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Jonathan Ouellet

Abstract This study explores X-ray fluorescence (XRF) analysis to examine Georgian–Sasanian coins, a coinage type modelled after Sasanian designs but featuring Georgian inscriptions. By analysing the metal composition of these coins and comparing them to centrally minted Sasanian and Arab–Sasanian coins, the research aims to determine whether these coins conform to Sasanian standards or represent some level of independent activity. The findings suggest that Georgian–Sasanian coins exhibit silver content consistent with Sasanian minting standards.[1]

As a rapidly evolving field, archaeology has begun to use new scientific methods to learn more about the material properties of the items we find. This paper is concerned with techniques being used for the study of the coinage of the Sasanian empire in particular, and the existence of a particular type of coinage that was created using a Sasanian model, but with the inclusion of Georgian letters. Given that the Sasanians were known for their high-quality minting standards and high level of state control in the minting process, this potential imitation is of great interest. This series of coins have long been understudied, often only being looked at by a small number of scholars from the former Soviet Union, particularly Georgia. Therefore, these coins need more in-depth analyses.

The following article intends to use XRF analyses to help formulate a working theory as to the true intention of the issues of Georgian–Sasanian coins, namely whether they were an attempt at Georgian independence, or whether they were simply a propaganda tool. The article is a continuation of my previous article which established the typology and explained a number of stylistic and typological aspects of these coins (Ouellet 2022, 15–22). Together the two articles present a plausible working theory for the reasoning behind the minting origins of these coins. Beyond this, it presents a data set that can help to contribute to our understanding of late antique numismatics and metallurgy

The coins are currently housed in separate institutes, so the tests were conducted in Qatar, in conjunction with the Museum of Islamic Art in Doha, and the Bode-Museum in Berlin and the National Museum of Georgia.

The Museum of Islamic Art in Doha, Qatar (MIA) provided 41 Sasanian coins and 16 Arab-Sasanian coins. They were selected from approximately 80 Sasanian coins and close to 2,000 Arab-Sasanian coins in the collection. The coins were purchased some time ago and are part of the partially unpublished Samir Shamma Collection. The Sasanian coins have been defined using the classifications created by Göbl (1971). Beyond this, we have listed the weight, diameter, mint location and regnal year when possible, which has been catalogued by staff at MIA. The coins used in the Doha tests were not Georgian–Sasanian coins, but Sasanian coins that are well attested as being centrally minted and therefore are being used as a comparison to the possible imitation coins of Georgia. Additionally, 16 Arab–Sasanian coins from the Museum of Islamic Art in Doha were tested to create more comparisons. Examples of the three groups are shown in figures 1–3.

Figure 1 Georgian Sasanian, Tsotselia Type 3b, Bode-Museum 18238820

Figure 2 Sasanian, MIA 7343

Figure 3 Arab–Sasanian coin, MIA 7311

Circumstances of the testing

In Qatar analyses were carried out using a handheld XRF Olympus Innov-X Delta Premium with a 4W, 40kV Rh anode X-ray tube. The instrument has a 3-millimetre collimator that restricts the beam and allows the analysis of small samples. The analytical method used is Alloy Plus UCL 3mm. This is a modification of the factory set-up method Alloy Plus. The differences lie in the presence or absence of certain reported elements, while the method is additionally calibrated for analysis with the 3-millimetre collimator in place. The tests were conducted at the Museum of Islamic Art in Doha by Tiffany Martin and Jonathan Ouellet, with guidance from Dr Myrto Georgakopoulou and the assistance of Hanan Mohamed Al Said.

At the Bode-Museum the tests were conducted by Dr Hans-Ulrich Voss using a Niton XL3 GOLD D+ handheld XRF-spectrometer calibrated using a German 10-euro coin (92.8 per cent silver and 7.5 per cent copper) and an 1888 Prussian 2-mark coin (91.5 per cent silver and 7.7 per cent copper). Six coins were subjected to this test.

Tests were also conducted on five coins by Dr Nino Kebuladze at the National Museum of Georgia using an ElvaX spectrometer.

A key issue for silver coins in analysis is the effect that corrosion and cleaning has on them. Sasanian objects are

1 This paper is adapted from a chapter of my MA thesis on Georgian–Sasanian coins (UCL Qatar 2016). The coin images in this paper are not to scale.

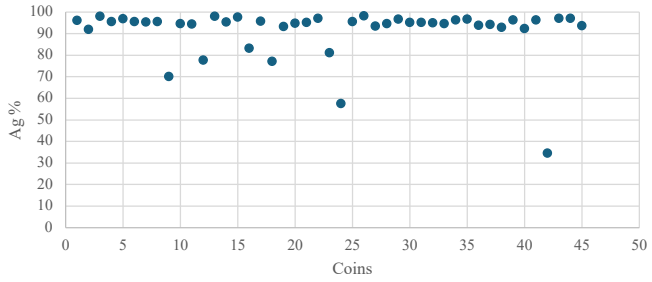

Figure 4 Sasanian silver content, per cent

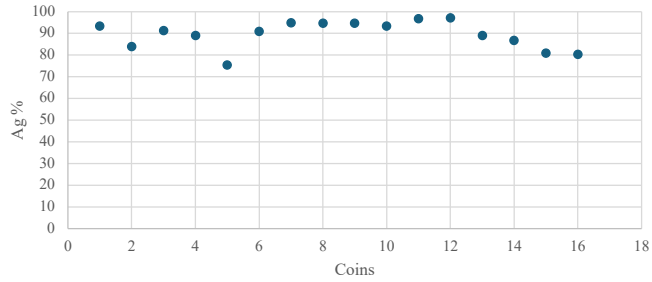

Figure 5 Georgian–Sasanian silver content, per cent

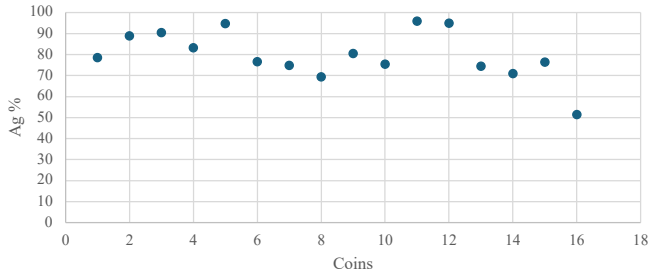

Figure 6 Arab–Sasanian imitations silver content, per cent

known to have a high silver content (Bacharach and Gordus 1972, 338). Coins and other objects, even today, are usually made of metals manufactured with a variety of elements to change their structure. Pure silver, for example, is too soft and malleable for coin production, and it would be likely to lose its shape and design features during the minting process. To counter this, copper is added, which strengthens the metal and helps it retain detail (Hughes and Hall 1979, 331). This then means that although many of the coins in this study are mostly silver, there will be some copper present and it is possible that during the corrosion process or chemical treatments such as cleaning, copper could leach from the interior of the coins, causing it to appear at the surface ('surface enrichment', see Beck et al. 2004, 160; Butcher et al. 2014, 91). This may give a false reading that suggests a coin has a lower silver content than it actually has. Cleaning done in the past may also give misleading readings, as it may have unwittingly taken layers off the coins that could have been key to understanding their true metallurgical nature (Shugar and Mass 2013, 221). Also, regarding the Arab-Sasanian coins, high levels of mercury have been detected in some of the coins. Some recent research has tried to understand what this presence means. Both Uhlir and Heideman have noted that the mercury may be because the coins could have been dipped into mercury, a method used in antiquity to increase the coin's brightness (Heideman et al. 2014, 90; Uhlir et al. 2016, 165).

Data from several coins from the work of Sodaei et al. (2013) were also used. This is noted in the data table as 13–18 Sodaei. This was done to provide information from more

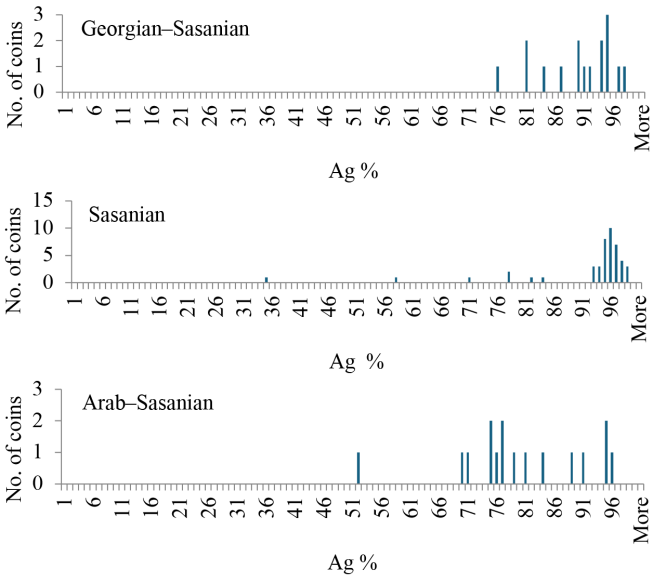

Figure 7 Number of Sasanian coins tested plotted against silver content

centrally minted coins to compare with the Georgian–Sasanian specimens. This does create a small problem of variance though, as multiple tests done with multiple machines with multiple technicians can cause there to be a discrepancy. There is also the issue of only 11 Georgian–Sasanian coins being used, as it may be too small a number to show a firm pattern. As there are only 40 known specimens though, with 10 having unknown providence, this is not only a problem for this study but for the field as a whole. It also important to note, as hinted above, that the location of the minting of the coins in Georgia is currently unknown. Furthermore the centrally minted coins are from a variety of mints such as Bishapur, Hormizd-Ardashir, Jayy, Shiraz and Yazd. This variation of mints could lead to different results as mints may vary in minting techniques and quality.

The XRF analysis results are shown in table 1 at the end of this paper. The data is split between Georgian–Sasanian, Sasanian and Arab–Sasanian and the results are shown in the graphs. As mentioned above, Sasanian coins are known to have a high silver content (figure 4), so imitations might be expected to have a lower silver content. But figure 5 shows that the Georgian–Sasanian coins show levels of silver content comparable to that of the centrally minted Sasanian coins, whereas the silver content in the Arab-Sasanian coins having somewhat more variation (figure 6).

The average silver content of the 11 Georgian–Sasanian coins was 90.1 per cent while the average of the 47 Sasanian coins was also around 91 per cent. The Arab–Sasanian coins on the other hand had an average silver content of around 70 per cent and the graph shows that this is clearly a much less well-defined group of coins. These averages put the Georgian–Sasanian coins well within the range of the coins from the central Sasanian area.

This can also be seen in the histograms, figure 7, where frequency of the high percentage of silver is plotted against the number of coins. It is also very clear here that the Georgian–Sasanian coins and the centrally minted Sasanian coins are very close. This is in comparison with the Arab–Sasanian coins that clearly have a greater range.

Several of the coins, MIA 7308, 7311, 7317, 7323 and

Bode 18238820, show as being with low silver content, but of the five with content below 80 per cent only one is of Georgian–Sasanian origin (figures 8–10).

Figure 8 Arab–Sasanian coin, MIA 7311

Figure 9 Georgian Sasanian, Tsotselia Type 3b, Bode-Museum 18238820

Figure 10 Sasanian, MIA 7343

When looking at figure 4 with the silver data of only the 11 Georgian–Sasanian coins analysed, there is a clear average which as stated before is 90.1 per cent. Bacharach has stated that during the period of Hormizd IV and Khusrow II the average coin contained 85 per cent silver or more for Hormizd IV and during the reign of Khusrow II the coins averaged between 85 and 99 per cent, as during his reign there were several periods of fluctuation (Bacharach and Gordus 1972, 282). What this means is that most of the Georgian–Sasanian coins fall within the average silver purity for coins minted by the Sasanians during this period. It is worth noting as well that of the 11 Georgian-Sasanian coins analysed, though, four are potentially from the Khusrow II period and average at 91 per cent.

Something that is worth comparing is the silver content against the copper percentage. In the Georgian–Sasanian coins, it appears in the graph that while most of the coins have a similar profile, with copper less than 10 per cent, one is over 20 per cent copper with silver under 80 per cent. The rest average around 91 per cent silver and 7 per cent copper (figure 11).

In comparison, 15 of the Sasanian coins analysed show a high copper content (over 10 per cent, figure 11). This is in comparison with an overall 5 out of 16 Georgian–Sasanian coins that had relatively high copper content, some over 20 per cent copper (consitfigure 12). All of these coins also have notes on their data sheets that high levels of corrosion were present on the coins, potentially indicating that this may be the cause of this copper content, as copper has leached into the silver content through corrosion, causing it to appear more in surface analysis, as was pointed out earlier in the analytical setup. A similar pattern is present with the Arab–Sasanian coins, but these coins also have higher than normal quantities of lead and mercury, which could be what is causing the results to show lower silver content (figure 13). The lead and mercury may be the result or poorer refinement processes or perhaps different source of silver.

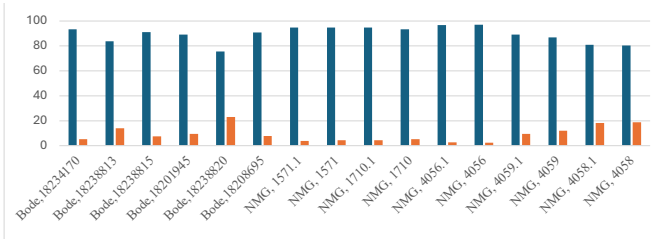

Figure 12 Relative silver and copper content (%) of the Georgian–Sasanian coins, blue columns are silver, orange are copper

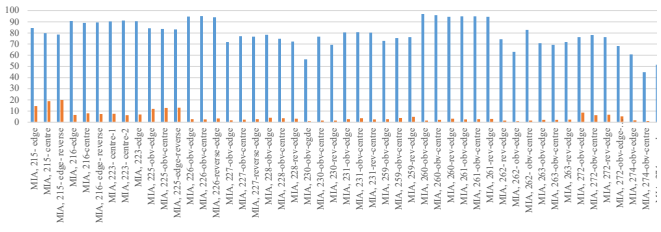

Figure 13 Relative silver and copper content (%) of the Arab–Sasanian coins

This in turn can be seen in figure 14, which compares the percentages of silver and copper in all three groups.

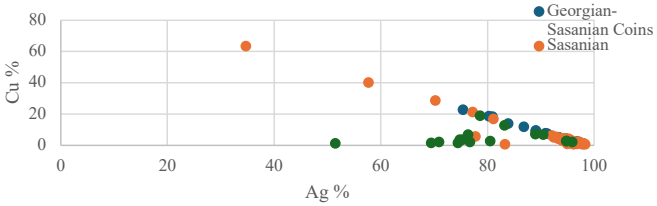

Figure 14 Comparison of silver content againts the copper in all three coin types

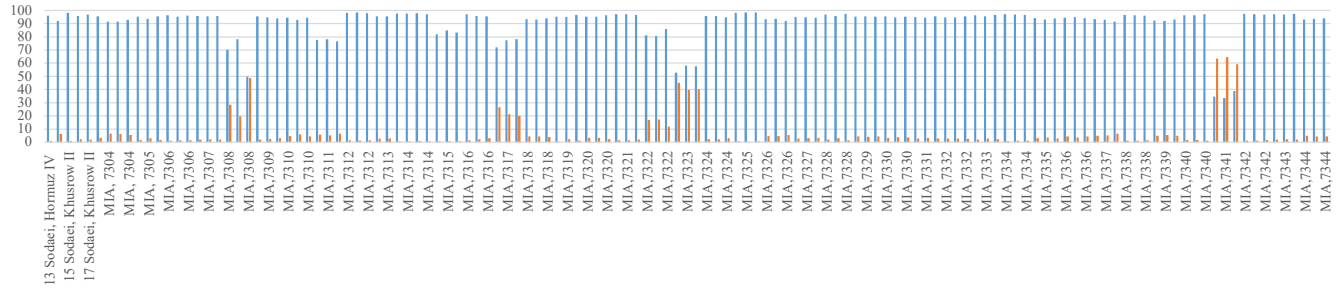

Figure 11 Relative silver and copper content (%) of the Sasanian coins, blue columns are silver, orange are copper

Conclusions

What is clear is that the Sasanian coins that are of lower quality are those which were noted as having high levels of visible corrosion. The Arab–Sasanian coins that have a low silver and high copper content, are the ones that had very high lead and mercury counts, with one (figure 14) as high as 40 per cent lead and 11 per cent mercury. As noted in the analytical set up though, the relatively high mercury level may be the result of mercury surface enrichment to brighten the coin's silver lustre (Heideman et al. 2014, 90).

Figure 14 MIA 274

The main point illustrated by these graphs is that the silver content of the Georgian–Sasanian coins do in fact fall within the pattern that the Sasanian coins present. While none of this data is conclusive, it suggests that the Georgian–Sasanian coins are made with a high degree of silver quality comparable to that of the centrally minted coins of the Sasanian empire, which suggests that the Georgian territories were well integrated into it.

The main Sasanian series shows a consistency of production quality and standards, while the Arab–Sasanian series shows how imitative coins will tend not to have these qualities, i.e. they will tend to be adulterated and the metal content will be much more variable.

The study shows that it will be worth investigating further with analysis of coins from other regions controlled or influenced by the Sasanians to see if this pattern is matched elsewhere and what the political implications of that might be.

Acknowledgement

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References

Bacharach, J. and A. Gordus (1972) 'The purity of Sasanian silver coins: An introduction', *Journal of the American Oriental Society* **92**, 280–3

Butcher, K., M. Ponting, J. Evans, V. Pashley and C. Somerfield (2015) *The Metallurgy of Roman Silver Coinage* Cambridge

Göbl, R. (1971) *Sasanian Numismatics* Braunschweig

Heidemann, S., H. Riederer and D. Weber (2014) 'A hoard from the time of Yazdgard III in Kirmān', *Iran* **52**, 79–124.

Hughes, M. and J. Hall (1979) 'X-ray fluorescence analysis of late Roman and Sassanian silver plate', *Journal of Archaeological Science* **6**, 321–44

Ouellet, J. (2022) 'An analytical examination of Georgian–Sasanian coins and their meaning in numismatics', *Journal of the Oriental Numismatic Society* **249**, 15–22

Shugar, A. and J. Mass (2013) *Handheld XRF for Art and Archaeology* Leuven

Sodaeia, B., K. M. Parasto and M. Khazaieb (2013) 'A study of Sasanian silver coins employing the XRF technique', *Interdisciplinaria Archaeologica* **4**, 211–15

Uhlir, K. Padilla-Alvarez, R. Migliori, A. Karydas, A.G. Božičević Mihalić, I. Jakšić, M. Zamboni, I. Lehmann, R. Stelter, M. Griesser, N. Schindel and M. Alram (2016) 'The mystery of mercury-layers on ancient coins: A multianalytical study on the Sasanian coins under the reign of Khusro II', *Microchemical Journal* **125**, 159–69

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Table 1 XRF data

Coins:	*Ag*	*Pb*	*Cu*	*Au*	*Fe*	*Hg*
Bode,18234170	93.305	0.301	5.073	0.437	0.442	
Bode,18238813	83.855	0.5	14.05	0.707	0.227	
Bode,18238815	91.223	0.459	7.35	0.445	< LOD	
Bode,18201945	89.059	0.283	9.532	0.394	< LOD	
Bode,18238820	75.438	0.445	22.877	0.498	0.196	
Bode,18208695	90.891	0.499	7.867	0.355	< LOD	
NMG, 1571.1	94.9	0.83	3.848	0.422	0	
NMG, 1571	94.662	0.587	4.303	0.448	0	
NMG, 1710.1	94.721	0.413	4.31	0.556	0	
NMG, 1710	93.417	0.894	5.161	0.529	0	
NMG, 4056.1	96.775	0.217	2.6	0.409	0	
NMG, 4056	97.172	0.185	2.227	0.416	0	
NMG, 4059.1	89.051	0.975	9.37	0.604	0	
NMG, 4059	86.841	0.859	11.86	0.441	0	
NMG, 4058.1	80.949	0.375	18.284	0.391	0	
NMG, 4058	80.29	0.547	18.825	0.338	0	
13 Sodaei, Hormuz IV	96.2	0.8	0.8	0.8	1.4	
14 Sodaei, Khusrow II	92.1	0.8	6.3	0.7	0	
15 Sodaei, Khusrow II	98.1	0	0.9	1	0	
16 Sodaei, Khusrow II	95.7	0	2.3	0.8	1.3	
17 Sodaei, Khusrow II	97	0	2	1	0	
18 Sodaei, Khusrow II	95.6	0	3.3	1.1	0	
MIA, 7304	91.60	1.24	6.44	0.63	<LOD	<LOD
MIA, 7304	91.56	1.30	6.39	0.67	0.03	<LOD
MIA, 7304	92.86	1.03	5.45	0.67	<LOD	<LOD
MIA, 7305	95.27	1.07	1.67	0.86	0.04	0.08
MIA, 7305	93.68	1.65	3.09	0.79	0.03	0.05
MIA, 7305	95.44	0.95	1.65	0.82	0.11	<LOD
MIA,7306	96.38	1.90	1.15	0.57	<LOD	<LOD
MIA,7306	95.38	2.48	1.56	0.54	0.04	<LOD
MIA,7306	96.14	1.80	1.44	0.58	<LOD	0.05

Table 1 continued

Coins:	*Ag*	*Pb*	*Cu*	*Au*	*Fe*	*Hg*
MIA,7307	95.93	1.24	1.95	0.70	0.06	0.11
MIA,7307	95.65	1.35	2.15	0.68	0.08	0.09
MIA,7307	95.72	1.37	1.99	0.69	0.17	0.06
MIA,7308	70.26	0.31	28.57	0.25	0.16	<LOD
MIA,7308	78.09	1.20	19.66	0.22	0.11	0.04
MIA,7308	49.94	0.36	48.72	0.20	0.30	0.05
MIA,7309	95.59	1.54	2.01	0.05	<LOD	0.59
MIA,7309	94.78	2.13	2.61	0.10	<LOD	0.09
MIA,7309	93.85	1.77	2.94	<LOD	<LOD	1.16
MIA,7310	94.48	0.24	4.56	0.72	<LOD	<LOD
MIA,7310	92.93	0.23	6.13	0.71	<LOD	<LOD
MIA,7310	94.55	0.30	4.45	0.71	<LOD	<LOD
MIA,7311	78.06	5.16	5.29	0.45	0.43	9.08
MIA,7311	76.68	1.98	6.63	0.49	0.16	12.31
MIA,7312	98.08	0.36	1.42	<LOD	0.08	<LOD
MIA,7312	98.39	0.33	1.23	<LOD	0.06	<LOD
MIA,7312	97.92	0.40	1.57	<LOD	0.05	<LOD
MIA,7313	95.52	0.97	2.70	0.73	0.04	0.04
MIA,7313	95.45	1.09	2.74	0.72	<LOD	<LOD
MIA,7313	97.77	0.25	0.61	0.84	0.36	0.18
MIA,7314	97.78	0.38	0.75	0.98	<LOD	0.11
MIA,7314	98.04	0.26	0.83	0.81	<LOD	0.06
MIA,7314	97.08	0.32	0.71	1.14	<LOD	0.74
MIA,7315	81.94	2.06	0.61	0.21	<LOD	13.32
MIA,7315	84.94	1.54	0.67	0.27	0.03	11.25
MIA,7315	83.32	1.88	0.77	0.23	<LOD	12.28
MIA,7316	97.23	0.21	1.55	0.81	0.16	<LOD
MIA,7316	95.89	0.32	2.32	0.81	0.13	<LOD
MIA,7316	95.48	0.39	3.16	0.84	0.07	<LOD
MIA,7317	71.99	0.65	26.64	0.68	0.04	<LOD
MIA,7317	77.25	0.70	21.30	0.71	<LOD	0.04
MIA,7317	78.27	0.92	19.96	0.79	0.06	<LOD
MIA,7318	93.29	1.67	4.29	0.47	<LOD	<LOD
MIA,7318	93.11	1.68	4.43	0.47	0.05	<LOD
MIA,7318	94.00	1.33	3.95	0.47	0.03	<LOD
MIA,7319	95.24	0.63	0.45	0.65	0.10	2.89
MIA,7319	94.97	2.04	2.20	0.68	0.06	0.05
MIA,7319	96.60	1.46	1.08	0.72	0.05	0.09
MIA,7320	95.25	0.73	3.25	0.76	<LOD	<LOD
MIA,7320	95.21	0.79	3.27	0.73	<LOD	<LOD
MIA,7320	96.37	0.71	2.13	0.74	0.05	<LOD
MIA,7321	97.11	0.52	1.53	0.77	<LOD	0.07
MIA,7321	97.19	0.48	1.47	0.80	<LOD	0.06
MIA,7321	96.69	0.60	1.86	0.81	<LOD	0.05
MIA,7322	81.14	1.16	17.00	0.56	0.03	<LOD
MIA,7322	80.64	1.35	17.24	0.57	0.09	<LOD
MIA,7322	85.87	1.56	11.84	0.57	0.07	<LOD
MIA,7323	52.69	0.99	45.12	0.51	<LOD	<LOD
MIA,7323	58.18	0.94	39.65	0.51	<LOD	<LOD
MIA,7323	57.65	0.91	40.20	0.55	<LOD	<LOD
MIA,7324	95.68	0.55	2.18	0.79	0.04	0.05
MIA,7324	95.75	0.57	2.20	0.78	0.04	<LOD
MIA,7324	94.83	0.55	3.17	0.72	0.05	<LOD
MIA,7325	98.21	0.48	0.66	0.65	<LOD	<LOD
MIA,7325	98.45	0.36	0.47	0.70	0.04	<LOD
MIA,7325	98.37	0.38	0.57	0.69	<LOD	<LOD
MIA,7326	93.53	1.23	4.59	0.65	<LOD	<LOD
MIA,7326	92.11	1.79	5.41	0.69	<LOD	<LOD
MIA,7327	94.95	1.84	2.70	0.45	<LOD	<LOD
MIA,7327	94.71	1.75	2.97	0.45	0.07	<LOD
MIA,7327	94.36	1.83	3.24	0.47	0.05	<LOD
MIA,7328	96.86	0.23	2.11	0.66	0.14	<LOD
MIA,7328	95.85	0.31	3.08	0.60	0.17	<LOD
MIA,7328	97.52	0.15	1.48	0.65	0.19	<LOD
MIA,7329	95.37	0.28	4.30	<LOD	0.05	<LOD
MIA,7329	95.42	0.49	4.05	<LOD	0.04	<LOD
MIA,7329	95.21	0.45	4.29	<LOD	0.04	<LOD
MIA,7330	95.44	0.34	3.45	0.74	0.04	<LOD
MIA,7330	94.83	0.45	3.87	0.74	0.04	<LOD
MIA,7330	95.20	0.41	3.54	0.72	0.07	<LOD
MIA,7331	95.00	1.46	2.83	0.63	0.03	<LOD
MIA,7331	94.47	1.45	3.40	0.63	<LOD	<LOD
MIA,7331	95.59	1.03	2.68	0.64	0.06	<LOD
MIA,7332	94.77	1.60	2.92	0.65	0.06	<LOD
MIA,7332	94.85	1.77	2.66	0.65	0.07	<LOD
MIA,7332	95.45	1.34	2.47	0.68	0.05	<LOD
MIA,7333	96.46	0.87	2.06	0.53	0.04	<LOD
MIA,7333	95.59	0.89	2.73	0.58	0.14	<LOD
MIA,7333	96.48	0.72	2.19	0.56	0.04	<LOD
MIA,7334	97.05	1.32	1.01	0.55	0.03	<LOD
MIA,7334	96.76	1.35	1.06	0.51	0.27	<LOD
MIA,7334	96.58	1.53	1.29	0.52	<LOD	<LOD

Table 1 continued

Coins:	*Ag*	*Pb*	*Cu*	*Au*	*Fe*	*Hg*
MIA,7335	94.10	2.27	2.93	0.70	<LOD	<LOD
MIA,7335	93.05	2.70	3.48	0.68	0.09	<LOD
MIA,7335	94.02	2.36	2.88	0.68	0.06	<LOD
MIA,7336	94.39	0.33	4.36	0.90	0.03	<LOD
MIA,7336	95.07	0.36	3.60	0.88	0.05	0.04
MIA,7336	94.31	0.44	4.46	0.79	<LOD	<LOD
MIA,7337	93.34	0.85	4.99	0.82	<LOD	<LOD
MIA,7337	92.98	0.91	5.30	0.81	<LOD	<LOD
MIA,7337	91.52	1.02	6.60	0.86	<LOD	<LOD
MIA,7338	96.49	1.50	1.27	0.69	0.06	<LOD
MIA,7338	96.46	1.64	1.16	0.70	0.03	<LOD
MIA,7338	96.15	1.48	1.49	0.70	0.15	0.04
MIA,7339	92.44	1.29	4.92	0.72	0.03	0.05
MIA,7339	92.03	1.32	5.38	0.72	<LOD	0.06
MIA,7339	93.06	1.14	5.05	0.69	<LOD	<LOD
MIA,7340	96.40	1.19	1.71	0.66	0.04	<LOD
MIA,7340	96.41	1.16	1.73	0.62	0.08	<LOD
MIA,7340	97.10	0.90	1.31	0.65	0.04	<LOD
MIA,7341	34.68	0.77	63.49	0.15	0.03	0.06
MIA,7341	33.58	0.62	64.50	0.15	0.02	0.28
MIA,7342	97.45	0.35	1.32	0.81	0.07	<LOD
MIA,7342	97.21	0.38	1.27	0.85	0.29	<LOD
MIA,7342	96.98	0.49	1.66	0.81	0.06	<LOD
MIA,7343	97.21	0.34	2.07	0.16	0.03	0.05
MIA,7343	96.98	0.39	2.28	0.16	<LOD	0.06
MIA,7343	97.40	0.39	1.89	0.13	<LOD	<LOD
MIA,7344	93.18	1.23	4.84	0.66	0.04	<LOD
MIA,7344	93.73	1.11	4.35	0.66	0.05	<LOD
MIA,7344	93.86	0.91	4.48	0.66	0.03	<LOD
MIA, 215- edge	84.47	0.23	14.38	0.66	0.18	0.05
MIA, 215- centre	79.73	0.20	18.93	0.61	0.33	0.06
MIA, 215- edge- reverse	78.64	0.39	19.91	0.61	0.38	<LOD
MIA, 216-edge	90.75	0.99	6.49	1.23	<LOD	<LOD
MIA, 216-centre	88.97	1.01	8.03	1.23	<LOD	<LOD
MIA, 216- edge- reverse	89.37	1.31	7.34	1.22	<LOD	<LOD
MIA, 223- centre-1	90.25	1.13	7.65	0.82	<LOD	0.15
MIA, 223- centre-2	91.14	1.48	6.36	0.87	<LOD	0.16
MIA, 223-edge	90.48	1.37	7.02	0.87	0.04	0.22
MIA, 225-obv-edge	84.33	1.52	12.04	0.61	0.42	1.09
MIA, 225-obv-centre	83.62	1.72	12.81	0.65	0.17	1.04
MIA, 225-edge-reverse	83.22	2.18	13.06	0.63	0.14	0.77
MIA, 226-obv-edge	94.79	1.17	2.79	1.09	<LOD	0.13
MIA, 226-obv-centre	95.13	1.11	2.49	1.08	<LOD	0.15
MIA, 226-reverse-edge	94.00	1.34	3.42	1.03	0.06	0.15
MIA, 227-obv-edge	71.88	0.93	1.69	0.64	<LOD	23.52
MIA, 227-obv-centre	77.06	0.87	2.26	0.74	<LOD	17.55
MIA, 227-reverse-edge	76.68	1.23	2.72	0.77	<LOD	17.31
MIA, 228-obv-edge	78.42	2.95	3.97	0.57	0.06	12.45
MIA, 228-obv-centre	74.78	3.22	3.52	0.55	<LOD	16.30
MIA, 228-rev-edge	72.35	2.40	3.21	0.50	0.03	19.54
MIA, 230-obv-egde	56.48	24.72	0.90	<LOD	0.27	16.00
MIA, 230-obv-centre	76.77	3.88	1.59	<LOD	0.21	16.16
MIA, 230-rev-edge	69.41	16.96	1.57	<LOD	0.23	10.48
MIA, 231-obv-edge	80.53	0.74	2.83	0.62	<LOD	13.79
MIA, 231-obv-centre	80.58	0.73	3.69	0.59	<LOD	13.10
MIA, 231-rev-centre	80.34	0.65	2.58	0.59	<LOD	14.20
MIA, 259-obv-edge	72.84	2.17	2.84	0.54	<LOD	19.71
MIA, 259-obv-centre	75.34	3.37	3.76	0.62	0.03	15.03
MIA, 259-rev-edge	76.22	2.89	4.75	0.56	0.03	13.83
MIA, 260-obv-edge	97.00	0.62	1.46	0.86	<LOD	0.06
MIA, 260-obv-centre	95.92	1.03	2.08	0.85	<LOD	0.07
MIA, 260-rev-edge	94.50	1.33	3.15	0.81	0.03	0.12
MIA, 261-obv-edge	94.99	1.46	2.64	0.73	<LOD	0.10
MIA, 261-obv-centre	94.86	1.51	2.75	0.71	<LOD	0.08
MIA, 261-rev-edge	94.54	1.49	3.06	0.74	<LOD	0.08
MIA, 262- obv-edge	63.12	21.17	0.92	0.25	0.09	10.88
MIA, 262- obv-centre	82.78	2.54	1.55	0.58	<LOD	10.85
MIA, 263-obv-edge	70.92	1.30	2.18	0.46	0.05	23.35
MIA, 263-obv-centre	69.42	1.28	2.20	0.46	0.04	24.89
MIA, 263-rev-edge	71.93	1.34	2.26	0.48	0.04	22.17
MIA, 272-obv-edge	76.25	1.71	8.58	0.51	0.04	11.70
MIA, 272-obv-centre	78.18	1.96	6.38	0.50	0.10	11.85
MIA, 272-rev-edge	76.34	1.98	6.79	0.49	0.08	13.18
MIA, 272-obv-edge-coating?	68.25	14.49	5.35	0.31	0.50	9.25
MIA, 274-obv-edge	60.68	22.69	1.63	0.42	0.07	11.42
MIA, 274-obv-centre	44.93	40.87	1.09	<LOD	0.09	8.86
MIA, 274-rev-edge	51.51	33.21	1.23	0.18	0.10	9.55