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Indian High-Tin Bronzes and the Grecian and Persian World

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Abstract

This paper attempts to draw together some of the literary and archaeometallurgical evidence pointing to cross-cultural interactions and encounters in the use and occurrence of metals and alloys in the Indian subcontinent broadly in the 1st millennium BCE to the early common era, spanning the Iron Age to early historic period. As is generally known, aspects of the material culture of this period shows discernible external influences, such as from the Grecian, Hellenistic or Persian world, central Asia as seen in some examples of statuary, coinage and jewellery and so on. However, there are other examples which this paper aims to highlight of certain finds from the Indian context which seem to be more distinctive to the Indian region as also corroborated by evidence and accounts from the Hellenistic world. In particular the specialised alloy of wrought and forged high-tin beta (23%) bronze vessels provides an interesting case study, with the author's archaeometallurgical investigations pointing to finds from the South Indian and peninsular Indian Iron Age of the early 1st millennium BCE (Adichanallur, Nilgiri, Mahurjhari, Taxila, Fig. 1), ranking amongst the earliest known such vessels, as well as continuing traditions (Srinivasan and Glover 1995, Srinivasan 2010). Some Southeast Asian examples of the latter part of the first millennium also show Indian connections in design suggesting an Indian provenance. Sassanian examples of about the 7th century are also known. This paper attempts to thus explore cross-cultural influences in the Indian examples, and the ways in which high-tin bronzes seem to have eventually become part of the wider Asian network of trade and interaction in antiquity.

Key words: Adichanallur, Fluting, Hellenistic, High-tin bronze, Kerala, Megalithic, Nearchus, Nilgiris, Polishing, Quenched beta bronze, Sassanian, Surviving traditions, Taxila, Vessels

1. Introduction

As such in antiquity tin was alloyed to copper to make bronze as it gave improved properties of hardness. However the use of bronze with a lower tin content was much more widely prevalent in the Old World since bronze gets brittle with increasing amounts of tin much beyond 15% tin.

Nevertheless, recent studies have increasingly been bringing to light the use of skilled bronzes in some parts of Asia using higher tin contents including India from where apparently some of the earliest known fine examples are found.

Binary high-tin beta bronze refers to an unusual alloy of only copper and tin with a tin content approaching 23%. Increasing amounts of tin beyond 15% leads to embrittlement of as-cast bronze due to the formation of the alpha plus delta eutectoid phase. However, beta bronze specifically refers to an alloy of 23% tin which would have been heat treated and quenched or rapidly cooled by plunging in water. This would have resulted in the retention of the beta phase which is an inter-metallic compound of equilibrium composition of 22.9% tin in a martensitic transformation. The exploitation of the properties of this alloy gives effects of increased tensile strength and musicality.

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Fig. 1. Map with find-spots of Indian and Asian high-tin bronzes

Such alloys shot to archaeometallurgical attention after significant finds of vessels and bracelets from Thailand, from the Iron Age burial complex of Ban Don Ta Phet and Ban Chiang, datable from around the 4th century BCE were subjected to systematic study (Rajpatik and Seeley 1979, Rajptiak 1983, Bennett and Glover 1992, Wheeler and Maddin 1976, Piggott et al 1992). In their seminal paper, Rajpatik and Seeley (1979) pointed to the similarities with finds from the Nilgiri cairns some of which were analysed by Breeks (1873, p. 63) and also found to be of high-tin bronze. They speculated that such examples might have had Thai origins.

However, subsequent ethno-archaeological and archaeometallurgical studies by the author pointed to long standing metallurgical practices of making quenched beta tin bronzes in Kerala. These linked well to related Iron Age finds from the Nilgiri Cairns and Adichanallur burials of Tamil Nadu of 23-24% tin, astonishingly very close to the composition of the

pure beta phase inter-metallic compound (Srinivasan 1994, Srinivasan and Glover 1995). These are attributed to about 1000-500 BCE and rank amongst the earliest known such heavily forged and quenched bronzes. Glover and Bennett (2012) and Glover and Jahan (2014) and also have since pointed to Indian figurative designs on some Thai high-tin bronzes of the latter part of the first millennium BCE apparently suggesting Indian provenances for them.

It seems this alloy was not in vogue much in the Mediterranean world where low tin sheet bronze was used much more widely. Nevertheless, at least in stylistic terms there seem to some intriguing connections in the early historic period of vessel types with the Hellenistic and Iranian world which this paper attempts to further elucidate.

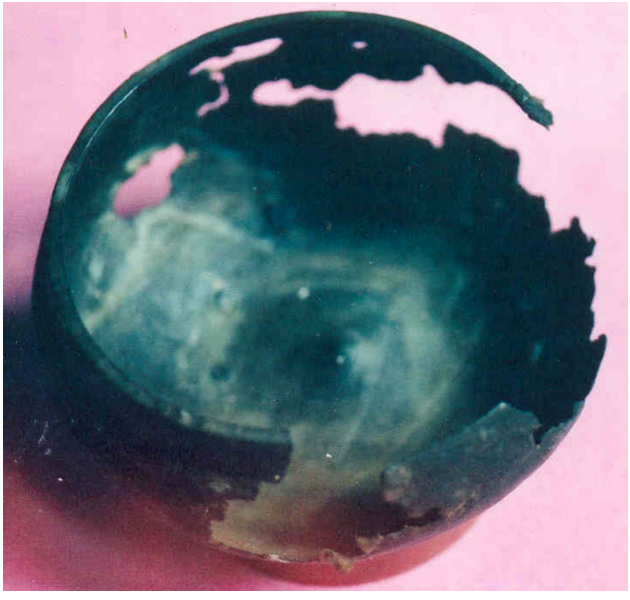

Fig. 2. High-tin bronze vessel from Iron Age burial of Adichanallur, Tamil Nadu

2. High-tin bronzes from the Indian Iron Age and evidence for local traditions

The highly sophisticated metal finds from the cairns and burials associated with the south Indian Iron Age from the Nilgiris and Adichanallur in Tamil Nadu represent some of the most enigmatic and intriguing of finds from antiquity, An extensive urn burial site at Adichchanallur was discovered in 1876 by Dr. Jagor of the Berlin Museum. During the 1910's Alexander Rea (1915) excavated unearthed gold diadems, iron objects, bronze vessels, some with lids with fine finials depicting vegetal and animal motifs and thousands of potsherds of the characteristic black and red ware. The Adichanallur finds include metal vessels with animal finials and extraordinarily finely wrought vessels (Fig. 2) including strainers. From numerous cairns in the Nilgiris, Breeks (1873) uncovered several terracotta vessels with animal finials, not unlike the Adichanallur examples, as well as very elegant metal vessels, of which over forty seem to be in the collections of the British Museum and others are in the Government Museum Chennai. Allchin and Allchin (1982) attributed the south Iron Age to about 1000 BCE. As the finds are not securely dated these assemblages may range in dates from the early first millennium to the early historic period. The style of bronze vessels with finials from Adichanallur resemble those from the megaliths of Mahurjhari in the Vidarbha region of central peninsular India excavated in the 1970s by Deccan College, Pune (Deo, 1973). There were a couple of carbon dates of about the 7th century BCE for the Vidarbha megaliths (Deo, 1973, p. 32).

While Breeks (1873, p. 94, 63) pointed to some of the Nilgiri vessels being of 23% tin-bronze, and Paramasivan (1953: 418) reported a sample from Adichanallur of 23% tin, such higher tin artefacts were thought to have been imported (Leshnik, 1974, p. 156). The possibilities of a local or continuing tradition had not been considered until the author's studies connecting these to surviving beta high-tin bronze making traditions in Kerala (Srinivasan 1994). Metallurgical investigations by the author (Srinivasan 1994) of two vessels samples from the Nilgiri Cairns (Fig. 3) and Adichannallur burials indicated that they were extraordinarily made of wrought and

Fig. 3. Fluted High-tin bronze vessel from Nilgiri Iron Age Cairns, Tamil Nadu

Fig. 5. Extremely finely wrought and quenched high-tin beta bronze (24.9% tin) from Nilgiri Cairns in Government Musuem, Chennai (1000X)

quenched high-tin beta bronze of a controlled composition of about 23.9% tin and 22.9% tin respectively, analysed by AAS.

Their micro-structures (Figs. 4 & 5) confirmed that they were fabricated by extensively hot forging or hammering out such an alloy between 586-798^0 C in which temperature and composition range a plastic beta intermetallic compound (Cu_5Sn) of equilibrium composition of 22.9% tin forms. Then the bowls were annealed again to the high temperature range of formation of beta phase and quenched which resulted in the predominant retention of needle-like beta phase. The manufacturing process could be correlated with the author's studies of a previously unknown surviving tradition of making wrought and quenched high-tin beta bronze in Kerala by traditional Kammalar or bronzesmiths at Payangadi (Figs. 6 & 7), first documented in 1991 (Srinivasan 1994). The extensive degree to which this alloy could be hot forged was due to the quasi-superplastic properties while the quenching prevents the formation of brittle delta phase. On polishing, the alloy was found to take on a brilliant golden lustre which could explain why it was used in the past. The alloy also had tonality and musical properties and the vessels so made were called *talavettu* or musical vessels. Craddock et al. (2007) also reported compositions of wrought and quenched 23% beta bronze amongst a few of the

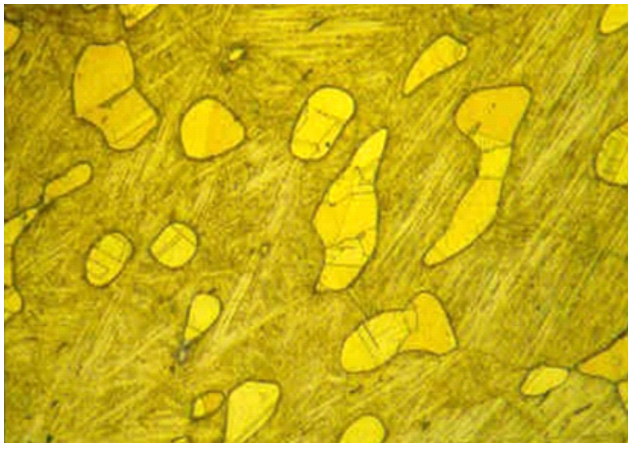

Fig. 4. Micro-structure of wrought and quenched high-tin beta bronze vessel with 23.9% tin from Iron Age burial of Adichanallur, Tamil Nadu, 400 X

Fig. 6. Hot forging of high-tin beta bronze ingot in Kerala, 1998

Fig. 7. Wrought and quenched high-tin bronze bowl made in Payangadi in 1991 with 23% tin

investigated vessels from the Nilgiri Cairns in the British Museum collections.

A vessel from Mahurjhari from the Vidarbha megaliths investigated by the author was found to have a micro-structure of a cast and quenched high-tin bronze with 21% tin analysed by EPMA (Srinivasan 2010). A vessel fragment from the Gandharan Grave Culture, Taxila, was also found to have 21% tin from SEM by the author, generally attributable to the early part of the first millennium BCE (Srinivasan and Glover 1995). A few examples of bronzes of a tin content upto 19% were also reported by Park and Shinde (2013) from the Vidarbha megaliths and from the Gangetic Valley by Datta et al. (2007) although the micro-structures published therein did not seem to clearly correspond to the kind of quenched martenstic beta bronze structures of 23% tin that the author had reported from south Indian megaliths. Finds are also reported by Ravich (1991) of Scythian and Sarmatian hot-forged high tin bronze mirrors of the sixth to fifth centuries BCE from Central Asia.

As such it is not really possible to speculate on the origins or links between such finds while the origins of the megaliths themselves is not well understood. Nevertheless, it seems that the extensive hot forging seen in the beta bronze vessels from Adichanallur and Nilgiris is something unique, with rim thinnesses of no more than 0.2 mm, ranking amongst the most highly hot forged high-tin bronze vessels known in the world, which lends strength to the notion that these represent a longstanding local or Indian tradition. A sample of unleaded bronze of 22% is also reported from the Indus Valley site of Mohenjodaro (*c.* 2500 BCE) (Mackay, 1938, p. 480; Srinivasan, 1997a) although it cannot be inferred if this was intentionally alloyed and quenched beta bronze or simply as-cast bronze without the micro-structural study. Even so, given that many analysed Harappan bronzes are unleaded, it could point to a longstanding Indian tradition of experimenting with unleaded bronze leading upto the use of binary high-tin bronze by the megalithic period (Srinivasan, 2013). The *Arthaśāstra*, the Mauryan economic treatise dated to the 3rd century BCE also mentions the use of *kamsa tala*, translated as bronze of different proportions (Kangle 1972, Srinivasan, 1998). The Tamil classic *Śilapadikaram*, dated to the early common era, mentions the use of *kāmsa-tāla* for musical accompaniment, ie. cymbals (Srinivasan 1958: 9-16). High-tin bronze is also used in contemporary times to make cymbals in Kerala due to the musicality (Srinivasan 2010) and to make gongs in Assam (Blurton 2011). The *Rasaratna-samuccaya*, a 12th century alchemical text (Ray 1956) refers to *kāmsa* as an alloy of 80% copper and 20% tin which appropriates to the composition of high-tin bronze. That high-tin bronzes were prevalent in several parts of the Indian subcontinent in the first millennium BCE may thus be established by the above discussion. In the following section the intriguing issue of connections with the Greek and Persian world especially from the early historic period is explored.

3. Explorations into Greek and Persian connections

The northwestern Indian subcontinent, lying as it did at the crossroads of Asia, witnessed

some of the most innovative cross-cultural exchanges in antiquity in the first millennium BCE and early centuries CE. Under the Achaemenid Persian empire, created by Cyrus the Great (559-530 BCE), Persian control stretched from Egypt and the Aegean to Afghanistan and the Indus Valley around the 5th-4th centuries BCE. The rich material culture of the Bactrian region is best exemplified by the famed Oxus gold treasure with Persian and Hellenistic influences. As is well known, following the incursions of Alexander in 326 BCE, the material culture of the Buddhist region of Gandhāra of northwest Pakistan bears a rich legacy of numerous Hellenistic and Persian influences, most notably the emergence of forms of coinage and statuary. A good example of Greco-Bactrian cross-cultural influences is found in a Gold coin of Kuṣāna King Kaniṣka, in British Museum with Bactrian written in Greek script of the 1st century (Errington and Crib 1992: 166). This portrays him in a knee length tunic and boots in a similar way to Achaemenid depictions related to the Zoroastrian rite of offering libation with a cup, as seen in some examples of gold work from the Oxus treasure, but holding a rather more Indian looking rounded vessel.

Interestingly, however, although more evidence is forthcoming in terms of Hellenistic influences on metalware, there is an interesting Grecian account concerning the high-tin bronze alloy which reaffirms the notion that this was one type of metalware which already prevalent in the Indian subcontinent, which the author has also pointed to from the study of megalithic finds. This account of Nearchus as elucidated further indicates that the high-tin bronze alloy was not really in vogue in the Grecian and Mediterranean and was encountered rather as a novelty in the Indian region.

Rajpitak and Seeley (1979) first pointed to an interesting account in Strabo's Geography (xv 1.67) whereby Nearchus is said to have mentioned that Indians used vessels that broke like pottery when dropped on the ground. They inferred that this referred to the high-tin beta bronze vessel alloy related to Asian bronzes which is rather brittle as discussed before. As elaborated by Mair (2006, p. 45), Alexander's Greek general Nearchus in 325 BCE explored the Indus region to report on the customs of the people and mentioned that the bronze vessels of that area were cast, not forged, and so that they broke rather than crumpled when dropped. This generally implies that the type of metal encountered in the north-western Indian region did not conform to a Mediterranean's experience. In the Mediterranean and Grecian world it was generally sheet bronze that was used, which was initially in vogue in Troy and Mycenae. As pointed out by Welter (2004) in the Hellenistic and Roman world low tin bronze of no more than 8-10% tin were heavily worked into sheets, such as the famous Herculaneum vessel fragments with 8% tin. Indeed Mair (2006, p. 46) uses this account of Nearchus to underscore that sheet-metal vessel making was a distinctive regional Mediterranean tradition. The 'crumpling' effect described with respect to Mediterranean bronzes refers to the fact that low tin bronze tends to dent under impact, in comparison with brittle fracture observed in high tin bronzes seen from the subcontinent. This is exemplified by two examples seen from the Indian subcontinent, one a megalithic vessel from Mahurjhari, in Deccan College collections. The bottom part was found from the author's analyses to be made of forged unleaded 8% low-tin bronze shows some denting along broken edges akin to 'crumpling' (Fig. 8). The other is a high-tin bronze from Nilgiris (Fig. 3) which clearly shows breakage more akin to brittle fracture seen in high-tin bronze and of the kind that could be expected from 'dropping pottery' as described by Nearchus. The fact that high-tin bronzes have not really come to light so far from a Mediterranean context thus underscores the above observations.

The region that Nearchus' account refers to, ie the northwestern Indian region encompassing

Fig. 8. Megalithic rounded vessel from Mahurjhari

Fig. 9. Vase with figurative decoration of chariot, Kulu Valley

Fig. 10. Vase, Kulu Valley of the colour of high-tin bronze

Taxila, is also one from where finds of early high-tin bronzes are known. An unleaded quenched high-tin bronze vessel with 21% tin from the Gandharan Grave Culture, attributed to the early first millennium BCE was analysed by the author (Srinivasan and Glover 1995). The Greco-Bactrian kingdom (c. 250-125 BCE) included Afghanistan while the Indo-Greek kingdom extending into northern India, Iran and Pakistan lasted until around 10 AD. From the early historic Gandhāran Buddhist Bhir mound at Taxila, Marshall (1951, p. 567) reported eight bronze vessels and mirrors with more than 20% tin, datable broadly from the fourth century BCE to the first century CE.

However, although the high-tin bronze alloy found in the Indian subcontinent seems to have been distinctive from that used in the Mediterranean region and were prevalent prior to the influx Hellenistic influences into the Indian subcontinent going back to megalithic times as indicated earlier, there are nevertheless cross-cultural influences in stylistic terms in the early historic Indian high-tin bronze vessel types with Hellenistic/Indo-Bactrian/Iranian/Indo-Greek material assemblages. A good example of this is a vase (Figs. 9, 10) from Gondla, Kulu Valley, Himachal Pradesh, northern India, *c* 1st century BCE (Errington & Cribb 1992, p 163, no. 1880.22, Glover and Jahan, 2014**),** in the collection of the British Museum which was found from surface XRF analysis to be of a higher tin content. The colour of the vase as well as the nature of the breakage is not inconsistent with high-tin bronze,

while the well rounded shape is typically Indian, recalling to the megalithic vessel from Mahurjhari in the peninsular Vidarbha region (Fig. 8) discussed before.

The figurative design however, bears some distinct Bactrian/Greco-Bactrian influences in the depiction of the chariot with four horses and large wheels (Fig. 10) akin to the chariot and horse quadriga seen in the spectacular gold chariot from the famed Achaemenid Bactrian Oxus treasure with distinctly Persian/Achaemenid/Parthian looking figures one with knee length tunic. The figures on the chariot of the Kulu vase, however, are similar to other early historic depictions from the Indian subcontinent related to Buddhist sites such as at Sanchi and Barhut, showing syncretism between Indian and Greco-Bactrian motifs. Other examples of high-tin bronzes with similar figurative decorations relating to early historic Indian sculptural motifs are found in Thailand such as a vessel probably from Khao Sam Khaeo in the Buddhadasa Indapano Archives in Bangkok attributed by Glover and Jahan (2014) to the Indian subcontinent. They pointed to the similarities of the decorative motifs to early historic Indian art such as the 'griffin' motif coming into Sunga and Satavahana art through Greco-Bactrian influences from North-western India. The mythical griffins, described in Black sea myths, have the body of a winged feline with the head and beak of an eagle. Greek legends describe their fearsome nature in relation to Scythian and Samartians whose tombs had images of griffins on gold artefacts. Glover and Jahan (2014) attributed an Indian origin to the vessel as griffins are not encountered in the early prehistoric art of southeast Asia.

The early historic vessel from Taxila from National Museum (Fig. 11), which from the colour appears to be of high-tin bronze, seems to be made in a style whereby the shallow bowl and pedestal is reminiscent of Persian and Greek examples of calyx style vessels. Some bronze vessels from the Nilgiri Cairns in the Government Museum

Fig. 11. Early historic vessel from Taxila with pedestal

collection (Figs. 3 & 12) also share similarities with 2nd century Sassanian examples of silver vessels with fluting and with pedestals although the designs etched on them are more Indian. Indeed, Leshnik (1974) had postulated a West Asian origin for megalithic vessels such as at those Mauli Ali in Andhra Pradesh which were found to have 21% tin, perhaps on the basis of such perceived stylistic similarities. However, as Gunter and Jett (1992) point out, not much bronze is in fact found from the Achaemenid and Sassanian periods (from about the 6th century BCE to the 2nd century CE) from where more gold and silver vessels are known. The analyses of two bronze vessels are published in Gunter and Jett (1992, pp. 65-67), one of which is a shallow low-tin bronze vessel with 81% copper and 15% tin and 4% lead with flower petal motifs running around. Another Achaemenid vessel (*c* 5th century) (Gunter and Jett 1992, pp. 67) was found from

Fig. 12. Beta high-tin bronze vessel from Nilgiris with fluting and striations indicating it was polished using a hand lathe

surface XRF to have 28% tin; however since tin tends to segregate to the surface of bronze it is not possible from this to infer if it is high-tin bronze. Both these look cast and they do not resemble Indian examples enough either stylistically or technically to suggest that the Indian examples of quenched high-tin bronze were Iranian/West Asian imports. The broader similarities that may be more suggestive of contact and shared motifs than a case of Indian examples being West Asian imports. It seems that more examples of high-tin bronze vessels, included finely wrought and decorated examples, are known from the Indian subcontinent in the early first millennium BCE and early centuries CE than from the Iranian context, so that this alloy can be more firmly attributed to the Indian subcontinent than the Iranian region. Furthermore, the example of the Nilgiri high-tin bronze vessel discussed before with fluted patterns with Indian decorative designs also shows evidence of being polished by a hand lathe from the striations (Fig 12). This is very similar to surviving practices in Kerala observed by the author in 1991 at Payangadi where the high-tin bronze vessels were decorated with concentric circles using hand lathes (Fig 13) similar to megalithic finds. These suggest that these were more likely of Indian manufacture. However, it is remains an exciting prospect that there may have been some general shared stylistic influences between the Indian and Iranian examples of metalware such as the fluting observed so markedly in Sassanian silver and gold examples, and also seen in its own distinct way in the Nilgiri high-tin bronze bowls and in the type of pedestal bases of some bowls.

By the 7th century CE Sassanian period, highly sophisticated examples of Iranian high-tin bronzes are known with elaborate chased decorations, such as that published in Gunter and Jett (1992, p. 145) of a flat vessel with raised rims and a sphinx-like winged lion figure. Although decorated high-tin bronzes are known from the early historic period from the Indian subcontinent, medieval Indian examples of high-tin bronzes with such complex decorations have not readily come to light. As the author has pointed out elsewhere, the 23% beta high-tin bronze crafts of Kammalar in Kerala survive exclusively on re-cycling as they are able to identify the alloy visually, so that many antiques do get melted down in the Indian context (Srinivasan 1997a). In the Sassanian vessel with the bird-lion motif discussed, notwithstanding the Iranian decoration, it is interesting that the general flat vessel shape with the raised rim with internal circles resembles one type of high-tin bronze vessel commonly found and still made in Kerala (Fig. 13), with numerous examples in the possession of the Toda community of the Nilgiris. Intriguingly, the 11th-12th century Geniza documents of Cairo talk of old vessels being sent to the Malabar and new ones being made and sent back to West Asian ports (Goiten 1963); giving a sense of the importance of the Malabar metalworking crafts. Given that bell metal crafts as practiced by the traditional bronze-smiths or Kammalar is one of the most significant of traditional metal industries still surviving in Kerala, one is tempted to speculate that high-tin bronzes could have formed part of such a trade whereby such vessels have been shaped to a certain degree in the Malabar and then sent for finer working further west. This is not far-fetched

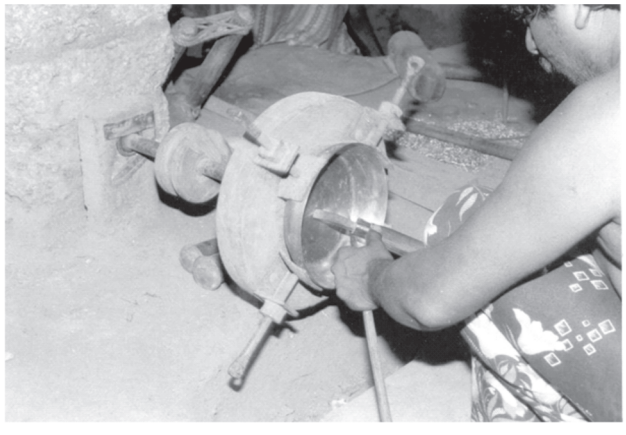

Fig. 13. Polishing of high-tin bronze vessel at Payangadi by hand lathe in 1991

when one considers the significant evidence for the export of high-carbon steel wootz ingots as raw materials to Persia for forging the skilled 'watered steel'/Damascus steel swords as indicated by the well known 17th century accounts of French traveler Tavernier (Srinivasan 2007), or the evidence from the early historic site of Pattinam for the export of semi-precious stone blanks from Kerala to the Roman world for the finer carving of intaglios.

4. Conclusion

While it seems that high-tin beta bronzes were already prevalent in the Iron Age of the Indian subcontinent in the first millennium BCE and seem to have had some distinct technological features that could characterise them as 'local' rather than as imports, there are nevertheless some interesting stylistic influences coming in from the Hellenestic/Greco-Bactrian/Persian world as detected in some finds ranging from Taxila in north-western India to the Nilgiris in Tamil Nadu in southern India. While they seem to have been part of a wider network of exchange with southeast Asia, further research may be needed to more fully explore the place of Indian high-tin bronzes in terms of West Asia or Persia as well the connections, if any, to other finds of high-tin bronzes from Asia such as from the Scythian and Samartian world reported by Ravich (1991).

There are other examples of Indian metal artefacts being part of exchange networks with the Mediterranean or Iranian world. At Taxila, Marshall (1951) reported a couple of specimens of steel of over 1% carbon, closer to a composition of 'wootz' or high-carbon crucible steel. The Europeanied term 'wootz' deriving from the south Indian word for steel, *ukku*, is linked to the Tamil word, *uruku* (i.e. boiling); suggestive of the process of carburising of wrought iron in crucibles to steel. Zozymus the Greek also mentions in 300 CE an account that suggests that Indians made steel in crucibles (Craddock 1995: 279). The author had investigated crucibles from ferrous metal production from the megalithic site of Kodumanal (3rd century BCE) and specimens of hypereutectoid wootz steel of about 1.2-1.5% carbon from the historic Indo-Roman site of Pattanam (Srinivasan 2007). There are historical accounts suggesting the export of 'Seric' iron to the Roman world which some scholars have related to Chera or south Indian steel while the Greek physician Ctesa is said to have praised the swords of Indian steel presented to the King of Persia (Bronson, 1986, 18; Warmington 1928).

Specimens of brass of high-zinc content of 34% are reported from the early historic Bhir mound of Taxila, (Marshall 1951) thought to be made of alloying metallic zinc from copper. The primacy of zinc production in India is indicated by unique evidence for zinc smelting from the Zawar area of Rajasthan (Craddock et al 1998). Intriguingly, lead isotope analysis also suggests that some finds of Hellenistic Aegean brass from Thermi analysed by Stos-Gale (1992) had their source in Ambaji in Western India (Srinivasan 1999). The medieval Geniza documents point to continuing trade in metal with southern India and the Malabar in the 11th and 12th centuries (Goitien 1963, Friedman and Goitien 2013).

Thus, the Indian high-tin beta bronzes could also have represented a rich and distinctive metallurgical tradition that played a significant role in terms of cross-cultural exchanges, through long distance land or maritime routes by the early historic period. It has been noted that tin is a scarce resource in India (Chakrabarti 1979), which explains the fact that bronzes are perhaps not found in abundance in terms of size or quantity in Indian prehistory when compared to some other parts of the Old World. The connection with tin-rich southeast Asia and Afghanistan could have been important as sources. Even so, the author has pointed also to the unexpected finds of old bronze smelting slags from Kalyadi in Karnataka in southern India (Srinivasan 1997b), to suggest that

minor tin deposits such as those reported in parts of India in north Karnataka and Hazaribagh in eastern India could have also been exploited in antiquity. Even without being able to pinpoint sources what the studies so far indicate is a much more dynamic picture of cross-cultural exchanges in the use of metals than previously realised in the Indian subcontinent.

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