SUOMALAISEN TIEDEAKATEMIAN TOIMITUKSIA
ANNALES ACADEMIÆ SCIENTIARUM FENNICÆ

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SOUTH ASIAN ARCHAEOLOGY 1993

Proceedings of the Twelfth International Conference
of the European Association of South Asian Archaeologists
held in Helsinki University 5–9 July 1993

Edited by
Asko Parpola & Petteri Koskikallio

Volume II

Helsinki 1994
SUOMALAINEN TIEDEAKATEMIA

Srinivasan, S. 1994. "High-tin bronze bowl making from Kerala, South India and its archaeological implications." in *South Asian Archaeology 1993*. Ed. A. Parpola, A. and P. Koskikallio, pp. 695-705. Helsinki: SuomalainenTiedeakatemia.

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

Sharada Srinivasan

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 super-plastic 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; Bennet & 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 1941: 87–90), Nilgiris (Breeks 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 Sātavāhana dynasty has been found to consist of 18–19% tin bronze (Sastry *et al.* 1983: 21–29). Recent studies indicate that Andhra Viṣṇukuṇḍin 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, Breeks (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 Piljian. 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 (Aiyappan 1951). Ms Piljian 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-k-kuḻi* with the construction ascribed to the Pāṇḍavas (Congreve 1847: 77–146; TL 1924–39, V: 2597a). Ms Piljian said these bowls were known to come from Kerala and were made of *veṇ-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 *kammāḷar*, 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 *kammāḷan* Bhaskaran was said to comprise 10 kg of pure copper with 2.75 kg of *veḷḷīyaṁ* or tin, with up to 500 gr 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 the size 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.

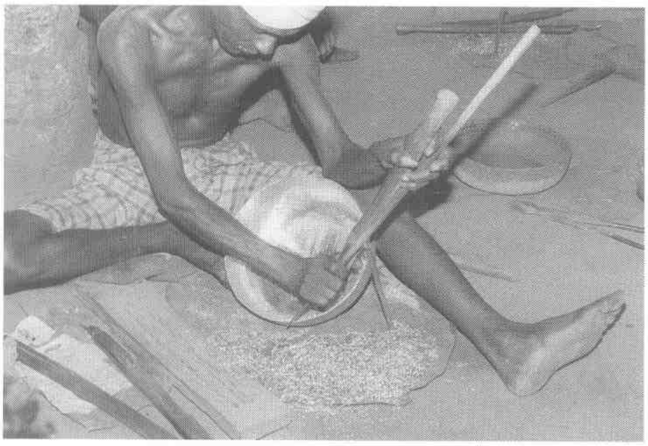

Fig. 59.2. Scraping the skin off the quenched bowl to reveal the golden lustre of beta bronze; an unpolished quenched bowl can be seen in the background.

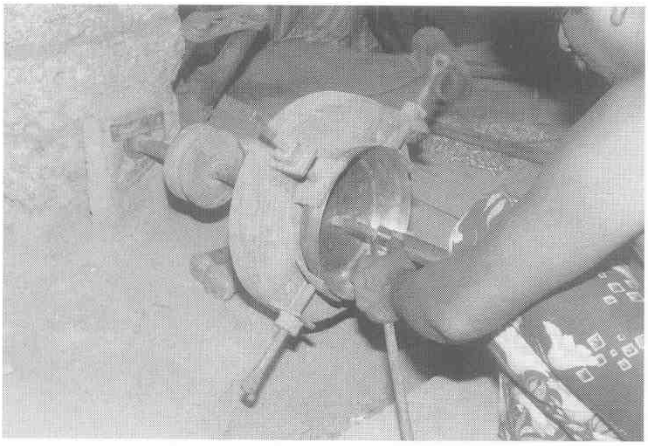

Fig. 59.3. The drawing of concentric arcs using steel scrapers with the bowl mounted on a lathe.

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 *kiṇṇaṁ* or plates, *caṭṭuvaṁ* (a ladle for rice), flat circular gongs used in temples, *ila-t-tāḷaṁ* 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 vessels, as copper and tin were prohibitively expensive. They had only a few traditional 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 Nachiarkoil 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 Irinjalakuda, Trichur District. The other was from a shop in Madurai, where the shopkeeper referred to it as *tālavĕṭṭu* in Tamil, made in Nachiarkoil 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 *tālavĕṭṭu*, 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 *veṇ-kalam* (cast bell metal) could even be used to boil milk the *tālavĕṭṭu* should not be used directly on the fire; this could reflect the fact that the metastable beta phase could be affected by temperature changes.

She added that *pittaḷai* 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 *kāṁsābaṇiks*, hammered and enlarged ingots of bell metal or *kāṁsā* alloyed to the above high-tin proportions to make gongs called *kāṃsāṛ* 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 inscriptional 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 *kāṁsya* or bell metal. The Mauryan economic treatise of the *Arthaśāstra* (Kangle 1972: 108) recommends the setting up of factories for working alloys including *kaṁsā-tāla*; this has been interpreted as bronzes of different propor-

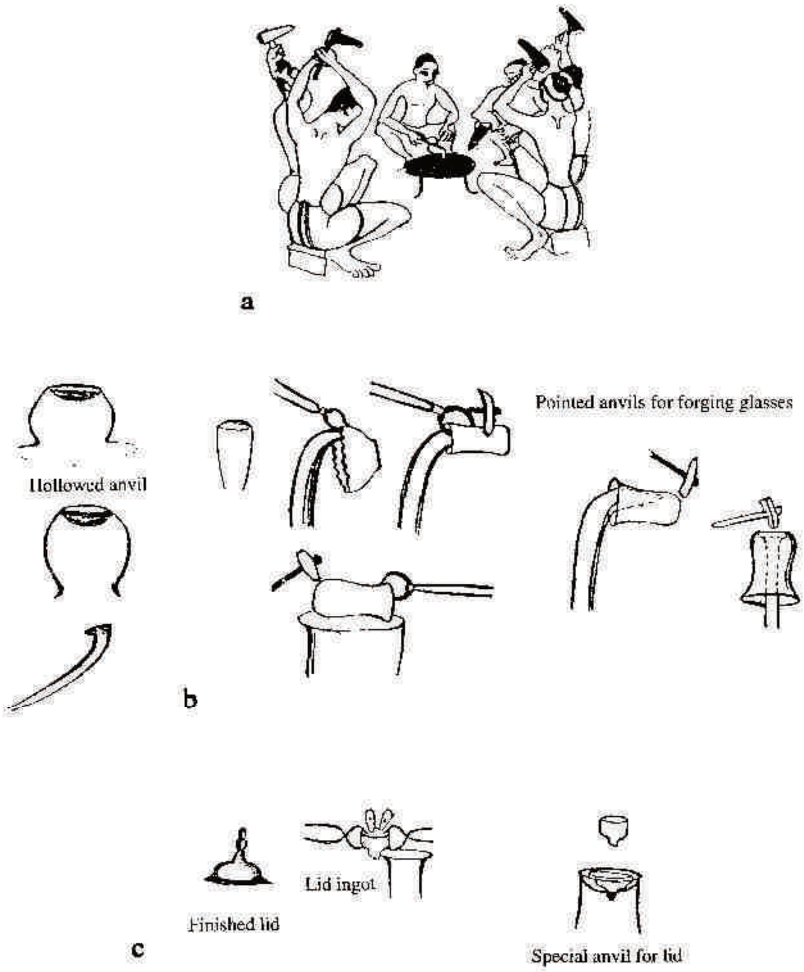

Fig. 59.4. Process of 'wrought bell metal' working at Khagra, West Bengal as illustrated by Mukherjee (1978: 343–345).
59.4a. Group of men hammering the ingot on an anvil. *59.4b.* Different anvil shapes for forging vessels. *59.4c.* Making peaked lids by forging the lid ingot in specially shaped anvils.

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.

Kañcam, probably derived from the Sanskrit *kāṁsya*, is used in the Tamil classic *Cilappatikāram* (3rd–5th century AD) to describe bronze (*Cilapp.* 14.

174). *Tāḷam* is used in *Tiruvācakam* (7th–9th century AD) by *Maṇikkavācakar* (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 & 23, no. 51). A Chola inscription of the period of Parāntaka I (Hultzsch & Krishna Sastri 1929: 241) describes temple donations of five *tālam-vaṭṭil*, translated as plates and cups, and *caṭṭuvam* translated as a ladle. Inscriptions from Rājarāja's reign also mention *tāla* in the context of a dish (Hultzsch, Venkayya & Krishna Sastri, n.d.: 9), while *vaṭṭil* is translated as a cup and *oṭṭu-vaṭṭil* as shell-shaped cup (Hultzsch, Venkayya & Krishna Sastri, n.d.: 9, 18). Such terms relate to colloquial usage by the artisans and shopkeepers interviewed in Tamil Nadu and Kerala to describe various high tin bronze artefacts, such as musical symbals, bowls and ladles, and in fact the Tamil term used for the bowls, i.e. *tālaveṭṭu* 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 Adichanallur and Nilgiris and of two platters or *tālam* 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 Adichanallur 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 *tālam* 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

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

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.

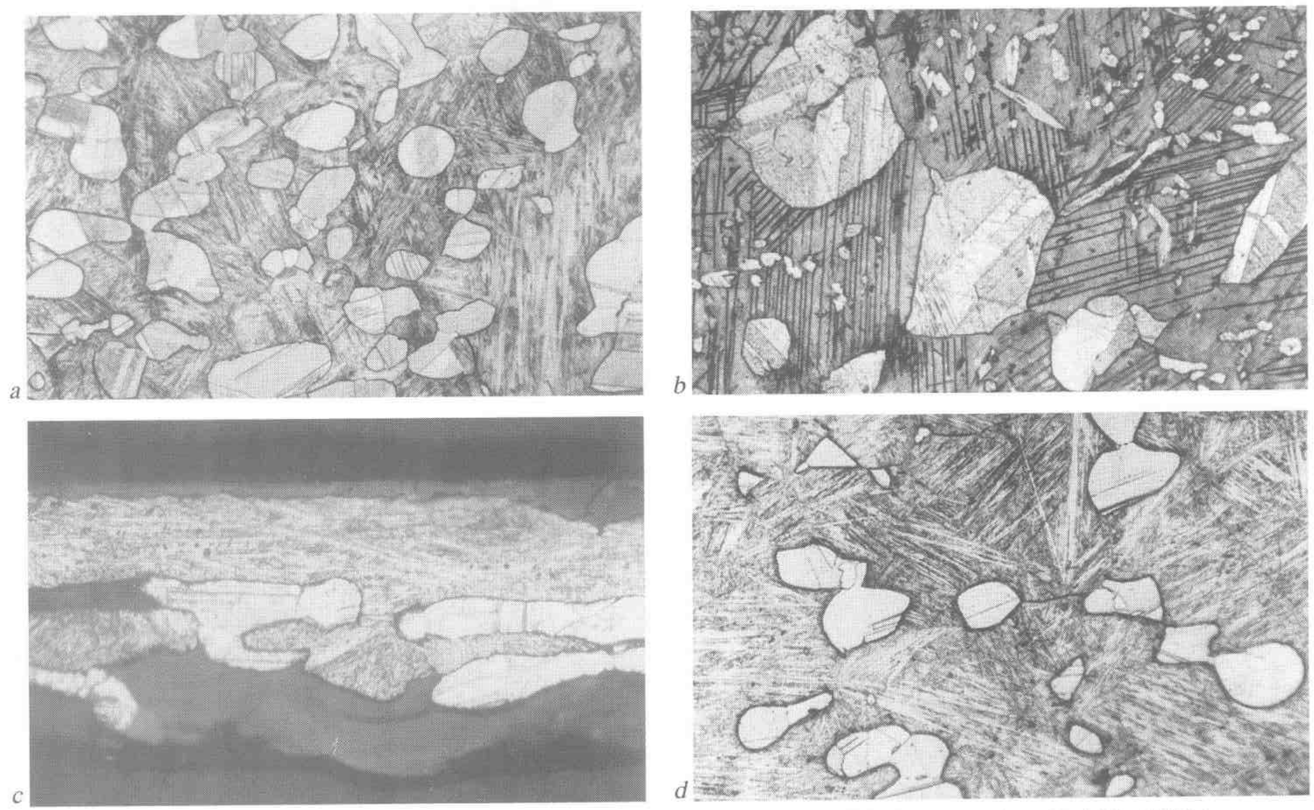

Fig. 59.5. Micro-structures of some wrought and quenched beta bronze vessels from South India. (Photos here diminished 50%.) *59.5a.* Photomicrograph of bowl manufactured at Payangadi, Kerala taken at x230. *59.5b.* Photomicrograph of jug from the Iron Age burial of Adichanallur taken at x230. *59.5c.* 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 Dambal 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.

Acknowledgements

My special thanks are due to Dr Nigel Seeley, Dr John Marr and Dr Ian Glover for their invaluable support in the cultural and technical aspects of my study; to Dr Anna Bennett, Dr John Merkel, Dr David Scott, Mr Kevin Reeves and Mr Alan Horsler for their technical insights and Ms Evam Piljian for her ethnographic contribution. I am most grateful to the Madras Museum: former curator Dr Srinivasa Desikan, Dr Devasahayan, and Mr Balasubramanian; Tamil University, Thanjavur: Dr Subbarayalu and Dr Rajan; and Mr Krishnamurthy, Dinamalar, for their encouragement in my investigations. Last but not the least my sincere thanks are due to Mr Bhaskaran, the Nadavarambu Bell Metal Co-operative Society, and all the artisans and shopkeepers for their co-operation; and to Mr Digvijay Mallah for his assistance in my field investigations with interpreting Malayalam and the photographic documentation.

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