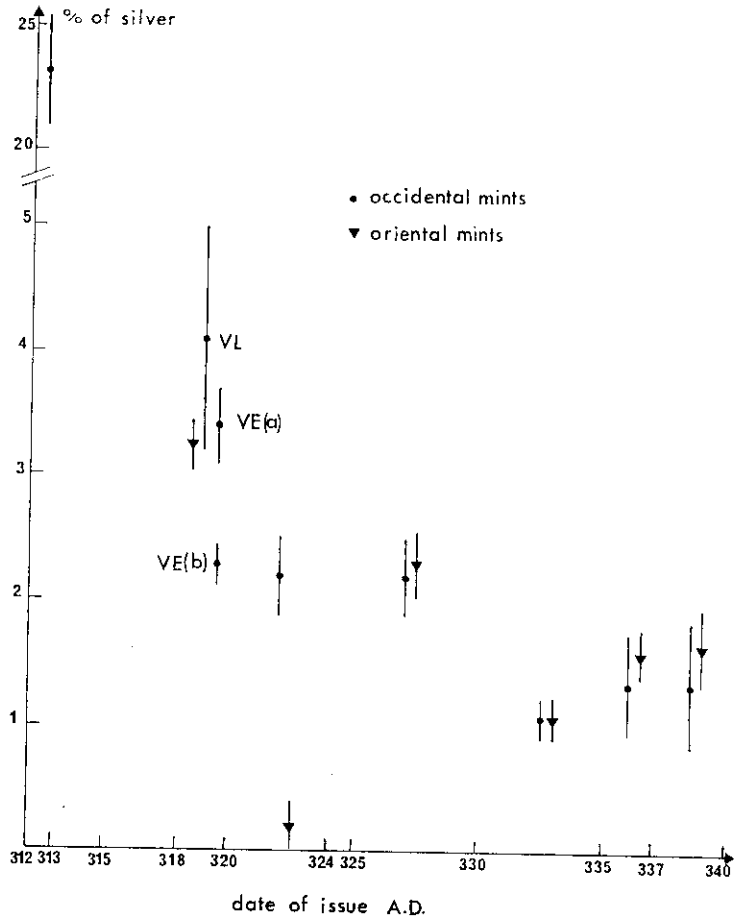

Figure 6

able nuclear properties, for non-destructive studies of coin composition. With such a source we can perform a fast and accurate determination of gold, silver, copper and tin in coins.

The general description of our analyses has already been presented at Rome in a preliminary form (Barrandon and Brenot 1975). Taking into account the subsequent additions, we wish to include figures 6 and 7 which show the averages for the percentages plus the mg of silver in each one of the periods considered. It is interesting to note that from 324, the silver content was approximately the same in Occident and Orient.

In conclusion, we would like to draw attention to the care with which the alloy was adjusted. A comparison of the most typical divergences shows that the remedium of the fineness is weaker than that of the weight. This can be explained by the conditions of fabrication, the individual cutting of coins being susceptible to a greater imprecision than the global determination of an alloy's composands. The results obtained encourage us to develop this type of research, by the constitution of a programme covering all Mediterranean coinage in Antiquity.

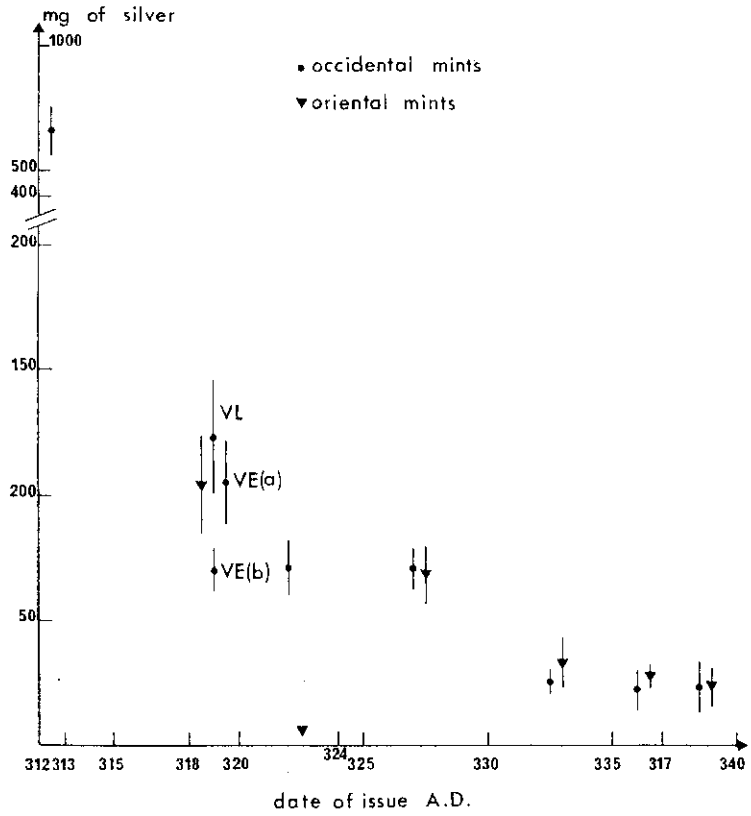

Figure 7

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