Technical studies of silver punch mark coins from Narhan (Gorakhpur U.P.), India — 600 BC–200 BC

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Abstract

Nineteen silver PMC coins from Narhan (Gorakhpur Uttar Pradesh), India, 600 BC–200 BC were examined to determine the fabrication technique used in their manufacture. Examination using x-ray diffraction, metallography, spectrographic analysis etc. revealed that the metal used in the coins was extracted from argentiferrous galena ore, and was worked, annealed and punched, whereas other silver PMC coins reported from different sites in India from 600 BC–900 AD were fabricated by casting and punching, without annealing.

Introduction

Explorations conducted all over India have yielded large numbers of silver punch mark coins some of which were issued locally by small Janapadas and Mahajanapadas in their respective states after the great Bharat war (11th cent. BC). Coins belonging to this period are the earliest that have been found. Later these states were absorbed by the Magadha empire around 5th–4th cent. BC. Gupta [1] reported that "The various states of which the coins are known are: Surasena (Modern Braj, the region around Mathura), Uttara Panchala (the Rohilkhand region), Dakshina Panchala (the doab area stretching from the Ganga to the Chambal), Vatsa (the region south of the Ganga, extending up to Avanti or Ujjain), Kunala (probably modern Gonda-Bahraich districts), Kosala (the area bounded by the Gomti on the west, Sarpika-Modern Sai on the south, Sadanira-Modern Gandak on the east and the Nepal hills on the north), Kashi (the region around Varanasi including parts of the districts of Jaunpur, Ghajipur and Mirzapur), Malla (the district of Deoria and its surroundings), Magadha (the area bounded by the Ganga on the north, the Son on the west, dense forest reaching the plateau of Chhota Nagpur to the south, and the Bhagalpur region to the east), Vanga (Bengal), Kalinga (the Coastal area from Vaitarni in Orissa to the borders of Andhara, extending in the west into the hilly forests as far as Amarkantaka), Andhara (the delta of the Godavari and the Krishna), Asmaka (the area south of the Godavari in Maharashtra), Mulaka (neighbouring state of Asmaka, including Hyderabad), Surashtra (the Kathiawar region) and Gandhara (north-western region on the border of Afghanistan). These states were probably using metal as currency and money for exchanging the material with other states around 8th cent. BC. The coins of each of these states differ from one another in their execution, fabric, weight, quality of metal and symbology. Who the pioneers in this field were and how they developed their coin technology is still a mystery.

Narhan [2] (lat 26°–19′N, long 83°–24′E) is located on the left bank of the River Ghaghara in Bansgaon tehsil of the district of Gorakhpur (Uttar Pradesh). It was explored several times in the past but the recent excavations in 1984–85 yielded a variety of silver punch mark coins, copper coins, copper vessels, iron objects like chisels and nail sealings, plaques and toy cart wheels (all terracotta), beads of glass, bangles and agate etc. Fifty one punch mark silver coins from this site were received for technical studies and preservation in the National Research Laboratory for Conservation of Cultural Property, Lucknow (Uttar Pradesh) from the department of Ancient India History Culture & Archaeology, Banaras Hindu University, Varanasi. Nineteen coins were selected as worthy of detailed metallurgical investigation. The studies included (a) metallographic examination (b) x-ray diffraction examination and (c) chemical analysis. The objectives of these studies were to determine.
i) the ores used for extraction of metal,
ii) the fabrication technique adopted by these smiths, and iii) the types of corrosion products present on these coins.

1. Metallographic investigation

All the fifty one coins were in good condition and free from radical cracking and age embrittlement. The coins bore the stamping mark on only one side, the other being blank. The symbols are well punched and deep. There was not much variation in weight, except for two triangular coins. Most of the coins were covered with a grey coloured patina but some of them had a green coloured patina. Five coins of different shape, size and curvature, Fig 1, were selected for detailed metallographic examination from the nineteen selected for technical studies.

The Guardians of museum materials often do not allow even small samples to be taken from artifacts in their collection as it spoils their antique appearance. Bearing this in mind, it was decided not to cut any section for metallographic examination from these coins. Instead a sandwich technique was developed for embedding the complete coin in transparent thermoplastic resin, Fig 2. This technique has two great advantages: it uses only a very small area on the coin rim for metallographic investigations, and the thermoplastic resin is soluble in

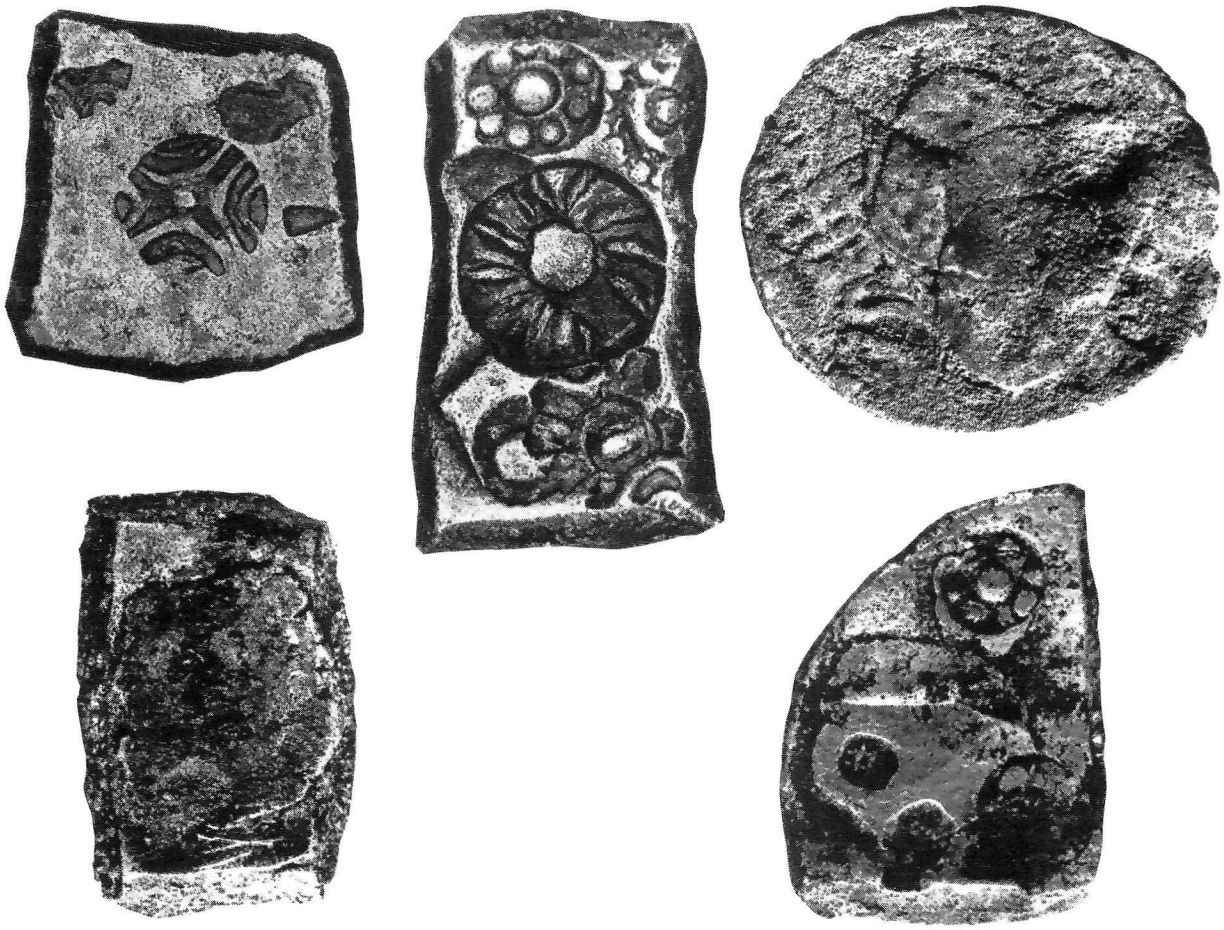
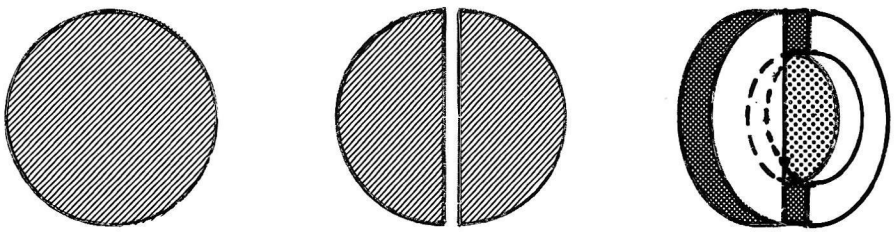


Fig 1: Silver punch mark coins from Narhan (Uttar Pradesh) 600 BC–200 BC. (a) coin PMC5, (b) coin PMC7, (c) coin PMC9, (d) coin PMC17, (e) coin PMC19



(a) (b) (c)

Fig 2: Sketch showing the sandwiching of the coin. (a) blank mould, (b) mould cut into two parts, (c) sandwiching of the coin

Table A: Archaeological description of silver punch mark coins from Narhan (near Gorakhpur, UP) 600 BC–200 BC

Sl No	Shape	Weight grams	Thickness mm	Dimensions mm	Patina etc.
1	Square (convex curvature)	5.57	2.0	1.70×1.70	Blackish green
2	Circular	5.42	1.5	2.5 dia	Blackish green
3	Circular	5.64	2.0	2.5 dia	Predominantly black with few patches of green patina
4	Semi circular (convex curvature)	5.59	2.0	3.0 dia	Predominantly black with few patches of green patina
5	Square (convex curvature)	5.63	2.0	1.60×1.60	Predominantly black with few patches of green patina
6	Circular (convex curvature)	5.67	2.5	2.0 dia	Predominantly black with few patches of green patina
7	Rectangular (convex curvature)	5.65	2.0	2.5×1.5	Predominantly black with few patches of green patina
8	Circular (convex curvature)	5.63	4.0	1.40 dia	Predominantly black with few patches of green patina
9	Circular with convex curvature	5.77	3.0	2.00 dia	Black
10	Circular with convex curvature having crack in the inverse side	5.54	2.0	2.10	Black
11	Circular	5.61	4.0	1.5 dia	Blackish green
12	Triangular with convex curvature	5.55	2.0	2.0×1.9×2.1	Green
13	Rectangular with convex curvature	7.29	1.5	3.3×1.2	Black
14	Rectangular with convex curvature	5.55	3.5	1.9×1.2	Blackish green
15	Rectangular with convex curvature	5.65	1.0	2.4×2.0	Blackish green
16	Triangular with convex curvature	7.24	2.5	2.5×2.4×0.9	Blackish green
17	Rectangular	5.51	4.0	1.8×1.0	Blackish green
18	Triangular with slight convex curvature	5.63	2.0	2.2×1.5×2.7	Blackish green
19	Triangular	5.48	3.0	2.0×1.5×2.4	Almost clear surface with very little black colour patina

chloroform so that after the study, the coin can be returned to the custodians without any noticeable change.

In the technique, a blank mould of transparent thermoplastic resin is first prepared. Then it is cut into two pieces and the complete coin held in a vertical position between these two pieces, which are joined with transparent cold setting resin. All five coins were embedded in this way and allowed to stand for about two hours. After setting, small areas on the rims of the coins were polished in the usual manner, ending with 0.05 μm Gama Alumina emulsion powder, and then etched. Vickers micro-hardness values of the coins were measured using a 20 g load.

Interpretation of micro structure

1. Silver punch mark coins Lab No. 5, 7 and 9

All three coins had concave curvature.

Macro-examination of the polished areas showed that the white coloured metal was surrounded by a very thin corrosion layer. Examination of the small polished areas indicated the presence of spherical and irregular shaped gray and black inclusions and corrosion cavities. The black coloured inclusions (lead) were more numerous in PMC no.7 than in the others. The alloy structure in all three coins consisted mainly of a silver-copper solid solution matrix whose crystals showed twin lines [3, 4], Fig 3. The average microhardness values of these silver PMC coins were 79, 80, 82 HV/0.02.

Conclusion

The above examination indicated that the metal contained lead as an impurity and that the coins were prepared from clippings from cast bars, which had been worked, annealed and punched. All these coins had been struck while hot on an anvil, which resulted in their concavity [5, 6 and 7].

2. Silver punch mark coins Lab No. 17 and 19

In contrast, these two coins have flat surfaces. Macro examination of the polished rims at ×125 showed white-coloured metal cores, having few corrosion cavities, but black-coloured (lead) inclusions, surrounded by very thin layers of corrosion product. Etching showed the metal to have a distorted dendritic structure near the inverse sides of these two coins, Fig 4, while examination of the areas near the punched embossed surfaces showed very faint twin lines. The average microhardness values of the PMC coins were 82 and 85 HV/0.02 respectively.

Conclusion

A possible explanation for the fabrication technique of these two coins was that they were prepared from metal that had been cast into strip-shaped bars of a desired thickness. Later these bars were clipped into

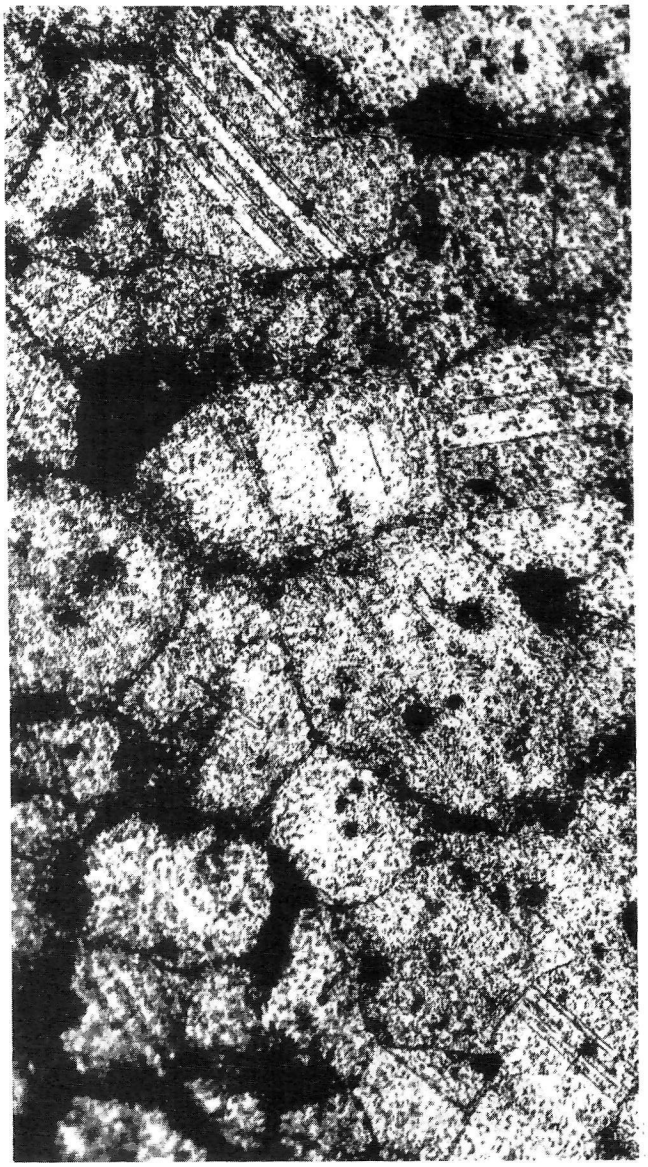


Fig 3: Photomicrograph of the silver PMC No. 7, revealing twin lines in the crystal. Etchant acidic dichromate ×250

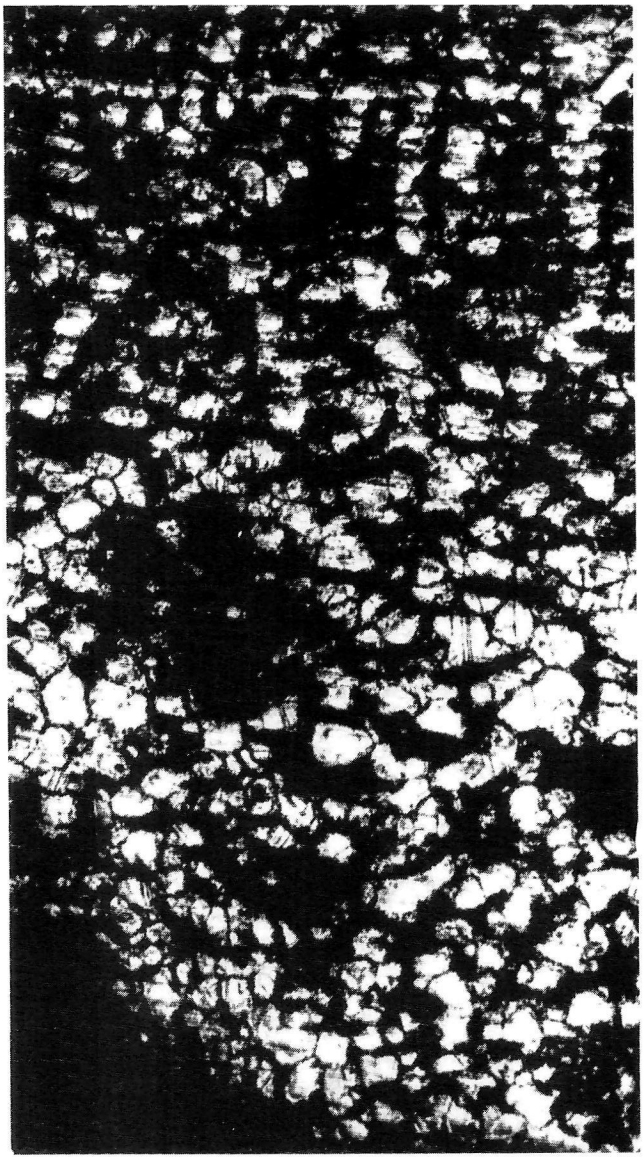


Fig 4: Photomicrograph of the silver PMC No. 17, revealing dendritic structure. Etchant acidic dicromate ×125

pieces of different shapes that were beaten out flat and partially annealed. This resulted in the formation of distorted structures with a few new twinned grains.

2. X-ray diffraction investigation

Corrosion products were scraped from the coins with fine wooden tools and were subjected to x-ray diffraction analysis. The diffraction pattern of these corrosion products revealed that the grey coloured corrosion products were mainly silver chloride whereas the green coloured products were mainly copper chloride.

3. Spectrographic and chemical analysis

Very minute samples were taken from all nineteen coins by drilling with a 0.5 mm dia. iron carbide drill in the periphery area. The first drillings were discarded and the subsequent drillings collected for analysis. The samples were divided into two portions. The first portions were analysed qualitatively by emission spectrography, and the second portions were used for quantitative analysis by atomic absorption spectrometry. The results obtained indicated that silver, and copper are present in major amounts, whereas lead, and gold are in minor amounts. The elements silicon, magnesium, titanium, aluminium, and calcium were present in trace amounts. The results are recorded in Table B.

Interpretation and discussion

The x-ray diffraction analysis indicated that the grey

Table B: Composition of silver punch mark coins from Narhan (Uttar Pradesh) 600 BC–200 BC

Si No	Ag	Cu	Pb	Au	Si	Mg	Ti	Al	Ca	Total
1	94.64	3.28	0.44	0.90	Tr	Tr	Tr	Tr	Tr	99.20
2	94.32	3.62	0.94	0.95	Tr	Tr	Tr	Tr	Tr	99.47
3	94.95	3.44	0.52	0.85	Tr	Tr	Tr	Tr	Tr	99.76
4	94.78	3.18	0.65	0.77	Tr	Tr	Tr	Tr	Tr	99.38
5	95.19	2.89	0.74	0.78	Tr	Tr	Tr	Tr	Tr	99.60
6	95.17	3.10	0.58	0.71	Tr	Tr	Tr	Tr	Tr	99.56
7	94.90	2.85	0.86	0.91	Tr	Tr	Tr	Tr	Tr	99.52
8	Sample not taken									
9	96.20	2.63	0.35	0.91	Tr	Tr	Tr	Tr	Tr	100.09
10	94.40	3.45	0.94	0.89	Tr	Tr	Tr	Tr	Tr	99.68
11	Sample not taken									
12	93.89	3.82	0.89	0.71	Tr	Tr	Tr	Tr	Tr	99.35
13	95.70	2.30	0.83	0.95	Tr	Tr	Tr	Tr	Tr	99.78
14	93.48	3.92	0.68	1.35	Tr	Tr	Tr	Tr	Tr	99.43
15	95.29	3.26	0.39	0.74	Tr	Tr	Tr	Tr	Tr	99.68
16	95.40	2.67	0.59	0.97	Tr	Tr	Tr	Tr	Tr	99.63
17	94.32	2.96	0.75	0.97	Tr	Tr	Tr	Tr	Tr	99.00
18	94.00	3.76	0.48	0.79	Tr	Tr	Tr	Tr	Tr	99.03
19	94.05	3.08	0.61	0.86	Tr	Tr	Tr	Tr	Tr	99.60

and green colour corrosion products on these coins were silver chloride and copper chloride respectively. Metallographic studies conducted on the coins no. 17 and 19 indicated that they were fabricated by hammering and partially annealing pieces clipped from cast flat strip-shaped bars. Whereas the coins no. 5, 7 and 9 were fabricated by hammering, annealing, and punching the metal pieces clipped from the cast bar in the warm state. The studies indicated that either the coins no. 17 and 19 belong to an earlier period than the coins no. 5, 7 and 9 or of the same period but prepared in a slightly different way. However, a survey of the literature on silver PMC coins which had been used over a long period revealed that they had been re-marked on the reverse side for recirculation, but no such mark was noticed on any of these coins. Hence it is clear that these two techniques were used in the same period. Annealing and partial annealing had produced strain free metal in these coins. This is the reason why all the coins were free from cracks and embrittlement. Furthermore, the softness of the metal permitted production of the clear embossing on the coins.

Metallographic investigations done by earlier scientists on silver punch mark coins from Taxila 400 BC [8] indicated that they were fabricated from the cast metal pieces of appropriate composition without subsequent annealing.

Bhardwaj [9] reported a coin from Rajghat, 9th cent. AD Varanasi having a crack and dendritic structure, which resulted from cold working and age embrittlement. Coins from Kausambi [10] 600 BC–100 AD indicated that they had been cast and impressions punched in them. Three punch marked silver coins 300 BC examined by Chatterjee [11] also indicated the same technique as noticed in the Kausambi coins. Ramchandram [12] found cast and cold worked structures in six punch mark silver coins from the Mamblam hoard (Madras) of 100 AD.

The work done by earlier archaeo-metallurgists on silver punch marked coins indicated that none of the coins were worked and annealed. However, Narhan is the first site where we have come across the technique of working, annealing and punching. These steps were employed for better fabrication of punch mark silver coins. The only previous report of silver coins fabricated by working and annealing before punching, as well as by the more usual technique of casting and punching, is by Elam [13, 14] who reported on Greek coins containing 93–99% silver, of the period 500–300 BC.

The quantitative analyses revealed that all these silver PMC coins are similar in composition and the presence of silver contents between 93.48% and 96.20% must be considered deliberate and was clearly the aim of the moneyers. The lead contents vary from 0.35% to 0.95%. Lead's presence is also indicated by metallographic and spectrographic analysis. This shows that the cupellation process was done very skilfully, by the artisans of this area. Copper contents vary from 2.30% to 3.92%, the presence of copper up to this amount indicates that this metal was probably added after cupellation to lower the melting point, and increase the wear resistance and strengths of the resultant alloys [15, 16]. The amounts of gold vary between 0.70 and 1.35%. Earlier Satya Prakash and Ravat [17] also reported the presence of gold as a trace element in three coins from Kausambi (600 BC–300 BC), but gold was not detected in the other silver PMC coins from Kausambi, Table C. Hamid [18] has reported 10.53% gold in a silver PMC coin, which was one of the fourteen coins, possibly of the same period

Table C: Composition of silver coins and artifacts in ancient India 1100 BC–900 AD

Sl No.	Description of the antique	Site or Place	Period	Ag	Cu	Pb	Au	Fe	Ni	Sb	As	S	Sn	CaO	Zn	CO	Insoluble	Total
1	Silver pieces	Gungeria copper hoard	1100 BC –800 BC	96.30	–	–	3.70	–	–	–	–	–	–	–	–	–	–	100.0
2	Silver PMC	Kausambi	600 BC –500 BC	84.71	14.64	0.09	Tr	0.21	0.06	0.20	–	–	0.10	–	–	–	–	100.01
3	Silver PMC	Kausambi	600 BC –500 BC	27.59	70.43	1.31	–	0.07	0.09	Tr	0.13	–	0.18	–	0.21	–	–	100.01
4	Silver PMC	Kausambi	500 BC –300 BC	76.80	21.78	0.98	Tr	0.15	0.11	–	Tr	–	0.11	–	–	–	–	99.93
5	Silver PMC	Kausambi	500 BC –300 BC	77.41	21.31	0.92	Tr	0.11	0.06	–	–	–	0.14	–	–	–	–	99.95
6	Silver PMC	Kausambi	500 BC –300 BC	76.90	21.81	0.90	–	0.16	0.09	–	–	–	0.12	–	–	–	–	99.98
7	Silver PMC	Kausambi	400 BC	91.72	7.32	0.12	–	Tr	–	0.18	Tr	0.26	Tr	–	–	–	0.40	100.00
8	Silver PMC	Kausambi	400 BC	86.33	12.31	0.34	–	Tr	–	0.13	Tr	0.27	–	–	–	–	0.62	100.00
9	Silver PMC	Kausambi	400 BC	20.47	72.23	0.21	–	0.23	0.04	–	Tr	0.47	Tr	–	–	–	1.35	100.00
10	Silver PMC	Kausambi	200 BC –100 AD	51.88	46.86	–	–	0.41	0.61	Tr	0.09	–	0.19	–	Tr	–	–	100.04
11	Silver PMC	Taxila Hoard	400 BC	84.14	13.01	0.15	–	0.15	Tr	Tr	Tr	0.20	Tr	–	–	Tr	2.25	99.90
12	Silver PMC	Taxila Hoard	400 BC	74.87	22.40	0.10	–	0.15	Tr	Tr	Tr	0.10	0.45	–	–	–	1.96	99.96
13	Silver PMC	Taxila Hoard	400 BC	72.08	25.16	0.23	–	0.20	0.15	Tr	–	Tr	0.10	–	–	Tr	2.40	100.32
14	Silver PMC	Taxila Hoard	400 BC	78.40	20.12	0.40	–	0.06	0.20	Tr	Tr	Tr	–	–	–	–	1.20	100.38
15	Silver PMC	Mambalam Hoard Madras	100 AD	74.80	25.08						Trace impurities 0.38%							100.26
16	Silver coin	Kshatrapa	200 AD –400 AD	80.28	18.16	0.86	–	–	Tr	Tr	Tr	–	–	–	0.17	–	–	99.47
17	Silver coin	Kshatrapa	200 AD –400 AD	79.37	18.47	1.21	–	–	Tr	Tr	Tr	–	–	–	0.21	–	–	99.26
18	Silver coin	Rajghat (Varanasi)	900 AD	61.54	32.14	0.50	–	0.54	0.50	Tr	Tr	0.20	0.57	0.52	–	–	3.40	99.91
19	Silver PMC coin	State Museum Lucknow	–	13.63	75.82	–	10.53	–	–	–	–	–	–	–	–	–	–	99.98

Tr→Trace
(–)→not reported by the analyst

as those described in this work, and from the Jaunpur area (Uttar Pradesh) acquired by the State Museum, Lucknow (Uttar Pradesh) [19]. Gold was also reported in silver pieces from Gungeria (copper hoards 1100 BC–800 BC) Maharashtra [20], but coins from Taxila 400 BC, Mambalam hoard (100 AD), Kausambi and Kshatrapa (200 AD–400 AD) [21] did not contain gold.

During the processing of an ore to metal, the amount of gold remains essentially unchanged. Therefore, the gold content of the metal may be considered to be indicative of the gold content of the parent ore. Conversely, parts of the other elements are lost in the process of smelting and cupellation. Thus, the gold contents in these coins indicate that the metal used in them was possibly derived from the same source. Bismuth can also be used as an indication of silver sources, but it was not detected in these coins, and it is not present in the ores from the mines of Rajpura Dariba and Rampura Agucha (Rajasthan).

Silver was extracted in ancient times from lead–zinc blende, and argentiferous galena [22], and such ores are found in Bihar, Orissa and Rajasthan. The ores from Bihar and Orissa are not rich in silver. However, the ores from Zawar [23] and other mines in Rajasthan are tolerably rich [24], and they were reputed to have been used for silver extraction from 200 BC onwards. The joint exploration conducted by Craddock and Hegde in the mines of Rajpura Dariba and Rampura Agucha in Rajasthan State also confirmed the above findings [25]. Forbes [26] reported earlier that a cupellation process was known as early as 1500 BC, and the separation of silver from gold was probably worked out around 1000 BC, but was not commonly used by smiths. It is probable that the metal used in these coins had been extracted from lead from argentiferrous galena ores by efficient cupellation. Moreover, the composition of the metal suggests that the ores might have been taken from the Rajasthan mines.

Conclusion

Within the limits of our material, which included nineteen silver PMC coins from the Narhan site, the study has shown that the corrosion patina was mainly due to silver chloride. The smiths of this area were more skilled in coin technology than the smiths of Taxila (West Pakistan 400 BC), Kausambi (near Allahabad in Uttar Pradesh, 600 BC–100 AD), Rajghat (near Varanasi in Uttar Pradesh, 900 AD), Mambalam (Madras 100 AD) and Kshatrapa (200 AD–400 AD). The coins reported from all these sites were fabricated by punching cast metal. The smiths of Narhan not only master-minded the technology of extraction of metals from argentiferrous galena ore but also knew the effect of annealing on metal. The ore used for the manufacture of these coins may have come from the Rajasthan mines. The suggested sequence of fabrication steps involved in the manufacture of silver PMC coins from Narhan are casting of bars of the desired shape and thickness by pouring the metal into moulds, working clipped pieces to the required shape with appropriate annealing, and embossing or punching.

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