High-tin bronze bowl making in Kerala, South India, and its archaeological implications

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Introduction

High-tin beta bronzes are an unusual group of binary copper-tin alloys of 20–25% tin which have special properties skilfully exploited in different contexts in Asian antiquity to make bowls, gongs, coins and bracelets. Although the alloy is quite brittle with limited workability, it can be annealed and worked to a considerable extent in the temperature range of 586–775°C due to the formation of a superplastic martensitic beta phase. This beta phase is meta-stable and may be retained only by quenching in the above temperature range, but its retention leads to improved tensile strength and reduces the brittleness of the alloy. The alloy also has musical properties and is bright golden when polished.

Early finds of high-tin bronze bowls and bracelets from about the 4th century BC from Ban Don Ta Phet in Thailand have been technically examined and described (Rajpitak & Seeley 1979; Bennett & Glover 1992). The recent manufacture of gongs of wrought and quenched beta bronze is recorded from the Philippines, and inferred from early European accounts for China and Indonesia (Goodway & Conklin 1987). Such studies formerly placed the development of these alloys in Southeast and East Asia.

Finds of high-tin bronzes of 20–25% tin, particularly of bowls and coins are also reported in a range of cultural and geographical contexts in the Indian subcontinent from the second half of the first millennium BC to the early centuries AD. The earliest of these finds from the South Indian Iron Age burials are roughly contemporaneous with those from Thailand and have certain stylistic affinities. Commentators have tended to view such bowls as possible imports from Southeast Asia with the spread of Indian cultural influences due to the poor contexts, the scarcity of tin in India compared to tin-rich Southeast Asia and the lack of comparable ethnographic evidence from the subcontinent. The use of high-tin bronze coinage in the early historic period, however, seems to be an Indian rather than Southeast Asian phenomenon.

This paper puts forth new ethnographic evidence from Kerala in South India on the manufacture of bowls, gongs, etc. of wrought and quenched high-tin bronze. The study throws fresh light on the methods of fabrication of the high-tin bronze bowls of Asian antiquity, for which a continuing tradition has not been reported elsewhere in Asia. Moreover, it calls for some revision in the understanding of high-tin bronze working in the Indian subcontinent: as a continuing and perhaps even indigenous tradition rather than in an imported context alone. In fact such continuity from an early period, particularly in South India, is supported by the analytical, ethnographic, literary and etymological evidence presented here.
High-tin bronze in Indian antiquity

Bowls of about 20–25% are reported from disparate sites of the second half of the first millennium centuries BC from Taxila (Marshall 1951, II: 567–569), the burials and megaliths of South India such as Adichanallur (Paramasivan 1942: 87–90), Nilgiris (Brock 1873: 63, 156), Mauli Ali (Leshnik 1974: 156) and from the Assur graves in eastern India (1st century BC–1st century AD) (Chakrabarti 1979: 66, 73).

Potin coinage of about the 1st to 2nd centuries AD of the Andhra Śrāvāhana dynasty has been found to consist of 18–19% tin bronze (Sastry et al. 1983: 21–29). Recent studies indicate that Andhra Viṣṇukumāra bronze coins of about the 4th century AD contain about 23% tin and are found to have the micro-structures of annealed, quenched beta bronzes (Vijaykumar et al. 1987: 137–147). A few coins of the Eastern Pañcāla dynasty (1st century BC–1st century AD) are also reported to be made of 20–22% tin bronze (Chakrabarti 1979: 66). Such coinage appears to have been made by hot striking in the plastic beta temperature range, and the golden colour of polished beta bronze may have been desired.

High-tin beta bronze working in Kerala

In his report on the analyses of some bowls and tom toms from the Nilgiri cairns, Brock (1873: 63, 156) significantly mentions that these resembled a bowl he purchased from Calicut in Kerala with 22.8% tin. The idea of a possibly continuing tradition in Kerala of high-tin bronze working was reinforced by discussions I had with Toda anthropologist Evam Pilijian. The Todas are the native inhabitants of the Nilgiris with burial and pastoral practices which are generally thought to link them to the ancient Megalithic cultures of this area (Aiyappa 1951). Ms Pilijian mentioned that in the past people from the plains gave the Todas bronze bowls as tribute. This was because the Todas were revered as the descendants of the legendary Pāṇḍavas from the epic Mahābhārata; and indeed South Indian megaliths are sometimes referred to in Tamil as pāṇḍava-kuli with the construction ascribed to the Pāṇḍavas (Congreve 1847: 77–146; TL: 1924–39, V: 2597a). Ms Pilijian said these bowls were known to come from Kerala and were made of ven-kalam (in Tamil and Malayalam usually used to refer to bell metal, cf. TL 1924–39, VI: 3775a, or an alloy with about 20–30% tin); she showed me a collection of such vessels which were clearly wrought.

Thereafter, in October 1991, I visited Trichur in Kerala, a well-known centre for the manufacture of lathe-turned cast bell metal lamps, vessels and bells. In Irinjalakuda village in Trichur District, I came across a shop with a stack of gongs and shallow, thin-rimmed, damaged bowls which the shopkeeper said were made by beating out the alloy and then immersed in water. He told me that this was an old practice which now only survived in a few places in Palghat District and Malappuram District.

Following his leads I found a family of traditional kammūlar, i.e. a traditional class of braziers, in Payangadi village in Palghat District, 40 km from Trichur.
and 15 km from Pattambi, the nearest significant town. They were making wrought vessels when I arrived; the analytical investigations confirm that the process is of wrought and quenched high-tin bronze bowl making.

Method of manufacture

The alloy used by kammāḷar Bhaskaran was said to comprise 10 kg of pure copper with 2.75 kg of veḷḷiyara or tin, with up to 500 g of extra tin added to compensate for losses due to 'heating', i.e. oxidation. This gave a proportion of tin within the beta bronze composition range of about 21–25%.

The kammāḷar exploited the super-plasticity of the alloy in the beta temperature range (586–775 °C) to hammer out a flat circular ingot into a thin concave bowl. The ingot of 15 cm diameter and 1–1.5 cm thickness had first been made by casting the alloy into a circular depression in the ground. It was then put on a low charcoal fire and heated to the beta temperature range, which Mr Bhaskaran said was estimated as being not too hot nor too cold, with a rosy pink rather than red hot flame. Then the ingot was taken off the flame and held with a long pair of tongs while four men hammered it with massive, powerful consecutive blows. The hammer consisted of a huge wedge-shaped iron head mounted in two wooden supports which was held by both hands and swung down from over the head (fig. 59.1). The ingot was then turned slightly and the blows repeated working outwards from the centre. After a couple of sequences of hammering it was heated again to prevent cooling from the beta temperature range with the concave face down on the flame and the cycles of hammering and annealing were repeated till the ingot attained a perfectly concave bowl shape. The process of fashioning the ingot into a bowl was remarkably skilled and controlled and took some three hours or so of sustained effort. The original diameter of the circular ingot formed the flat base of the concave bowl.

By this process an ingot 15 cm in diameter and 1–1.5 cm thick had been wrought into a thin concave bowl 25 cm in diameter, 8 cm high with a rim thickness of only 1.5 mm; achieving a high degree of plastic deformation to dimensions nearly twice of the original ingot. Such extensive working is not described by Goodway and Conklin (1987) in their account of wrought high-tin beta bronze gong making in Southeast Asia where only the rims seem to have been raised.

Then the bowl was again heated to the beta temperature range on a bed of charcoal and rapidly quenched in a tank of water beside it. This would have the effect of freezing the meta-stable martensitic beta phase. If slow cooling were allowed the beta phase would transform into the delta eutectoid, making the alloy very brittle. The kammāḷar demonstrated their empirical understanding of this by saying that if this was not done the bowl would break easily.

After quenching, the bowl acquired a blackened surface or skin. Wooden mallets were used to further smoothen the inner surface. The rough flanges on the bowls were cut off with shears. The inner surface was scraped and polished with steel chisels to bring out the bright golden lustre of beta bronze while the outer
Fig. 59.1. Process of hammering out the high-tin bronze ingot into a bowl at Payangadi, Palghat District.

Fig. 59.2. Scraping the skin off the quenched bowl to reveal the golden lustre of beta bronze; an unpolished quenched bowl can be seen in the background.

Fig. 59.3. The drawing of concentric arcs using steel scrapers with the bowl mounted on a lathe.
surface was left blackened and unpolished for contrast (fig. 59.2). The interior of
the base was decorated with a series of closely-spaced arcs using long hand-held
steel scrapers.

The bowl could also be decorated with a pattern of rings. To do so the bowl
was first affixed into four rivets on a vertical wooden board mounted on an axle.
Then two steel scrapers were set like a compass centred inside the bowl and the
axle was turned leaving rings in the base of the bowl (fig. 59.3). Many of the
early historic bowls from the Nilgiris, Adichanallur and Thailand have up to nine
distinctive concentric rings in the centre; these could have been made in a similar
way.

The method of the working from the centre outwards left a discernable spiral
pattern of dimpled marks on the surface of Payangadi bowls. Such patterns as well
as the typical concave shapes are also shared with the Nilgiri bowls which I
inspected from the British Museum collection.

Aspects of the contemporary use of high-tin bronze in South India

Kammāḷan Bhaskaran mentioned that the items made by this method included
kinnan or plates, caṭṭuvāni (a ladle for rice), flat circular gongs used in temples,
illa-tāḷāḷ is or small hand cymbals with a high ringing tone used to accompany classical dance and rituals. He said that the older vessels and articles tended to
be bartered and recycled while the ladles could be hot-worked and re-polished
again if tarnished. He claimed that this was a very old tradition and that formerly
people often used articles of this nature.

The kammāḷan lamented that it was increasingly difficult for his family to
stay in the trade. The practice now survived almost entirely by recycling old ves-
sels, as copper and tin were prohibitively expensive. They had only a few tra-
ditional customers left and were increasingly marginalised by the stainless steel and
aluminium industry. Moreover craftsmen are moving away from labour intensive
traditional methods: for instance in Nachiarcoil in Tamil Nadu cymbals are now
made of brass with recent sand casting and box mould techniques.

But it is very likely that there are a few other centres of manufacture of such
vessels in Kerala and Tamil Nadu, as I purchased two more high-tin bronze bowls
of similar type of about 15 cm diameter and rim thickness of 0.6–0.8 mm. One of
these was bought in Iriyalakuda, Trichur District. The other was from a shop in
Madrurai, where the shopkeeper referred it as tāḷavēṭṭu in Tamil, made in
Nachiarcoil in Tamil Nadu.

My late grandmother from Tamil Nadu also testified to the extensive use of
bronze utensils and bell metal vessels in the past and threw interesting light on the
functional aspects of such vessels. She showed me a similar shallow plate used in
the past called tāḷavēṭṭu, which she said would shatter if dropped and was used
mainly for storing food such as curds, rice, milk, pastes, etc. She mentioned that
while veṭṭu-kalam (cast bell metal) could even be used to boil milk the tāḷavēṭṭu
should not be used directly on the fire; this could reflect the fact that the meta-
stable beta phase could be affected by temperature changes.
She added that pitthal or brass (i.e. copper alloy with zinc) was, however, not used for food purposes as it tarnished easily. The preferred use of bell metal utensils appears to be based on properties such as better resistance to corrosion and less toxicity. Of the high tin bronze alloys, quenched high-tin beta bronze would be especially resistant to corrosion owing to the stress relief brought about by annealing and the retention of the high temperature beta phase. Indeed many of such bowls from antiquity are in a good state of preservation.

Other ethnographic evidence of high-tin beta bronze working in the subcontinent

An anthropological study on metal craftsmen of India by Mukherjee (1978: 89–91) gives an eye witness description of vessels made of 'wrought bell metal' which, in retrospect, can be identified as high-tin bronze work. Such 'wrought bell metal' workers are reported in Nagarcoil in Kerala (Mukherjee 1978: 408–410), parts of Andhra, Nepal (Mukherjee 1978: 444–450) and several in West Bengal (Mukherjee 1978: 342–345) and Orissa (Mukherjee 1978: 354–356). The alloying proportions used by all these craftsmen fall in the high-tin bronze composition range of 20-22% tin (Mukherjee 1978: 342, 354, 410, 450). The braziers of Orissa and West Bengal, called kāṁsāris and kāṁsābadāṇīks, hammered and enlarged ingots of bell metal or kāṁsā alloyed to the above high-tin proportions to make gongs called kāṁsār and rice bowls called kāṁsā. Indeed her study takes on significance as it seems to indicate quite a widespread and well-entrenched pan-Indian tradition of working high-tin bronze.

Mukherjee's account from Khagra in West Bengal sketchily describes a process similar to Payangadi of the ingot being hammered into a vessel on an anvil by four men and polished using a lathe. Particularly noteworthy are her drawings (Mukherjee 1978: 342–346) of the specialised shapes of anvils against which various shapes of vessels could be hammered out, e.g. pointed anvils for tall glasses, hollowed ones for curved lids with special techniques for making raised peaks on the lids (fig. 59.4). Indeed, such suitably shaped anvils could also have been used as moulds to forge some of the more complex shapes seen in the high-tin bronze vessels of South Indian antiquity; such as the raised jugs from Adichanallur and perhaps the knob based bowls of the Nilgiris.

Some linguistic and etymological considerations

Correlations between the properties of high-tin bronze articles, colloquial usage and etymological and inscriptive evidence support their usage in Indian antiquity. The term kāṁsā used by the eastern Indian craftsmen in Mukherjee's account to describe bowls, gongs, braziers, etc. is a corruption of the Sanskrit word kāṁśya or bell metal. The Mauryan economic treatise of the Arthaśāstra (Kangle 1972: 108) recommends the setting up of factories for working alloys including kāṁsā-tālā; this has been interpreted as bronzes of different propor-
Fig. 59.4. Process of 'wrought bell metal' working at Khagra, West Bengal as illustrated by Mukherjee (1978: 343–345).

59.4a. Group of men hammering the ingot on an anvil. 59.4b. Different anvil shapes for forging vessels. 59.4c. Making peaked lids by forging the lid ingot in specially shaped anvils.

tions with tāla implying measures. Kāṁsya is further described in the 12th century alchemical text of the Rasaratnasamuccaya as an alloy of eight parts copper to two parts tin (Ray 1956: 185), i.e. around 20% tin. In fact in Goodway's study of the high-tin bronze gong makers of the Philippines (Goodway & Conklin 1987) the term used by the artisans for the alloy is gangha, which she points out, is a corruption of the Sanskrit kāṁsya. Such evidence in fact encourages speculation that it was Indian traditions that influenced Southeast Asian bronze makers rather than the reverse.

Kāḷikam, probably derived from the Sanskrit kāṁsya, is used in the Tamil classic Cilappatikāram (3rd–5th century AD) to describe bronze (Cilapp. 14,
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Tāḷam is used in Tiruvācakam (7th–9th century AD) by Maṇiṅkavācakar (17.8) in a musical context in the sense of cymbals held in the hands of devotees. Tāḷam, also a rhythmic unit, is used to describe cymbal in a Chola inscription of the period of Rājarāja I (10th century AD) (Srinivasa Rao 1952: 2, nos. 3 & 25, no. 51). A Chola inscription of the period of Parantaka I (Hultzsch & Krishna Sastri 1929: 241) describes temple donations of five tāḷam-vattil, translated as plates and cups, and caṭṭūram translated as a ladle. Inscriptions from Rājarāja’s reign also mention tēla in the context of a dish (Hultzsch, Venkayya & Krishna Sastri, n.d.: 9), while vattil is translated as a cup and ottu-vattil as shell-shaped cup (Hultzsch, Venkayya & Krishna Sastri, n.d.: 9, 18). Such terms relate to coloquial usage by the artisans and shopkeepers interviewed in Tamil Nadu and Kerala to describe various high tin bronze artefacts, such as musical symbols, bowls and ladles, and in fact the Tamil term used for the bowls, i.e. tāḷavēṭṭu may have connotations of a musical vessel due the high ringing tone of the quenched alloy when struck.

Analytical results

The results of the compositional analysis of the modern bowls purchased from Payangadi, Irinjalakuda and Madurai, vessels from the Iron Age burials of Adichanalur and Nilgiris and of two platters or tāḷam from the Medieval Chola Period are presented in table 59.1 which confirm that these are all of high-tin bronze.

The micro-structures of two modern bowls from Payangadi (fig. 59.5a) and Irinjalakuda confirm the wrought and quenched process as described before. Quenching in the beta temperature range is indicated by the presence of the matrix of prominent acicular or needle-like bundles of martensitic beta phase. Islands of alpha phase can be seen in the matrix of beta: these show distinct annealing twins, distortion or elongation of shape and occasional strain lines indicative of annealing and working in the plastic beta range.

The micro-structures of a jug from the Adichanalur burial (fig. 59.5b) and a bowl from the Nilgiri megaliths (fig. 59.5c) compare well with the modern examples indicating a wrought and quenched process of fabrication. The twinned islands of alpha phase show considerable deformation and elongation, indicating extensive working with a more expansive beta matrix due to the slightly higher tin composition in the pure beta range. In all the structures discussed above, precipitation of needles of alpha phase embedded in the beta matrix are also seen; the formation of which is perhaps due to an insufficient rate of cooling through the critical temperature for quenching the beta phase (Reeve, Bowden & Cuthbertson 1953: 49–52).

The micro-structures of the two large Medieval Chola platters called tāḷam also indicate a similar process of fabrication (fig. 59.5d) with sharp acicular beta needles surrounding twinned alpha grains and with prominent strain lines. These structures support the epigraphical evidence presented before for possible usage of high-tin bronze vessels in the Medieval Period.
Table 59.1
Composition of some high-tin bronze vessels from South India

<table>
<thead>
<tr>
<th>No.</th>
<th>Artefact</th>
<th>Provenance</th>
<th>Period</th>
<th>Copper %</th>
<th>Tin %</th>
<th>Iron %</th>
<th>Nickel %</th>
<th>Arsenic %</th>
<th>Total %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Bowl</td>
<td>Payangadi, Kerala</td>
<td>Modern</td>
<td>77.645</td>
<td>22.538</td>
<td>0.013</td>
<td>0.025</td>
<td>0.112</td>
<td>100.332</td>
</tr>
<tr>
<td>2.</td>
<td>Bowl</td>
<td>Irinjalakuda, Kerala</td>
<td>Recent</td>
<td>77.406</td>
<td>22.439</td>
<td>0.031</td>
<td>0.030</td>
<td>0.126</td>
<td>100.031</td>
</tr>
<tr>
<td>3.</td>
<td>Jug</td>
<td>Adichanallur, Tamil Nadu</td>
<td>Mid-first mill. BC</td>
<td>77.612</td>
<td>22.922</td>
<td>0.083</td>
<td>0.057</td>
<td>0.020</td>
<td>100.726</td>
</tr>
<tr>
<td>4.</td>
<td>Bowl</td>
<td>Nilgiris, Tamil Nadu</td>
<td>Mid to late first mill. BC</td>
<td>75.422</td>
<td>23.954</td>
<td>0.123</td>
<td>0.014</td>
<td>0.133</td>
<td>99.495</td>
</tr>
<tr>
<td>5.</td>
<td>Platter 1</td>
<td>Thanjavur district, Tamil Nadu</td>
<td>Medieval Chola</td>
<td>76.368</td>
<td>24.621</td>
<td>0.296</td>
<td>0.108</td>
<td>0.292</td>
<td>101.700</td>
</tr>
<tr>
<td>6.</td>
<td>Platter 2</td>
<td>Thanjavur district, Tamil Nadu</td>
<td>Medieval Chola</td>
<td>76.960</td>
<td>24.949</td>
<td>0.553</td>
<td>0.101</td>
<td>0.153</td>
<td>102.842</td>
</tr>
<tr>
<td>7.</td>
<td>Bowl</td>
<td>Madurai town, Tamil Nadu</td>
<td>Modern</td>
<td>77.01</td>
<td>21.76</td>
<td>0.174</td>
<td>n.a.</td>
<td>n.a.</td>
<td>98.934</td>
</tr>
</tbody>
</table>

Nos. 1-6 analysed by Electron Probe Micro-Analysis on polished cross-sections using JOEL Superprobe JXA- 8600 at 20 KV with ZAF correction, within instrumental accuracy of 1% over 100%. No. 7. analysed by Flame Atomic Absorption Spectrometry using Pye Unicam SP9. All other elements are trace or not detected; n.a. = not analysed.
Fig. 59.5. Micro-structures of some wrought and quenched beta bronze vessels from South India. (Photos here diminished 50%.)

59.5a. Photomicrograph of bowl manufactured at Payangadi, Kerala taken at x230. 59.5b. Photomicrograph of jug from the Iron Age burial of Adichanallur taken at x230. 59.5c. Photomicrograph of bowl from Iron Age megaliths of Nilgiris taken at x460. 59.5d. Photomicrograph of Medieval Chola platter from Tanjore District taken at x460.
Conclusions and discussion

The analytical investigations presented herein demonstrate the use of vessels of wrought and quenched high-tin bronze in South Indian antiquity in the Megalithic Period, the Medieval Period and into the present day, all periods having technical and stylistic affinities. Considering the other finds of high-tin bronze discussed before and the familiarity with such alloys suggested by the ethnographic, literary and etymological evidence, it is reasonable to postulate considerable antiquity for the use of high-tin bronze in the Indian subcontinent.

The source of tin in Indian antiquity, whether imported or local, remains the major problem in addressing questions of local manufacture. However, exploitation of some of the meagre tin reserves of the subcontinent in antiquity cannot be dismissed without further investigations. A case for such exploitation comes especially from eastern India where there are minor tin reserves in Bihar State in the Hazaribagh and Singhbhum region (Mukherjee & Dhaneshwar Rai 1978: 345–350) with the finds of high-tin bronze from the Early Historic Assur graves being proximal to these deposits. Moreover, from Mukherjee’s accounts there also appears to be a strong ethnographic tradition in eastern India of working high-tin bronze. In South India sparse placer tin (alluvial tin) deposits are noted in the auriferous Damhal region (Foote 1874: 140) of North Karnataka, the exploitation of which would not, however, leave many traces.

Considering the early finds of high-tin bronze in Iron Age contexts, a point for speculation is the linkage between the technological development of wrought iron working — and possibly also quenched steel making — with wrought and quenched high-tin bronze working. Probable evidence for crucible steel making comes from an iron-rich Megalithic site, Kodumanal in Tamil Nadu (3rd century BC), with finds of crucibles stacked in a furnace (Rajan 1990: 93–102); some of these were found to be iron-rich on analysis. Copper alloy bowls similar in type to the Adichanallur high-tin bronze bowls were also found at this site.

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References


