RECENT ADVANCES IN ARCHAEOLOGICAL INVESTIGATIONS OF SOUTH INDIA

PROCEEDINGS

(2nd International Seminar in Commemoration of
Padma Shri Iravatham Mahadevan)

Government of Tamil Nadu
Department of Archaeology
Chennai - 600 008
2024 Tiruvalluvar Year 2054

Recent Advances in Archaeological Investigations of South India

Proceedings

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Chennai - 600 008

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Early Forged Bronze and High-tin Beta Bronze from Tamil Nadu and India

Dr. Sharada Srinivasan

Introduction

As-cast binary copper-tin alloys with over 15% do not seem to have been widely used in antiquity due to problems of brittleness. Nevertheless, the author's researches have reported the use of wrought/hot forged and quenched high-tin beta bronze (ie with the prevalence of the beta intermetallic compound phase of bronze with 23% tin), from Iron Age sites in India and especially the megalithic sites in southern India and Tamil Nadu, such as Nilgiris and Adichanallur (Fig 1) ranking amongst the earliest known and most extensively forged such alloys known (Srinivasan 1994, 1998a, 2017, Srinivasan and Glover 1995). Ethnometallurgical studies by the author served to identify pockets of such crafts in Kerala giving insights into production mechanisms.

However, some of the metal finds on which the above studies were made were from the collections of Government Museum, Chennai and British Museum, London made in the 19th -20th century from the Nilgiris and Adichanallur in Tami Nadu by British colonial officers such as Elliot, Breeks and Rea, from cairns and burials which were not then systematically excavated and are hence not very well dated (Srinivasan 2022). To that effect, more recent systematic excavations around the banks of the Thamirabarani or Porunai reiver have thrown further light on have thrown further light on the Iron Age urn burial complexes at Adichanallur and Sivagalai. It is further established here from preliminary scientific investigations using XRF that high-tin bronzes were indeed already prevalent at Adichanallur and Sivagalai to at least 1200 BCE as per recent AMS dates, ranking amongst some of the earliest known, which also seem to corroborate the findings mentioned earlier by the author. of longstanding traditions of high-tin bronze working particularly in the Tamil region and southern India.

Although the source of metal for these early bronzes had not been ascertained before, it has generally been thought that southern India is not as rich in metal and mineral resources as northwestern of northeastern India. However, the lead isotope ratio investigations on a vessel reported here from Kodumanal (5th century BCE) matched those of the mine of Agnigundala in Andhra Pradesh, indicating that Agnigundala was a copper source for Kodumanal. This suggests that external sources outside the Deccan need not necessarily be invoked with respect to sources of metal.

This paper also points out that with respect to a possible trajectory from earlier prehistory, there is a trend of using binary unleaded bronzes in the Harappan period in the northwest part of the Indian subcontinent, although these are primarily low-tin bronzes with one or two exceptions. However, this does suggest that the high-tin bronze working tradition associated with the South Indian megalithic might have emerged out of a longer prior period of experimenting with binary forged bronze in a region more familiar with copper-bronze metallurgy, which emerges somewhat without precedent in the context of Tamil prehistory. The use of the unusual terminology of vettu/vettil in Tamil/Malayalam and in Brahui and Sindhi in the northwest region associated with the Dravidian language group is also thus intriguing and does lend itself to furthering speculation about migration from the Indus region into the Tamil region.

Most highly wrought Tamil high-tin bronze vessels and continuing traditions

As-cast binary copper-tin alloys with over 15% were not widely used in the ancient world as they are embrittled due to the presence of the delta phase component. Previously, the Indian subcontinent had not been regarded as a significant region in the exploitation of tin and bronze. However, metallurgical investigations by the author on artefacts from megalithic contexts and early historic contexts, continuing into medieval to modern south India demonstrated longstanding familiarity with the exploitation of the intermetallic properties of binary high-tin bronzes, as seen in the manufacture of vessels, coins and musical instruments of wrought and quenched beta bronze with 22-5% tin, and the manufacture of mirrors of delta bronze with about 33% tin (Srinivasan 1994, Srinivasan and Glover 1995, Srinivasan 2016e), which are also the last surviving crafts of their kind in the world.

Astonishingly, highly sophisticated and thin-rimmed bronze vessels have been uncovered from the Nilgiri megalithic cairns and Iron age burials of Adichanallur (Fig 1), Tamil Nadu (c. 1000-500 BC), while metallurgical investigations on some of these by the author confirmed that they were of hot forged and quenched binary unleaded high-tin beta (23% tin) bronze (Srinivasan 1994, Srinivasan and Glover 1995, Srinivasan 2010). Such an alloy of copper and tin with around 23% tin can be forged greatly at high temperatures due to the presence of a high temperature plastic intermetallic beta phase which when quenched gives additionally properties of strength and lustre to the alloy. These extraordinarily thin-rimmed vessels were fabricated by extensively hammering out such an alloy between 586-7980 C when a plastic beta intermetallic compound (Cu_5Sn) of equilibrium composition of 22.9% tin forms. This was followed by quenching which resulted in the retention of needle-like beta phase (as seen in the microstructure undertaken by the author of tiny fragment of a vessel from Adichanallur from Government Museum, Chennai in Fig. 2) and prevents the formation of brittle delta phase and also gives a golden polish. Low-tin bronzes have limited workability in comparison. Such high-tin bronze vessels have continued to be used among the local communities of the Nilgiris such as the Todas. Such high-tin beta bronze vessels also show high corrosion resistance due to the retention of the beta intermetallic compound phase as also seen in a Nilgiri vessel from Government Museum Chennai (Srinivasan 1994). The making of such high-tin bronze vessels by similar processes survived in many places till recently, such as in Kerala and in Nacharkoil in Tamil Nadu. The author observed large vessels being made in parts of Kerala especially in Palghat district in the 1990s of 23% beta bronze, 25 cm in diameter and 1mm rim thickness, being wrought and hot forged from ingots of 15cm diameter and 1.5 cm thick followed by quenching (Srinivasan 1994, Srinivasan and Glover 1995). However this tradition has virtually died out today. The analyses by Breeks (1873: 63) of a few vessels from the Nilgiri cairns showing them to be of 20-25 wt% tin-bronze, were in fact the earliest identifications of high-tin bronze though it was not recognised as such due to the lack of metallurgical study.

Some of the distinctive finds from the Tamil region include the strainer fragment of less than 0.2 mm rim thickness from Adichanallur shown from metallography to be of wrought and quenched high-tin bronze (Srinivasan and Glover 1995). Yet another fine perforated vessel of less than 0.2mm thickness with a floral and bird motif patterns from Kodumanal (Fig 3) excavated by the Tamil Nadu State Department of Archaeology and analysed by EPMA analysis by the author was found to have 24% tin i.e. beta bronze. Recent AMS dates from Kodumanal done at Beta Analytics have pushed back the antiquity to 5th century BCE (Rajan pers comm.).

It has also been pointed out by the author that the Adichanallur and Nilgiri examples studied metallographically by the author were much more thin-rimmed and with much greater deformation in the high-temperature plastic beta range than the Thai examples from Ban Ta Phet (Rajpitak and Seeley 1972), which were only lightly cast and quenched, showing greater mastery in the Tamil examples of the wrought and quenched high-tin bronze working technique. Whereas higher tin bronzes have been reported by author from other parts of the Indian subcontinent, they are not quite true wrought and quenched beta martensitic (23%) bronzes like the examples discussed from Adichanallur and Nilgiris which have rim thinness down to an incredible 0.2 and 0.1mm suggesting very high degree of skills in forging high-tin bronze. A fragment of a thicker rimmed vessel of 1mm rim thickness with a ray-like finial reminiscent of floral stamen is also found from Mahurjhari, a megalithic site in the Vidharbha region of Maharashtra, with affinities to Adichanallur material was analysed by the author. This was found to be a cast and quenched high-tin beta bronze of 21% tin (Srinivasan 2010); however this was not much hot forged unlike the Tamil examples as seen by the remnant dendritic structure. The megaliths of Vidarbha had a carbon date or two to 7th century BCE (Deo 1973). Park and Shinde (2013) also reported finds with 19% tin from the Vidarbha megaliths, while carinated or knob-based vessels of the 6th century with 19% tin are also reported from the Gangetic Valley with 19t% tin (Datta and Ray 2007). However, it must be stressed that these do not approach the composition of true high-tin beta bronze of 22-24% tin bronze and do not reflect a true mastery of beta bronze working. Even so, although they are not quite full-fledged high-tin beta bronze they do suggest a phase of experimentation in that direction. Indian influences were also discerned in examples of high-tin bronze vessels found in Thailand in southeast Asia (Bennett and Glover 1992, Glover and Jahan).

Preliminary X-ray fluorescence investigations

Preliminary X-Ray Flourescence analysis using the portable Olympus instrumentation procured by Prof Sharada Srinivasan under the DST-SHRI scheme was used to undertake non-destructive in situ analysis of specimens at the sites, and undertaken by her with technical support by Madan Sundarraj. Although XRF is a surface analytical technique is preliminary as it also analyses the surface corrosion, nevertheless it was helpful in identifying some specimens of bronze of a higher tin content which seem to confirm the findings of the early prevalence of higher tin bronze in Tamil sites such as Adichanallur. The Iron Age site of Sivagalai excavated by Tamil Nadu State Department of Archaeology was dated from AMS dates on paddy to c 1125 BCE done at University of Arizona. A bronze vessel (Fig 4a,b,c,d) found in a disturbed context from Sivagalai reported here, was also found from XRF analysis by the author and her team to be of high-tin bronze with 24% tin (analysed courtesy of Dr Kameshwar and Dr Rajan).

Just to indicate that the analysis by the XRF machine under conditions of no corrosion are accurate and to show the veracity of the above results, the investigations on gold foil from Sivagalai (Fig 5a,b,c) are also included here. The analysis of the gold foil piece from the well dated context of 1150 BCE from AMS dates was found to have about 87% gold, 9% silver and 2% copper, all adding upto nearly 100%, pointing to the efficacy of the XRF analysis on uncorroded metal.

In particular, a specimen reported here from analysis from Locality C, excavated in 2021 by Archaeological Survey of India (by Dr Arun Raj and Dr Yateesh) and analysed by the author and her team in situ in September 2022, showed a markedly high-tin bronze composition from surface X Ray Fluorescence analysis with more than 50% tin compared to copper (Fig 6a, 6b). The associated AMS dates go back to 1384 BCE undertaken at IUACD (Glimpse of Iconic Site of Adichanallur, p 15) with an overall date for finds of higher tin bronze being around 1200 BCE. This finding further confirms and underscores and corroborates the findings that the author has reported before establishing the use of high-tin bronze at the Iron Age sites of Adichanallur, Sivagalai and Kodumanal. It must be mentioned however, that proper metallography and SEM and EPMA analysis is required to fully characterise and confirm that they are wrought and quenched high-tin beta bronzes, in the way that the author had managed to do earlier for some specimens from the Government Museum, Chennai collection.

On sources of copper and tin and intriguing local evidence

Although tin is scarce in India compared to other regions such as southeast Asia, it is possible that some minor local tin deposits were accessible in antiquity. Eastern India has tin deposits in the Hazaribagh region (Chakrabarti 1979, 1985-6), where Mallet observed the pre-industrial smelting of tin by local tribals in furnaces resembling shaft furnaces for iron smelting. Investigations by the author on slags from the ancient mining region of Kalyadi within Hassan district of Karnataka indicate that these are bronze smelting slags with up to 7% tin from co-smelting copper and tin ores due to the presence of metallic iron, rather than casting slags from alloying copper and tin (Srinivasan 1997), which might suggest the exploitation of minor local sources of tin.

Lead isotope ratio analysis is a useful tracer for source of lead. Although it is more effective for bronzes intentionally alloyed with over 1% lead, from which lead can be easily extracted without concerns of contamination and had been attempted by the speaker on leaded bronzes using TIMS, it was also attempted in a collaboration between Dr Oli Pryce and speaker using LA-ICP on unleaded bronzes with LA-ICP for lead isotope ratios attempted through Dr Pernicka. Lead isotope ratio of one binary bronze from Kodumanal (5th century BCE) was found to have lead isotope ratios approximating to Pb 208/Pb 206 as 2.167 and Pb 207/206 Pb as 0.92. A probable match for this sample is with galena collected from the Agnigundala mine in Guntur district, Andhra Pradesh (Fig 7) by the author and analysed for her at Oxford Research Laboratory for Art and Archaeology (Srinivasan 1996) which had lead isotope ratios around 2.16 and 0.94. This is a fascinating finding suggesting local exploitation of copper in the southern Indian region at an early date, which had not been thought feasible or likely before. This points to future directions in terms of exploring ore sources and that although the question of external sources is open, one need not rule out the prospects of some exploitation of local metal sources.

Interlinked etymology of vettil/wattau linking Brahui and Tamil?

There are some interesting insights that emerge from the etymologies of words seemingly used to describe the alloys used to describe high-tin bronze and bronze at large. It seems that in Tamil and Malayalam the word that is used to describe high-tin bronze by the high-tin bronze working community of Kammalar in Kerala is talavettu and olavettu, where vettu refers to vessel. Interestingly, the term vettu is not much used in present day parlance but is found in old Tamil. A Chola inscription of Parantaka I (Hultzsch and Krishna Shastri 1929, South Indian Inscriptions III: 241) mention temple donations of talam-vattil, or plates and cups, while Rajaraja's inscription mentions ottu-vattil or shell-shaped cup (Hultzsch, Venkayya and Krishna Shastri n.d., South Indian Inscriptions II, 9. 18). Such terminologies relate are similar to those still used by Kammalar (Srinivasan 1998a), while a term related to tin is also vengalam.

It is also intriguing that these terms differ significantly from the prevalent Sanskrit terms for bronze. The Arthasastra, the Mauryan economic treatise dated to the 3rd century BCE mentions the use of kamsa tala, translated as bronze of different proportions (Kangle 1972, Srinivasan 1998b). The terms Kangsa banik used to describe braziers in Orissa might be linked to the word Kamsya (Srinivasan 1998). The term Kamsya may well also be connected to Greek/Indo European terms for tin ore which is also known as cassiterite. Surviving bronze cymbal making was also documented in Assam similar to the author's documentation in Kerala (Blurton 2011).

However, the term vettil not only markedly different from Sanskritic words but is also astonishingly very similar to words in Brahui and Sindhi for cup or vessel, which is wattau as found by the author during discussion with a Sindhi correspondant. The author's query to the linguistic scholar Peggy Mohan (pers. Comm.) confirmed that wattau was also the Brahui term for vessel and that the Sindhi term came from Brahui. One may well speculate that these terms of vettil/vettu in Tamil/Malayalam and wattau in Brahui and Sindhi with few recent connections may re-affirm the proto-Dravidian/Dravidian origin connections between Brahui from Baluchistan, the epicentre of pre and early Harappan cultural manifestations, and the languages of the deep southern peninsular, whereby the migration of the Indus people to the deep south may well explain the prevalence of these terms in Tamil and Malayalam. These notions also fit with the opinions of Indus scholars such as Iravatham Mahadevan and Asko Parpola and the broader scholarly consensus of the likelihood of Dravidian connections of the Harappan language (Srinivasan 2021) pre-dating the advent and spread of Indo-European languages in the subcontinent. As pointed out by the author (Srinivasan 1997a), although there is a mention of a binary bronze or two of 22% tin and 27% tin from Mackay's excavation at Mohenjodaro, there is no micro-structural study of these to indicate if these are intentionally made and quenched high-tin beta bronzes or not or just accidental mixtures; however it does point to some degree of experimentation with bronzes of different compositions as a prelude to the eventual emergence of true high-tin beta bronze working technologies.

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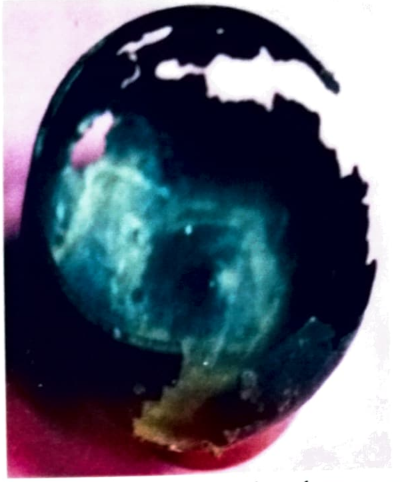


Fig 1. Adichanallur high-tin beta bronze vessel with 23% tin, Government Museum, Chennai

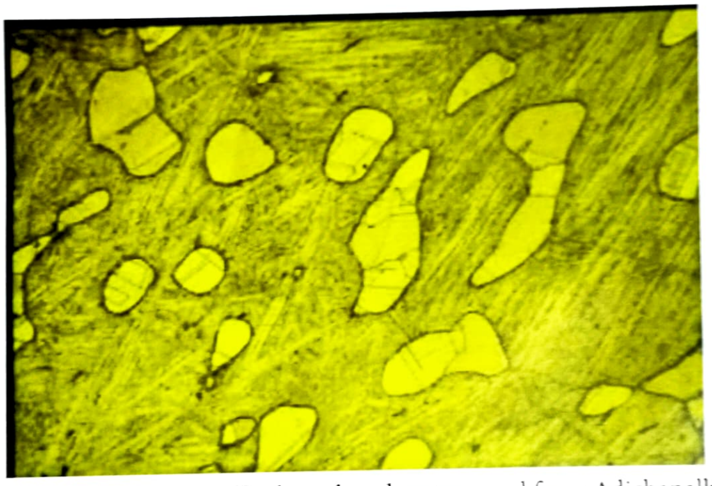


Fig 2 Micro-structure of high-tin beta bronze vessel from Adichanallur showing extensive beta martensite needles (23% tin bronze) from hot forging and quenching

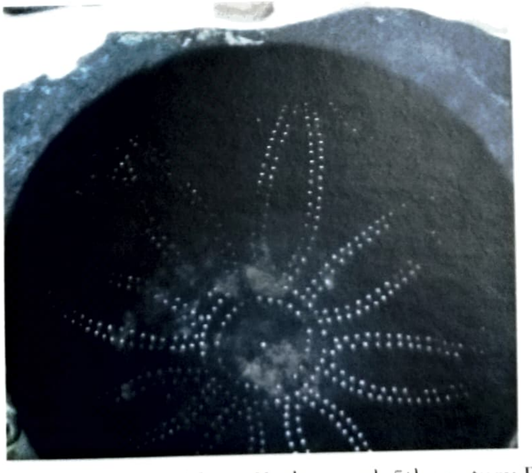


Fig 3 Perforated vessel from Kodumanal, 5th century BCE, with 24% tin analysed by EPMA from State Archaeology Collection

XRAY FLOURESCENCE ANALYSIS OF BRONZE VESSEL FROM SIVAGALAI

UNDERTAKEN BY
PROF SHARADA SRINIVASAN as PI, NATIONAL INSTITUTE OF ADVANCED STUDIES, BANGALORE

Copper alloy bowl collected from disturbed burial

Preliminary semi-quantitive analysis indicated a binary high tin beta bronze composition of 24% tin (when examining a relatively uncorroded region)

Similarity toexcavated terracotta bowl, Sivagalai

Aiming XRF beam of 8 mm dia collimeter

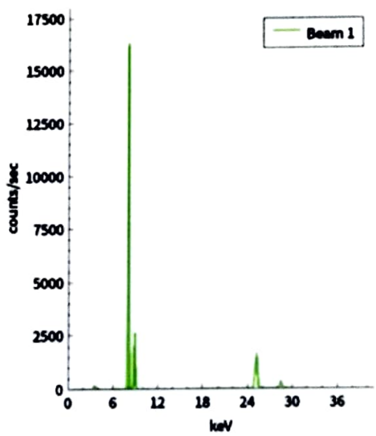
Site : Sivagalai,TamilNadu, Acc No : SGL/SP.3/C1, uncovered by TNSDA

Fig 4a Sivagalai bowl found to be of high-tin bronze with comparison of terracotta style

Fig 4b XRF Analysis at Sivagalai with author and NIAS team members and TNSDA members

El	%	+/-3σ
Fe	0.291	0.018
Ni	0.033	0.009
Cu	74.51	0.11
Sn	24.93	0.11
Sb	0.121	0.020
Pb	0.097	0.008
Bi	0.023	0.005

Fig 4c Elemental analysis of surface composition by XRF
of Sivagalai bowl showing it is of high-tin beta bronze of 24% tin



Spectrum
Fig 4d Spectrum of XRF analysis of Sivagalai high-tin bronze bowl

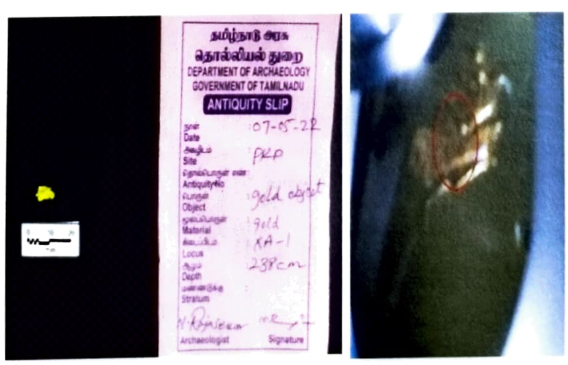
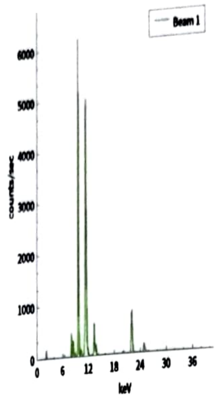


Fig 5a Sivagalai excavated gold foil piece, acc no PKP/XA-1/GOLD,
carbon dated to about 1125 BCE;
Area on which non-destructive surface XRF analysis was undertaken



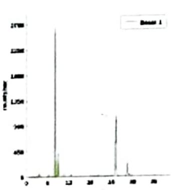
Spectrum

El	%	+/- 3σ
Cu	2.152	0.036
Ag	8.849	0.061
Au	87.698	0.080
Pb	0.038	0.011

Fig 5b, 5c Spectrum and analysis of uncorroded gold foil

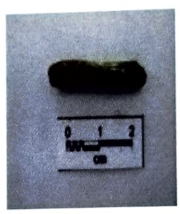
El			
Fe	1.927	%	+/-3σ
Cu	43.81	0.22	
Sn	53.38	0.22	

Elemental composition

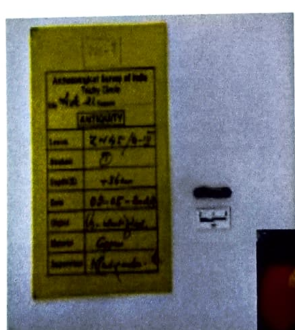


Spectrum

Aiming Image : ZN45/Q-3/7:



Adichanallur
High tin copper alloy rod fragment?
Analysis by semi - quantitative/preliminary XRF which is a surface analytical technique was done on the corroded surface and it was found to be of unusually high tin content, even more tin than copper at 53% tin bronze. Although there is a possibility that this might be due to stannous or tin oxide corrosion products, nevertheless it does fit well within the past observations of finds of higher tin bronzes from Adichanallur



Site : Adhichanallur ADC, Tamil Nadu
Acc No. :ZN45/Q-3/07

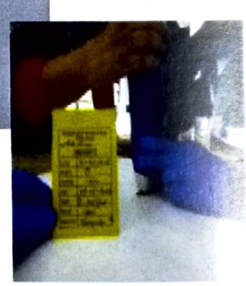


Fig 6a XRF analysis of high-tin alloy from Adichanallur from context of approx. 1200 BCE

El			
Fe	1.927	%	+/- 3σ
Cu	43.81	0.22	
Sn	53.38	0.22	

Fig 6b XRF analysis of high-tin alloy from Adichanallur showing more tin than copper

Fig 7 Agnigundala old copper working visited in 1992 by author
(for which galena matched lead isotopes of Kodumanal bronze)