



## Probable Sources and Refining Technology of Parthian and Sasanian Silver Coins

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### ABSTRACT

Parthians and Sasanians refined silver to mint coins, and to make luxury utensils and decorations popular within royal and wealthy families. Most silver used in Persia was extracted from galena and cerussite mines. These ores were refined for silver during which other metals such as lead were extracted. Some of these matrix elements remained in the refined silver. In this article we compare the concentrations of lead in select coins in order to better understand the technology of extraction and to identify the sources of the silver used during both dynasties.

### 1. Introduction

The chemical composition of ancient coins is useful for understanding the political and economic conditions of the period of study. The chemical elements present in coins may identify the sources of the metal, and the level of technology used to extract metal for minting.

#### 1.1 Sources of silver

Silver was used by officials, jewelers and in coins. This metal played a major role as a monetary instrument in classical Iran. Due to the lack of silver mines in Iran, silver was a byproduct of lead and zinc ores extracted from cerussite mines in the Parthian and Sasanian periods.

The first commercially available silver artifacts can be seen in Tape Sialk and other archeological sites in Iran (Nezafati *et al.* 2008, 337–338). In a broad geological survey Momenzadeh (2006) located more than 34 lead-zinc mines from prehistory to the Islamic period. Momenzadeh made note of several additional historic mines that were destroyed and have not been located. Other mineralogical work conducted in Anatolia by Jesus (1978, 97–102) criticized Yakar (1976, 118–28) whose research was limited to surface finding with

little on the sources of silver in Beraz and Balya, and did not include any metallurgical study. In a later surface survey Yener reported on several silver mines from the Neolithic to the Ottoman period (1986, 169–472) in Anatolia. In other exemplary research Yener (1983, 1–15) examined prehistoric exchange models and conducted chemical and lead isotope analysis (these are more reliable than other isotopes due to their proximity in time to the sites in Iran). These scholars focused on identifying sources of ores and were not seeking to identify relationships to silver production nor to connect artifacts to source mines.

It is thought that lead concentrations in silver coins reflect the quality of refining technology: the less lead, the better process of extracting silver from lead and zinc ores. It is possible that silver in all the ancient mines was extracted by reducing the amount of lead in the silver by cupellation. The average concentration of the remaining lead was between 0.5 to 1%. In the Parthian and Sasanian periods lead mines produced silver largely from oxidizing ores such as cerussite and argentiferous galena (PbS) (Meyer 2003, 271–288). Specific ores or specific geological deposits also have different ratios of traces of rare earth elements, that correspond to the ratios found in refined silver.

In our study of possible sources of silver in Iran we investigated the occurrence of gold present (Meyer 1972,

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Figure 1. Parthian mint houses.

183–193) in silver ores and silver coins during the thousand year period of the Parthian and Sasanian dynasties.

## 1.2 Analytical technique

Many non-destructive spectroscopic methods are used on silver objects including PIXE (Smith 2005) and XRF. Both XRF and PIXE were deemed suitable for use in this research, and in both lead was selected as the traces element. These instruments have advantages and disadvantages that have been thoroughly discussed in the literature.

Several scholars including Hall (Hall *et al.* 1963, 53–78) have demonstrated the application of XRF with ceramics. Condamin (Condamin, Picon 1964, 98–105) used it to study corrosion on silver coins which would otherwise have altered spectroscopy findings. XRF can help us study the provenance of an object (Banks, Hall 1963, 31–36), its paint (Cesareo *et al.* 1972, 65–78) and enamel. Of course, newer instruments like the Neutron Activation Analysis (NAA) have been applied to similar ends, but XRF and PIXE are the most commonly used non-destructive approaches. XRF and PIXE can help determination, chemical composition, methods of manufacture and the provenance of archaeological metals (Guerra 1998, 78).

After working on more than two hundred coins with NAA, Gordus identified the relationship between fineness of Sasanian silver issues and numismatic classifications (Gordus 1995, 613–619). Several studies have been done on Sasanian silver coins and their contemporary issues (Hajivaliei *et al.* 1999, 645–650; Vijayan *et al.* 2004, 353–356; Rautray *et al.* 2011, 1385–1389), but these have only reported on the chemical composition of the coins and not their sources or refining technology.

## 1.3 Historical Background

After the invasion of Persia by Alexander the Great (356–323 BC) the Seleucid dynasty ruled for nearly three centuries. The

Parthians forced the Seleucids out of Persia and later from Iran. The fabled leader Arasces (247–211 BC) developed his power base in Parthia, from which the Parthians expanded during the reign of Mithridates I (171–138 BC), extending their power to the east and recapturing several Seleucid satrapies under the power of the Seleucid king. After Mithridates I Parthian expansion abated for a time.

After the long war with the Seleucids the Parthians came into contact with the Roman Empire and a long struggle ensued over the occupation of Mesopotamia and Armenia. Parthian rule was effectively ended by another Iranian dynasty under Ardashir I (224–241 AD), and known as the Sasanian kingdom. Ardashir I occupied Parthia, ending the rule of Artabanus V, and re-organized the occupied kingdom. Shapur I (241–272 AD) went on to establish a political settlement that continued until the long war with Roman weakened both dynasties. Sasanian rule was ended by a Muslim army and small kingdoms established throughout Iran.

## 1.4 Parthian and Sasanian coins

Parthians (247 BC–224 AD) issued bimetallic silver and copper coins (Figure 1). It seems that gold coins were not regularly issued. In the cities authorized administrators issued bronze coins every year, but silver coins remained the main currency for commercial purposes. Parthians minted drachms for use in their homeland. The weight of their coins equaled Greek attic standard 4 gram (Sellwood 1979) while in Mesopotamia they issued tetradrachms (16 grammes). They kept this standard until the end of their kingdom. On each coin the Kings head is on the obverse and an archer seated on a throne is on the reverse. All Parthian coins carried Greek legends on their reverse, and after Mithridates I, the Seleucid date in years and months appeared on the reverse along with the minting house mark.

Silver issues were the backbone of the monetary system, economy and history of the Sasanians (224–651 AD,

Figure 2. Sassanian mint houses.

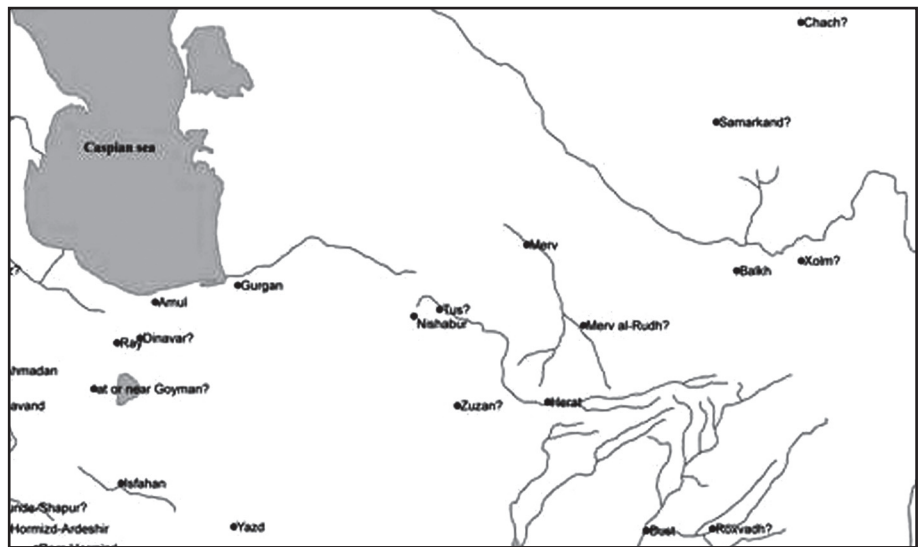


Figure 2). On each, the King’s portrait was on the obverse (Goble 1971), and a Zoroastrian fire altar on their reverse. From Shapur II (241–272 AD) onwards two standing figures are seen on the reverse. There are a variety of gold and copper issues. The writing on all Sasanian coins was in Pahlavi script, with the year of coronation was indicated on them. Their bimetallic issues were gold and silver. Gold only issues were mainly ceremonial. Silver coin weights were not compatible with Attic and Roman standards, though double dinars may have been based on the Roman standard.

## 2. Material and Methods

### 2.1 Preparation of samples

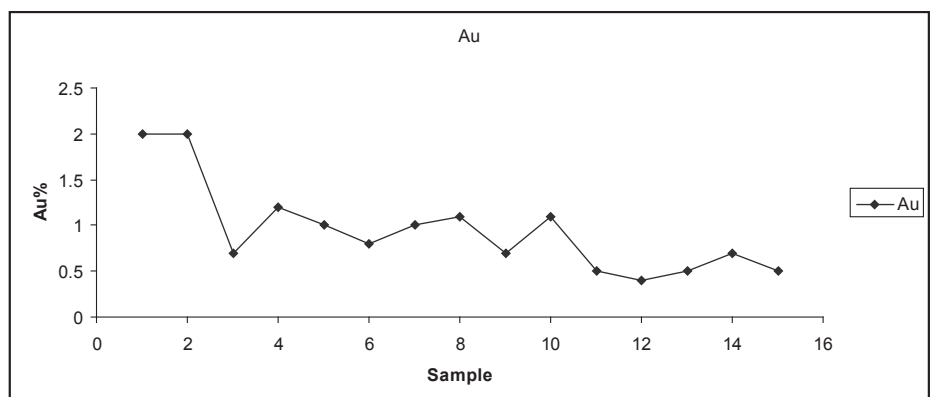
Selected Parthian and Sasanian silver coins from the excavation layer were selected after cleaning from conservation division of the national museum. Coins were cleaned with 5% formic acid. They were cleaned again with alcohol in the XRF and PIXE lab to remove NaCl, following which they were submitted for spectroscopy.

### 2.2 Experimental setup

A 2 MeV proton beam with a current of 2–3 nA from an AEOL Van de Graff accelerator was used. Coins were kept in a multipurpose scatter chamber under high vacuum ( $10^{-5}$  Torr). X-ray emissions from the samples were detected by an ORTEC Si (Li) detector (FWHM 170 eV at 5.9 keV). GUPIX software was used to analyze the captured spectra. Results are shown in Table 1 and include major elements (10% of metallic composition), minor elements 0.1–10% and trace elements (less than 0.1%). The overall uncertainty for the PIXE method was 5% for major elements, 5–10% for minor elements and 15% for trace elements. Uncertainty was not only statistical, but also originated from the roughness of coin surface, chemical corrosion and/or wearing of the objects, which altered the accuracy of the results.

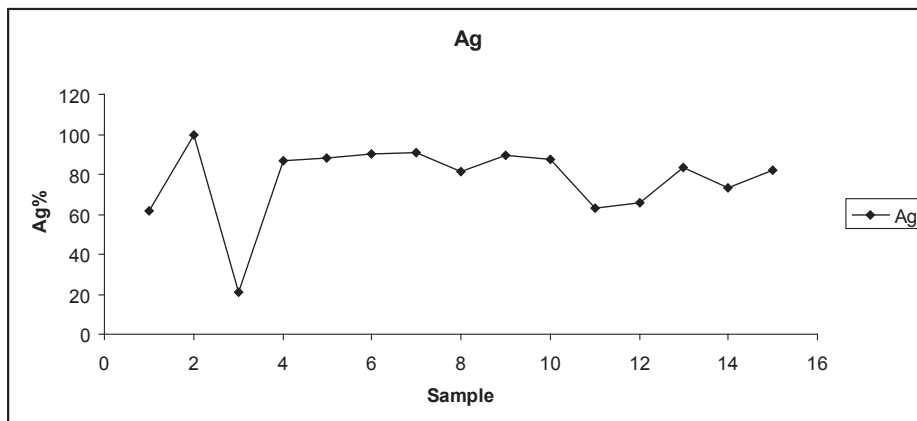
In another method for determining silver chemical composition, X-ray microanalysis using wavelength dispersive spectrometry (WDS) provides usable results, and allows for small sample sizes ( $<1 \text{ mm}^3$ ). It is a relatively fast technique, and does not require the sample to be destroyed (Verita *et al.* 1994). However, since WDXRF results can be improved by

Figure 3. Percentage of Gold in Parthian silver coins, using PIXE.

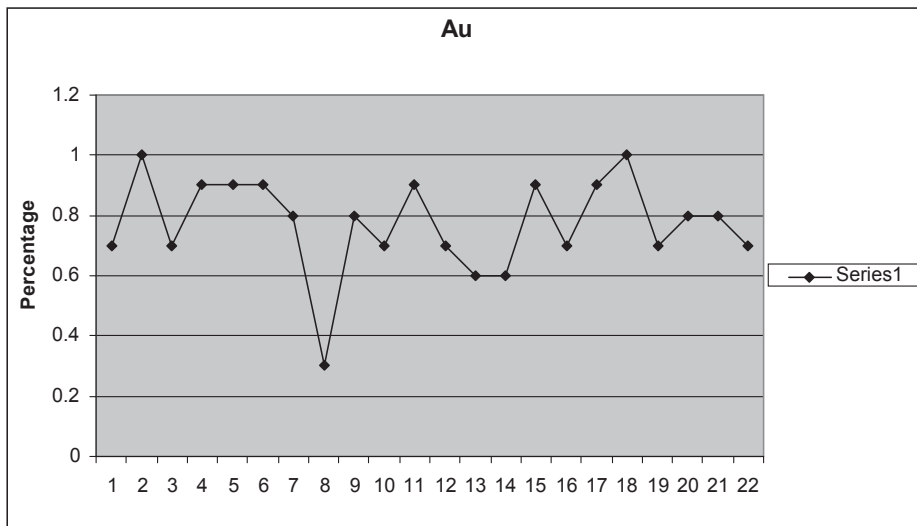


**Table 1.** Percentage of chemical elements in Parthian using PIXE. Remarks: coins number 3 seems to be billon (coins containing 50 percent silver) or copper and was removed from table.

Sample	N. Muse	Cl	Ca	Fe	Cu	Zn	Ag	Ti	S	Name King	Weight
1	147	1.9	3.7	1.3	23.9	2.9	61.6	0	0	Orodes II	4.01
2	144	0.7	0	0.1	5	0.1	100	0	0	Orodes II	3.35
3	144	0	1.3	0.3	75.4	0	21.3	0	0	Orodes II	3.55
4	1289	0	0.9	0	10.1	0	86.8	0	0	Orodes II	3.93
5	1289	0	0	0	10	0	88	0	0	Orodes II	3.99
6	1289	0	0	0	8.2	0	90.2	0	0	Orodes II	4.09
7	1289	0	0	0	6.8	0	90.9	0	0	Orodes II	4.00
8	1289	0	0	0	16.5	0	81.3	0	0	Orodes II	3.91
9	1289	0	0	0	9.1	0	89.5	0	0	Orodes II	4.03
10	1289	0	0	0	9.6	0	87.7	0	0	Orodes II	4.5
11	K:5	3.9	2.5	0.7	16.3	0.1	63.1	0	1.4	Phraates IV	3.61
12	K:5	1.3	1.1	0.5	21.1	0	66.1	0	0.5	Phraates IV	3.92
13	K:5	3.6	1.3	0.1	9.1	0	83.1	0	0.5	Phraates IV	3.94
14	K:10	4.3	2.7	0.3	4.9	0	73	0	7.9	Phraates IV	3.62
15	K:3	2.9	1.3	0.1	12	0	81.7	0	0	Phraates IV	3.69
<b>SUM</b>		<b>18.6</b>	<b>14.8</b>	<b>3.4</b>	<b>238</b>	<b>3.1</b>	<b>1164</b>	<b>14.2</b>	<b>14.2</b>	<b>0</b>	<b>10</b>
<b>Aversilver</b>		<b>1.24</b>	<b>0.987</b>	<b>0.227</b>	<b>15.867</b>	<b>0.207</b>	<b>77.62</b>	<b>0.95</b>	<b>0.95</b>	<b>0</b>	<b>0.7</b>
<b>STDEV</b>		<b>1.643</b>	<b>1.187</b>	<b>0.365</b>	<b>17.381</b>	<b>0.746</b>	<b>19.13</b>	<b>0.5</b>	<b>0.58</b>	<b>0</b>	<b>2</b>
<b>SE</b>		<b>0.424</b>	<b>0.306</b>	<b>0.094</b>	<b>4.4878</b>	<b>0.193</b>	<b>4.94</b>	<b>0.13</b>	<b>0.15</b>	<b>0</b>	<b>0.5</b>



**Figure 4.** Percentage of silver present in Parthian silver coins.

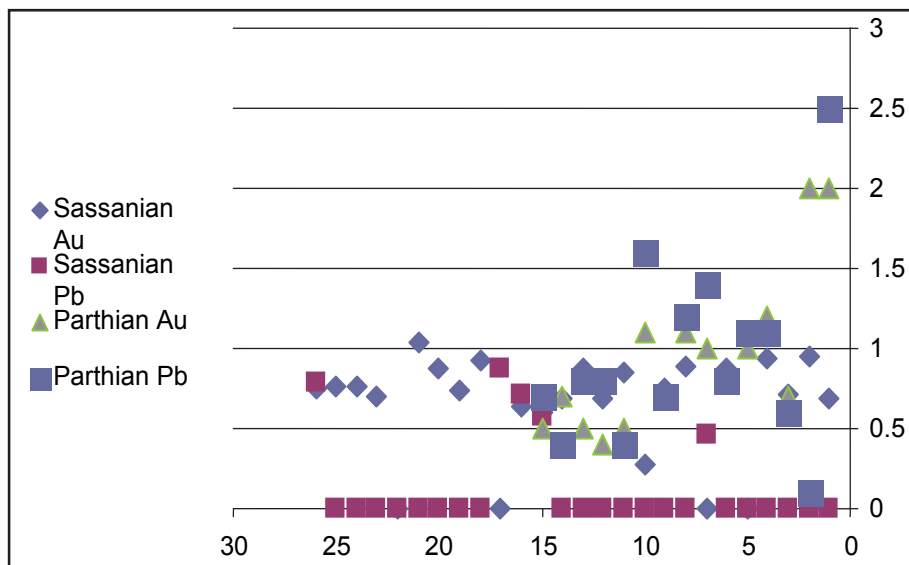


**Figure 5.** Percentage of Gold in Sasanian silver coins using XRF.

**Table 2.** XRF results for Sassanian silver coins, in percent

Diameter	weight	Unit weight	Mint house	Regal year	King name	Coin No.
2.8	4.14	Drachma	Istakhr	–	Piruz	1
2.8	3.77	Drachma	Ardeshirkhoreh	–	Piruz	2
2.9	4.11	Drachma	Ardeshirkhoreh	–	Belash	3
2.7	3.96	Drachma	Istakhr	–	Kavad	4
2.7	3.56	Drachma	Istakhr	25	Kavad	5
2.8	3.57	Drachma	Ardeshirkhoreh	30	Kavad	6
2.9	3.36	سولف	Darabgird	30	Kavad	7
2.8	4.00	Drachma	Istakhr	30	Kavad	8
2.6	4.14	Drachma	Darabgird	34	Kavad	9
2.9	3.99	Drachma	Darabgird	37	Kavad	10
3.2	3.99	Drachma	Ardeshirkhoreh	40	Kavad	11
3.1	4.03	Drachma	Ramhormuz	30	Xusro I	12
2.9	3.40	Drachma	Istakhr	41	Xusro I	13
3.0	3.54	Drachma	Bishapur	43	Xusro I	14
3.15	4.08	Drachma	Bishapur	9	Hormuz IV	15
3.1	4.11	Drachma	Istakhr	15	Xusro II	16
3.2	3.93	Drachma	Istakhr	23	Xusro II	17
3.2	3.98	Drachma	Ecbatana	25	Xusro II	18
3.2	4.14	Drachma	Ardeshirkhoreh	35	Xusro II	19
3.4	4.11	Drachma	Sistan	36	Xusro II	20
3.1	3.98	Drachma	Sistan	38	Xusro II	21
3.1	4.15	Drachma	Ecbatana	2	Kavad II	22
3.2	4.11	Drachma	Iran	2	Kavad II	23
3.1	4.17	Drachma	Istakhr	2	Ardeshir III	24
3.2	4.10	Drachma	Bishapur	2	Ardeshir III	25
3.2	4.01	Drachma	Sistan	19	Yazdgird III	26

Cu	Ca	Fe	Au	Pb	Ag	Coin No.
2.583	0.484	0	0.69	0	93.833	1
1.289	0.681	2.13	0.952	0	81.371	2
1.326	0.947	7.188	0.714	0	82.531	3
1.045	1.378	0.3	0.941	0	93.787	4
6.455	1.904	3.524	0	0	72.083	5
3.375	0.899	0.286	0.874	0	90.527	6
85.504	9.724	0.182	0	0.457	0	7
2.448	1.47	0	0.883	0	92.084	8
1.28	5.244	0.278	0.756	0	83.176	9
4.337	1.778	0.921	0.275	0	78.865	10
3.088	12.829	0.425	0.845	0	77.633	11
3.174	6.187	0.591	0.689	0	80.923	12
2.652	0	0	0.872	0	95.79	13
9.578	4.321	0	0.686	0	77.688	14
0.579	11.111	1.136	0.595	0.57	73.093	15
5.324	2.732	0	0.643	0.709	77.493	16
1.347	0.77	0.223	0	0.88	89.285	17
0.821	1.721	0	0.924	0	83.113	18
1.98	0	1.112	0.737	0	83.948	19
1.793	2.371	0	0.879	0	86.283	20
3.135	2.087	0	1.033	0	89.071	21
3.992	0	0	0	0	92.892	22
2.134	0	0	0.697	0	95.319	23
1.305	2.438	0.249	0.758	0	90.343	24
1.855	0.995	0	0.761	0	87.682	25
5.801	0.527	0.326	0.748	0.782	83.154	26



**Figure 6.** Results in percents, XRF could not detect the Pb concentration of some coins.

processing powdered samples, several Parthian and Sasanian coins were pulverized for spectroscopy using a Philips PW2404 XRF instrument calibrated to CPM standards for the most accurate results, and limitation of detection was 0.01%.

### 3. Results and Discussion

Spectroscopy of Parthian and Sasanian coins (Table 1 and 2) shows that the silver was of a higher quality than contemporary neighbouring civilizations. After analyzing Roman and Sasanian silver plates by Hughes (Hughes, Hall 1979, 365–73) also concluded that there is less lead in Sasanian silver plates compared to Roman coins. This is thought to indicate a greater effort on the part of Sasanian metal workers as silver was the primary exchange metal, while the Romans preferred gold. In any case silver had a critical economic role in the Sasanian period.

Lead content is a determinant of technology and quality (Figure 6) in the Parthian and Sasanian period. This chart shows the extraction of silver in Sasanian period were very better in compare with Sasanian period. Figure 4 shows variation of silver in the Parthian period as it is not observable in the Sasanian silver coins. Gold helps identify the sources of mines of silver in different silver sources from different lead-zinc mines during the Parthian period. Coins no. 1 and 2 on Figure 3 and coin number 8 on Figure 5 belonging to the Sasanian period has similar features as those of the Parthian period, that is, new sources for silver metals was used for extraction.

### 4. Conclusion

It seems that Sasanian concentrated their efforts on refining silver, possible driven by the importance of silver to the royal

household and needs. The higher purity of Sasanian silver coins, compared to Roman coins, indicates that Sasanian were better than Romans in refining silver. It also indicates that Sasanian metal workers were more skilled compared to their Roman contemporaries. The concentration of Au/Ag in the silver coins used to identify the sources of silver, are almost same in both the Parthian and Sasanian periods, and it is possible that several same mines were in use.

The concentration of gold in silver coins during the Parthian period shows that the sources of silver coins 1 and 2 were different. The silver coin no. 8 of Sasanian period is similar to coins 1 and 2 denoting that its source is different.

It may be inferred that during political and economic crises Parthian reduced the percentage of silver in their silver Drachma coins, but Sasanian kept silver in their silver coins during hard times and in order to cope with political and economic crises they increased taxes instead of decreasing percentage of silver in their issues.

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