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INVESTIGATION OF SILVER FORGERIES OF ANCIENT COINS: CASE STUDY OF SILVER COINS OF PARTHIA (ORODES II AND PHRAATES VI)

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Abstract

The investigation into the elemental composition and microstructural characteristics of ancient coins gives valuable information to researchers which greatly aid in the detection of counterfeits. This research aim is analysis encompasses an examination of major and trace elements present in the coins of Parthia, to identify forgery techniques utilizing the PIXE technique. The results show the elements Cl, Ca, Fe, Cu, Ag, Au, Pb, Sn, and Zn were identified and according to the ratio Ag/ Cu, can be said that the Parthia period occasionally used forged silver-plated coins. The elemental composition of silver coins of Orodes II and Phraates IV observes these coins are made with plating silver and affixed to the core utilizing a silver-copper eutectic layer, while the core itself consists of copper, and quantities of tin (Sn) were detected which may have been intentionally added for metallurgical, political, or historical reasons.

Keywords: *Parthia, Coins, Silver, forgery, PIXE*

Introduction

Since most museums and even collectors of works of art are facing the problem of counterfeits and forgeries work, therefore, examining forgery works is important for a correct understanding of past events and art history. Forgery involves copying or creating a copy of coins and circulating them alongside real money or official coinage that has a long history and dates to 2500 years ago. Therefore, the forgery of coins was common in the ancient world, as evidenced by the number of forgeries investigated using silver-based metals. Almost counterfeit exists for virtually all precious metal coins minted since ancient times [1]. Jones believes that the primary objective of the ancient counterfeiter was to achieve economic gain by utilizing the minimum amount of precious metal in the production of coins, while still maintaining a sufficiently authentic appearance to successfully pass them off as genuine [2]. The prevalent approach to accomplish this task involved employing one of the diverse techniques to envelop a core/flan made of base-metal such as copper, bronze, or lead, with the precious metal, specifically silver, being commonly utilized for this purpose. We must pay attention to these coins until are introduced as forgery coins, they are the original. The best way to identify these works is to use laboratory methods. The identification of forgery coins has always been of interest to numismatists, chemists, and metallurgists over the years. For the first time in Iran, an American Chemist Clay examined 300 coins of Orodes II. The aim was to identify the economic situation of the Parthian kings through the element copper found in silver coins. The results show that due to the Iran-Rome wars and economic conditions at this time, bronze coins of past kings were melting to increase the volume of silver metal [3]. Thompson and Chattergee examined a plated didrachm of Neapolis dated to approximately 300 BC. The result shows copper-silver eutectic alloy present

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between the two overlapping silver foils, it was a clear–cut example of the use of solder [4]. Campbell examined Thirty- seven coins dating from the fifth century BC to the first Century AD, and the result showed that the coins are of plating type [5]. Also, Baloge examined Arab Sasanian dirhams, dated to 665AD, He put them in the group of plating coins [6]. The geographical spread of coins plated with silver foil seems to indicate that it was a well-established technique, at least in the Mediterranean area, perhaps as early as the fifth century BC and certainly the Roman [7] Yussri and Essam studied copper and bronze coins preserved in a private collection in Egypt using optical and scanning electron microscopy. The results revealed that chemical composition and micro structural features related to ancient manufacturing processes and internal damage can contribute to detecting forgery [8]. Perucchetti and Dowler analyzed six coins from Ithaca in the British Museum collection using a bench Bruker Artax X-ray fluorescence spectrometer on a polished surface. The result shows coins are chemically different, and one is suspected of being a modern forgery [9]. Joel studied Population identification strategies for counterfeit coin detection by using 3-D imaging. This study using modern manufacturing methods allows the alloy, construction, and striking image of coins to be more readily reproduced [10]. Petean et al analyzed several forged 3-Polker coins found in Transylvania by SEM microscopy coupled with EDS elemental spectroscopy for complex microstructural characterization and XRD for phase identification. They have identified Three distinct types of forgery methods that including the amalgam method is the first used for copper blank silvering, the second method is immersion in melted silver and the third method is the tin plating of copper coins [11]. Li et al studied the Tang Dynasty alloy coins to identify counterfeiting activities by morphological and metallographic images and lead isotope. The result shows that most of the coins were minted using a Cu-Pb syngenetic ore rich in many elements from Fe, As, Sb, and Sn and utilizing a by-product of local ore smelting which was called the speiss which explains repeated failures of central government's attempts to eliminate coin counterfeiting, especially for those mining areas [12]. The purpose of this article is to examine the chemical composition of certain Parthia coins in the National Museum of Iran to identify forgery techniques utilizing the PIXE technique.

Material and Methods

Elemental composition analysis is a fundamental tool in the study of ancient coins. To know about counterfeit coins, it is best to use cross-sectional analysis to reveal the metal core because some coins are coated with a layer of corrosion product or metal oxide [13-14], but due to the limitations of this research, we have used the non-destructive PIXE method. Utilizing the proton-induced X-ray emission (PIXE) technique for the analysis of ancient coins is widely regarded as a prominent non-destructive approach to ascertaining the chemical composition of historical metals [15]. This technique has shed light on multiple facets of the study period. The insights gained from this information can be effectively utilized to deduce or identify counterfeit coins. Among the diverse range of spectroscopic techniques available, PIXE stands out as an invaluable and non-destructive method that equips archaeologists with exceptionally valuable information [16-17]. PIXE has also been utilized in a non-destructive manner to accurately identify and quantify trace elements [18]. It is worth noting that PIXE exhibits sensitivity for elements within the range of Argon (Ar) to Zirconium (Zr). Furthermore, by manipulating the energy of the proton beam, PIXE allows for the comprehensive characterization of layered structures situated at or near the surface [19]. A proton beam with an energy of 2 MeV and a current of 2-3 nA, generated by the Van de Graff accelerator operated by the Atomic Energy Organization of Iran (AEOI), was utilized to irradiate the coins. These coins were carefully placed within a versatile scattering chamber, which maintained a high vacuum level of 10-5 Torr. The emitted characteristic X-rays from the coin samples were subsequently detected using an ORTEC Si (Li) detector, which exhibited a full width at half maximum (FWHM) resolution of 170 eV at 5.9 keV. To analyze the acquired spectra, the GUPIX software, known for its reliability and accuracy, was employed. The resulting data and findings are presented in Table 1. In this context, major elements are defined as those contributing 10% to the overall composition, while minor elements encompass the range of 0.1-10%. Trace elements, on the other hand, constitute less than 0.1% of the composition, reaching down to the detection limits. It is important to note that the overall uncertainty associated with the PIXE method used in this study was estimated to be 5% for major elements, 5-10% for minor elements, and 15% for trace elements. These uncertainties are not solely of a statistical nature; they also arise from factors such as the surface roughness of the coins, chemical corrosion, and wear on the objects. These factors can potentially impact the accuracy of the obtained results, as discussed in references [20-21].

Selection of Samples

The Parthia silver coins that have been studied are currently housed in the National Museum of Iran. These particular coins were crafted and issued under the reigns of Orodes II and Phraates IV and were exclusively minted in the city of Ecbatana. All coins underwent a meticulous cleaning process utilizing a solution of formic acid ranging from 3% to 5% concentration. This solution was applied for a brief duration, followed by gentle scrubbing using a toothbrush. To ensure thorough cleanliness, the coins were then meticulously cleaned using cotton soaked in alcohol.

Results and Discussion

The recreation and fraud of the old coins were done for numerous reasons and the counterfeiters utilized different procedures to mint coins [8]. Also in the past, governments have issued forgery coins due to political and financial conditions, and techniques employed by counterfeiters throughout history demonstrate their significant ingenuity [22]. Studies show in the ancient period there were some types of techniques of forgery coin utilized by some governments. The first technique involves substituting cheaper metals, such as copper, for a portion of the silver content, or even using an entirely different white metal or alloy, such as tin, lead, bismuth, or arsenic. To enhance the silvery appearance of the debased coin, a method known as depletion silvering is employed, which involves pickling the coin in a corrosive liquid to remove the copper from its surface [23]. These coins are approximately 10-15% below the specified weight standard due to variations in the specific gravity of the base metals compared to silver [5-7]. This method is known as plating silver which is very economical [24-25]. Over time, methods of forgery have improved. They employed three methods, which included: 1: applying a silver sheet onto the copper core, in this method silver foil is approximately one-tenth a millimeter thick, and through heat, it causes silver to cover the surface of the core. The heat required for this method is 780°C. [5-7], 2) applying a eutectic alloy/solder that was a mixture of copper and silver. This method would create a thicker silver-colored layer around the core, which to recognize should be used from a deep cut to expose the core [26], and 3) the silver shavings were sprinkled over the core of copper and then they heated it to create a thicker silver casing around the core [5-7]. Counterfeit coins made in this method did not last long and they were destroyed due to the circulation of their shells. These techniques involve of an alloy band, frequently adorned with silver-rich dendrites, placed between the silver plating and the copper core. The first step includes delicately soldering silver foil onto the copper or copper alloy flan, using a strong solder made of silver and copper [4-5-7]. The other method is referred to as self-soldering, also known as Sheffield Plating, which was prevalent in the production of counterfeit goods in the 18th and 19th centuries. In this process, the foil is wrapped around the core and subjected to heat, but no filler metal or solder is employed between the plating and the core. Instead, the bonding relies on the intimate contact of the two metals at a temperature that permits limited melting of the copper and silver. In practical terms, this necessitates a temperature exceeding 780C but below the silver's melting point of 960 C [5-27-28-29-30]. The distinction between the techniques is the silver substance. in the plating technique, the surface of the plated coin will possess a substantial silver content. Conversely, in the eutectic technique, the silver content will be comparatively lower, typically aligning with the eutectic composition consisting of 70% silver and 30% copper. These two distinct methods of silver plating are executed through separate techniques. The attachment of silver foil to a copper or iron core is achieved by employing an appropriate flux and a hard solder with a melting point lower than that of silver. However, in the case of copper cores, the silver foil can also be affixed using a process commonly referred to as Sheffield plating. This method involves covering the clean copper with silver foil and subsequently subjecting it to a temperature significantly below the melting point of either metal [31]. Under the influence of thermal energy, a phenomenon occurs wherein silver and copper undergo inter-diffusion, resulting in the formation of an alloy with a notably low melting point at the interface between these two metals. Once the temperature surpasses the melting point of this alloy, it effectively transforms into a solder-like layer, connecting the silver foil and the copper core. The key to the success of this silver application method lies in ceasing the heating process after the eutectic has formed before the entirety of the silver foil dissolves into the molten alloy. At a temperature of 800°C, it has been observed that the concentration of copper in the liquefied state reaches approximately 40%. Consequently, no further copper will separate from the core and emerge onto the fluid surface at this specific temperature. These experiments demonstrate that the successful self-soldering of counterfeit coins necessitates heating up to 800°C, or even slightly lower temperatures, for only a very short duration [32-31]. In the following, we will examine the silver coins studied in the National Museum of Iran.

Parthia Empire was established in approximately 247 B.C. in ancient Iran and they used the method of Seleucids to mint silver coins. Since the Greeks knew the techniques of forging coins, the kings of Parthia also learned these techniques from them and used them at times [33-34]. From the historical point of view: Orodes II rose to the position of royalty in 57 B.C. One of the important events of this period was the war between the Parthians and the Rome. In this War, the Parthian by Surena with his light and heavy cavalry crushed Crassus in the fight of Carrhe in 53 B.C. It is thought that Orodes II, with this triumph, was able to settle troubles in the east. In 37 B.C. Orodes II was killed by his child Phraates IV and then Phraates rose to the position of royalty. About 30 B.C. a conflict arose between Iran and Rome resulting in the Romans being defeated and Armenia being annexed Parthian but Phraates IV misbehavior caused unrest among the people, leading to rebellion and his subsequent flight to Central Asia where he sought refuge with the Scythians. It was in 26 BC that he gained authoritative control over regions of Iran. He again went to war with the Romans and ultimately, a peace treaty was reached between Rome's empire (Augustus), and Phraates IV in 20 B.C. [35], for studying forgery coins, six drachma coins from the Parthia era were meticulously examined. These coins specifically pertain to the reigns of Orodes II (55-38 BC) and Phraates IV (38-2 BC), all of which were minted in Ecbatana. Consequently, the coins were classified into distinct groups based on the respective kings. The first group encompasses coins belonging to Orodes II. Coin 1: the obverse depicts the bust left of the ruler with a short beard wearing a diadem, the crescent and star can be seen behind the king and in front of the king's face is a star. On the reverse, the archer is sitting on the throne and holding a bow in their right hand, and behind the throne is observed an anchor. Below the bow observed Greek letters in seven lines .On the surface, this coin is observed corrosion, and we see that the amount of silver has decreased considerably in level. Also, lead oxide are observed on the surface of the coin (Fig. 1).

Coin No 2: the obverse depicts the bust left of the ruler with a short beard wearing a diadem, on the back of the king's bust, a bird and a ring can be seen and on the reverse, the archer is sitting on the throne and holding a bow in their right hand, and behind the throne observed an anchor. Below the bow observed Greek letters in seven lines. The weight of the drachma is three and a half. The obverse of this coin has no corrosion, but copper oxide can be seen on the reverse (Fig. 2).

Fig. 1. Coins No1. Orodes II (National Museum of Iran,No. 144)

Fig. 2. Coin No 2. Orodes II (National Museum of Iran, No. 147)

The style of these coins might appear to be poor but in fact, it would be acceptable as an issue from the Iranian mint which the reverse monogram implies [33]. The measured elements in the studied coins encompassed Cl, Ca, Ti, Fe, Cu, Zn, Br, Ag, Au, and Pb. Among the coins attributed to Orodes II, coin No. 1 exhibits a notable composition ratio of 75.4% copper (Cu) to 21.3% silver (Ag). Furthermore, it contains a minor quantity of lead (Pb) at approximately 0.58%, along with trace amounts of iron (Fe) as impurities (Table 1). Coin No. 2, on the other hand, displays a distinct composition ratio of 24.1% copper (Cu) to 61.3% silver (Ag). Additionally, it encompasses 2.5% lead (Pb), 2.9% tin (Sn), and 1.31% iron (Fe), with tin and iron also present as impurities (Table 1).

Table 1. Elemental composition of Parthian silver coins acquired through PIXE analysis (Orodes II)

Samples	Cl	Ca	Ti	Fe	Cu	Sn	Br	Ag	Au	Pb	Wt
1	0.48	1.28	-	0.29	75.4	-	-	21.3	0.68	0.58	3.35
2	1.83	3.67	0.18	1.31	24.1	2.9	0.26	61.3	1.96	2.5	3.69

Surveys show the first coin covered with silver metal foil/casings and around a base-metal flan, heated to fuse the metals, and struck probably from a set of hand-carved dies that imitated an official type. Also, the weight of the coin is less than the standard weight of the period and the elemental composition also shows a high amount of copper compared to silver. This coin is included in the category of forgery coin, which may be made using the plating silver method, and the second coin, according to the ratio of silver and copper, probably the Sheffield Plating was used. As mentioned above the distinction between the techniques is the amount of silver. in the plating technique, the surface of the plated coin will possess a substantial silver content than the first coin. As the surface is destroyed, the amount of silver has also decreased. Conversely, in the eutectic technique, the silver content will be comparatively lower, typically aligning with the eutectic composition consisting of 70% silver and 30% copper, that the elemental composition of the second coin it shows. Group two belongs the Phraates IV (38-2 BC)), coin 3, the obverse depicts the bust left of the ruler with a short beard wearing a diadem, and Nicke be seen behind the king (Fig 3), coins 4 and 5: the obverse is the bust of the king with a short beard and it lacks Nike (Fig 4-5), and coin 6: the obverse depicts the bust left of the ruler with a short beard wearing a diadem, and can be seen bird with a ring on its beak behind the king (Fig 6), and the reverse of coins observed the archer is sitting on the throne and holding a bow in their right hand, also observe Greek letters in seven lines. Those coins are type 41.44S and 54/7 in the Sellwood catalog [36]. The style of these coins also appears to be poor but it would be acceptable as an issue from the Iranian mint. The measured elements in the studied coins encompassed S, Cl, Ca, Ti, Mn, Fe, Cu, Sn, Br, Ag, Au, and Pb (Table 2). The coins No. 4 and 5 the ratio Ag/ Cu has decreased. They contain 29.9%, 31.5% of silver, and 51.7%, 56.8% of copper.

Table 2. An analysis of the elemental composition of Parthia silver coins by PIXE (Phraates IV)

Samples	S	Cl	Ca	Ti	Mn	Fe	Cu	Br	Ag	Sn	Au	Pb	Wt
3	0.5	2.56	1.34	-	-	0.13	45.1	-	42.5	5.3	-	2.6	3.61
4	1.53	13.2	2.74	-	0.04	0.27	51.7	-	29.9	0.68	-	-	3.62
5	0.85	3.02	3.4	0.26	-	1.49	56.6	-	31.5	-	-	2.9	3.69
6	1.31	3.73	3.1	0.5	0.09	0.14	43.6	-	40.4	5.96	0.5	0.7	3.60

Fig 3. Coins of the Phraates IV coin (National Museum of Iran, No. 14327)

Fig. 4. Coins of the Phraates IV (National Museum of Iran, No. 14284)

Fig. 5. Coin of Phraates IV (National Museum of Iran,No. 14663)

Fig. 6. Coins of Phraates IV (National Museum of Iran.No. 14337)

Number coins 4 and 5 showcase the silver interior at the high points of both the obverse and reverse, thus revealing dark areas. Probably, these coins are made by the plating method given their worn-off appearance and the relatively small amount of silver present. The weight of the coins is also less than the standard. The weight standard for this type is 4.0 gm. Coins numbered 3 and 6 are almost without erosion, and the ratio Ag/Cu is almost equal, but a high amount of Sn is found in these coins. Tin content varied between 0.68 and 5.96 % in silver coins. The presence of tin in ancient coins indicates that they were made by the soldering method [5-7- 11]. Probably, due to political conditions and war, this metal (Sn) has been deliberately added to the coins. According to the PIXE results, the important elements in the elemental composition of silver coins studied are Ag, Cu, Pb, and Fe, which were measured in all the coins. Ag-Cu, elements are the main constituents in silver coins. There are significant differences between the forgery and authentic coins regarding the Ag content of silver coins. In studied coins, the Ag content in silver coins Orodes II is between 21.3 - 61.3 wt %, and this value dropped to 29.9- 42.4 wt% during the Phraates IV, and The Cu content in silver coins Orodes II is between 0.68- 1.96% wt % and this value has increased to 43.6- 51.6 wt% during the Phraates IV, which may be because of the many wars in which he was engaged. During this period to preserve the appearance, physical properties, and approximate weight of the coins, the reduction in Ag content was compensated by the less expensive metal copper. Copper is naturally presented in silver coins at a level of less than 2wt.%, but if the amount of this element is more than 2wt.%, it is not considered that originate from natural resources [37]. The other element is Pb which was present in both genuine and counterfeit silver coins in varying percentages. Craddock believed that the residual lead in cupelled silver could fall anywhere between 0.05% and 2.5%. Lead will often segregate towards the surface of an artifact during solidification, but lead is more prone to corrosion than silver or copper and so will be preferentially leached out of the surface layers of a coin [38]. So lead concentration from the surface analyzed is higher than it is in the bulk of the coins. Therefore, when a non-destructive surface technique such as XRF or PIXE is used, Pb the concentration found will always be higher than its bulk value [39]. On the other hand, when Ag is obtained from a Pb ore, Pb concentration is relatively high in silver. However, if Electrum is used, Pb levels are lower. In conclusion, a relatively high concentration of Pb is a strong indication that the coin is authentic. Pb concentrations in forgery coins are less than 0.060% and on average, around 0.028% [39]. During the study of coins, it was found that the Pb content in silver coins of Orodes II ranges between 0.57-2.5 wt%, while in the case of Phraates IV, it is between 0.7-2.6 wt%. As a result, all the coins have relatively high Pb values. Although on the base the Pb values of fake coins (less than 0.06%) are not suspicious, but according to there is a positive correlation between Pb and Cu in counterfeit coins; when the Cu content is high, the Pb concentration is also higher than the impurity in copper. This could create the impression that the coin is authentic. Therefore, these coins should not be considered authentic based on their copper content, amount average of Cu in these coins is 49.42 wt%.

Conclusions

Identification and recognition of authenticity are crucial for museum coins. One of the best methods used is the application of archaeometry to measure the physical and chemical properties of coins. In this study, the non-destructive PIXE method was utilized to examine six silver coins from the Parthian Kings (Orodes II and Phraates IV), which are housed in the National Museum of Iran. The results revealed that the main components of the coins were silver, copper, lead, and tin. Since the Ag-Cu, elements are the main constituents in silver coins and there are significant differences between the forgery and authentic coins regarding the Ag content of silver coins. Therefore, the ratio of copper and silver is considered in this study. The silver (Ag) content ranges from 21.3 to 61.3 wt.%, with an average amount of 37.82 wt%. and the copper (Cu) content ranges from 24.1 to 75.47 wt.%, with an average amount of 45.52 wt%., the Ag content in silver coins Orodes II is lower than 50% (amount average 41.3 wt %) and This value dropped to less than 40% during the Phraates IV period (amount average 36.08 wt%). The historical documents show that Orodes II and Phraates IV engaged in numerous conflicts with the Roman Empire. The high expenses of these wars, such as army salaries, led to a decrease in the silver content of coins. This resulted in the need to produce more silver coins and to use limited silver sources more efficiently by reducing the silver content and increasing the Cu content of the coins. To create the appearance of high silver content, silver coins were sometimes coated with tin (Sn), and bronze coins were silvered using amalgamation technology. Therefore, these coins may be used for local ,production and do not hold as much value outside of the coin producer’s territory making them .susceptible to forgery.

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