SOURCE OF THE METAL IN THE LEAD COINS OF THE KSHATRAPA PERIOD

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FORTY-FIVE lead coins were recovered in stratified association with sherds of Roman amphoræ, Red Polished Ware, Painted Ware and crude Black and Red Ware, all of which belong to the early centuries of the Christian era, in an excavation of the early historic site at Nagara (70° 38′ 33″ E, 20° 41′ 15″ N) in Cambay Taluka, Kaira District, Gujarat State. The excavation was carried out by the Department of Archæology and Ancient History of the Faculty of Arts, M.S. University of Baroda, during the field seasons of 1963-64 and 1964–65, under the direction of Professor R. N. Mehta.[1]

Lead coins in similar stratigraphic association have been recovered from Vadnagar,[2] Devnimori[3] and Shamalaji.[4] But as the coins carried only motifs without any legend or date, it was not possible to ascribe them to any particular dynasty of rulers.

On chemical treatment for removal of corrosion incrustation, several among the Nagara coins revealed bull motif on the obverse, mountain and moon motifs on the reverse. A few of them also revealed a human figure with dots on the obverse, lion or mountain and moon motifs on reverse or *Vajra* symbol on the obverse, horse and wheel motifs on the reverse.

One of these coins was particularly interesting because it revealed a standing bull on the obverse, mountain and moon motifs on the reverse and below them there was the date of issue of the coin which was deciphered by the excavator as the year 285 in Saka era, that is, 363 A.D. On the basis of this date and the motifs which the coins carry it has now been possible to tentatively ascribe these coins to the Kshatrapa dynasty,[5] which ruled parts of Western India from the beginning of 2nd century A.D. to the end of 4th Century A.D.

These coins were found in circular, rectangular and square shapes. They were all thickly encrusted with corrosion compounds. After chemical treatment for reduction of corrosion incrustation, most of them were found to be highly worn out. Their weight varied from 6·136 gm. to 1·263 gm. Their thickness was not uniform.

As these lead coins were widely circulated in Western India and now firmly dated, it was considered desirable to investigate the source of the lead metal. An analytical study carried out on the Kshatrapa silver coins had indicated that the silver metal was not extracted from the indigenous source but was probably imported.[6] It was, therefore, interesting to know whether the lead metal of the coins was extracted from the locally available source or imported. It was also considered desirable to learn the quality of the metal, whether it was pure or deliberately alloyed.

For the purpose of analytical study sound core of the metal was selected from two coins after their chemical treatment for corrosion incrustation. The coins were partially worn, but both clearly carried extant remains of the Kshatrapa motifs of bull on the obverse, mountain and moon symbols on the reverse.

FIG. 1. Obverse and reverse of the date bearing lead coin excavated from Nagara, × 2.

Source of the Lead Metal.—The principal ore of lead is galena or lead sulphide, PbS. Lead deposits are also found as anglesite, $PbSO_4$, lanarkite, PbO. $PbSO_4$ and cerussite $PbCO_3$. Galena in small quantities, sometimes accompanied by cerussite, has been found at many places in India. Larger deposits of the ore are observed at Dhadka in Bihar, Metri in Mysore, Riasi and Kistewar in Kashmir and the Aravalli region in Rajasthan.[7] Among these deposits, the Rajasthan deposits are the largest. They are located at several places on the Aravallies. One of these is at Zawar, 15 miles south of Udaipur. This deposit, spread over a large area, comprising Mochia Mangra, Baror Mangra and Zawar Mala hills, is also observed to have been worked for centuries as there are vast lead metallurgical slag heaps in the area.[8] The ore here mainly constitutes argentiferous galena, associated with zinc blende.

The Aravalli region lead deposits were the closest to the Kshatrapa kingdom. Probably the ore deposits were within the limits of the kingdom. In view of the fact that the Zawar deposits were worked for centuries, it was interesting to investigate whether it was possible to link the Kshatrapa period lead coins with the Aravalli region galena deposits.

All ancient metal objects contain a large number of elements, some of them in minute traces, as impurities. These impurities are chance inclusions in the metal. They are drawn into the composition of the metal from the raw material from which the metal was extracted. A comparative study of impurity patterns in the objects and the likely ore deposits is helpful in determining the geographic origin of the metal of the objects.

Therefore a spectrometric study was carried out in samples cut from the coins and the ore deposit, obtained from Zawar, to determine their respective impurity patterns. The study revealed the data as shown in Table I.

Table I shows that the pattern of impurities in the ore sample and the coins is almost the same. The coins contain all the impurities present in the ore except calcium and beryllium in coin I and calcium in coin II. Further, the coins do not contain additional impurities which the ore in itself does not contain. Therefore, it is possible to observe that the metal of the coins was probably extracted from the Zawar galena deposits. From this it is also possible to observe that the Indian lead metallurgical industry was at least sixteen centuries old, probably two centuries older.

Quality of the Metal.—Lead is one of the softest and heaviest of common metals. It can be cut by knife. It can be rolled and extruded. It is, therefore, not a suitable coinage metal. Coins need a stronger and harder metal. The only endearing quality of lead for coinage is its high resistance towards corrosion. Strength and hardness of lead can be improved by alloying with antimony, arsenic or copper. It was, therefore, interesting to investigate whether this metal was used in minting the coins as extracted or alloyed.

A quantitative chemical analysis in the two coins revealed the following percentage composition.

TABLE II

Specimen	Composition							
	Pb	Zn	Mg	Al	Cu	Sb	As	Undetermined
Coin I	97·40	1·26	0·26	0·38	tr	tr	tr	0·70
,, II	97·21	1·18	0·42	0·29	,,	,,	,,	0·90

The percentage composition of the coins indicate that the lead metal was used as extracted. It was not alloyed to improve its hardness and strength.

TABLE I

Specimen	Impurity pattern																								
	Zn	Ag	Au	Cu	Fe	Mg	Ca	Al	Mn	Cr	Co	Ni	Hg	Bi	Cd	As	Sb	Sn	Be	V	Ru	Pt	Mo	Ir	U
Galena ore ..	+	+	+	+	+	+	+	+	+	–	–	–	–	–	+	+	+	+	+	+	+	+	–	–	–
Coin I ..	+	+	+	+	+	+	–	+	+	–	–	–	–	–	+	+	+	+	–	+	+	+	–	–	–
,, II ..	+	+	+	+	+	+	–	+	+	–	–	–	–	–	+	+	+	+	+	+	+	+	–	–	–

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MORPHOLOGY OF THE "SQUAMELLAE" IN THE LIGHT OF THEIR ONTOGENY

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SQUAMELLAE (or colleters), which are a characteristic feature of the Apocynaceæ, Asclepiadaceæ and others,[8-12] have been variously interpreted in the literature, *viz.*, as hairs,[12] stipules,[2,6,8-11] ligules[9] and receptacular outgrowths.[8,9] But all these workers have drawn conclusions from the mature structure of the squamellæ and their organographic position rather than on their ontogeny. The authors present here their findings on the ontogeny of the squamellæ in *Allamanda cathartica* L., and *Tabernœmontana divaricata* (L.) R. Br. (Apocynaceæ), because of the conclusive nature of the evidence they provide relating to their morphology.

Allamanda cathartica: The squamellæ occur only at the leaf-base towards its adaxial side (Fig. A). Each leaf bears 10 to 13 squamellæ arranged in a transverse row which in young buds cover the shoot apex; none occur on the sepals unlike in some other species of the family,[1,8,9] though one or two are borne on the distal margin of the bracts and bracteoles (Fig. N). While young, the squamellæ secrete a sticky substance which coats the shoot apex all over, probably providing it protection. The substance is brown-yellow and transparent, insoluble in water, alcohol, acetone, benzene and petroleum ether, but liquefies at high temperature; hence it is considered to be a high polymer resin. The squamellæ are 1·5 mm. long and 0·3 mm. broad, differentiated into a stalk and a head (Fig. B). The stalk is nearly cylindrical, but abaxially more curved (Fig. J), while the head, obliquely placed on the stalk, is somewhat flattened parallel to the leaf surface as shown by its transection (Fig. K). In longisections the epidermal cells of the stalk appear isodiametrical to elongated and those of the ground tissue mostly isodiametrical (Fig. M), whereas the head consists of palisade-like epidermis of densely stained cells and ground tissue of mostly elongated elements (Fig. L). The stalk is green and photosynthetic, whereas the head is brown-coloured, and glandular in nature. The details of the ontogeny are as follows:—

Squamellæ develop from primordia consisting of protoderm and the subtending subprotoderm elements appearing at the base of the leaf on its adaxial face when it is about 500 μ long (Fig. C). At this stage the leaf consists of mere protoderm, ground meristem and procambium indicating the phase of its cell multiplication rather than differentiation of any tissues. The primordial cells appear distinctive from the adjacent ones due to their relatively dense cytoplasm (Fig. C). The protoderm cells divide anticlinally, with occasional oblique and periclinal divisions, while the subprotoderm cells in various planes, particularly in transverse ones (Figs. C and D). Consequently, the primordium becomes elongated and grows upward, parallel to the leaf on which it is borne (Fig. E). The epidermal as well as ground elements of the squamellæ at this stage remain nearly isodiametrical (Figs. E and F). Later, while the ground cells elongate axially, the epidermal cells divide through rapid anticlines (occasionally in