

Early Indian Metallurgy: The Production of Lead, Silver and Zinc through Three Millennia in North West India

by

P. T. Craddock, K. T. M. Hegde, L. K. Gurjar and L. Willies
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A pioneering contribution of the Indian subcontinent in terms of the history of science and technology was the mastery of the metallurgy of zinc production. Tucked away in the Aravalli ranges of north western India, amongst rich polymetallic mineral deposits is a maze of old workings, mining galleries, slag heaps and retorts which bear testimony to the early extraction of lead and silver at Dariba and Agucha and, most uniquely of zinc, at Zawar. This astonishing saga has been unravelled in the informative book '*Early Indian metallurgy: The Production of Lead, Silver and Zinc through Three Millennia in North West India*' published by Archetype press. This tome covers the committed efforts over decades through archaeometallurgical investigations of the principal author of the book, P. T. Craddock, who was Head of Metallurgy, Department of Scientific Research of the British Museum with cover page author credits also shared with collaborators, late K. T. M. Hegde, L. K. Gurjar of Hindustan Zinc Ltd., and Lynn Willies. The individual chapters also have contributions by scholars A. P. Middleton, C. R. Cartwright, K. Eckstein, I. C. Freestone, D. R. Hook and N. D. Meeks, pointing to the fruitfulness of sustained international co-operation. In the introductory chapter, Craddock points to how the enlightened interest of the leading mining corporation, Hindustan Zinc Ltd., and H. V. Paliwal, and Zinc International led to the genesis of a project together with late K. T. M. Hegde of the Maharaja Sayajirao University of Baroda, and Lynn Willies of the Peak District Mining Museum into the mining history of the region.

Of the eight metals commonly used in antiquity of gold, silver, copper, lead iron, tin, zinc and mercury, zinc was the most difficult to extract in metallic state due to the fact that zinc sublimates at the temperature needed to reduce it from ore at around 1000 °C. Hence finds of metallic zinc are not reported much from early antiquity, although the use of cementation brass itself was known in the Hellenistic world, whereby the zinc vapour formed from the reduction of the zinc ore of calamine would directly get absorbed into molten copper, thereby forming brass with a limited amount of zinc. However, the Zawar area near Udaipur has yielded unique evidence suggesting that the extraction of metallic zinc flourished on an almost semi-industrial scale by the mid-14th century as indicated by some carbon dates from the archaeometallurgical debris presented in Chapter 6. Surveys and excavations revealed the extensive presence of furnaces or *koṣṭhis*, intended for an ingenious process of zinc extraction by downward distillation which are richly photographed and illustrated in Chapter 6. The furnaces consisted of a top chamber into which the zinc ore was packed into retorts and charged, whereby stem shaped condensers attached to the retorts were fixed within a thick perforated terracotta grill, so that the zinc vapour that was reduced from the smelted zinc ore which was charged within the top of the retort in the top chamber, could drastically cool through the condenser stem and thereafter the melt could collect and solidify in the bottom chamber.

The role played by Maharana Lakha Singh (AS 1382-1421) in giving an impetus to zinc mining and production at Zawar is touched upon, with the mines said to have been active until the 16th century bringing prosperity to the region. As discussed in Chapter 3, by the time James

Tod who wrote the *'Annals and History of Rajputana'* was in the region in the early 19th century, the mines at Zawar seem to have been deserted. Another important dimension of the book is the credible correlations made between various processes as uncovered from archaeometallurgical excavation and textual evidence in various alchemical treatises such as the *Rasaratnasamuccaya* of about the 14th century of the process of *tiryakpatana* or downward distillation as outlined in Chapter 11. In Chapter 13 in the summary and overview the probable influence of Indian zinc production methods in spurring the first large scale production of zinc using downward distillation and patented by William Champion in 1738 is touched upon: as an intriguing instance of transfer of technology from east to west. The Chinese process of zinc production which thrived in the 16th century is also touched upon in the last chapter, whereby a variation was devised in which the condensation and collection of the metallic zinc could take place within the smelting retort itself.

Chapter 11, a survey on production of brass and zinc in antiquity points out that cementation brass making limited the amount of zinc in brass to about 30%. Craddock also points to a few stray analyses from the early historic period such as a vessel from Taxila reported by Marshall in the 1950's with about 34% zinc, which suggests that they could have been made by directly alloying zinc metal to copper, so that one might surmise that zinc metal was prevalent by that period, although the early evidence seems less conclusive. From earlier periods, however, there is remarkable evidence that the book puts together for the mining and extraction of lead and silver from argentiferous lead at Dariba and Agucha which may even be traced back to the Mauryan period from when abundant finds of silver punched marked coins are well known. Rich archaeometallurgical debris such as cupels could be uncovered from Dariba and Agucha indicating two stages in the production of silver, one of smelting ores to concentrate argentiferous or silver-rich lead, and then the separation of silver from lead as an impurity by cupellation, the findings of which are summarised in Chapter 10. Relevant insights from texts such as the *Arthasāstra* on assaying of metals are touched upon. An interesting international dimension is provided through comparisons with silver mining and extraction by the Greeks at Laurion (4th–5th century).

The sumptuously illustrated Chapter 5 by Lynn Willies,

Gurjar and Craddock would in some ways be the most exciting for a lay reader. It takes one through the adventure of spectacular old mining galleries in Zawar Mala, Zawar Mochia from where primarily zinc oxide may have been retrieved and Dariba and Rampura-Agucha where lead and silver ores were extracted. Heady views with enormous chambers with giant timber revetments, ladders and stairways and meandering shafts through lodes are interspersed with meticulous explanatory drawings. Remarkably, a few such timbers from Dariba were dated to the latter half of the first millennium BCE. Chapter 6 illustrates the different kinds of refractories and remnants of retorts, cupels and furnaces, complimented in Chapter 7 by a rich repository of photomicrographs and thin sections of refractories and slags that give some insights into the various processes. The use of plant tempers is noted in the refractories, such as from Dariba, which reminded the author of her findings of the use of plant tempers such as rice hulls in making highly refractory crucibles for wootz steel making in southern India; pointing to the need to study both the inorganic and organic underpinnings of traditional artisanal practices. The book brings to bear an array of scientific techniques in the analysis of slags, refractories and metal artefacts including compositional analysis and studies on firing temperatures.

Of course, sometimes the analytical investigations intriguingly raise more questions than they answer as seen for example in a few results from lead isotope analysis which can be a useful method of provenancing metal artefacts by correlating the lead isotope ratios of lead in the artefact to that of the ore source. In Chapter 2 lead isotope ratios are plotted for some north western Indian silver sources (which usually contain some lead) in relation to silver punch marked coins of the Mauryan period. While these do suggest that a few of these silver punch marked coins could have come from the Zawar area, none of those investigated seem to match the lead isotope signatures of the Agucha mines, a major silver producing area as might be expected. Although there is a rich tradition of bronze and brass icon usage in the Indian subcontinent, and zinc-based Persian influenced Bidri ware in southern India in the later medieval period, it also not fully understood as to what much of the zinc produced at Zawar around the 14th century in particular was being used for. Another dimension is that lead isotope analysis of some zinc coins from the Himachal region of the 15th–16th

century did not fit the Zawar area, raising the prospect of other sources or locations of zinc production. The author also undertook lead isotope analysis of a zinc coin ingot with a Deccan Brahmi inscription attributed to the early historic Andhra region (i.e. Satavahana/ Ikshvaku) which had lead isotope ratios that matched an early historic brass vessel from the Andhra region but which did not match lead isotope ratios for the Zawar region (Srinivasan, S. *Journal of Metals* 2016, Tamil Chola bronzes and Swamimalai Legacy) raising the prospect of other sources also for the southern Indian brass or zinc.

Overall, the scientific expositions are enlivened by historical notes, mentions, memorabilia and old photographs of a diverse range of communities engaged in traditional mining and metallurgy ranging from the Hindu Rajput rulers overseeing the western Indian mining areas, to the Bohra Muslim businessmen who made purchases from miners, to the Jain sculptural depictions around Zawar, to the Agaria tribal iron smelters in east Central India. The last chapter gives an insightful contrast whereby metallurgical activities were getting increasingly mechanised in Europe for scaling up production by the pre-industrial period, even as they remained more human labour intensive in the Indian subcontinent. Chapter 3 co-authored by L. K. Gurjar of Hindustan Zinc also gives a useful perspective into the post-Independence historical development of modern mining under the Hindustan Zinc Ltd. The book in its own way emphasises the towering and seminal contributions of Paul Craddock to the history of metallurgy and in placing Indian primacy in zinc metallurgy on the world map. However, an aspect that the rather comprehensive book perhaps misses is a glimpse into the motivations and contributions of late K. T. M. Hegde who was involved in the early surveys and excavations and is regarded as a pivotal figure in his own right in terms of Indian archaeology and development of the then nascent discipline of archaeometallurgy. The fairly well referenced book is a compelling compendium of history of metallurgy which would be an invaluable resource for scholars and students alike, even though it must be pointed out that this book, which is rather heavy going and overpacked with information at times, would be an easier read for a somewhat informed reader rather than for somebody looking for an entry into the rich and complex topic of archaeometallurgy. One also wishes that some of the photographs of the mining galleries and such

like could have been of a larger size to get a better appreciation of them. It is also hoped that the book raises awareness of the need to better preserve the rich legacies of mining history and archaeometallurgical remains, including uninteresting looking slag heaps, which nevertheless are repositories of important technological histories in their own right.