

NOTES ON THE CHEMICAL COMPOSITION OF PARTHIAN COINS WITH SPECIAL REFERENCE TO THE DRACHMS OF ORODES I¹

EARLE R. CALEY,
Department of Chemistry,
The Ohio State University,
Columbus, Ohio

Over a thousand ancient coins of Greek and Roman origin have been assayed or analyzed, but only a few Parthian coins have been so investigated. It might reasonably be expected, however, that the chemical investigation of the coins of the Parthian Empire would lead to results just as interesting as those that have been obtained from the chemical investigation of the coins of other ancient states. Indeed, in view of our total lack of ancient literary information concerning the coins of this great eastern empire, it might be expected that the results of the chemical investigation of such coins would lead to results of relatively greater interest. Furthermore, since the coins constitute the chief, and almost the only certain, archaeological remains of the Parthian Empire, any information that can be obtained from a chemical study of these coins will not only be a contribution to the obscure numismatic history of this empire but may be a contribution to its still more obscure economic history. This paper contains a summary of what little has been done in the past on this subject, the results of chemical analyses of some Parthian silver and bronze coins, and interpretations of some of these results.

PREVIOUS WORK

Prior to the present investigation only 16 Parthian coins appear to have been investigated chemically in any way, and these were all silver coins that were analyzed by fire assay for their silver and gold content only. The results of these assays are shown in Table I.

From these results it would seem evident that the earliest coins contain the highest proportions of silver, and that later coins, leaving out of consideration the one late tetradrachm, contain moderately high amounts. There is no indication of any serious or progressive debasement in this series of Parthian drachms such as occurs in the series of denarii of the Roman Empire. These results also indicate that individual coins of some rulers differ considerably from each other in silver content. The proportions of gold in these coins, though high from the standpoint of modern silver coinage practice, are similar to those in the silver coins of many other ancient states. In light of the results of the present investigation, certain of these conclusions, which seem so obvious from the results of previous work, are actually not valid.

SOURCES AND IDENTIFICATION OF THE COINS

With the exception of six drachms of Orodes I, the coins analyzed in this investigation were purchased by the author from dealers here and abroad at various times. The coins of Orodes I were presented to him for purposes of chemical study by Professor S. H. Weber, formerly Curator of Special Collections, Princeton University. According to information supplied by Dr. L. C. West, Curator of Coins and Medals, Princeton University Library, they came originally from a hoard of some 600 Parthian drachms accidentally dug up by a native worker in 1923 in a small village near Ahar, 75 miles northeast of Tabriz, Persia.

The British Museum Catalogue of the Coins of Parthia, London, 1903, and

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Head's *Historia Numorum*, Oxford, 1911, were used as the principal authorities for the identification of the coins that were analyzed, due consideration being given to the uncertainties that still exist as to the proper attribution and dating of certain of the coins.

TABLE I
ASSAYS OF PARTHIAN SILVER COINS

No.	RULER	DATE	FINENESS IN PARTS PER THOUSAND	
			Ag	Au
1	Tiridates I, or Arsaces, son of Tiridates I.....	248/247-211/210 B. C..... 210-191 B. C.....	946	...
2	Mithradates I.....	171-138 (?) B. C.....	923	2
3	Mithradates I.....	171-138 (?) B. C.....	899	5
4	Mithradates I.....	171-138 (?) B. C.....	892	2
5	Phraates II.....	138-128/127 B. C.....	709	3
6	Artabanos II.....	88-77 B. C.....	854	1
7	Artabanos II.....	88-77 B. C.....	728	2
8	Tiridates II (?).....	26 B. C.....	611	2
9	Orodes II.....	4-6 A. D.....	798	2
10	Orodes II.....	4-6 A. D.....	622	3
11	Gotarzes.....	40/41-51 A. D.....	805	3
12	Gotarzes.....	40/41-51 A. D.....	755	2
13	Mithradates IV.....	130-147 (?) A. D.....	749	4
14	Volagases III.....	185 A. D.....	334	1
15	Volagases IV.....	191-207/208 A. D.....	779	3
16	Artabanos V.....	213-227 (?) A. D.....	746	4

NOTES TO TABLE I

- a. No. 1 was assayed at the Prussian mint and the result was first published by A. von Rauch in *Zeitschrift für Numismatik* 1, 37 (1874). This coin was attributed by von Rauch to Arsaces I, probably on the basis of the inscription on it, but it is now believed that this ruler issued no coins. On the assumption that the inscription was simply $\text{A P \Sigma A K O Y}$ it is here attributed to one of the two rulers listed. In spite of this uncertainty as to its exact attribution, it is reasonably certain, at least, that this coin is the earliest in the series here listed.
- b. The other coins were assayed at the Austrian mint and the results were first published by F. Imhoff-Blumer in his "Monnaies Grecques," Amsterdam, 1883, p. 474. The attributions and dates are those given by B. V. Head in "Historia Numorum," Oxford, 1911, pp. 818-822. A question mark indicates some uncertainty in attribution or date.
- c. All these coins were drachms except No. 14 which was a tetradrachm. This coin was attributed by Imhoff-Blumer to Volagases IV, but since it bore the date 497 in the Seleucid Era, this places it in the reign of Volagases III according to the system of attribution at present generally accepted.

ANALYSTS AND METHODS OF ANALYSIS

The six drachms of Orodes I were cleaned electrolytically before analysis and were analyzed by the author. The other silver coins and the bronze coins were not so treated and were analyzed by Mr. C. D. Oviatt under the direction of the author. The author hereby thanks Mr. Oviatt for his careful analytical work and the authorities of the Graduate School of the Ohio State University for a grant that enabled Mr. Oviatt to do this work.

Before being analyzed, the specific gravity of each of the silver coins was measured at 25° C/25° C by the method of Archimedes. The coins were next filed smooth and the specific gravities of the blanks were also measured by the same

method. These blanks were then divided into samples of suitable size for analysis. The specific gravities of the bronze coins were not measured, though samples were prepared for analysis in the same way.

For the analysis of the silver coins, accurately weighed samples of about a gram were treated with nitric acid for the separation of gold and tin. The ignited and weighed residue from the nitric acid treatment was extracted with cold, dilute aqua regia to dissolve the gold, and the resultant solution was diluted and treated with either ferrous sulfate or oxalic acid to precipitate the gold. This gold was then collected on paper, ignited, and weighed. By subtracting the weight of the gold from the weight of the residue, the weight of stannic oxide was obtained from which the weight of the tin was calculated. In some experiments, as a check, the weight of the stannic oxide was also measured directly. The filtrate from the separation of the gold and tin was treated with hydrochloric acid to precipitate the silver as chloride, this precipitate being collected in a filter crucible, dried, and weighed in the usual way. The filtrate from the separation of the silver was treated with sulfuric acid, and the solution was evaporated until fumes of sulfur trioxide appeared. After cooling, the residue was treated with water, and the lead sulfate was collected in a filter crucible, dried, and weighed. Copper was determined by electrolysis in the filtrate from the separation of the lead, and from the small amount of lead dioxide collected on the anode and the previous weight of the lead sulfate, the total lead content was found. The filtrate from the separation of the lead and copper was evaporated to small volume and treated with ammonium hydroxide solution to precipitate the iron, the precipitate being collected, ignited, and weighed in the usual way. In the filtrate from the separation of the iron, nickel was precipitated with dimethylglyoxime and weighed in this form. The filtrate from the separation of the nickel was treated to remove organic matter and examined for the presence of zinc with phosphate, the results being negative except for one coin which contained a sufficient amount for quantitative determination. The coins were also examined for the presence of arsenic and sulfur, but the results were negative.

The procedure for the analysis of the bronze coins was similar except that the steps for the determination of gold and silver were omitted, neither being found in appreciable amount in any of the coins. Sulfur was found to be absent but arsenic was present in all but one. For the determination of the arsenic a sample was first dissolved in concentrated nitric acid, the solution was evaporated to dryness, and the residue was baked to decompose the nitrates. This baked residue was dissolved in concentrated hydrochloric acid, and the hydrochloric acid solution after adding ferrous sulfate, was distilled. In the distillate, properly diluted, the arsenic was precipitated as arsenious sulfide with hydrogen sulfide. This precipitate was collected in a filter crucible, washed first with water, next with carbon disulfide, and finally with ethyl alcohol, after which it was dried and weighed.

This is merely an outline of the methods of analysis, many necessary manipulative details being omitted for the sake of brevity. Where sufficient material was available, duplicate determinations were made. The closeness of most of the summations to 100%, as shown in the tables of results, is an indication, at least, of the generally satisfactory nature of these methods and of the experimental manipulation.

RESULTS OF MEASUREMENTS AND ANALYSES

The results of the specific gravity measurements are shown in Tables II, III, IV, and V. The calculated figures for silver content from specific gravity shown in the second column of each of these tables are based upon the assumption that the silver in the coins was alloyed only with copper. As shown by the chemical analyses (Table VI) this assumption is not correct, but copper is the usual and often the sole alloying metal in silver coins, and no other assumption appears possible in estimating the silver content of such coins from their specific gravities

alone. In making the calculations the specific gravity of pure silver was taken as 10.50 and that of pure copper as 8.90. The formula used for the calculations was:

$$\% \text{ Silver} = \frac{S_1 S_x - S_1 S_2}{S_1 S_x - S_2 S_x} \cdot 100$$

Where, on the same temperature basis for each,

S_1 is the specific gravity of pure silver.

S_2 is the specific gravity of pure copper.

S_x is the specific gravity of a given coin.

This formula is based upon the ideal relationship between specific gravity and composition in a binary alloy in which no change in total volume of the com-

TABLE II
SPECIFIC GRAVITY AS AN INDEX OF SILVER CONTENT
GROUP I—UNTREATED COINS

Coin No.	Specific Gravity	Silver Content from Specific Gravity	Silver Content by Analysis	Difference
		%	%	%
1	10.29	88.5	94.2	—5.7
2	9.95	69.5	92.9	—23.4
3	10.09	77.5	90.6	—13.1
4	9.84	62.5	76.9	—14.4
5	9.66	51.5	74.3	—22.8
6	9.92	67.5	73.4	—5.9
7	9.59	47.0	67.9	—20.9
8	9.34	31.0	52.2	—21.2
				Ave. = —15.9

TABLE III
SPECIFIC GRAVITY AS AN INDEX OF SILVER CONTENT
GROUP II—ELECTROLYTICALLY CLEANED COINS

Coin No.	Specific Gravity	Silver Content from Specific Gravity	Silver Content by Analysis	Difference
		%	%	%
1	9.91	67.0	69.8	—2.8
2	9.73	56.0	58.2	—2.2
3	9.53	43.5	51.0	—7.5
4	9.48	40.0	47.3	—7.3
5	9.38	33.5	43.1	—9.6
6	9.42	36.0	41.8	—5.8
				Av. = —5.9

ponents occurs on alloying. Alloys of silver and copper fall in this class, and it has been shown experimentally that the silver content of modern coins may be closely approximated from their specific gravities.² No study appears to have been made before of the possibility of estimating the silver content of ancient coins from such measurements. If applicable, this method of estimation would be very useful since ancient silver coins are often of such rarity and value that chemical analysis is not practicable. However, because of the greater complexity of ancient

²Karmarsch, *Dinglers polytech. J.* 224, 565–573 (1877).

monetary silver and the possible presence of corrosion products on or in coins long buried in the ground, it might be expected that the method would be less certain than with modern coins.

Actually, as is shown in Tables II, III, IV, and V, large differences were found to exist between the silver content calculated from specific gravity and the silver content as determined afterwards by chemical analysis. These discrepancies are most marked in the results on the untreated coins (Table II). These low results can not be ascribed to any deposit of soil or to any crust of oxidation products of low specific gravity on the surfaces of the coins, as they were metallic in appearance and at the most were but slightly tarnished. It is likely that these coins, which

TABLE IV
SPECIFIC GRAVITY AS AN INDEX OF SILVER CONTENT
GROUP Ia—BLANKS OF UNTREATED COINS

Blank No.	Specific Gravity	Silver Content from Specific Gravity	Silver Content by Analysis	Difference
		%	%	%
1	10.35	92.0	94.2	— 2.2
2	10.14	80.5	92.9	—12.4
3	10.18	82.5	90.6	— 8.1
4	10.05	75.0	76.9	— 1.9
5	10.06	75.5	74.3	+ 1.2
6	10.09	77.5	73.3	+ 4.2
7	9.85	63.5	67.9	— 4.4
8	9.63	49.5	52.2	— 2.7
				Av. = — 3.3

TABLE V
SPECIFIC GRAVITY AS AN INDEX OF SILVER CONTENT
GROUP IIa—BLANKS OF CLEANED COINS

Blank No.	Specific Gravity	Silver Content from Specific Gravity	Silver Content by Analysis	Difference
		%	%	%
1	9.97	70.5	69.8	+0.7
2	9.86	64.0	58.2	+5.8
3	9.78	59.0	51.0	+8.0
4	9.64	50.5	47.3	+3.2
5	9.57	46.0	43.1	+2.9
6	9.52	42.5	41.8	+0.7
				Av. = +3.6

were obtained from dealers, had been cleaned mechanically. However, as is shown in Table IV, considerably better agreement was found between the calculated silver content and the actual silver content of the cleaned blanks of these same coins. This seems to indicate that the surface layers of the coins contained porous metal as the result of selective removal of base metal during burial in the ground or that these layers contained corrosion products of low specific gravity as a result of intergranular corrosion. As shown by the results in Table III much better agreement was found between the calculated and actual silver content of coins of the same type that had been cleaned electrolytically, especially for the two having the highest silver content. Apparently this cleaning procedure not only reduces visible surface oxidation products but reduces also the intergranular corrosion products below the surface, and in effect consolidates the metal. From Table V

it will be seen that for the blanks of the electrolytically cleaned coins the silver content as calculated from the specific gravity was found to be actually higher than that found by analysis, which is another indication of the internal consolidation of the metal by electrolytic cleaning. These higher results would be expected on compact metal of the composition found by analysis, by reason of the gold and lead present. All these results seem to show that the estimation of the silver content of untreated ancient coins from their specific gravities is a very unreliable procedure, but that useful rough results may possibly be obtained by measurement of the specific gravities of electrolytically cleaned coins. This whole question deserves extensive study.

The results of the chemical analyses of the coins are shown in Table VI. On comparing the percentages of silver given in this table with the figures for the fineness of Parthian drachms given in Table I some interesting similarities and differences are apparent. Both groups of results indicate that only in the early coins of this Parthian series is the silver content of the coins really high, and that in most later coins it falls considerably below this high standard. Though the figures of Table I indicate that it does not fall below 60%, the new results of Table VI shows clearly that it may fall nearly as low as 40%. These new results are in

TABLE VI
ANALYSES OF PARTHIAN SILVER COINS

Coin No.	Ag %	Au %	Cu %	Sn %	Pb %	Fe %	Ni %	Zn %	Total %
1	94.17	0.11	5.02	0.26	0.37	0.05	0.05	none	100.03
2	92.86	0.30	5.81	0.08	0.85	0.04	0.03	none	99.97
3	67.88	0.27	29.33	1.54	0.92	0.04	none	none	99.98
4	90.57	0.27	8.36	0.08	0.63	0.03	none	none	99.94
5	69.77	0.42	27.74	0.75	1.15	0.02	0.02	0.10	99.97
6	58.19	0.53	37.29	1.26	2.65	0.02	0.03	none	99.97
7	50.97	0.35	43.97	2.35	2.34	0.03	0.02	none	100.03
8	47.29	0.43	49.10	1.83	1.41	trace	0.03	none	100.09
9	43.10	0.33	52.26	2.64	1.51	0.05	0.04	none	99.93
10	41.84	0.34	51.92	3.44	2.48	0.04	0.02	none	100.08
11	76.87	0.38	21.75	0.34	0.64	0.04	none	none	100.02
12	74.30	0.27	24.42	0.27	0.54	0.07	none	none	99.87
13	73.33	0.35	24.16	1.36	0.86	0.01	none	none	100.07
14	52.05	0.21	44.52	1.16	1.41	none	0.03	none	99.38

ATTRIBUTIONS AND DATES

- Nos. 1 and 2. Mithradates I. 171-138 (?) B. C.
 No. 3. Sinatruces. 77-70 B. C.
 No. 4. Phraates III (?). 70-57 B. C.
 Nos. 5 to 10 inclusive. Orodes I. 57-38/37 B. C.
 No. 11. Gotarzes. 40/41-51 A. D.
 No. 12. Vardanes I. 41/42-45 A. D.
 No. 13. Volagases II. 77/78-146/147 A. D.
 No. 14. Volagases V. 207/208-221/222 (?) A. D.

direct contradiction to certain general statements that have been made in regard to the fineness of the Parthian silver coinage. For example, Burns³ states that the high initial standard continued with little alteration down to the end of the Parthian Empire in 227 A. D. However, as far as the present results show, the issue of really base silver drachms was confined to the reign of a single ruler, Orodes I of the period 57-38/37 B. C. It will be seen that in three of the six coins analyzed the silver content is below 50%. The average silver content of the six is only 51.69%. This is in marked contrast to the high silver content of 90.57% in a

³Burns, A. R. Money and monetary policy in early times. New York, 1927, p. 164.

coin (No. 4 of Table VI) of an immediate predecessor of Orodes I and to the generally high silver content of the coins of all his predecessors. Evidently a marked debasement of the silver coinage occurred during the reign of this ruler. The fact that the silver content of the coins of Orodes I is spread over a considerable range is not only a sign of debasement but is a sign of progressive debasement during his reign. It is obvious, as a general rule, that when no debasement occurs during the reign of a ruler his individual coins selected at random will not only be of high standard but will differ little from each other in fineness, but that if debasement of the coinage begins and continues during a reign such individual coins will differ considerably from each other in silver content. Some illustrative data are shown in Table VII. This table is derived from Tables I and VI, and shows the range of silver content and average silver content of all Parthian silver coins of which two or more of a given ruler have now been assayed or analyzed. It is not claimed that these figures are very reliable since so few individual coins of each ruler have been analyzed. The data based upon only two determinations are especially open to question. However, these are the only such figures possible at present, and they at least appear to give significant indications. It will be seen that the percentages of silver in the five coins of Mithradates I range over only 5%, whereas in the six coins of Orodes I they range over 28%. Then in the three coins of Gotarzes the range is again only 5%, with the coins of the other two rulers in intermediate positions. In the group as a whole a consistent inverse

TABLE VII
RANGE OF SILVER CONTENT AND AVERAGE SILVER CONTENT
OF COINS OF CERTAIN PARTHIAN RULERS

Ruler	Date	No. of Coins	Range in Silver Content %	Average Silver Content %
Mithradates I.....	171-138 (?) B. C.....	5	5.0	91.7
Artabanos II.....	88-77 B. C.....	2	12.6	79.1
Orodes I.....	57-38/37 B. C.....	6	28.0	51.7
Orodes II.....	4-6 A. D.....	2	17.6	71.0
Gotarzes.....	40/41-51 A. D.....	3	5.0	77.6

relationship exists between range and fineness. Apparently the debasement of the coinage during the reign of Orodes I was followed by considerable improvement during the reigns of the succeeding rulers, though the original high standard was never again restored.

The percentages of gold shown in Table VI are in approximate agreement with the fineness figures of Table I. In the analyses of Table VI the average percentage of gold is 0.33, and in the assays of Table I the average gold content in terms of percentage is 0.25. There is a greater discrepancy in the ratios of gold to silver in the results of the two tables, but this lack of exact agreement may be ascribed to the difference in the methods of determining the gold. It is likely that the present results are more accurate. As compared to those of modern silver, the proportions of gold in Parthian coinage silver are very high, but such proportions of gold are characteristic of ancient silver in general. The gold in the Parthian coinage silver was evidently present as a mere fortuitous impurity that accompanied the silver, and it varied considerably in proportion in accordance with the source of the silver and the details of its metallurgical treatment. It seems improbable that ancient metallurgists had any means of separating these small proportions of gold from silver, or that they were even aware that their silver contained gold in such proportions.

As the figures of Table VI show, copper is the main alloying component of Parthian coinage silver. That it was introduced into the alloy as the metal itself is very improbable as will appear from a consideration of the proportions of tin and lead in the coins.

Though the percentages of tin are not very high numerically, being above 3% in only one coin, they are nevertheless very high for ancient silver. They are generally higher in the debased silver coins of Orodes I than in the other coins that were analyzed, especially the earlier coins of high silver content. Tin, when not absent entirely, is usually present in ancient coinage silver to the extent of only a few hundredths or tenths of a percent. In a series of sixteen ancient Greek silver coins analyzed by Bibra,⁴ three were found to contain a trace of tin, the others none, and in a series of twenty-two Roman Imperial silver coins, many of them debased, which were analyzed by this same investigator, tin was either absent or present as a mere trace in eleven, the highest proportion found being

TABLE VIII
ANALYSES OF GREEK AND ROMAN SILVER COINS SIMILAR
TO THE COINS OF ORODES I IN FINENESS

Ag %	Au %	Cu %	Sn %	Pb %	Fe %	Ni %
73.96	0.25	23.94	none	1.35	trace	none
56.76	1.81	40.63	none	0.75	0.23	trace
54.92	0.15	43.80	0.20	0.75	0.11	0.07
43.97	0.10	55.26	0.21	0.31	trace	0.15
43.41	0.72	54.69	none	trace	0.97	0.21
40.66	0.17	58.70	0.10	0.13	0.24	none

TABLE IX
ANALYSES OF GREEK SILVER COINS OF VERY HIGH FINENESS

Ag %	Au %	Cu %	Pb %	Fe %	Ni %
99.40	trace	none	0.46	trace	none
99.19	0.34	none	0.13	trace	none
99.09	trace	none	0.40	trace	none
99.07	trace	trace	0.43	trace	none
98.98	0.003	none	0.63	trace	none

0.71% and the average only 0.13%. The analyses in Table VIII show his results on coins having about the same range of silver content as the coins of Orodes I. According to the analyses of Bibra, tin is likely to be absent especially from coins of very high silver content. This appears to be confirmed by some more recent analyses by Elam⁵ which are shown in Table IX. Apparently tin was absent from all these coins of very high fineness, or else the analyst did not think it worth while to determine the small amounts that could have been present. The absence of tin from all such coins is what might be expected from its usual absence from deposits of silver ores. In general, then, tin is not normally associated with the silver of ancient coinage alloys, and there is no reason to believe that the Parthian coinage alloys were exceptional in this respect. It seems very probable, therefore, that most of the tin in the Parthian alloys was introduced along with the copper.

⁴Bibra, E. von. *Ueber alte Eisen- und Silber-Funde*. Nürnberg and Leipzig, 1873, pp. 37, 40.

⁵Elam, C. F. *J. Inst. Metals* 45, 57-69 (1931).

Similarly, the percentages of lead shown in the analyses of Table VI, especially in the coins of Orodes I, are unusually high for ancient coinage silver, as may be seen by comparing these percentages with those shown in Tables VIII and IX. All these percentages are further compared in Table X, where it will be seen to what extent the proportions of lead in the coins of Orodes I are abnormally high. Evidently a fairly constant small proportion of lead is almost always present in ancient fine silver, apparently as a residue from the imperfect cupellation of argentiferous lead, but the proportions of lead in the debased coins of Orodes I are so abnormally high that it seems necessary to conclude that only part of this lead was introduced into the alloy along with the silver and that the rest was introduced along with the copper.

The small percentages of iron shown in the analyses of Table VI are probably without much significance, as iron is almost a universal accidental impurity in ancient metals and alloys. However, as shown by the analyses of Table IX, the iron content of ancient silver coins of very high fineness is usually very small, so that it might well be that the noticeably larger proportions found in these Parthian coins were introduced into the alloys along with the copper rather than with the

TABLE X

COMPARISON OF COINS OF ORODES I WITH EARLIER PARTHIAN COINS AND WITH CERTAIN GREEK AND ROMAN COINS IN RESPECT TO SILVER CONTENT, LEAD CONTENT, AND RATIO OF LEAD CONTENT TO SILVER CONTENT

GROUP	Ag %	Pb %	Ratio of Pb to Ag
Parthian Coins Prior to Orodes I.....	Max. = 94.17 Min. = 67.88 Av. = 86.37	Max. = 0.92 Min. = 0.37 Av. = 0.69	Max. = 0.014 Min. = 0.004 Av. = 0.008
Coins of Orodes I.....	Max. = 69.77 Min. = 41.84 Av. = 51.69	Max. = 2.65 Min. = 1.15 Av. = 1.92	Max. = 0.059 Min. = 0.016 Av. = 0.039
Greek and Roman Coins of Similar Fineness..	Max. = 73.96 Min. = 40.66 Av. = 52.28	Max. = 1.85 Min. = trace Av. = 0.63	Max. = 0.025 Min. = 0.000 Av. = 0.010
Greek Coins of Very High Fineness.....	Max. = 99.40 Min. = 98.98 Av. = 99.14	Max. = 0.63 Min. = 0.13 Av. = 0.41	Max. = 0.006 Min. = 0.001 Av. = 0.004

silver. It is still more likely that the small proportions of nickel shown in the analyses of Table VI were introduced with the copper rather than the silver. In these analyses nickel is invariably present in the coins of very high copper content (over 35%) but absent from more than half the others. Furthermore, the analyses cited in Table IX indicate that nickel is not normally associated with ancient silver, and this same lack of association is apparent from other analyses of ancient silver coins of high fineness. The small proportion of zinc found in one coin (No. 5) is in all probability a mere accidental impurity that was introduced along with the copper. Neither arsenic nor sulfur in weighable amounts was found in any of these silver coins.

The results of the analyses of the bronze coins are shown in Table XI. These are apparently the first analyses of any kind of a Parthian bronze object that have been reported. It will be seen that the two earliest coins are very similar to each other in composition, and that the two coins of Orodes I are also very similar to each other. Larger differences exist in the composition of the two coins of Sinatruces, but they are similar to each other in the proportions of lead they contain,

and their lead content clearly groups them together as distinctly different from the earlier and the later coins. These similarities in the composition of coins issued in the same reign seem to indicate the existence of at least some standardization and control in the preparation of the bronze coinage alloys.

Though these coins viewed as a whole are not very different in composition except in lead content, this one difference is very marked. The relationships of the proportions of the main components of the alloys to each other are perhaps more readily evident from the ratios of the percentages, shown in Table XII, than from the percentages themselves. For the coins of Sinatruces and of Orodes I these ratios were calculated from the average percentage figures for each pair of coins. It will be seen that in the two earliest coins the ratios of the components are essentially the same, and that in the group as a whole there is little change in the ratio

TABLE XI
ANALYSES OF PARTHIAN BRONZE COINS

No.	Cu %	Sn %	Pb %	Fe %	Ni %	As %	Total %
1	88.64	6.72	3.88	0.15	0.07	0.26	99.72
2	89.54	6.97	3.18	0.09	0.08	0.11	99.97
3	88.31	4.71	6.60	0.08	0.18	0.05	99.94
4	83.90	7.24	8.54	0.04	0.07	none	99.79
5	82.19	5.17	12.03	0.08	0.10	0.24	99.81
6	80.69	6.08	12.65	0.04	0.08	0.21	99.79

ATTRIBUTIONS AND DATES

No. 1. Mithradates I. 171-138 (?) B. C.

No. 2. Mithradates II. 123-88 B. C.

Nos. 3 and 4. Sinatruces. 77-70 B. C.

Nos. 5 and 6. Orodes I. 57-38/37 B. C.

TABLE XII
RATIOS OF MAIN COMPONENTS IN PARTHIAN BRONZE COINS

Period B. C.	Ratio of Sn to Cu	Ratio of Pb to Cu	Ratio of Pb to Sn
171-138 (?).....	0.08	0.04	0.6
123-88.....	0.08	0.04	0.5
77-70.....	0.07	0.09	1.3
57-38/37.....	0.07	0.15	2.2

of tin content to copper content. The most striking and significant fact is the progressive increase in the ratios of lead content to copper content and of lead content to tin content. This same sort of chronological change in these ratios, with the ratio of tin content to copper content remaining relatively constant, has been previously observed in various series of Greek bronze coins, and has been explained as being the result of the remelting of old worn bronze coins of previous issue with lead in order to obtain metal for the issue of new coins.⁶ However, the lead content of these Parthian coins is generally lower than that of contemporaneous bronze coins issued elsewhere in the ancient world, even in localities near Parthia. This is illustrated by the analyses listed in Table XIII of a series of coins struck in Syria.⁷ In this one respect, at least, Parthian bronze coins of the period covered by the analyses have a composition that is distinctive.

⁶Caley, E. R. *The Composition of Ancient Greek Bronze Coins*. Philadelphia, 1939.

⁷From Table XVIII, pp. 92-93, of the work cited in Reference 6.

The percentages of the various impurities listed in Table XI are similar to those generally found in ancient coinage bronze. The nickel content is noticeably higher than in most ancient coinage bronze of the same period, and this may be of some significance as a distinctive characteristic. Though there appears to be some systematic variation in the arsenic content from one reign to another, this is probably fortuitous, as the arsenic content of ancient coinage bronze, like the iron content, usually varies in an erratic manner, thus indicating that both are mere accidental impurities. Neither zinc nor sulfur, often present in ancient coinage bronze, was found in any of these Parthian coins.

THEORY OF DEBASEMENT OF THE DRACHMS OF ORODES I

In the preceding discussion of the analytical results it was shown that nearly all the tin, iron, nickel, and part of the lead, were introduced, in all probability, into the debased silver coins of Orodes I along with the copper. Such a mixture in the approximate proportions indicated by the analyses would constitute a bronze. Consequently, it may logically be inferred that the debased coinage silver of

TABLE XIII
ANALYSES OF SYRIAN BRONZE COINS

No.	Cu %	Sn %	Pb %	Fe %	Ni %	Zn %	As %	S %	Total %
1	88.72	8.54	2.56	0.11	0.04	none	0.04	0.02	100.03
2	90.80	6.52	2.25	0.29	0.02	none	0.02	0.01	99.91
3	80.12	6.18	13.12	0.01	0.03	0.05	0.26	0.17	99.94
4	80.84	5.94	11.84	0.01	0.07	0.03	1.32	none	100.05
5	64.32	4.07	31.70	0.01	none	none	trace	0.01	100.11
6	67.13	7.62	24.90	0.14	0.02	0.01	0.10	none	99.92

ATTRIBUTIONS AND DATES

- No. 1. Antiochus II. 261-246 B. C.
- No. 2. Antiochus III. 222-187 B. C.
- No. 3. Seleucus IV. 187-175 B. C.
- No. 4. Demetrius II. 146-138 B. C.
- No. 5. Antiochus VIII. 121 B. C.
- No. 6. Antiochus VIII. 114 B. C.

Orodes I was manufactured by alloying silver of good quality with bronze. Furthermore, the composition of this bronze could be calculated closely from the results of Table VI providing the composition of this silver were known. Though there seems to be no way to find out the exact composition of this silver, certain plausible assumptions as to its composition may be made. These are: A. That it was fine silver of the highest quality known in the ancient period, and that its composition was about the average of the analyses shown in Table IX. B. That it was Parthian coinage silver of high quality obtained by melting together worn coins of earlier reigns, and that its composition was about that of the average of the analyses of Coins 1, 2, and 4 of Table VI. C. That it was Parthian coinage silver of high quality produced mostly by melting down coins of the reign immediately preceding that of Orodes I, and that its composition was about that of Coin No. 4 of Table VI. In view of the usual practice in mints, assumptions B and C seem more likely than A, and possibly C is more likely than B. Shown in Table XIV are the results of calculations, based on these three assumptions, of the probable composition of the bronze used in producing the coinage alloy for each of the six coins of Orodes I. In making these calculations the gold was counted with the silver and no allowance was made for preferential loss of components of the bronze by

oxidation or volatilization during the melting of it with the silver. Actually, the calculated figures would not have differed materially if allowance had been made for various small losses that could have occurred in this way. It will be seen that the three sets of figures for each coin are similar to each other, in the proportions of the main components at least, regardless of which assumption is made as to the composition of the silver that was debased. Hence the exact composition of this silver is not a matter of great importance for estimating the essential composition of this bronze. In general, as shown by the closer absolute and relative correspondence of the figures based on the three assumptions, the greater the degree of debasement the less the importance of the exact composition

TABLE XIV

PROBABLE COMPOSITION OF THE BRONZE USED IN DEBASING THE COINS OF ORODES I CALCULATED ON THREE POSSIBLE ASSUMPTIONS AS TO THE COMPOSITION OF THE ALLOY THAT WAS DEBASED

Coin No.	Assumption	Cu %	Sn %	Pb %	Fe %	Ni %
5	A	94.63	2.55	2.68	0.07	0.07
	B	94.57	2.63	2.80	none	none
	C	93.98	3.03	2.90	none	0.09
6	A	90.93	3.07	5.88	0.05	0.07
	B	90.62	3.19	6.16	none	0.03
	C	90.16	3.42	6.33	none	0.09
7	A	90.66	4.85	4.39	0.06	0.04
	B	90.43	5.08	4.47	0.02	none
	C	90.10	5.28	4.55	0.02	0.05
8	A	94.11	3.51	2.32	none	0.06
	B	94.12	3.62	2.22	none	0.04
	C	93.91	3.76	2.27	none	0.06
9	A	92.79	4.69	2.36	0.09	0.07
	B	92.73	4.86	2.29	0.06	0.06
	C	92.54	4.98	2.32	0.08	0.08
10	A	89.94	5.96	4.00	0.07	0.03
	B	89.72	6.19	4.03	0.04	0.02
	C	89.49	6.33	4.08	0.06	0.04
All	Max.	94.63	6.33	6.33	0.09	0.09
	Min.	89.49	2.55	2.22	none	none
	Av.	91.97	4.28	3.67	0.03	0.05
9 and 10 only	Max.	92.79	6.33	4.08	0.09	0.08
	Min.	89.49	4.69	2.29	0.04	0.02
	Av.	91.20	5.50	3.18	0.07	0.05

of the silver. Though there are considerable differences in the calculated compositions of the bronze used in the manufacture of the alloys for the individual coins, these compositions viewed as a whole are not radically different. Because of the lesser importance of the exact composition of the silver, and the greater accuracy of the computations, especially as regards the figures for the minor components, the figures calculated for Coins 9 and 10 are probably more reliable than the others. The average figures for these two coins, shown at the bottom of Table XIV, may be taken as representative of the probable composition of the bronze that was used in producing the debased silver drachms of Orodes I.

The source of this bronze may have been earlier Parthian bronze coins. It seems significant that the average figures calculated for Coins 9 and 10 are similar to the analytical figures for the bronze coins of Mithradates I and Mithradates II given in Table XI. Bronze of the composition of the bronze coins of Orodes I, either in the form of the coins of this ruler or in the form of bulk metal, evidently was not used in producing his debased silver coins. Furthermore, it is improbable that bronze having the composition of the bronze coins of Sinatruces, or bronze coins of this ruler, could have been used for the purpose. Only one principal qualitative discrepancy exists between the calculated composition of the bronze used for debasing the silver coins of Orodes I and the analytical figures for the two early Parthian bronze coins. This is the presence of arsenic in these coins. However, it is entirely possible that the arsenic in the bronze coins was completely oxidized and volatilized on remelting and that as a consequence none was incorporated in the debased silver.

• That bronze in the form of coins, rather than in any other form, was used in debasing silver for the production of the drachms of Orodes I is probable. It is the usual practice in mints to obtain most of the metal for the issue of new coins by melting down earlier ones, especially if these are worn, and at the time of Orodes I it is almost certain that most of the bronze coins of Mithradates I and Mithradates

TABLE XV

CORRELATION BETWEEN ANALYTICAL FIGURES ON COMPOSITION OF DEBASED SILVER COINS OF ORODES I AND THEORETICAL FIGURES

Coin No.	Source of Figures	Ag %	Au %	Cu %	Sn %	Pb %	Fe %	Ni %
9	Analysis.....	43.10	0.33	52.26	2.64	1.51	0.05	0.04
	Calculation...	43.10	0.13	51.32	3.32	1.99	0.07	0.04
10	Analysis.....	41.84	0.34	51.92	3.44	2.48	0.04	0.02
	Calculation...	41.84	0.13	52.45	3.41	2.03	0.07	0.04

II still in circulation were in poor condition. Furthermore, the bronze coins of these two rulers are of larger diameter and greater weight than the bronze coins issued by later rulers, and this could have been an additional reason for withdrawing these particular coins from circulation and using them as a source of metal.

In Table XV are shown the results of calculations on the composition of the debased silver that could have been produced by melting bronze of the average composition of the coins of Mithradates I and Mithradates II with silver of the composition of Coin 4 of Table VI to produce alloys having the silver content of Coins 9 and 10 of Table VI. In making these calculations it was assumed that all the arsenic was volatilized from the bronze, and an allowance was made for a loss of 10% of the tin and lead by preferential oxidation in the process of remelting and alloying. The degree of debasement for Coin 9 is 52.41% and for Coin 10, 53.80%. It will be seen that there is substantial agreement between the actual and the theoretical figures. On the whole, therefore, it does not appear at all unlikely that the metal for the debased drachms of Orodes I was made by melting down silver coins of his immediate predecessor, or more than one predecessor, with early Parthian bronze coins.

On the basis of present knowledge, serious debasement in the long series of drachms issued by the rulers of Parthia occurred only during the reign of Orodes I. Though such causes as the dishonesty of mint officials, a series of internal economic crises, or the effect of monetary changes in other countries may account for this

debasement, no historical evidence in support of any such causes appears to exist. The real cause may have been military conflict between the Parthian and Roman empires, which not only first occurred during the reign of Orodes I but occurred repeatedly during his reign.⁸ Analogous conflicts, both in ancient and modern times, have often resulted in the debasement of the coins of at least one of the combatants. The prolonged warfare between the Parthians and the Romans during his reign may have led to a need for a greatly expanded coinage or have caused other economic changes that made debasement of the coinage a necessary consequence. Moreover, it seems significant in support of this as a fundamental cause that the end of this warfare coincided with the end of the reign of Orodes I and that after his reign there was an era of peace between the two empires that lasted nearly a century. If the debasement of the coins was caused directly or indirectly by this warfare, the rise in the fineness of the coins of the successors of Orodes I may plausibly be explained by the succeeding long period of peace. Though the Parthians were later engaged in other warfare with the Romans, and probably fought other peoples at various times, these other conflicts may not have been on such a scale as to affect seriously the economy of the Parthian Empire, and for that reason did not lead to the debasement of the coinage. Generally speaking, the debasement of a coinage is often an index of warfare so intense or prolonged that the economy of a country is seriously altered. In conclusion, therefore, it does not seem improbable that the fundamental cause of the debasement of the coins of Orodes I was the warfare known to have occurred between the Parthian Empire and the Roman Empire during the reign of this ruler.

⁸Sykes, Sir P. *A History of Persia*. London, 1930, Vol. I, pp. 346-359.

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