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RECENT BRONZE HOARD FROM WEST BENGAL: ANALYTICAL STUDIES

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Two groups of bronze objects obtained from North Bengal have been analysed with an EDXRF system to obtain their elemental composition. One of the objects is a detached back-slab and another is a circular metal lid of a container. The rest are of deities – four Buddhist and nine Brahmanical. All the Brahmanical images were found to be homogenous, while the Buddhist images were highly non-homogenous. Although stylistically, the Buddhist images resembled those from Kurkihar, the presence of the element antimony and high concentration of iron suggests that they might have been made elsewhere.

Key words: Archaeology, EDXRF, Images, X-ray Radiography

Introduction

Thousands of Eastern Indian Bronzes (the word Bronze is often used by the archaeologist for any alloy of copper) objects are known from different sites, but only a very few of these have been analysed so far. Jayaswal[1], Sahai[2] and Leoshko & Reedy[3] have analysed a few bronze images from Kurkihar where the content of Sn varied from 2 – 3%. Lal[4] and Sahai[2] analysed some objects from Nalanda. They observed that in these objects the amount of Sn varied from 13 – 24%, Fe from 4 – 6% and Pb upto 5%. The largest number of bronze objects (66 in number) was found in Jhewari village in the district of Chittagang, Bangladesh. Mitra[5] and Bhattacharya[6] have analysed a few of them and found that some of those objects are mainly

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of Cu and Sn and others are of Cu and Zn. Traces of As, Sb and the presence of ppm level Ag and Au are also found in those objects. Sultanganj statues were analysed by Mitra[7], Neogi[8] and Schroeder[9] and these are found to be made of only Cu with traces of Sn, Fe and other elements. Chemical analyses of the images of Rangpur (Bangladesh) were reported by Spooner[10] where no Au or Ag was found, although these statues are supposed to be made of eight elements including Ag or Au. An image of Marichi from Jagajjibanpur was analysed by Datta and Chattopadhyay[11]. Mitra[12], Roy[13], Sahai[2] and Manowar Jahan[14] have also analysed bronze objects from the National Museum of Bangladesh.

In a recent communication[15], two groups of metal objects recovered from Salas and Gangarampur of North West Bengal have been discussed. Details of the objects are shown in Table 1(c). These objects are now preserved at the West Bengal State Archeological Museum, Kolkata. One of the objects is a detached backslab and is a circular metal lid of a container. The rest represent deities – four Buddhist and nine Brahmanical. The statues are datable between 10th and 12th centuries AD. Stylistically these objects are affiliated to the Pala-Sena idiom of Eastern India. Stylistic analysis[15] of the four Buddhist images has indicated that these objects bear a strikingly close resemblance to the Buddhist images from Kurkihar in Bihar, (India). The questions that may naturally arise in one's mind are: (i) What were the techniques adopted in making these images (ii) whether all these objects were made at the same place and (iii) if the Buddhist images were actually from Kurkihar.

Table 1(a). A summary of the compositional studies made on the bronze images found from Chousa, Jagibanpur and Kurkihar in Eastern India

Place/Ref.	Cu	Sn	Zn	Pb	Fe	Ni	As	Ag
Chousa								
B Sahai[2]	54.49	12.09	11.88	4.31	0.50			
MLD & PKC[11]	83.00	16.00	-	0.05	0.10	0.20	0.01	0.20
	83.00	16.00	-	0.05	0.15	-	0.10	0.20
Jagjibanpur								
MLD & PKC[11]	98.00	-	-	Tr.	0.01	-	0.01	Tr.
Kurkihar								
KP Jaiswal[1]	83.05	13.01	-	1.40	1.08			
B Sahai[2]	78.84	2.08	4.32	4.87	0.16			

Table 1(b). A summary of the compositional studies made on the bronze images found from Nalanda.

Place/Ref.	Cu	Sn	Zn	Pb	Fe	Ni	As	Ag
Nalanda								
BB Lal[4]	79.60	9.10	-	5.80	5.80	Tr.	-	-
	82.19	8.99	1.81	3.12	4.16	0.11	-	-
	76.98	16.19	-	2.78	0.36	0.05	-	-
	75.54	23.68	-	-	Tr.	Tr.	1.80	-
	81.23	14.62	0.44	2.64	0.92	Tr.	-	-
	79.71	7.88	4.82	-	3.21	Tr.	1.48	-
	91.62	1.19	2.61	2.22	1.39	0.18	-	-
	97.14	0.08	-	0.04	0.48	0.09	-	-
	79.58	0.40	1.64	2.08	1.12	1.20	-	-
	97.85	0.20	0.10	0.05	0.77	0.20	-	-
	85.25	1.15	7.54	3.10	2.41	0.09	Tr.	-
	89.20	8.90	-	5.17	3.86	0.09	-	-
	78.75	15.60	-	2.55	2.30	0.18	-	-
	80.84	15.09	0.05	3.06	1.30	0.08	-	-
	82.15	8.70	0.06	5.93	2.67	0.42	-	-
	78.95	0.74	15.15	3.03	1.47	0.65	-	-
	93.07	1.93	1.91	-	2.07	Tr.	-	-
	79.98	1.29	16.00	-	2.57	Tr.	-	-
B Sahai[2]	71.88	17.74	6.48	2.45	Tr.	-	-	-

To get the answers to all these questions, we first made x-ray radiographic analysis of all the images to form some idea about the technique that was used in making the images and then we employed the EDXRF technique to find out the elemental composition of the images with the hope that this might throw some light on their provenance especially of the four Buddhist images which are stylistically very similar to the Buddhist images from Kurkihar.

EXPERIMENTS

a) X-ray Radiographic analysis

To study the nature of casting of bronze images radiographic analysis was done to this entire hoard with the support of the National Test House, (NTH) Alipur, Kolkata. The instrument used was an ERESCO 300KV Portable X-Ray machine (Rich Seifert & Co) of German make. All the experimental conditions used in this measurement are shown in Table 2. From the x-ray

Table 1(c). A summary of the compositional studies made on the bronze images found from other places in Eastern India

No/Date/Name E: Early, L: Late.	Cu	Sn	Pb	Zn	As	Fe	Sb	Ni	Ag
5, 8th Viṣṇu	87	8.5	1.7	1.8	0.43	0.32	0.08	<0.3	0.02
18, L10th Buddha	83	4.5	3.1	7.9	>1.0	0.19	0.37	<0.3	0.03
19, L 10th Viṣṇu	83	1.8	4.8	9.5	0.43	0.31	0.09	<0.3	0.03
40, L11th Maitreya	84	2.3	5.7	6.6	>1.0	0.25	0.18	<0.3	0.02
52, E12th UmāMaheśa	90	<0.08	1.1	7.5	0.69	0.13	0.17	<0.3	0.02
9, E 9th Cūṇḍā	99	0.67	<0.05	0.28	0.04	0.35	<0.05	<0.3	0.01
37, 11th Namasangiti	99	0.67	<0.05	<0.2	0.04	0.01	0.11	<0.3	0.01
44, 11th Viṣṇu	99	0.10	<0.05	<0.2	0.04	0.07	<0.05	<0.3	0.02
58a, 12th Dūrgā	99	0.3	0.46	<0.2	0.08	0.15	0.11	<0.3	0.02
15, 10th Manasā	85	<0.08	3.2	10.5	>1.0	0.23	0.21	<0.3	0.02
39, L11th Maitreya	91	<0.08	<0.05	8.1	0.31	0.19	0.12	<0.3	0.01
45, L11-E12th Viṣṇu	92	<0.08	<0.05	6.8	>1.0	0.06	0.14	<0.3	0.01
48, E 12th Tārā	91	<0.08	0.92	6.7	0.65	0.12	0.23	<0.3	0.01
56, 12th Dūrgā	91	<0.08	0.92	7.0	>1.0	0.12	0.16	<0.3	0.02
58b, 12th Dūrgā fig.	91	<0.08	<0.05	7.9	0.05	0.02	0.12	<0.3	0.02
34, M 11th Buddha	97	2.3	<0.05	<0.2	0.4	0.17	0.08	<0.3	0.02
6, L 8th Sūrya	90	7.2	1.5	0.7	0.45	0.23	0.06	<0.3	0.02
7, E 9th Viṣṇu	88	8.7	2.2	0.6	0.35	0.29	0.05	<0.3	0.03
8, M 9th Viṣṇu	87	8.8	2.7	0.5	>1.0	0.30	0.09	<0.3	0.03
38, L 11th Gaurī	95	1.9	1.2	<0.2	>1.0	0.31	0.40	<0.3	0.03
58C, 12th Dūrgā	94	1.1	3.6	<0.2	0.35	0.19	0.27	<0.3	0.03

Table 2. Specification of the images and the set up of ERESCO 300KV Portable X-Ray machine at National Test House at Kolkata used for x-ray radiographic analysis

Accessn. No	Size in mm	Specification of the sample	S.F.D.* in cm	Voltage (KV)	Time (Min)
123	70 X 110 X 13	Buddha	91.44	190	8.5
124	80 X 110 X 15	Buddha	91.44	200	10.0
125	90 X 120 X 14	Buddha	91.44	195	7.0
126	70 X 100 X 12	Buddha	91.44	200	7.5
127	110 X 190 X 17	Hindu	91.44	180	6.0
128	90 X 165 X 30	Hindu	91.44	170	3.0
129	90 X 120 X 22	Hindu	91.44	200	8.5
130	110 X 120 X 10	Hindu	91.44	170	3.5
131	65 X 100 X 10	Hindu	91.44	185	7.5
132	70 X 70 X 11	Hindu	91.44	185	7.5
133	40 X 80 X 12	Hindu	91.44	170	5.0
134	50 X 80 X 10	Hindu	91.44	170	4.0
135	40 X 70 X 10	Hindu	91.44	150	2.5
136	80 X 130 X 9	Back slab	91.44	160	3.5
137	120 X 4	Circular Lid	91.44	170	3.5

*Source to film distance (S.F.D.) = 36"= 91.44 centimeter

radiographs, the conclusions that were drawn on the manufacturing techniques of the images are shown in Table 3.

b) Elemental Analysis by EDXRF Technique

This experimental set up consists of a 60 watt Kevex x-ray tube, an ORTEC Si(Li) detector with the necessary pulse processors and an OXFORD MCA card. The *bremsstrahlung* emitted from the tungsten anode of the x-ray tube was reflected from a secondary target. The secondary target in our present case was a pellet of a Ba compound. The characteristic x-rays from the secondary target were then used to excite the images. The resolution of the detector was 160 eV at 5.9 keV. The X-ray tube was run at 45 KV with a current of 0.15 mA. Four different spots on the surface of each statue were selected for the exposure. For each spectrum, the average time required was 30 minutes. Two typical spectra from sample No. 125 and 134 are shown in Figs 1(a) and 1(b). Using the same procedure as described by Mandal *et al*.[16], all the spectra were analysed and the concentration of the elements present in these 15 objects were obtained and shown in Table 4 and 5.

Table 3. Observations made from the X-ray Radiograph of the samples

Accessn No.	Type of Statue	Findings by X-Ray
123	Avalokiteśvara	Solid at the top,hollow at the bottom, no use of chaplets or armature was detected
124	Bejewelled Buddha	Solid but bottom is open, no evidence of armature or clay core was detected
125	Bejewelled Buddha	Solid but bottom is open, no evidence of armature or clay core was detected
126	Bejewelled Buddha	Solid but bottom is open, no evidence of armature or clay core was detected
127	Viṣṇu-Lakṣmī-Sarsvatī	Solid, no use of armature or clay was detected
128	Umā-Maheśvara	Solid, no use of armature back rest mechanically joined
129	Umā-Maheśvara	Solid, no use of armature or clay was detected
130	Gaṇeśa-Lakṣmī-Kuvera	Solid, no use of armature or clay was detected
131	Gaṇeśa	Solid, no use of armature or clay was detected
132	Śaivīte Cult Object	Hollow, no core or chaplet was used
133	Devī	Solid but bottom is open, no evidence of armature or clay core was detected
134	Devī or Goddess	Solid, no use of armature or clay was detected
135	Devī or Goddess	Solid, no use of armature or clay was detected
136	Backrest	Solid
137	Lid	Solid, geometrical design revealed below corrosion layers

Results and Discussion

For convenience of discussion, we shall divide the results into two groups. The first group, the results for which are given in Table 4, consists of the nine Brahmanical images, a back-slab (sample No. 136) and a metal lid (sample No. 137). For these eleven objects the results of EDXRF analysis done at four different spots on the surface of each of the samples are in fair degree of agreement. As an illustration, Figures 2(a) and 2(b) show the four spots chosen for sample No. 128. Consequently, for each of these samples, the average value of the four measurements is shown in Table 4.

We notice that the metal lid (sample No. 137) is of almost pure copper (> 99%), with very small (~ 0.2%) amounts of zinc and tin which

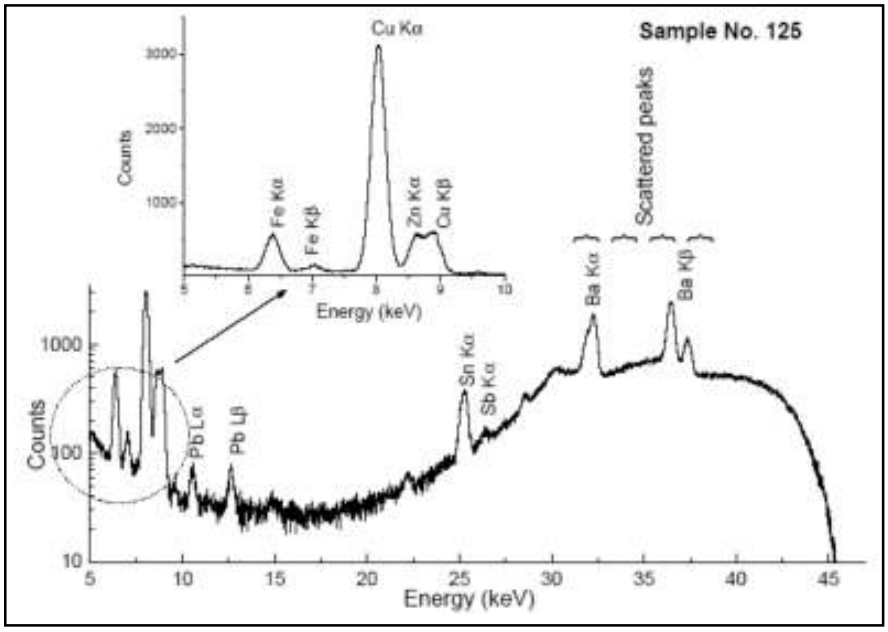

Fig. 1(a). EDXRF Spectrum from sample No. 125

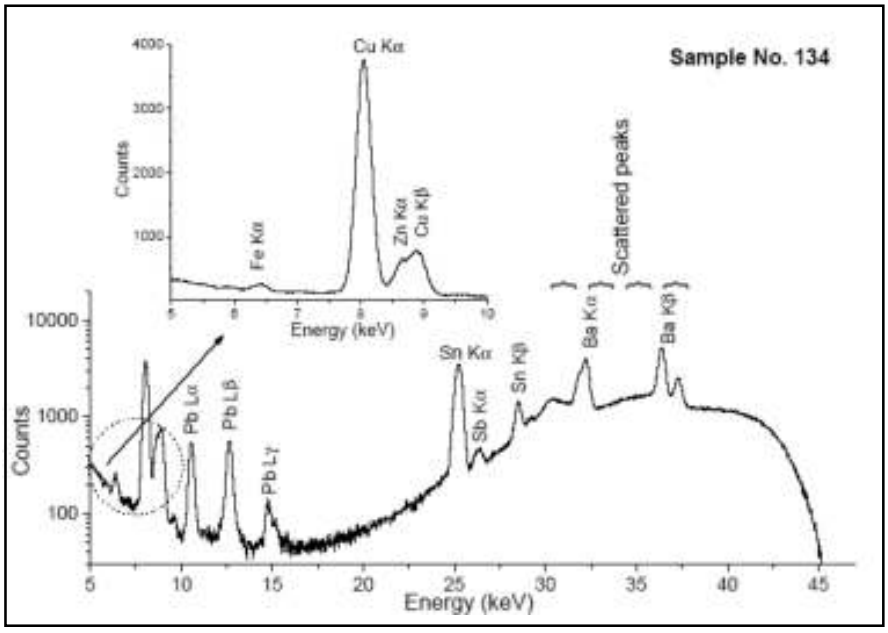

Fig. 1(b). EDXRF Spectrum from sample No. 134

Table 4. Compositional analysis of the nine Brahmanical images, a back-slab (Sample No. 136) and a metal lid (Sample No. 137), as obtained by the EDXRF

Sample No.	Fe	Cu	Zn	Pb	Ag	Sn	Sb
127	0.0	75.79	6.63	1.36	0.0	8.93	7.29
128	0.24	78.07	10.41	10.59	0.0	0.55	0.14
129	0.17	83.39	9.60	3.09	0.0	0.86	2.89
130	0.18	83.93	9.43	3.16	0.0	2.02	1.28
131	0.26	81.14	10.09	2.19	0.0	1.15	5.17
132	0.14	79.13	10.10	1.01	0.15	6.98	2.49
133	0.26	82.78	8.77	2.58	0.38	3.68	1.55
134	1.53	44.42	5.19	0.86	0.0	42.84	5.16
134m	1.22	46.55	4.13	0.54	0.0	43.64	3.92
135	0.28	86.28	6.23	2.66	0.17	1.49	2.89
136	0.46	75.25	10.30	6.09	0.0	0.76	7.1
137	0.0	99.55	0.27	0.0	0.0	0.18	0.0

Table 5. Compositional analysis of the four different spots of the Buddhist images by the EDXRF

Sample No.	Fe	Cu	Zn	Pb	Sn	Sb
123-1	12.09	70.40	13.92	3.18	0.06	0.35
123-2	73.30	3.59	1.16	21.90	0.04	0.01
123-3	85.97	7.58	2.04	4.03	0.08	0.30
123-4	74.70	18.20	2.06	4.34	0.20	0.50
124-1	80.25	10.00	1.50	0.63	5.32	2.30
124-2	26.22	29.00	4.17	0.21	37.9	2.50
124-3	56.50	29.85	3.70	0.35	8.50	1.10
124-4	78.60	9.96	0.84	0.56	8.89	1.15
124m	84.57	8.09	0.84	0.56	4.38	1.56
125-1	2.20	85.38	9.51	0.55	1.88	0.48
125-2	20.84	66.96	7.21	1.54	2.34	1.11
125-3	3.51	74.47	18.04	1.35	1.80	0.83
125-4	12.86	70.15	13.69	1.81	1.07	0.42
126-1	34.16	19.34	1.02	0.11	32.86	12.51
126-2	13.84	4.96	1.32	0.26	48.78	30.84
126-3	2.27	6.98	1.45	0.24	53.02	36.04
126-4	38.11	28.16	1.46	0.14	20.63	11.50
126n	1.76	22.11	1.74	0.19	37.21	36.99
126m	1.59	50.53	0.63	0.19	22.77	24.29

(a)

(b)

(c)

Figs. 2(a) and 2(b). Four different spots chosen for analysis of sample No. 134, Devī front and back, **2(c).** X-ray image of the sample No.134.

were probably present in the ore itself. Out of the rest, all objects except sample No. 134, contain mainly copper with varying amounts of zinc, lead, tin and antimony, and very small (~ 0.2 to 0.4%) amounts of iron. Three of the samples show trace (~ 0.2 to 0.4%) presence of silver.

Compositionally the sample No.134 [Figs. 3(a) and 3(b)] is entirely different from the other ten samples. It contains almost equal amounts of copper and tin, small amounts of zinc and antimony, and trace amounts of iron and lead probably from the ore. Keeping in mind that the EDXRF technique is surface sensitive, we filed off a few mono-layers from a small area at the back of the sample and exposed it to EDXRF analysis once again. The result of this is entered as sample No. 134m in Table 4. We notice that the results for sample No.134 and 134m are again in reasonably good degree of agreement.

Table 5 shows the compositional analysis of the four Buddhist images (Fig. 4). The results for the four different spots for a particular sample have been separately listed here because the respective compositions are widely divergent. In such a situation, taking averages would have been absolutely meaningless. This clearly indicates that these four metal images are definitely not of homogeneous composition.

Of the four images, the fourth one (sample No. 126) is very different from the other three. It contains sizable amount of antimony, whose presence in the other three samples of Table 5 is minimal. Similar to what we did for sample No 134, we located a plain area at the back of this image and measured the composition before (sample No.126n) and after (sample No. 126m) removal of a few mono-layers of material from this spot. Comparing the entries for 126n and 126m we notice that the relative composition of the metals have undergone noticeable change by the removal of some material from the spot. For example, the composition of copper has increased from 22% to 50%, while those of tin and antimony have decreased from 37% to 23% and from 37% to 24% respectively. Such a large variation of concentration is attributable to the highly inhomogeneous nature of the Buddhist images.

All the Brahmanical images were found to be homogeneous. Similar compositions were obtained from analyses of Bronze images from Nalanda and Jhewari. Except sample No. 134, all of the images have Cu as the major

(a)

(b)

(c)

Figs. 3(a) and 3(b). Four different spots chosen for analysis of sample No. 128, Uma Maheśvara front and back. **3(c).** is the X-ray image of the sample No. 128.

Fig. 4. Four analysed Buddhist sculptures, Avalokiteśvara and three bejewelled Buddhas, front side and back side.

element with Fe, Zn, Pb, Ag, Sn and Sb in varying proportions. The reason why the sample No.134 has almost equal amount of Cu and Sn may be answered from the compositional analysis of the images of Nalanda and Jhewari. It was observed[5] that images of the two places were mainly composed of Cu – Zn or Cu – Sn alloy with small admixture of other elements. The concentrations of Zn or Sn were also variable and in one of the images of Nalanda, the amount of Sn was as high as 23%.

So far as the Buddhist images are concerned, they have one thing in common – all the images are highly inhomogeneous, indicating that the places of origin of these images are perhaps different from those of the Brahmanical ones. With such a high degree of inhomogeneity, it is also difficult to compare the elemental composition of the images with those of Kurkihar whose stylistic features are very similar to the present images. In Table 1, no mention has been made about Sb content in the Kurkihar images. Moreover, it is also observed from the same Table that the Fe concentration in these images are very low. Present analysis of the Buddhist images (Table 5) shows the presence of Sb (maximum of 37% for sample No. 126) and a high concentration of Fe. So one might be tempted to suggest that the present images were fabricated at a place different from Kurkihar but to make them appear close to the images of Kurkihar, the manufacturer probably emulated the same stylistic convention.

It is observed from Table 1 that the maximum concentration of Fe in the Bronze images of this region is ~ 6%. It is really surprising to notice that although the maximum concentration of Fe in the Brahmanical images is ~ 2%, the Buddhist images show a maximum concentration value upto ~ 86%. At present, we are not in a position to suggest any explanation as to why do the Buddhist images have so high concentration of Fe.

Conclusions

(1) The Brahmanical images are homogeneous while the Buddhist images are highly inhomogeneous indicating, possibly, that the places of origin of these two types of images are different.

(2) Although the stylistic pattern of the Buddhist images is similar to those from Kurkihar, the presence of Sb and high concentration of Fe suggests that these four Buddhist images might have been made at a different place.

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