Analysis of umayyad islamic silver coins (Dirhams) by using instrumental neutron activation analysis*

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Abstract Islamic silver coins (Dirhams) running the period between 107 to 126 Hijri (726-743 AD), which belong to the Umayyad Empire period, 41-132 hijri (661-750 AD), were selected for analysis by using instrumental neutron activation analysis techniques. During this period (105-126H), (724-743AD), the Caliph Hisham Eben Abdlemalek ruled the Umayyad Empire. Dirhams were irradiated in a reactor neutron activation facility. Levels of various elements viz. Cu, Ag and Au were estimated. It was found that the average silver concentration, the base constituent of the Dirham, was about 88 wt%. Correlation between the composition of Dirhams and the historical implications was discussed.

Keywords

1 Introduction

During the Islamic civilization coins were given different terms according to the base metal. Golden coins were termed 'Dinar'; small letter silver coins were termed 'Dirham'; while copper coins were termed 'Fills'. Arabs minted round coins within the first hundred years of the Hijrah calendar year (Lunar calendar). It is related that Abdullah Eben Alzubeir was first to strike round coins. He engraved 'Mohamed the Messenger of Allah on the head and ' Allah ordained for justice and fidelity 'on the tail. In 76H (695 AD) Abdulmalek Eben Marwan added the name of the city where the coins minted. Gold and silver were preferred to other metals, because they resist natural forces, they are rare and too difficult to be forged and they have ever-lasting value. Governments used to mix cheap metals, such as copper, with the base precious metals. It is usually resorted to such cheating during financial crises, was and needs of money. Through the accurate knowledge of coin composition, we can obtain information about degree of fineness[1], coin depreciation that can be correlated to the economic decline, and the use of ores having the same geographical origin. Because of the historical and precious value of coins and other archaeological objects, non-destructive techniques, PIXE, NAA, XRF[2~8] were widely applied in archaeology.

The non-destructive methods for chemical analysis of old coins are evidently of interest to archaeologists. In this work INAA was used to study Umayyad Islamic Dirhams (Silver coins). This method has the advantage of being non-destructive, of giving a mean value for the whole object and of assuring a good accuracy and presision.[12]

The analyzed Dirhams belong to the period of Umayyad Empire 41-132 Hijri[13] (661-750 AD) and they covered the period 107-126 H (726-742 AD), when the Caliph Hisham Ebem Abdelmalek ruled the Umayyad Empire from 105 to 126 H. Four of these Dirhams were struck in Damascus; the Capital of Umayyad Empire (Capital of Syria at present) and the remaining three were made in Wasit (town in Iraq at present). The distance between Damascus and Wasit is about 900 km (see Fig.1)[14]

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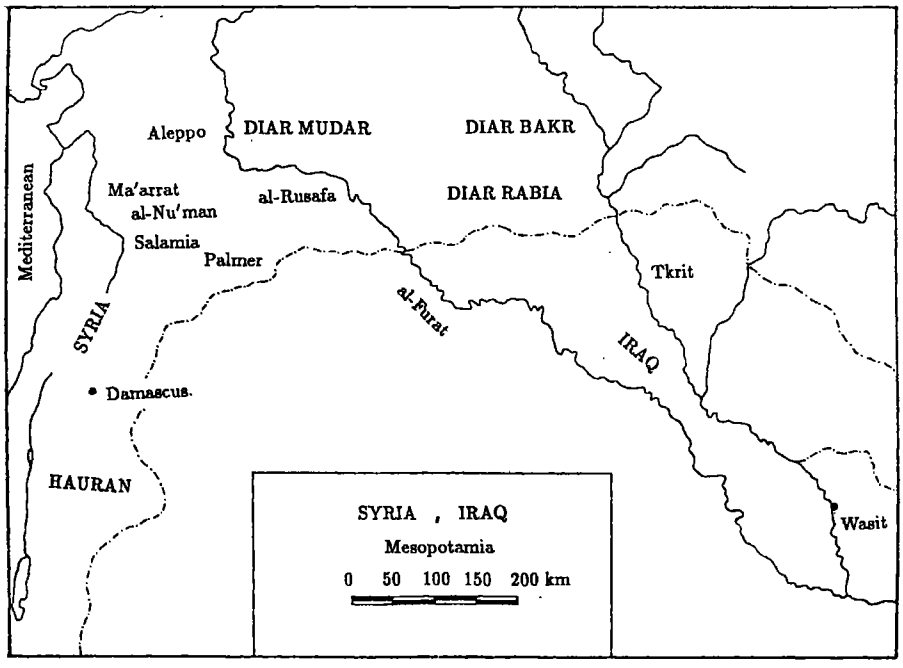

Fig.1 Map showing the distance between Damascus and Wasit

2 Experimental

2.1 Standard

The contents of determined elements in Dirhams were calculated using calibration curves. For this purpose a series of standards, obtained from National Union of Jewelry, were irradiated and we obtained the calibration curve by plotting the activity of radioisotope formed as a function of weight of the element. Fig.2 shows the calibration curve for analysis of silver. Standards are disks of thickness 1.6±0.1 mm

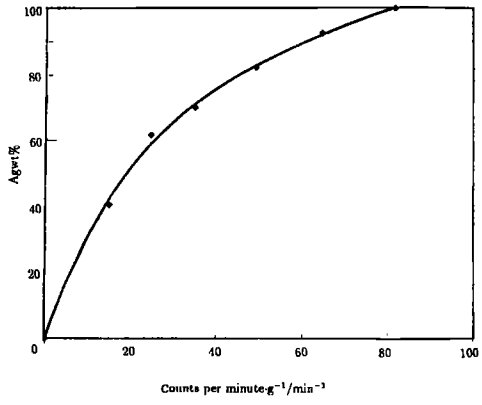

Fig.2 Calibration curve for analysis of silver

and diameter of 21±1 mm. The silver concentrations were 99.9%, 92.3%, 82.1%, 70.0%, 61.8% and 40.6% and the copper concentrations were 7.6%, 16.8%, 21.8%, 32.0% and 45.8%. Gold was the rest.

2.2 Sample preparation

The seven Umayyad Dirhams were cleaned with water and soap using steel brush. Cotton and acetone were used after drying the Dirhams to remove residues remaining on the surface of the coins.[7]

2.3 Irradiation and analysis of materials

Irradiation of samples was performed by using the Chinese designed Miniature Neutron Source Reactor (MNSR), (CEA, Damascus, Syria) with a pneumatic transfer system. The thermal neutron flux was $5\times10^{11}\,cm^{-2}\cdot s^{-1}$. Samples were irradiated for 4 s. After a decay of (900~1200) seconds, measurements of 300 real time were performed with a high pure Ge detector, of 25% relative efficiency and 1.85 keV resolution at 1332 keV gamma of ^{60}Co. A personal computer based multi-channel analyzer (MCA) using Gammapls software was used to collect and analyze the gamma ray spectra. The distance of sample and standard to detector was 10 cm. The instrumental was calibrated with standard radioisotope source (^{60}Co, ^{137}Cs) before measurements. Each measurement was done more than three times at different time

intervals. The activity of formed radioisotopes was measured at the energy 1039, 633 and 412 keV for ^{66}Cu, ^{108}Ag and ^{198}Au respectively. The elemental contents were then determined by using calibration curves. For testing the accuracy of this method, we used one sample of the same dimension as real Dirhams with known Cu, Ag and Au concentration (Cu33%, Ag57% and Au11%). We observed difference in the results in the range of ±0.5%. A correction for self-absorption of γ-ray activity due to coin thickness was employed by considering the mass absorption coefficient of the major components of coins. However, nosignificant differences in the results were observed.

3 Results and discussion

The weight and diameter of each Dirham analyzed are 2.7±0.1 g and 22.0±0.1 mm, respectively. Table 1 presents the place and date of issue and the percentage concentration of various constituents determined in the seven Dirhams, with the analytical errors. Each value presented in Table 1 is an average of at least three independent measurements. Lead (Pb) can not be determined by INAA, but we used the results for Pb obtained by X-ray fluorescence analysis.[15]

Table 1 Place, date of issue and the concentration of various constituents in the seven Umayyad silver coins (Dirhams) (wt%)

Sample No.	Date and place of issue	Ag	Au	Cu	*Pb
1	Damascus 107 H	83.56±0.62	1.26±0.02	2.10±0.08	0.27±0.04
2	Damascus110 H	88.52±0.58	1.45±0.03	1.33±0.04	0.12±0.02
3	Dammascus118 H	87.15±0.62	3.05±0.06	0.42±0.03	0.11±0.02
4	Damascus 124 H	89.06±0.61	1.34±0.04	0.32±0.04	0.24±0.04
5	Wasit 116 H	88.20±0.56	0.38±0.02	0.15±0.03	0.58±0.06
6	Wasit 121 H	87.86±0.57	0.42±0.02	0.17±0.02	0.60±0.06
7	Wasit 126 H	92.40±0.56	0.38±0.01	0.18±0.02	0.63±0.06

*Obtained by X-ray fluorescence analysis

The major constituents of the Dirhams Ag=83%-92% are Ag in all Dirhams, Cu in Dirhams No.1 and 2 mint in Damascus, the Capital of the Umayyad Empire, and Au in Dirhams No. 1,2,3 and 4 all struck in Damascus.

The average silver content of the Dirhams was about 88 wt% with maximum and minimum of 92.4 wt% and 83.6%, respectively. We notice that the Dirhams struck in Wasit have a gold amount of about 0.38 wt%, while those struck in Damascus have a gold amount of about 1.35 wt% except for Dirhams No.3, where gold content is about 3.05 wt%, but even if gold may give an indication on the silver ore provenance, it is hard to make assumption based only on that element. Kofahi *et al.*[7] attributed the variation in the concentrations of the major constituent in Abbasid Dirhams to the poor quality control practices at that time. They also attributed the high concentration of silver to the good quality of extraction of that metal at that time. The Procedure of the extraction of the metal had been known many centuries before the middle ages. The major elemental amounts indicate a debasement for any political/economical reason, because government used to mix cheap metals such as copper in different proportion with the precious metal. It is usually restored to such cheating during financial crises, wars and need of money. The high concentration levels of silver in general in the seven Dirhams struck in the period of Caliph Hisham Eben Abdelmalk indicate that the Umayyad Empire in that period (105~126 H) was strong and rich. From Table 1 we can also notice that the coins struck in Damascus have a higher gold content than those struck in Wasit. Also the lead amount is higher in Wasit than in Damascus. Table 2 groups together the coins under the ratio between the analyzed elements from each coin. In this way we obtained correlation which represents ratios of two different elements depending on another element or another ratio.[6] The coins forming cluster values indicate that those coins have a common source of raw materials and almost the same extraction or purification technology (for Ag in our case). Table 2 shows that, conies 5,6 and 7 which struck in Wasit have a cluster

values for Pb/Ag vs. Cu/Au, while coins 1,2,3 and 4 struck in Damascus show quite a large dispersion. This result indicated that the coins 5,6 and 7 used the same source of the raw materials, while mint in Damascus simultaneously used raw materials from different provinces. We obtained for the same coins struck in Wasit a cluster values for Pb/Au vs. Ag, while those struck in Damascus show also a large dispersion. This result indicated that the extraction or purification for Ag was the same in Wasit, while there were many techniques of extraction or purification of Ag in Damascus. Taking in account all these information and comparing it with the data in Table.1, historians can deduce some interesting conclusions about different sources of raw materials, the alloying technology and the economically good epoch, when Caliph Hisham Eben Abdelmalek ruled the Umayyad Islamic Empire.

Table 2 The ratios between the analyzed elements from each Dirham

Sample No.	Pb/Ag ($\times 10^{-2}$)	Cu/Au	Pb/Au	Ag
1	0.3	1.6	0.20	84.7
2	0.1	0.9	0.09	88.4
3	0.1	0.1	0.04	87.2
4	0.3	0.3	0.17	89.2
5	0.7^{a1}	0.5^{a1}	1.5^{b1}	88.5^{b1}
6	0.7^{a2}	0.4^{a2}	1.5^{b2}	87.8^{b2}
7	0.7^{a3}	0.6^{a3}	1.7^{b3}	93.3^{b3}

a: Cluster indicates the commons source for the raw materials. b: Cluster related to the silver sources or to the purification technology

Conclusion

INAA technique was used to analyze Islamic silver coins (Dirhams) covering the period 107~126 (726~742 AD) of the great Umayyad Islamic Empire. This can be done in spite of the unfavorable nuclear properties of major elements. The results show that the Dirhams minted at that period are of good quality and we could conclude also that the Umayyad Empire was strong and rich during the rule of Caliph Hisham Eben Abdelmalek.

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