

Table 3. Correlation matrix of pollutants concentration and meteorological variables

	O ₃	NO ₂	SO ₂	T _{max}	T _{min}	Rainfall	R _h	Wind speed
O ₃	1.0	-0.48*	0.05 ^{NS}	0.80**	0.43**	-0.27 ^{NS}	-0.81**	0.76**
NO ₂		1.0	0.84**	-0.76**	-0.95**	-0.55**	-0.04 ^{NS}	-0.59**
SO ₂			1.0	-0.48*	-0.85**	-0.73**	-0.38 ^{NS}	-0.30 ^{NS}
T _{max}				1.0	0.82**	0.27 ^{NS}	0.49*	0.75**
T _{min}					1.0	0.52**	0.04 ^{NS}	0.63**
Rainfall						1.0	0.52**	0.19 ^{NS}
R _h							1.0	0.11 ^{NS}
Wind speed								1.0

T_{max}, maximum temperature, T_{min}, minimum temperature, R_h, relative humidity

*p < 0.05, **p < 0.01, NS not significant

subcontinent. Because no single pollutant can be identified as being responsible for causing potential vegetation damage under field conditions, precise data are needed regarding the levels of major phytotoxic air pollutants and the timing of multipollutant exposure. This is specially important in seasonally dry tropical areas where frequent temporal variations in the concentration of phytotoxic air pollutants occur due to frequent climatic variations. Ozone concentrations peaked during dry summer days when it is known to be less toxic to plants^{18,19}. The concentrations of NO₂ were below those that produce visible injury or growth suppression in plants²⁰. However, the magnitude of the effects observed in the field studies was highly significant²¹. It is suggested that as there is normally a coincidence in the timing of SO₂ and NO₂ peaks, their combined rather than individual effects need to be considered while assessing vegetation damage, especially in winter months. However, in summer, ozone can have a greater impact. The results have implications in defining pollutant exposure regimes and to set the receptor-based air quality standards.

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Energy-dispersive X-ray fluorescence analysis of Kushan period coins

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Kushan period coins (78 AD), recovered from the Handwara region of South Kashmir (India) were subjected to non-destructive energy-dispersive X-ray fluorescence analysis to determine their elemental composition. Based on the observation and the uniformity of composition, it is concluded that the process of extraction of metals from their ores and techniques for the production of alloys was well known to the craftsman of that era.

The Department of Archives, Archaeology and Museums of the Jammu and Kashmir state (India) has

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been engaged in a search for the venue of Kanishka's Buddhist council in Kashmir and has carried out excavations at various sites¹. During these excavations, copper coins belonging to the Kushan period were unearthed at Maidan Chogul, Handwara, in South Kashmir^{1, 2}. The coins are of great historical and archaeological significance as their discovery lends authenticity to the fact that Kashmir formed a part of the Kushan empire, the prevalence of the Kushan coins in ancient Kashmir is thus a historic reality and not a mere accident or chance. That Kashmir formed a part of the Kushan empire is amply borne not only by literary evidence available in Vedic and Buddhist literature but also by the nomenclature of certain places of Kashmir such as Hushkapur, Jushkapur and Kanishkapur named after the Kushan emperors²⁻⁸.

Archaeological coins from different periods differ in average composition of major and minor elements. The trace element content could indeed be regarded to some extent as finger point of the coins of any king. Moreover the association of a number of trace elements in the coin material is an important criterion for identifying ancient coins from the modern fake ones. The quantitative analysis of the coins also yields evidence relating to the source of the metal used in minting, location of the mint of a group of coins, technological trends in minting, provenance of the object, etc. and these are of interest to archaeologists. So far little attention has been given in elemental analysis of coins^{10, 11} using the energy-dispersive X-ray fluorescence (EDXRF) technique. In the present study we describe the results of X-ray fluorescence spectrometry of the coins which seem to indicate that metallurgy of various metals like Cu, Fe, Ni, As, Sn and Sb and alloy-making was well developed in the Kushan period.

The coins were first cleaned by distilled water to remove the surface dirt etc., preserved to avoid further contamination and introduced as such into the sample holders for analysis. Mylar foil deposited with thin film of multielements Zn, Ba wrapped over the coin sample were used to calibrate the system for excitation and detection of characteristic X-ray from the range of elements of interest. The essential features of this system were reported elsewhere¹². The excitation of fluorescent X-ray spectrum of one of the coins is shown in Figures 1 and 2. A fundamental parameter approach is generally used to calculate the concentrations of various elements using the expression^{13, 14}

$$T_j = T_0 G K_j m_j A_j \quad (1)$$

where m_j is the concentration of the j th element, T_j the intensity of the fluorescent X-ray peak of any element j , T_0 the incident flux on the coins, G the geometrical factor, K_j the relative excitation efficiency and m_j the mass of the j th element present in the sample. A_j is the correction factor for the absorption of incident and

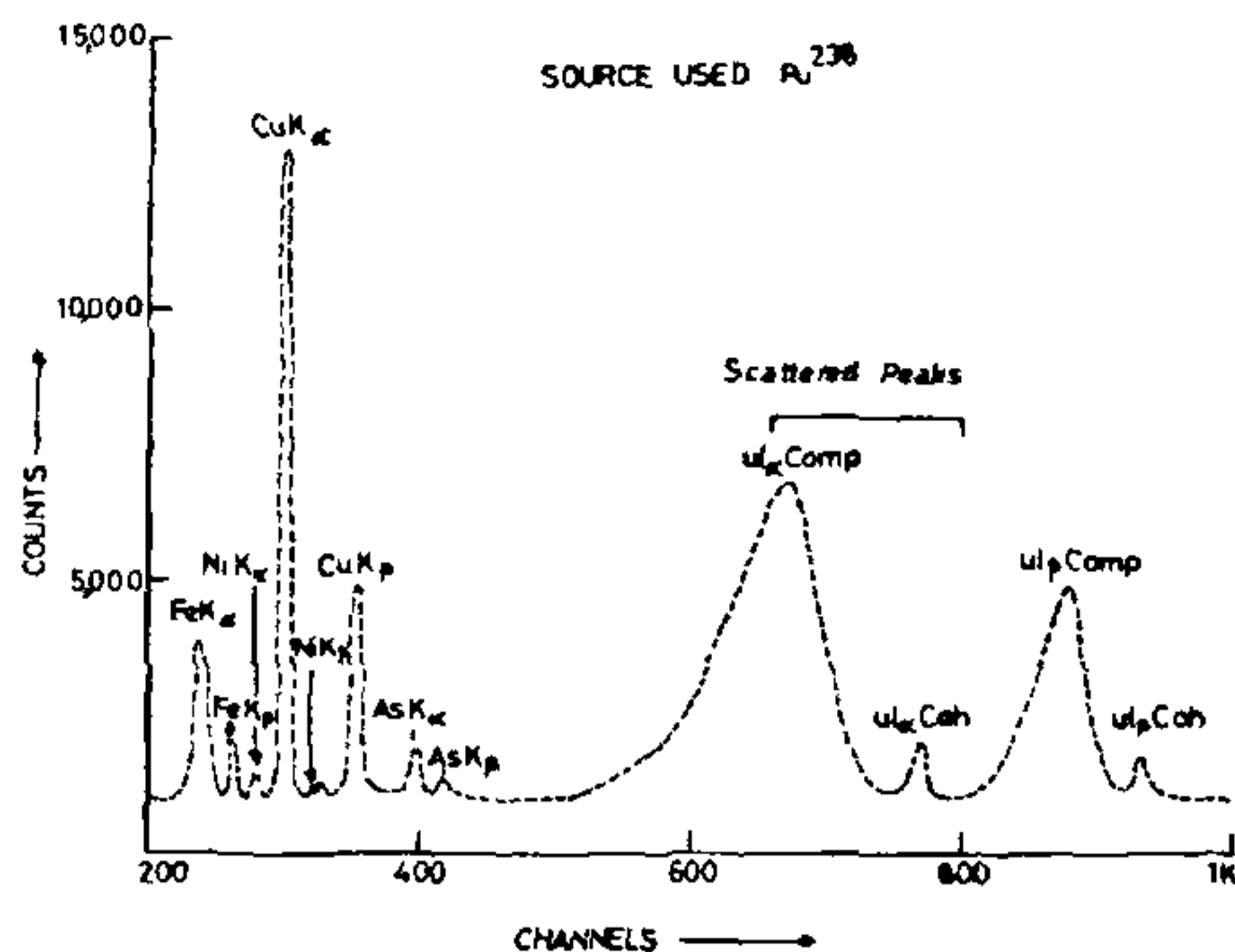


Figure 1. A representative X-ray spectrum of the Kushan coin sample using ²³⁸Pu excitation source

fluorescent X-rays of the j th element in the sample. The relative excitation efficiency is calculated as

$$K_j = T(1 - 1/J_{k,1}) W_{k,1} f, C, T, \quad (2)$$

where T is the photoabsorption cross-section at the exciting energy¹⁵ and $J_{k,1}$ is the jump ratio¹⁶ and $W_{k,1}$ is the appropriate relative fluorescent yield¹⁷, f the fractional intensity of the X-ray line under analysis. T is the transmission coefficients for the fluorescent X-rays through the Be window and air path and C the detector efficiency.

The peak intensities were corrected for absorption of incident and fluorescent in the sample matrix. In this analysis Cu, Fe was chosen as the sample matrix. A_j is given by

$$A_j = 1 - \exp \frac{(\mu_i \text{ cosec } \theta + \mu_f \text{ cosec } \phi) M}{\{\mu_i \text{ cosec } \theta + \mu_f \text{ cosec } \phi\} M}, \quad (3)$$

where μ_i and μ_f are the total absorption coefficients for the incident and fluorescent X-rays of element j respectively and θ and ϕ are the angles made by the incident and fluorescent X-rays normal to the sample and M the thickness of the sample (g/cm^2), while ²³⁸Pu radioisotope source was used for excitation of X-ray fluorescence in low and medium Z elements for heavier elements like radioisotope source.

Figures 1 and 2 show typical X-ray fluorescence spectra obtained from one of the sample coins. The most prominent feature is the strong CuK_α line at 8.04 keV along with similar intensity CuK_β , FeK_α and FeK_β at 8.95, 6.04, and 7.05 keV respectively. In addition, several line features due to As, Ni, Sn and Sb are also seen.

Table 1 summarizes the results from the elemental composition of the sample coins (Figure 3). The main

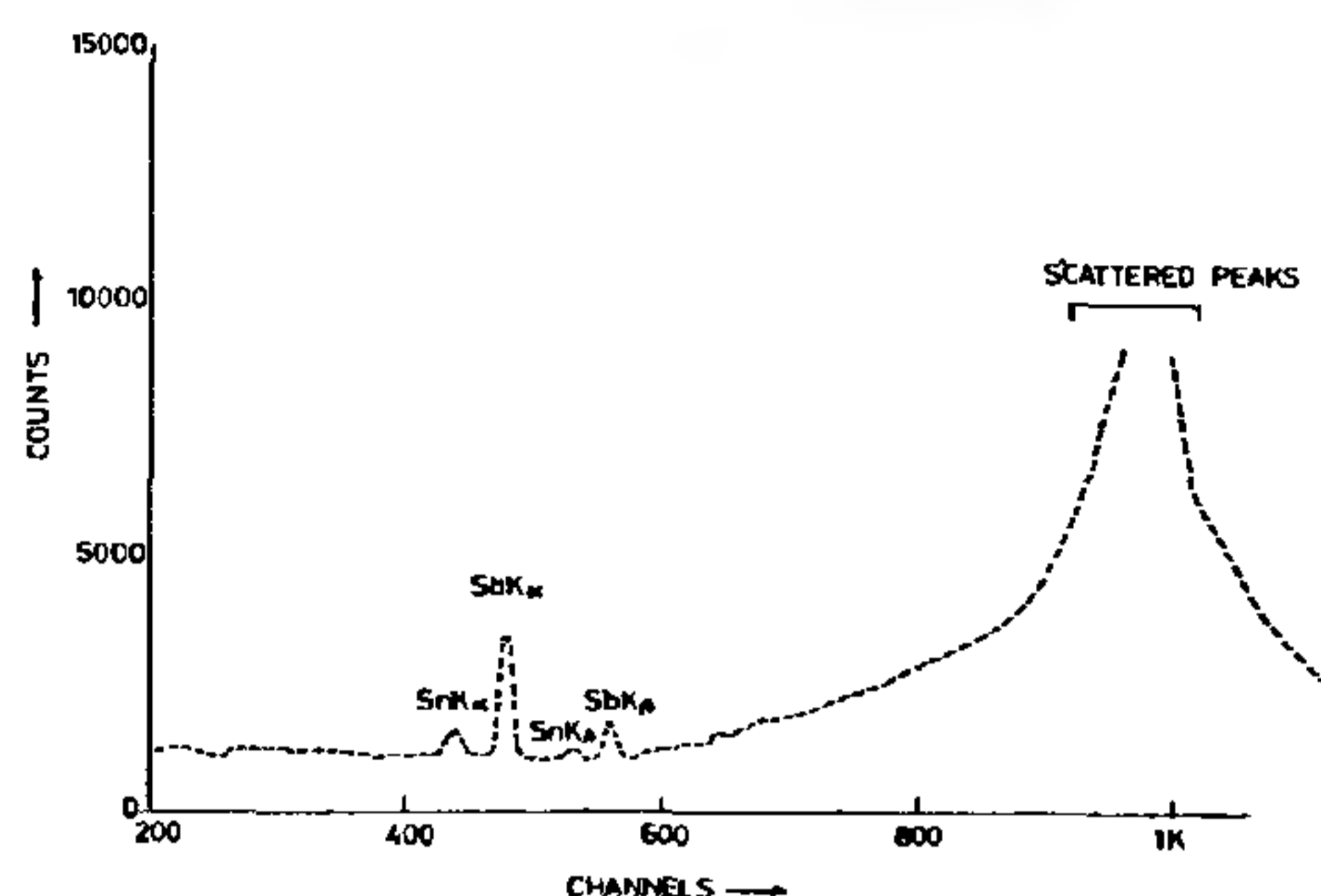


Figure 2. A representative X-ray spectrum of the Kushan coin sample using ^{241}Am excitation source

Table 1. Concentration of various elements of Kushan coins

Coins sample	Elemental concentrations					
	Fe% $\pm \sigma$	Cu% $\pm \sigma$	Ni% $\pm \sigma$	As% $\pm \sigma$	Sn% $\pm \sigma$	Sb% $\pm \sigma$
78 AD						
Sample 1	9.90 \pm 0.05	82.85 \pm 0.12	0.220 \pm 0.009	1.05 \pm 0.02	0.200 \pm 0.008	2.15 \pm 0.007
Sample 2	9.92 \pm 0.05	82.83 \pm 0.12	0.210 \pm 0.008	1.08 \pm 0.03	0.208 \pm 0.008	2.08 \pm 0.007
Sample 3	9.96 \pm 0.06	82.89 \pm 0.12	0.190 \pm 0.008	1.02 \pm 0.02	0.215 \pm 0.009	2.10 \pm 0.007
Sample 4	9.98 \pm 0.06	83.20 \pm 0.13	0.195 \pm 0.008	0.98 \pm 0.02	0.220 \pm 0.009	2.00 \pm 0.006
Sample 5	9.93 \pm 0.05	83.0 \pm 0.13	0.198 \pm 0.008	1.05 \pm 0.03	0.240 \pm 0.009	1.95 \pm 0.006
Sample 6	10.05 \pm 0.06	82.87 \pm 0.12	0.200 \pm 0.008	0.97 \pm 0.02	0.198 \pm 0.008	1.98 \pm 0.006
Sample 7	10.08 \pm 0.06	83.10 \pm 0.12	0.205 \pm 0.009	1.04 \pm 0.03	0.196 \pm 0.008	1.90 \pm 0.006

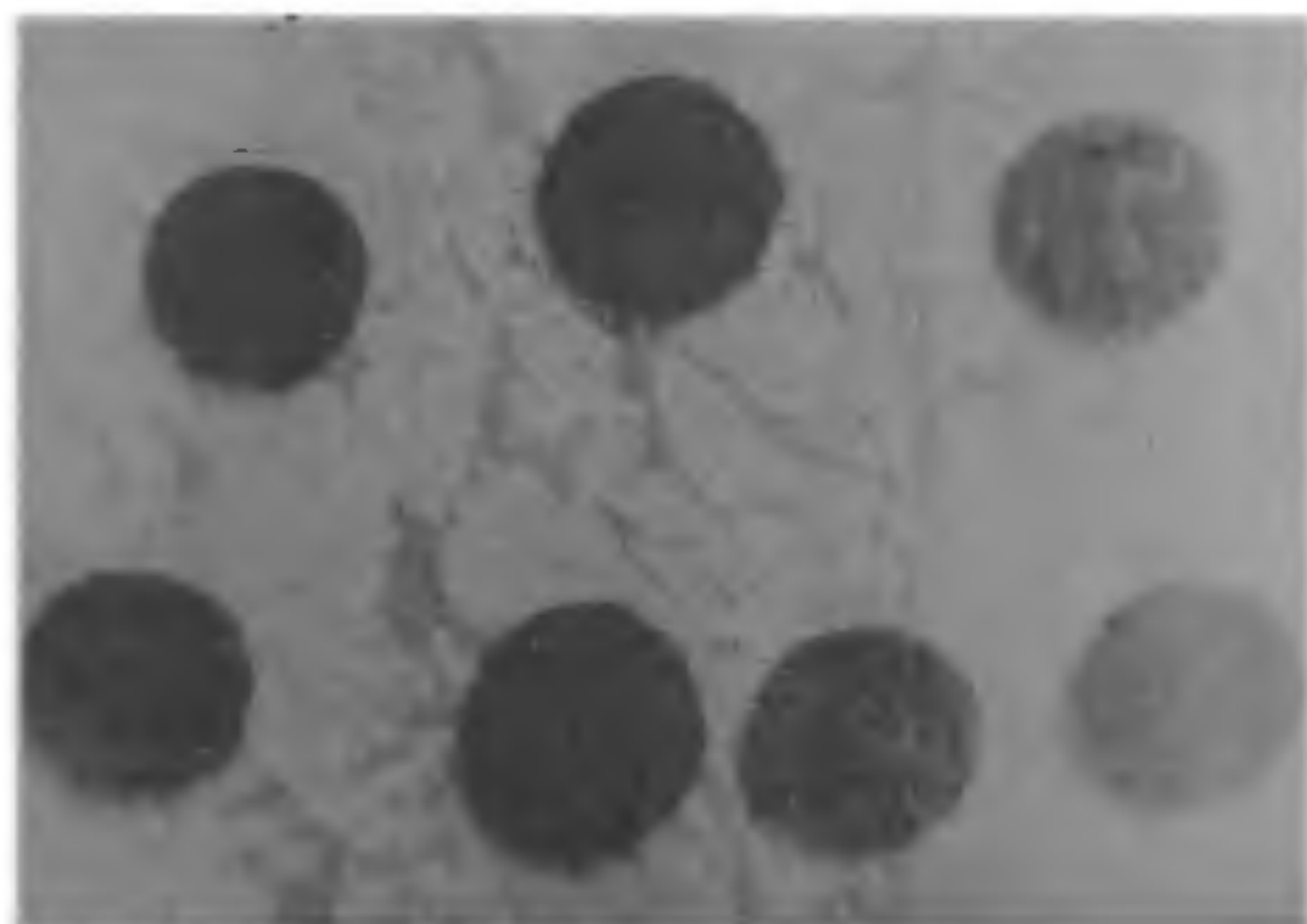


Figure 3. Kushan coins at the beginning of the Christian era

components are found to be Cu (83%), Fe (10%) and Sb (2%) with small concentration of Ni, As and Sn. A remarkable feature in Table 1 is the almost complete uniformity in composition of the various sample coins, suggesting that the coins were either made from the same parent mixture or if they were made from different

parent mixture these had to be quite similar to one another. The latter suggestion, if true, implies that alloy-making process was highly developed in this era, notwithstanding the fact that the identification of ores and extraction of different metals from them is a complex process. Thus it appears that the people of that era were not only aware of the extraction processes of metals but were quite well versed in the process of alloy-making.

The Kushan period coins analysed here provide positive indications of both a full-fledged commercial culture during this era as also the mastery gained by the craftsman of this era in metal extraction and techniques of alloy-making.

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Significance of bank material at Tilakwada in Lower Narmada Valley

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The alluvial gravels in the Lower Narmada Valley (LNV) at Tilakwada are tectonically controlled and appear to have accumulated in a graben. The three horizons of gravels distinguishable on the basis of their lithofacies point to their formation by the processes of debris and stream flows.

AN example of fluvial sedimentation controlled primarily by tectonism is provided by the alluvial gravels in the Lower Narmada Valley (LNV) near the Tilakwada town 60 km south of Baroda. The thick gravel deposits (20 m) are exposed in the cliffs along the river channel (Figure 1a). Chamyal and Merh¹ included the lower two horizons of LNV gravels in their Tilakwada Formation. However, at Tilakwada three gravel horizons are distinguishable on the basis of their lithofacies; and are separated by intervening thin horizons of sand or mud.

LNV lies within the Cambay graben structure and the channel as well as its neighbourhood, especially the trap

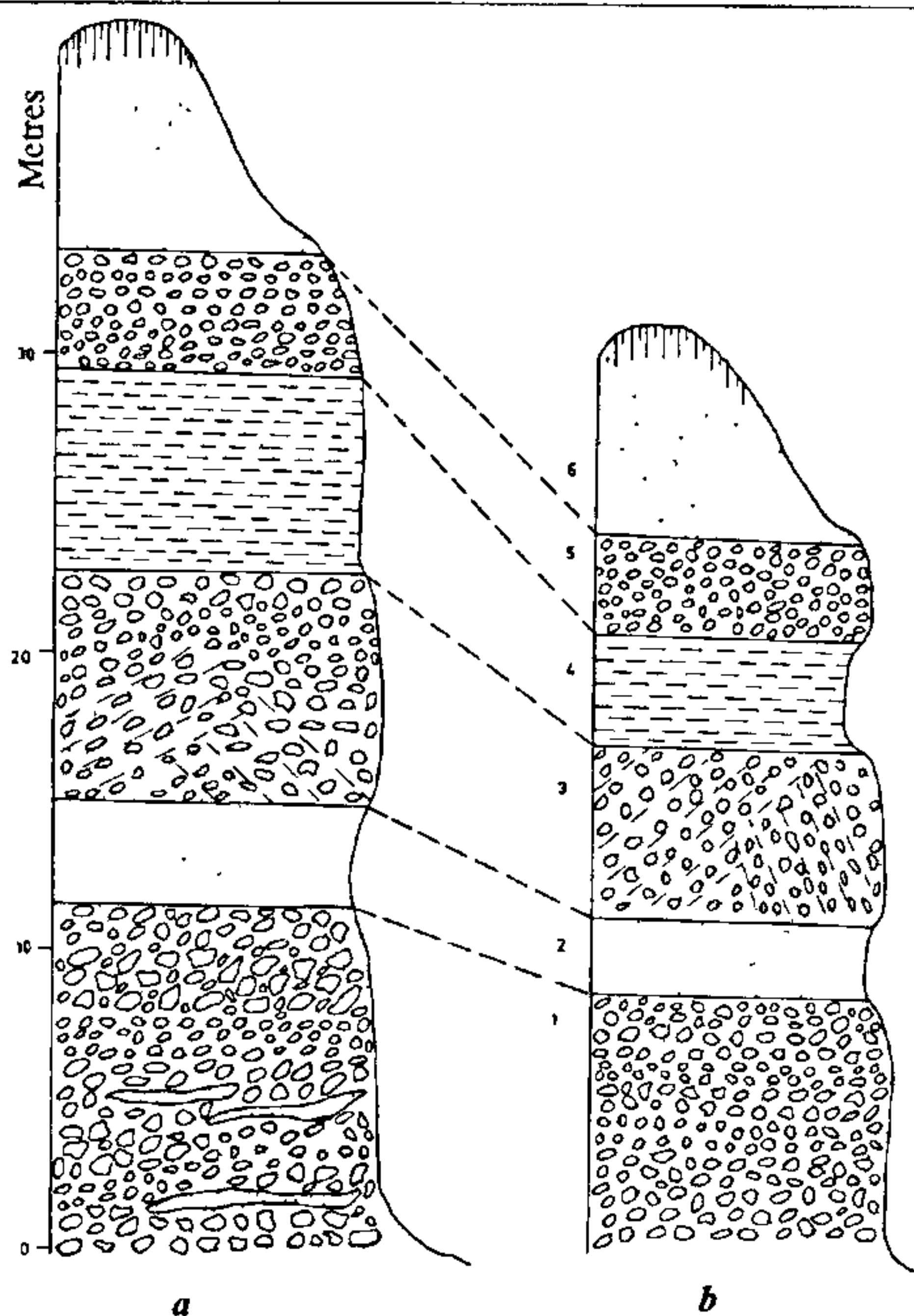


Figure 1. Quaternary sediment profile on Lower Narmada river (a) Tilakwada, (b) Maletha (after Chamyal and Merh¹) 1, Clast to matrix supported poorly sorted coarse gravel, 2, stratified sand, 3, stratified medium to fine gravel, 4, laminated mud/sand, 5, clast supported medium to coarse unstratified gravel, 6, Dunal sands

highlands to the south point to the existence of two sets of fractures N-S and E-W, related to the Cambay and Narmada basin tectonics^{2,3}. Bedi and Vaidyanadhan⁴ have shown an identical lineament pattern in LNV. The graben at Tilakwada is located quite close to the intersection of the eastern boundary of the Cambay basin and Narmada fault and has provided an appropriate depression in which the gravels got accumulated.

The gravels exposed on the right bank of the Narmada river around Tilakwada form a distinct 40 m high cliff (Figure 1a). Sequence of the gravels as given by Chamyal and Merh¹ along Narmada at Maletha is also taken into account (Figure 1b). The lithofacies type of lowermost gravel forms an accumulation of subangular to subrounded boulders, cobbles, pebbles and smaller clasts of volcanics, quartzites and sandstone and is either matrix or clast-supported. The entire thickness is rather unstratified and the mean dip of the longest axes of the gravels is in the upstream direction. Texturally, the lithofacies comprises gravel about 75%, sand 15%, silt 7% and clay 3%. The mean size (ϕ) and the