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PIXE ANALYSIS OF SILVER COINS FROM ILKHANID AND SAFAVID DYNASTIES IN IRAN: A CASE STUDY

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ABSTRACT

In this case study, Proton-Induced X-ray Emission (PIXE) analytical technique has been applied to thirty-eight Iranian silver coins, selected from a private collection. The purpose was to study the fineness evolution from beginning of the 13 to the 16th century AD in Iran. The content and variation of metallic and non-metallic elements Fe, Cu, Zn, Ag, Au and Pb were observed. It was found that Cu, Pb, Zn and Au were mainly present along with silver as major component. The content of Ag as the main constituent of the coins varies from 55 to 97 %. This significant variation in the content of the major constituent reveals the economical difficulties encountered by each dynasty. It could be also attributed to differences in the composition of the silver mine used to strike the coins in different locations. The results offer valuable information about the economy of the periods under study.

KEYWORDS: PIXE Analysis, Coins, Silver, Ilkhanid, Safavid, Iran

1. INTRODUCTION

One The Ilkhanat, was one of the four khanates within the Mongol Empire. It was centered in Persia, including present-day Iran, Iraq, Afghainistan, Turkmenistan, Armenia, Azerbaijan, Georgia, Turkey, and western Pakistan. It was based, originally, in Genghis Kha's campaigns for the Khwarezmid Empire in 1219- 1224, and the continual expansion of Mongol presence under the commands of Chormagan, Baiju, and Eljigidei. The Ilkhan means "subordinate Khan" and the dynasty was in theory under the authority of the Great Khan, although they lost contact with him. They unified much of Iran following several hundred years of political fragmentation. Adopting Islam, they oversaw what has been described as a Renaissance in Iran. They oscillated between Sunni and Shi'a Islam (Atwood,2004),Though after the beginning of the Safavid dynasty Iran would become officially Shi'a. although the Khanate disintegrated, it brought stability to the region for about a century. Their rule is usually dated from 1502 to 1736 A.D (Bosworth, 1996).

It is advisable to choose non-destructive methods in archaeological material analyses. Although, various nuclear techniques are used for such analyses, the proton- induced X-ray emission (PIXE) method is of special interest for archaeological specimens as the technique is not only non- destructive, sensitive and capable of simultaneous multi- elemental analysis, but also ensures that any size of sample can be quantitatively analyzed without sample destruction (Vijayan, 2003, Guerra, 1995, 1998, Torkih, 2010, Roumie, 2010).

Utilizing PIXE technique to study ancient coins is one of the prevailing methods for finding the chemical composition of ancient metals (Smith, 2005, 258-264). Such technique can be applied to make clear unknown aspects of the economy of the time. This information can be used to deduce information on economic conditions and possible sources of metals. PIXE has also been applied non- destructively in order to detect trace elements (Constantinescu, 1999). PIXE offers the maximum sensitivity for elements ranging approximately from Ar to Zr. The variation of the proton beam energy enables the characterization of layered structures at the surface (Linke, 2004: 127-178). The analysis of ancient coins can show the economy and the prevailing techniques of coins minting of the time (Deyell, 1990). Studies have been conducted on a number of Greek coins, according to experiments on ancient silver coins (drachms) issued by the Greek city Dyrrhachium during 68±43 years BC were analysed non-destructively by micro-PIXE method. The selected 27 drachms, including four imitations, belong to the numismatic collection of the Hungarian National Museum (HNM) (Uzonyi et al, 2000). The content of Ag as the main constituent of the coins is 92%. The results showed a good economic situation at the time. Also Moldavian Medieval silver coins groschen, that circulated during Late Middle Age on the Moldavian territory. The element composition of these coins exhibited different hypotheses regarding the manufacturing process and a close connection between the economical life of those ages and the corresponding historical events was revealed (Bugoi et al, 2002).

The evolution of coins, with their changing design, shapes, marking, patterns and epigraphs, provide a visual and factual picture of their contemporary culture. Thus, valuable information about the chronology can be obtained (Dacca, 2000, Uzonyi, 2000). Ancient coins are often struck with a well-controlled alloy by a known mint with a date of issue and for most of them references can be found in ancient documents dealing about their typology and metrology (Ben Abdelouahed, 2010). In this work, PIXE technique is employed to study thirty-eight Iranian silver coins, belonging to two successive dynasties from the beginning of the 13^{th} century (Ilkhanid dynasty 1256-1335 A.D) until the 16^{th} century (Safavid dynasty 1488-1736 A.D). During Ilkhanid period, approximate weights of silver coins were between 3.0 to 4.0 grams. Increasing and decreasing in the coins weight depended on the power of the King. Therfore, it is not surprising that such coins were issued in different weights. Safavid period have a unified monetary system and mint under central government. Coin's weights increased in this period (Table 1). The results showed an evolution in minting coins during 1256- 1736 A.D.

2. EXPERIMENTAL SETUP

Thirty- eight silver coins from Miri's private collection have been cleaned as follows: they have been kept in 3-5% formic acid solution for a few minutes, scrubbed with tooth brush, and finally cleaned with alcohol soaked cotton. Analyses were carried out in the Van de Graff accelerator of the Atomic Energy Organization of Iran (AEOL). A 2 MeV proton beam with a current of 2-3 nA was used to bombard the coins. Then coins inserted in a multipurpose scattering chamber maintained in high vacuum (10^{-5} Torr). The emitted characteristic X- rays were detected with an ORTEC Si (Li) detector (FWHM 170 eV at 5.9 keV). GUPIX takes in to account; the energy loss of the 2 MeV incident protons, the variation of X-ray production cross- sections with the decreasing proton energy, the absorption of X- rays from different depths in the target and the elemental effect, also used all the inputted specification of the Si (Li) X-ray detector to generate a theoretical curve for its efficiency and allows for the escape peak, sum peak and low energy tailing of X- ray (Ben Abdelouahed, 2010, Campbell *et al.* 2000). The results are shown in Table 1. Major elements are those contributing with more than 10% to overall composition, minor elements 0.1-10% and trace elements less than 0.1% down to detection limits. Overall uncertainty for the PIXE method was 5% for major elements; 5-10% for minor elements and 15% for trace elements. The uncertainties are not only statistical, but they also originate from the roughness of coin surface and from the chemical corrosions and wearing of objects, altering the accuracy of the result (Hajivaliei 2012, Sodaei 2013).

3. RESULTS AND DISCUSSION

In the coins under study, the metallic elements Ag, Au, Pb, Cu, Fe, and Zn were observed (Table 1). The percentage of Ag varies between 55% ant 97% (Table 1). The fineness of the Iranian silver coins during 13th and 16th century is summarized in Fig 1. According to the diagram, during Ilkhanid period (1258 to 1304 A.D), the fineness of the coins varies from 55.5 to 90.2%, which devaluation of the silver coins is noted. The same reference indicates that the weight of the silver coins was slightly reduced. From the historical point of view, in the early 13th century A.D., under the leadership of Genghis Khan, the Mongol empire grew out of the original homeland in the eastern zone of the Asian steppe and dominated most of Asia. After the death of Genghis Khan the empire was divided among his heirs, and consequently Hulagu Khan, Genghis Khan's son, founded the Ilkhanid dynasty of Iran. The Ilkhans consolidated their position in Iran and reunited the region as a political and territorial entity after centuries of fragmented rule by local dynasties. Hulagu Khan seized the Castle of Alamut, suppressed in 1256 A.D the Ismaili sect, and defeated the last Abbasid Caliph's army. Al-Musta'sim was captured and executed in 1258 A.D, ending 525 years of the Abbasid Caliphate. During Ilkhanid dynasty political and economic changes had been happened. The social- economic conditions in Iran were influenced by various factors which were social insecurity, disarray in business, as well as slaughtering and collective migration to other lands (Spuler 1986).

The given results can confirm the fact. The Fig.1 shows, later, during Safavid Empire, coins fineness were in good level. Ag amount in the silver coins was between 81.38 to %91.76. which shows an increasing in Ag amounts. It is worth mentioning that during 16th century, the Safavid Empire was the only significant government in Iran (1502- 1736 A.D). The Safavids as a largely nomadic society under the control of a centralized administrative machine that was used to finance a powerful army, created the basics of an impressive, modernized state machine that was controlled by a hereditary kingship and used religious authority and cultural terms (Ehsan Yar shatter, 1983).

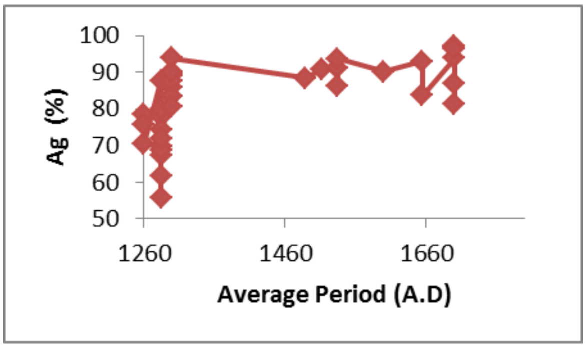

Figure 1: Fineness evolution diagram of medieval silver coins in Iran (Ilkhanid period, Safavid period)

The results also show that silver used in coins, had been replaced by copper during Ilkhanid period (Fig.2). Cu content in the Ilkhanid silver coins is between 2.95 and 20.65 %. Through Fig 2 a strong negative correlation can be observed between Ag and Cu in all Ilkhanid coins. Such a negative correlations can indicate that copper was deliberately added to silver. Content of Cu amount in the Safavid silver coins is between 0.48% and 8.32%, which may represent better economic conditions during Safavid period. Also, relevant studies coins of Greek explain related economical and political aspects such as the impetuous increasing of their amount in the century BC, especially before and during the Roman civil war between Pompeius and Caesar (Uzonyi, 2000).

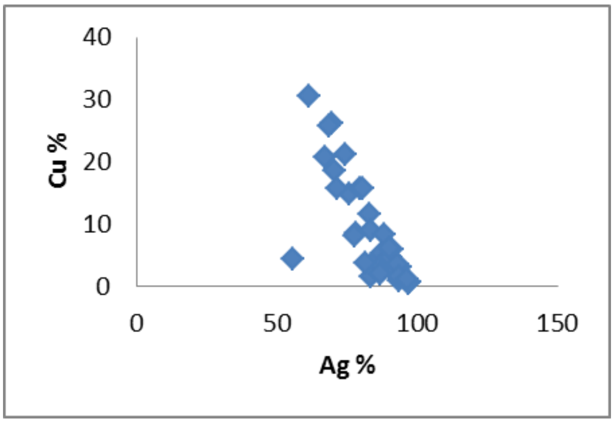

Figure 2: Correlation between silver and copper concentration in all the studied silver coins

4. CONCLUSION

A PIXE investigation was carried out on ancient Iranian coins. The obtained results show copper, silver, gold, zinc and lead as the main and considerable constituents. The study also show a fineness evolution in silver coins production, from the beginning of the 13th century (Ilkhanid dynasty 1256-1335 A.D) till the 16th century (Safavid dynasty 1488-1736 A.D). The concentration of Ag, presumably the main constituent of the coins, varies from 55 to 97 %. This significant variation in the concentration of the major constituent reveals the economical difficulties encountered by each dynasty. Variations of Cu amounts in the silver coins of Ilkhanid king's show that their reign had faced eco-political problem and Cu was deliberately added to silver, not only for hardening purposes but also for economic reasons (Tripathy 2010). Presence of Cu in the samples is an evidence of eco-political problems in that era. Thus, one can claim that metalworkers had deliberately added Cu to these silver alloys to reduce the costs. Low amounts of Pb and Zn in both periods indicate their comparative purity (Tylecote, 1962). It may also be concluded that in either periods, their mineralogy as well as their metallurgy was relatively developed.

Table 1: Element composition of medieval silver coins obtained by PIXE analysis

Sample	Ag (%)	Cu(%)	Pb (%)	Au (%)	Fe (%)	Zn(%)	Weight	Period
1	67.28	20.65	1.30	0.59		0.36	2.39	Ilkhanid
2	75.81	14.76	1.40	0.77	0.12	0.19	2.31	Ilkhanid
3	70.56	18.43	0.98	0.80		0.62	2.46	Ilkhanid
4	87.62	3.70	1.08	0.97	0.05		2.74	Ilkhanid
5	77.70	8.09	0.73	0.76	0.03		2.27	Ilkhanid
6	69.80	26.14	1.07	0.83			1.94	Ilkhanid
7	61.72	30.60	0.97	0.61	0.06		2.39	Ilkhanid
8	55.60	4.37	2.78	0.99			2.23	Ilkhanid
9	78.35	8.57	0.57	0.40			2.23	Ilkhanid
10	68.58	25.79	1.12	0.70	0.12	0.36	3.62	Ilkhanid
11	74.45	21.04	1.11	1.0	0.10		2.31	Ilkhanid
12	79.77	15.69	0.99	1.03			2.27	Ilkhanid
13	71.74	15.69	1.0	1.05	0.81		2.72	Ilkhanid
14	89.51	5.36	2.91	0.68			3.94	Ilkhanid
15	83.24	11.61	1.06	0.83			3.06	Ilkhanid
16	85.73	4.34	1.31	1.17	0.26		2.66	Ilkhanid
17	83.33	8.90	0.53	0.85	0.75		2.46	Ilkhanid
18	89.19	5.17	0.82	0.99	0.08	0.14	2.51	Ilkhanid
19	87.47	5.26	0.92	0.77	2.27		2.65	Ilkhanid
20	90.20	2.95	2.03	0.78	0.16	0.13	2.59	Ilkhanid
21	80.56	15.63	0.83	0.81			3.20	Ilkhanid
22	90.12	4.74	1.04	0.88			3.19	Ilkhanid
23	93.85	3.12	0.84	0.73			4.60	Safaveid
24	88.45	8.32	0.36	0.52	0.12		5.20	Safaveid
25	90.64	4.51	0.48		0.28		5.10	Safaveid
26	91.13	5.87	0.62	0.34	0.10		5.10	Safaveid
27	86.33	2.75	0.33	0.40	1.08		5.20	Safaveid
28	93.62	0.75	0.35	0.60	0.35		5.70	Safaveid
29	90.21	5.97	1.61		0.11		5.0	Safaveid
30	92.91	3.56	0.86	0.16			5.60	Safaveid
31	83.66	1.57	0.33		8.09		5.30	Safaveid
32	93.78	1.41	0.43	0.12	0.28		5.20	Safaveid
33	97.20	0.66	0.19	0.25	0.04		5.50	Safaveid
34	96.96	0.56			0.11		5.40	Safaveid
35	96.73	0.48	0.34	0.11	0.05		5.40	Safaveid
36	86.76	1.94	0.57	0.12			4.60	Safaveid
37	96.29	1.10	0.57	0.15			4.70	Safaveid
38	81.38	3.73	2.32		1.44		3.80	Safaveid

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