for this phase than for other phases. Our results on K_e as a function of cell fraction also indicate a maximum value for yeast cells at the mitotic phase of the cell cycle. This may be attributed to cytological and biochemical[26] evidences such as division of centriolar plaque, fusion of elements of endoplasmic reticulum and vacuoles, appearance of thread-like mitochondria and their introduction into bud and starting of nuclear division, local weakening of cell wall by secretion of suitable enzymes, rearrangement of glucan fibrils and starting of chitin synthesis. Dielectric behaviour at 2/3 bud stage is such that it is less dielectric than at 1/3 stage and its K_e value is higher than single cell value. As we examine the double cell we notice a further reduction in the dielectric behaviour of the cell which can be attributed to its size[27]. The variations exhibited by yeast cells at different growth phases are essentially owing to cytological and biochemical alterations and are in agreement with μDEP results. The biophysical experiment like cell balance technique throws light on the electrical character of the yeast cell at different growth phases from different points of view.

In conclusion, the alterations in electrical double-layer structure are important from biological and physiological points of view. But they have not been detected so far by electrophoretic experiments[23]. However, this dielectrophoretic study demonstrates that the variation in cytological and biochemical parameters influence the electrical double-layer structure of the membrane, which is reflected through its dielectric behaviour by dielectrophoresis. Thus the cell membrane can be regarded as a dynamic system whose electrical properties are demonstrated to be related to the physiological events of yeast cells.

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Chemical analysis of lead coins of the Ikshwaku period (3rd and 4th century AD)

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Fifty lead coins of the Ikshwaku period (3rd and 4th century AD) were chemically analysed both in respect of their major and minor constituents and the results interpreted in archaeo-metallurgical terms. Although, according to Puranas, seven kings have reigned in Andhradesa after Satavahana, coins belonging to only four Ikshwaku kings have been recovered from excavations so far. The chemical analysis does not show much difference in the coins of later Satavahana and Ikshwaku except for a few coins of Ikshwaku with higher silver content. Besides, evidences have been adduced to show that the coins were fabricated from the unrefined metal. Numismatic studies show that more than one mint were used in Ikshwaku period. Provenance of the ores used for minting coins have also been studied. No elaborate treatment for desilvering of crude lead seems to have been carried out for the lead coins.

THE Ikshwakus came to power during the first quarter of the 3rd century AD. Chantamula, the founder, established a mighty dynasty defeating the Satavahana at Vijayapuri and Dharanikota. The Ikshwakus of Vijayapuri ruled the Andhradesa during 3rd and 4th century AD. Many coins found at Nagarjunakonda, Tenali, Ongole, Nelakondapally, etc. of Andhra Pradesh provide the names of four known kings. Table 1 gives the genealogy of Ikshwakus and their legends. The Tenali hoard consists of the coins issued by all the four known kings and few coins from this hoard were chemically analysed.

Although Satavahana issued coins in many metals such as lead, copper, potin, silver, the Ikshwakus used

Table 1. Data on some of the 3171 lead coins excavated in Tenali by the Birla Archaeological and Cultural Research Institute, Hyderabad (1984–85). (Legends read by Sri R. Veerender)

Type	Genealogy of Ikshwakus	Legends on lead coins
I	Vasisthiputra Sri Chantamula (227–250 AD)	SIRI CHA
II	Mathariputra Sri Virapurishadatta (250–270 AD)	SIRI VI, SIRI VIRA
III	Vasisthiputra Sri Ehavala Chantamula (270–294 AD)	SIRIE, SIRI EHA, ETC.
IV	Vasisthiputra Sri Rudrapurishadatta (294–305 AD)	SIRERU, SIRI RUDA, ETC.

only lead throughout their coinage with an elephant on the obverse and an Ujjain symbol on the reverse. Why there is only one subject on all Ikshwaku coins and why this coinage was issued only in lead remains a puzzle. Probably, the Ikshwakus might not have issued a variety of coinage concentrating on their political stabilization and they must have made the best use of the lead metal from the mines like Agnigundala in Guntur district and Mailaram in Khammam district of Andhra Pradesh, located within their territory, a fact supported by the analysis of lead ores of these mines.

Cappadocian tablets prove the existence of a fully developed silver and lead production in the second half of the third millennium BC. The galena deposits of Asia, skilled metallurgists like the Chalybes further strengthen the view that refining of silver and lead was worked out in the early third millennium BC (ref. 1). From here, the knowledge of lead–silver metallurgy spread to ancient near-East, including India. Lead has been reported from the Harappan (2300–1750 BC) culture[2] both in elemental form as well as in the form of an alloy. Lead from Mohenjodaro[3] has been chemically analysed and found to contain 99.70% lead, 0.15% copper and traces of silver. The Romans were good users of lead and analysis of bone minerals suggests that the lead poisoning was a common disease amongst them[4].

Archaeological lead 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 print of the coins of any king. Moreover the association of a number of trace elements in the coin material is an important criteria for identifying ancient coins from the modern fake ones. The quantitative analysis of the lead coins also yield evidences relating to the source of the metal used in mintings, location of the mint of a group of coins, technological trends in minting, provenance of the object, etc., with which the archaeologists are most interested.

To date the lead coins of the Ikshwakus have not been fully investigated. Coins differentiated on the basis of its legends used by different kings have been analysed to detect any difference in the minting process as well as its chemical composition. An attempt has also been made for the correlation of trace element content of the coins with those of the ore deposits of the ancient mines. Atomic absorption spectrophotometer has been used for analysis, in preference to the wet chemical method.

Fifty lead coins were provided by the Birla Archaeological and Cultural Research Institute, Hyderabad, from its excavated Tenali hoard of coins (Figures 1 and 2). Measurement of diameter and weight of each coin was carried out. The lead coins were carefully cleaned by a nylon brush to remove adhering dust and then treated with 10% cold hydrochloric acid followed by 10% ammonium acetate to remove the surface incrustation of basic lead carbonate[5]. They were then washed with distilled water and dried. The coins were separated on the basis of legends into four different types belonging to four kings. Wherever the legends were incomplete or illegible, it was kept in type V. The sample for analysis was collected by gently rubbing the coin with a medium file, the first lot was rejected to avoid contamination. A few milligrams of the sample, uncontaminated by incrustation product, was collected by subsequent filing. Lead was analysed following Hillebrand and Lundell[6] method. The trace elements were estimated using Perkin-Elmer atomic absorption spectrophotometer. All reagents used in the analysis were AR grade.

The results of analysis of all the five types of coins are shown in Table 2. A comparison of lead coins of the Ikshwakus to that of the Satavahana (Table 3) has also been made. An attempt has been made to correlate the concentration of trace elements with the nearby lead ore mines of Agnigundala (Table 4).

Lead is the major constituent in all the coins and lead content varies between 98.08% and 99.62%. The presence of other metals like silver, iron, manganese, zinc, copper, etc. as traces may be identified as impurities from the ore.

A comparison with the Satavahana lead coins shows that the Ikshwakus adopted their coinage on the pattern of their predecessors Satavahana in some aspects. No appreciable difference in chemical composition of major and minor elements concentration has been noticed among the lead coins of different Ikshwaku kings. Since the Ikshwakus ruled the Andhradesa for a very short span, they have used the same metallurgical pattern and the same source of ore throughout. Circulation of the Ikshwaku coins seems to be within the limits of their empire as majority of the coins have been excavated from the mid-coastal Andhra. Hence, the only available means to differentiate the coins of different Ikshwaku kings is on the basis of its legends. During the time of later Satavahana, most of the kings issued lead coins with elephant and Ujjain symbol, which was followed by the Ikshwaku kings with very minor diffe-

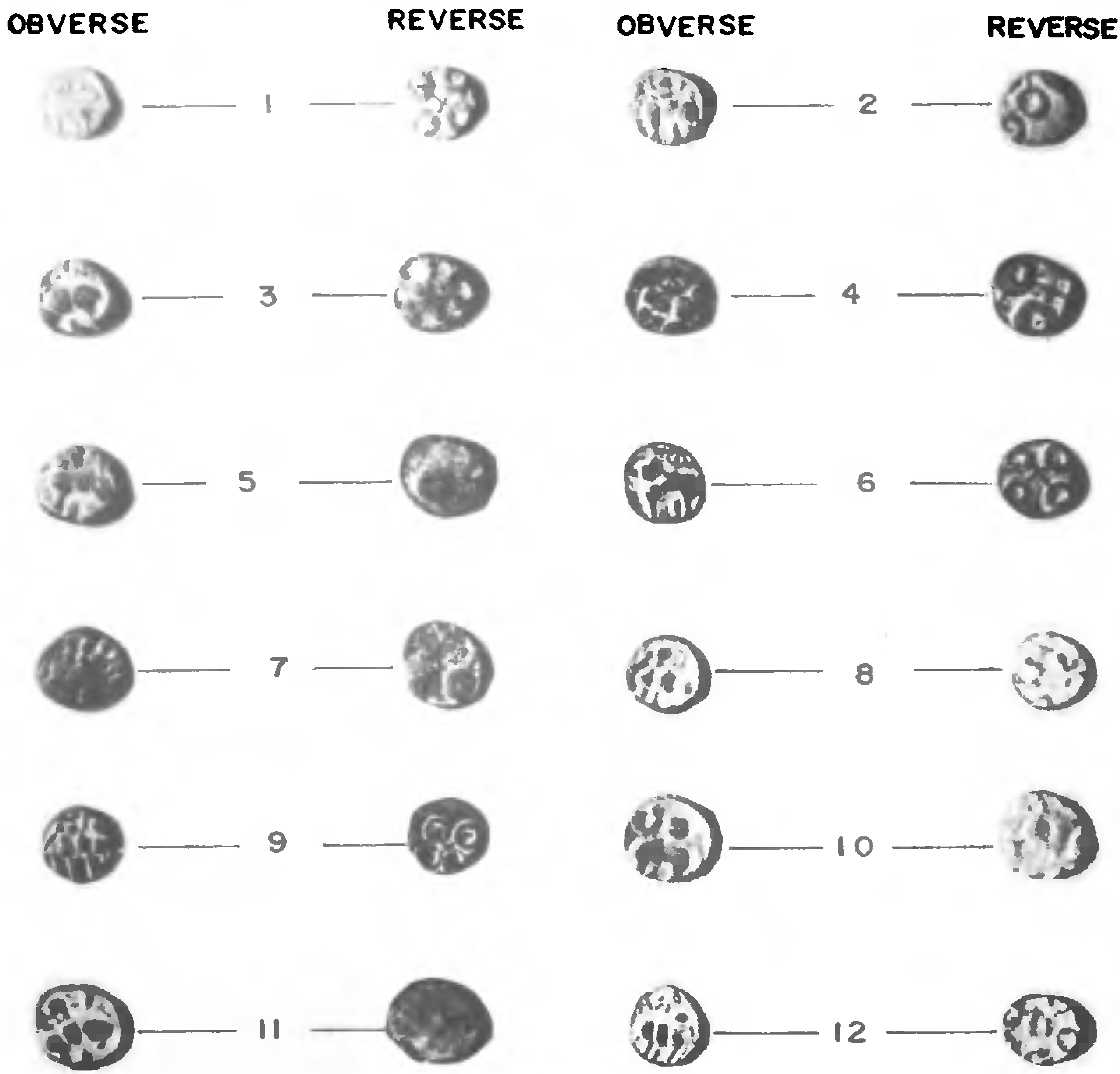
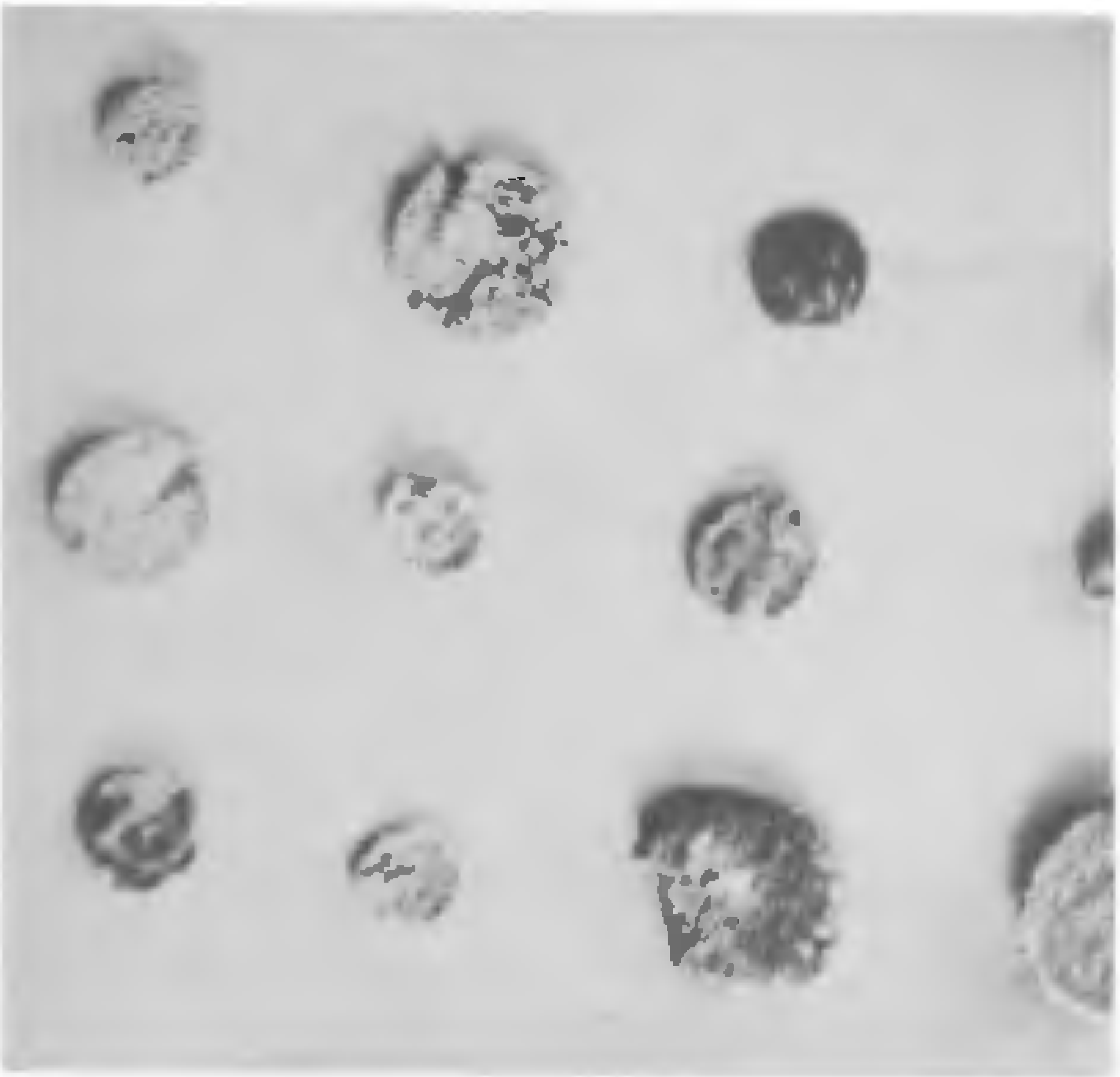


Figure 1. Ikshwaku lead coins from Tenali. (Courtesy: Birla Archaeological and Cultural Research Institute, Hyderabad).

rences. During the study, some differences in the Ujjain symbol on the reverse of the coin have been noticed. It seems during the reign of Sri Chantamula, it was a single, perfect Ujjain symbol which was changed by the subsequent Ikshwaku king (Figure 3). Therefore, on some coins, the symbol appears like an interlinked Ujjain symbol. In some coins, there are only circles without usual cross rods and these look like independent ones.

The presence of a number of trace elements associated with the lead coins suggests that no elaborate treatment was carried out for refining the metal. The higher silver content in the coin shows that no desilvering was done probably due to the complicated process of extraction of silver, political stabilization, etc. and hence the Ikshwakus used only lead. The trace element content of the coin seems to bear comparison with the lead ore samples at Agnigundala and Mailaram. Such resemblance only lend support to the view that the metal was not refined before being minted.

The important mines of galena reported to have been worked in ancient period in Indian subcontinent are Jewar mines of Rajasthan, Bawdwin mines of Burma, Agnigundala and Mailaram mines of Andhra Pradesh. An average trace element content of 100 lead ore



samples has been shown in Table 4. Resemblance of impurity pattern shows that the mines of Agnigundala and Mailaram have most probably been extensively used by the Ikshwaku kings for their coinage.

The difference in coins occurring at different places in Andhra Pradesh having different features indicates a variety of mints of Ikshwaku coinage. Even though the obverse and reverse symbols are the same, the physical features and representation of elephant differ.

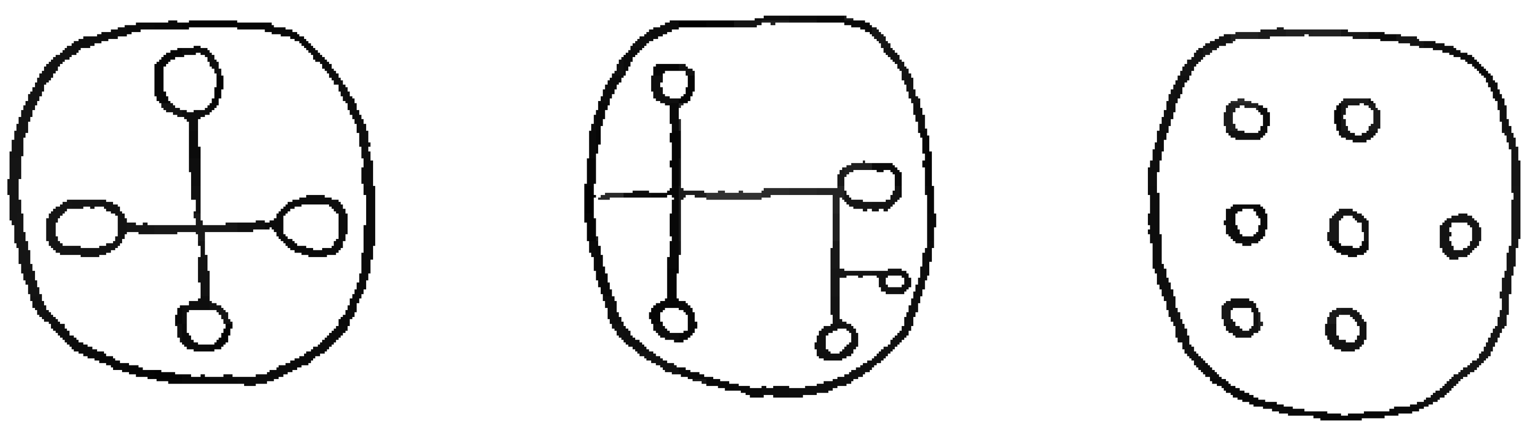


Figure 3. Coins with different Ujjain symbols.

Table 2.

Coin No.	Diameter (cm)	Weight (g)	pb (%)	Ag (ppm)	Fe (%)	Cu (ppm)	Zn (ppm)	Ni (ppm)	Co (ppm)
1	2	3	4	5	6	7	8	9	10
Type I (227–250 AD)									
36	1.4	2 875	98.95	250	0.208	80	10	< 10	< 10
90	1.5	2.806	98 65	240	0.535	60	15	< 10	< 10
370	1.4	2.476	99 14	130	0.232	90	10	< 10	< 10
443	1.4	2 768	99.55	270	0.072	60	15	< 10	< 10
450	1.5	2.882	99.47	40	0.078	45	10	< 10	< 10
1515	1.3	2.996	99.52	60	0.162	60	10	< 10	< 10
1839	1.4	2.387	98.88	360	0 103	85	20	< 10	< 10
1855	1.3	2.341	98.71	360	0 022	70	10	< 10	< 10
1870	1.3	2 438	98.65	80	0.085	60	10	< 10	< 10
2012	1.4	2.467	99 48	340	0.142	65	20	< 10	< 10
Type II (250–270 AD)									
168	1.5	3.441	98.95	70	0 042	70	20	< 10	< 10
434	1.5	3.088	98.36	130	0 033	45	15	< 10	< 10
606	1.6	3.245	99.42	200	0.142	120	15	< 10	< 10
1070	1.5	3.025	98.70	320	0.053	55	10	< 10	< 10
1268	1.3	2.375	99.11	590	0.047	45	20	< 10	< 10
1572	1 4	3 178	99.34	40	0.074	100	15	< 10	< 10
1611	1.3	2 408	98 65	120	0.037	55	15	< 10	< 10
1746	1 6	2.449	99.32	100	0.024	40	15	< 10	< 10
1794	1.6	3.717	98.76	150	0.049	80	20	< 10	< 10
1811	1.5	2.953	98.28	190	0.069	100	15	< 10	< 10
Type III (270–294 AD)									
80	1.4	2.142	98.08	60	0.216	100	10	< 10	< 10
145	1 4	1.966	98.75	210	0.208	65	10	< 10	< 10
273	1.4	2 160	99 12	80	0 098	70	15	< 10	< 10
625	1.3	2 230	99.32	200	0.142	65	15	< 10	< 10
690	1.4	2.575	99.45	150	0.046	45	10	< 10	< 10
972	1.5	2.178	99.43	170	0.090	90	10	< 10	< 10
1137	1.5	2.439	99 61	140	0.146	140	20	< 10	< 10
1444	1.4	2.282	99.13	650	0.416	55	15	< 10	< 10
1648	1.3	1 505	98 65	60	0.034	80	20	< 10	< 10
1920	1.2	1.926	98.58	130	0.085	75	10	< 10	< 10
Type IV (294–305 AD)									
253	1.3	2 217	98.73	110	0.063	80	10	< 10	< 10
334	1.2	1.844	98.75	80	0 030	60	15	< 10	< 10
551	1.3	1.970	99.13	90	0.018	75	20	< 10	< 10
809	1.4	1 983	99.21	660	0 050	45	25	< 10	< 10
820	1.2	2.311	99.33	310	0 126	85	25	< 10	< 10
902	1.2	2.138	98.35	420	0 142	60	30	< 10	< 10
1086	1.4	2 617	99.23	180	0 012	75	15	< 10	< 10
1126	1.3	2.209	99 53	180	0 092	40	20	< 10	< 10
1247	1 4	2 483	99 19	210	0.142	70	30	< 10	< 10
1470	1.3	2 348	99 61	80	0.083	80	20	< 10	< 10
Type V (coins with illegible legends)									
61	1.5	2 004	99 62	360	0.110	60	20	< 10	< 10
158	1.5	3.142	99.44	220	0 288	45	25	< 10	< 10
243	1.4	2.424	98 42	200	0 117	50	10	< 10	< 10
274	1 4	2.760	99.51	140	0 051	65	15	< 10	< 10
354	1.7	2.621	98 12	90	0 062	70	20	< 10	< 10
424	1.3	2.137	99.34	100	0 680	50	30	< 10	< 10
674	1 4	2 631	98 68	370	0 103	55	25	< 10	< 10
950	1.3	1 869	98 87	380	0.153	35	25	< 10	< 10
1313	1.5	3 060	98 99	200	0.107	40	20	< 10	< 10
1649	1.2	1.965	98.72	140	0.333	70	20	< 10	< 10

Table 3. Analysis report of the Satavahana lead coins*

Sl. No.	Particulars	Place at which located	Weight (g)	sp. gravity	pb (%)	Ag (ppm)	Zn (ppm)	Mn (ppm)
1.	Metal mostly circular in shape	A treasure drove at Chintalapet, Karimnagar Dist. (AP)	2.9282	11.35	98.40	37	73	17
2.	Metal mostly square in shape	Purchased from a coin dealer	8.7476	11.30	98.83	122	70	26

*Based on the analysis of Avadhanulu, A. B., Birla Archaeological and Cultural Research Institute Research Bulletin, 1979, 13.

Table 4. Trace elements content in the coins and an average of ore sample of Agnigundala

Element	Min. and max. in the coins (ppm)	Ore sample range (ppm)
Co	< 10	< 30
Ni	< 10	< 30
Zn	10 30	< 100
Cu	35 120	40–150
Ag	40–660	10–25

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Consequences of nectar robbing in the pollination ecology of *Vitex negundo* (Verbenaceae)

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More than 70% flowers of *Vitex negundo* were punctured by the wasps; *Rynchium* and *Ropalidia*. As a result very low percentage of pollination (9) and fruit set (7) was recorded in perforated flowers as against 96% pollination and 76% fruit set in the nonperforated flowers.

FLORAL nectar is offered as a reward for the biotic pollinating agents. However, certain insects do not enter the flowers via the opening of the corolla (perianth), but bite or prick a hole through it and get the nectar from the outside[1]. Such insects in effect rob the nectar as they do not help in pollination. Once an opening has been made, other insects, which would otherwise follow the regular path also use this opening and thus throw the pollination system out of balance. Such blossoms might be a total loss for the plant as they are not likely to be pollinated. But, there are conflicting views on the effects of nectar robbing on plant's pollination. Darwin[2], Kerner[3], Barrows[4], showed examples in which nectar robbing was deleterious to plants while, Hawkins[5], Macior[6,7] and Free[8] found no effect of nectar robbing on plant pollination. In this plant we enquire into the consequences of such nectar robbing on the pollination of *Vitex negundo* L., a member of the family Verbenaceae.

V. negundo plants flower almost throughout the year; the flowers anthese between 0830 and 1300 h, and produce nectar at dawn and complete by dusk. About 22 species of diurnal insects visit the flowers during this period. Among them, *Rhynchium metallicum* and *Ropalidia* sps start foraging at 0530 at dawn. These were seen puncturing the corolla tubes just above or at the juncture of the calyx and corolla tubes. These holes are single, ovoid in shape and are easily accessible to all types of foragers. By the time the other foragers appear on the plant the *Rhynchium* and *Ropalidia* sps puncture more than 70% of the flowers in the bud condition itself. Even the other foragers having free access to nectar through the regular entrance search for 'back doors' at the flower bases. If they happened to find the holes at the base, take the nectar without rendering any pollination. This type of marauding is seen with bees and ants. The ants were seen licking the calyx cups of the one-day-old flowers in addition to the perforated fresh flowers.

The plants available at Visakhapatnam formed the study material. After the cessation of the foragers' activity on five plants, a total of 651 stigmas were collected at random from perforated and nonperforated flowers, and mounted in lactophenol aniline-blue. The number of stigmas with and without pollen loads was counted and the percentage of stigmas pollinated was calculated. Perforated and nonperforated flowers ($n = 500$ each) were labelled at random on five plants and were scored for fruit set after a week.

Of the 651 flowers collected at full anthesis on the five plants, 520 were perforated, 131 nonperforated. Screening of the stigmas under a light microscope revealed that 9% of the stigmas of perforated flowers and 96% of the stigmas of nonperforated flowers contained pollen loads (Table 1). Under the circumstances

Table 1. Corolla perforation versus pollination and fruit set in *V. negundo*

Corolla condition	No. of flowers observed	No. of stigmas showed pollen	Flowers pollinated (%)	No. of flowers observed	No. of fruits set	Fruit set (%)
Perforated	520	46	9	500	35	7
Non-perforated	131	126	96	500	380	76