



Proceedings of the VII International Conference on  
'The Beginnings of the Use of Metals and Alloys'

BUMA-VII

METALS AND CIVILIZATIONS

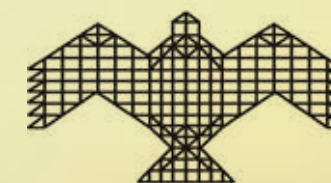
Eds.: Sharada Srinivasan, Srinivasa Ranganathan and Alessandra Giumlia-Mair

# METALS AND CIVILIZATIONS

National Institute of Advanced Studies



Editors:  
**Sharada Srinivasan**  
**Srinivasa Ranganathan**  
**Alessandra Giumlia-Mair**







## ABOUT THIS BOOK

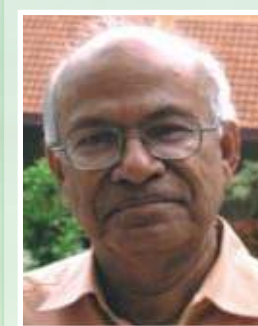
The proceedings of BUMA VII, held in 2009 in Bangalore as part of the renowned international conference series on the 'Beginnings of the Use of Metals and Alloys', are published as an edited volume entitled "Metals and Civilisations". With twenty eight valuable peer-reviewed papers covering inter-disciplinary research, it widens our knowledge of the use of metals in antiquity and several aspects of the archaeology, archaeometallurgy, historical metallurgy, crafts practices and metallurgical heritage of many Asian and some non-Asian countries

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# Metals and Civilizations

## Proceedings of the Seventh International Conference on the Beginnings of the Use of Metals and Alloys (BUMA VII)

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Chola Nataraja, Kankoduvanithavam, Tanjavur District, Government Museum, Chennai, with 8% tin and 9% lead showing details in high relief suggesting that not much post-cast tooling was done

*Sharada Srinivasan*



# Bronze image casting in Tanjavur District, Tamil Nadu: Ethnoarchaeological and archaeometallurgical insights

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**ABSTRACT** The profusion of metal images made in the Tanjavur region, going back to the early medieval Chola bronzes of the 9<sup>th</sup>-13<sup>th</sup> century ranks amongst the finest of Indian artistic expressions. Clusters of artistic and artisanal activities have thrived over generations in the Tanjavur district including metalworking workshops for bronze and bell metal casting of images and ritual objects especially around Swamimalai and Kumbakonam. Ethnometallurgical and archaeometallurgical insights on the making of icons at Swamimalai are highlighted from observations made over the past couple of decades, especially in relation to making comparisons with historical practices of bronze casting going back to Chola times. Since the processes are rapidly undergoing change, to get a better sense of the trajectory of past practices, this paper particularly aims to highlight unpublished observations made by the author going back to her first visits in 1990-1, as background to her doctoral work (Srinivasan 1996) and in relation to observations reported by other scholars going back to the early landmark efforts of Reeves (1962). These observations were particularly made by the author at the workshop of late master craftsman Devasena Sthapathy, in his time the most renowned of Swamimalai Sthapathis. His son Radhakrishna Sthapathy has now inherited this mantle. While Levy et al (2008) give a more recent account of image casting at the workshop of Radhakrishna Sthapathy, this paper attempts to also contextualise the previous trajectory that has not been covered much therein. Since their workshop now goes under the name of Sri Jayam Industries, for the sake of convenience it will be referred here by the same name.

## **Sthapatis of Swamimalai and social history**

In medieval south Indian temple worship, following Hindu *agamic* traditions, metal images were made as the *utsava murti*, i.e. images that were exclusively intended to be used in processional worship. While the Imperial Chola who ruled from the 9<sup>th</sup> to 13<sup>th</sup> centuries were predominantly worshippers of the Hindu god Shiva, they also patronised Buddhism, Jainism and temples to the Hindu god Visnu and hence a diverse range of images are found from this period. In the lost wax process or investment casting process, the image is cast by first making a model in wax, and then investing it with moulding material to form a mould, which is then heated to expel the wax. Finally the molten metal is poured into the hollow to solidify into the metal icon. The Sankrit phrase '*madhuchchehistavidhanam*' refers to the lost wax process and is described in the artistic treatise of the Manasara of the 4<sup>th</sup>-5<sup>th</sup> century (Reeves 1962: 29-31).

The Tanjavur district of Tamil Nadu, the former Chola heartland, still has traditional families of

*Sthapatis* or icon manufacturers of the status of *silpacari* (or art teachers), who make lost wax images. In the 60's, in her comprehensive work, Ruth Reeves observed over a hundred families engaged in making lost wax images in Tamil Nadu, and as many as fifty of these in the Tanjavur district (Reeves 1962: 101). Today there are far fewer families, mainly clustered around the village of Swamimalai, on the banks of the Kaveri river, and close to Tanjavur (30 km away). Traditionally speaking, South Indian bronzes were most often solid casts whereby the model was made of a single piece of wax with no clay core. This preference, despite the greater amount of metal required compared to hollow cast images, seems to have been based on ritualistic reasons. The process of casting images by the Sthapatis at Swamimalai also generally follows the solid lost wax process, although the hollow casting process is also now more widely in vogue to cast larger images. An early Chola inscription (Sivaramamurti 1963:14) describes the gift of an image of a deity which was *ghanamaga* or dense and heavy and of a *chcheyda rishabha* or hollowed bull. In a fine metaphoric poem,

Tamil women poet-saint Andal (c. 800) compares rain clouds to the mould holding wax to be expelled (Dehejia 2002:13) : this demonstrates that the process was widely known.

## Alloys past and present

In recent times the alloying compositions used by the master craftsmen in Swamimalai seem to be more akin to brass, going back to the 60's and 70's. Reeves (1962: 108) observed that alloys of 75 wt. % copper, 15 wt. % brass, and 5 wt. % tin were used by South Indian icon manufacturers. In another comprehensive study, Krishnan (1976:17) found that an alloy of twenty parts copper, four parts brass and one part lead was used at Swamimalai. During the researcher's field visits to the workshop of Sri Jayam Industries in 1990, the late master craftsman Devasenapathy Sthapathy indicated to her that they used an admixture of industrial ingots labelled as '15% brass, 82% copper and 3% lead' for image casting (Fig. 1 ). Presumably, here brass referred to an alloy of copper and zinc. A small image of Ganesa was cast by him for the researcher in 1990 (Fig. 2). A sample collected by micro-drilling with a 1mm drill bit was analysed by her by Atomic Absorption Spectroscopy at Institute of Archaeology, London in 1992-3 and was found to contain 84 wt. % Cu, 7 wt. % Zn, 5 wt. % Pb and 0.4 wt. % tin. Craddock (2007) reported that during his visits to the Sthapatis of Swamimalai, they claimed to use an alloy that contained zinc, tin and lead, whereas in fact an alloy procured from them was found to have 10% zinc, 4% lead and 1% tin. Although the date of these communications and procurement is not clearly indicated, it also reinforces the idea that in recent times leaded brassy alloys appear to be used.



**Figure 1** Industrial ingots at workshop of late Devasena Sthapathy of Swamimalai (1990) which they said was used for making icons, with ingots labeled as 82% copper, 15% zinc and lead 3%

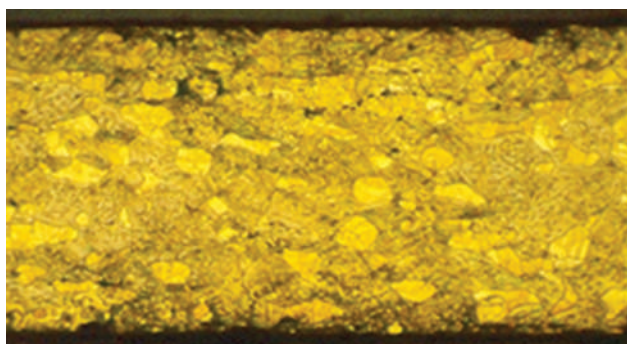


**Figure 2** Image of crawling baby Ganesa (the elephant-headed god), 8cm, cast as a *panchaloha* icon for Srinivasan by late Devasena Sthapathy of Swamimalai in 1990 found to have 84 wt. % Cu, 7 wt. % Zn, 5 wt. % Pb by AAS

On the other hand, investigations by the author- as previously reported in Srinivasan (1996, 2004, 2012)- indicated that a majority of the South Indian medieval bronzes were of leaded tin bronze. These investigations were undertaken on micro-drillings extracted from the bronzes using drill bits of 1-1.5 mm of tungsten carbide or HSS and which underwent dissolution for ICP-OES analysis. Analyses by such methods are usually regarded as being more representative of bulk analyses than other methods techniques like XRF. About 80% of 130 south Indian images analysed by the author (Srinivasan 1999, 2004) from the early historic to late medieval period were leaded bronzes with tin contents not exceeding 15% and keeping within the limit of solid solubility of tin in copper. Beyond this limit as-cast bronzes become increasingly brittle due to the increasing presence of delta phase. The average tin content in icons of the Chola period (c. 850-1070 CE) was the highest at around 7% for about 31 images, while a decline in tin to an average of 3.5 wt. % for 11 images is seen by the Later Nayaka period (c 1565-1800 CE) (Srinivasan 2004). In a few pieces, the maximum lead content went up to 25%. Of the total number of images only 15% were leaded brass images. In these brass images, the maximum zinc content went up to 25% zinc and images from the post-Chola period had higher levels of zinc. However, the use of zinc-brass was found also in early artefacts (Srinivasan 2007) such an analysed 5<sup>th</sup> century votive bowl in the Victoria and Albert Museum (acc no. IM-9-1924) recovered from an early Andhra Deccan Buddhist site, excavated from the Krishna delta with 14% zinc and 10% tin. The lead isotope ratios of this octagonal brass bowl closely matched those of a zinc ingot with a Deccan Brāhmī inscription dated to

about the 4<sup>th</sup> century, clearly suggesting the use of metal from the same source, although it is not as yet identified (Srinivasan 1998, 2007).

One may surmise that in medieval south Indian cast images, the use of low-tin leaded bronze, over bronzes with a higher tin content ( $\text{Sn} > 20 \text{ wt. } \%$ ), was deliberate rather than incidental, since increasing amounts of tin embrittles the as-cast alloy. For example, an as-cast Maitreya image from Chaiyabhum Province of Thailand, 7th–8th century, in the Philadelphia Museum of Art, found to have a composition of 20% tin, 88% cu, Pb 2% (Woodward 1997: 57–8), has a right arm broken off. In fact, a traditional *Kammalar* or metalworker from Tanjavur district, Tamil Nadu, from the region of Nacharkoil, who made bells, interviewed in 1991, mentioned to the author that alloys with too much *velliam* (i.e. tin) were not used for images, as it renders them breakable (Srinivasan 1997). However, a notable and longstanding trend in the selective and specialised use of high tin bronze alloys in ancient South India has been demonstrated from metallurgical investigations, one by the researcher on the making of wrought and quenched high tin bronze vessels from the Iron Age or megalithic period, such as the bowls from Adichanallur and Nilgiris in Tamil Nadu, the Vidarbha megaliths of Maharashtra and Gandharan Grave Culture of Taxila and continuing into recent times, as first observed in the 1990's (Srinivasan 1994, 1997, 2010). The micro-structure and analysis of a vessel from the workshop confirmed it to be wrought and quenched beta bronze of about 23% tin. Indeed, the deliberate use of bronzes of a higher tin content to make wrought and quenched high tin bronzes of about 23–24% tin is seen in the Chola period from the analysis of a platter (Fig. 3) from Government Museum, Chennai. Thus it appears that the functional aspects of working with different types of copper alloys of high and low tin bronze were appreciated in such cases in the past (Srinivasan and Glover 1995).



**Figure 3** Micro-structure of 11<sup>th</sup> Chola platter, Government Museum Chennai with a two-phase structure of wrought and quenched high-tin bronze alloy analysed to have 24% tin (200X)

Although South Indian bronzes are generally described as '*panchaloha*' or five-metalled icons

they are not really found to markedly have five different major alloying constituents. However, as Devasenasthapati explained in 1990 to the author, this was more a ritual prescription where gold and silver were added in very small amounts on the request of the interested client, as he did for the leaded brass Ganesa image cast for her (since the alloy they used already had, in his opinion, three constituents of copper, brass and lead), and as discussed in more detail later. Such accounts vary even across craftspeople. For example, Mukherjee (1978:127) reported that a mastercraftsman from Nagercoil described *panchaloha* as 'an alloy of copper, lead, silver, gold and iron dust'.

## Making of the wax model

The modelling of the wax images in southern India generally followed the artistic conventions of the treatises of the Silpasastras. The use of a traditional measuring system was used as explained by Radhakrishnasthapaty in 2006 (Fig 4) to the author whereby, in the preparation of the wax model the use of the *odiolai* or the palm frond is made with 124 divisions for the modelling of the male figure and 120 for the female figure.

Reeves (1962: 63) mentioned that the wax used for the models consisted of equal parts beeswax, powdered dammar resin with a little ground nut oil or gingelly (or sesame) oil. In Tamil Nadu and Kerala *Kunkuliyam* generally refers to dammar resin. Krishnan (1976: 10) mentioned that the wax model was made of twenty parts beeswax, twenty parts dammar resin and five parts groundnut oil; these accounts were mostly based on the practice of craftsmen in the Bangalore area. The use of groundnut oil was also noted during the author's interview of 1990 at Sri Jayam Industries. Furthermore, as told to her in 2014, harder paraffin wax has been used as an additive at their workshop for the past sixty years, as beeswax tends to get soft and loses shape more easily, given that the Tanjavur area can be quite hot with temperatures going up to 40 degrees in summer. As first observed by the author in 1989, for making the wax model, two different grades of wax were used: a softer grade richer in beeswax, used for finer details like ornaments, and a harder grade richer in paraffin for the main body parts of the images. The grade of beeswax is generally known as *tein meluhu* or 'honey wax'. Levy et al (2008: 56) also mention the use of equal parts of paraffin wax with resin, employed at this workshop for making the harder grade of wax. Nevertheless, the use of the more traditional harder dammar resin or *Kunkuliyam* was also observed by the author in the making of models for bells in the Nacharkoil region of Tanjavur in 1991 (Srinivasan 1997). It is believed that



this mixture renders the wax easier to melt out since it is has a lower melting point.



**Figure 4** Radhakrishna Sthapathy demonstrating the use of the *odiolai* for modelling the wax in 2008

The making of the wax model proceeded as follows: a rough model of the torso was made and then progressively built up and refined by warming the parts to be modelled with a heated steel spatula, to make it pliable before working it. The different parts of limbs, attributes and head were separately modelled and several of these were seen stored in buckets of cold water to keep them solid. (Fig. 5) shows wax copies of the well known Rishabhavahana image from Tanjavur Art Gallery being made in Devasena Sthapathy's workshop in 1990. Then these various solid pieces of moulded wax were heated along the edge over the brazier and attached to the main torso and the contours merged and smoothed over with melted wax. Then the ornaments and other details were added by pressing fine wax threads in place. The finished details of features and decorative details were left for tooling after the casting was completed. The ornaments were made from the softer grade richer in beeswax and darker in colour. The sprue cup and the riser were also made of the harder wax of cylindrical or conical shapes.



**Figure 5** Wax models at Devasenapathy Sthapathy's in 1990 showing a wax copy being made of the well known 11<sup>th</sup> century Chola bronze of Vrshabhavahanadeva in Tanjavur Art Gallery with some pieces of wax left in water to keep them solidified

As observed by the author at the workshop of Devasena Sthapati in Swamimalai in 1990, the mould was built up on the wax model, using successive layers of clay and leaving it to dry after each coat. The first coat was of very fine alluvial silt (*kaliman*) from the River Kaveri, very carefully and evenly smoothed down with no coarse inclusions and then left to dry (Srinivasan 1996: 108). The quality of this clay is such that the craftsmen say that even a finger-print can be visible on it, indicating a great ability to pick up details. The next layer was of slightly coarser clay from the river known as *vandal mann*. Finally, it appeared that a coat of *kaliman* mixed with *mannal*, (i.e. coarser siliceous sand) was applied. (Fig. 6) shows the successive layers of moulding clay being packed on the wax model placed on a linen cloth.



**Figure 6** Application of the layers of moulding clay on the wax model with wax runners

Accounts of different scholars suggest various practices at different times and places in the Tanjavur area. For example, while Craddock et al (2007) mention the observance in 1986 of the use of cowdung as being added to moulding clay, tallying with the account of Krishnan (1976: 14), this was not observed by the author at Devasenasthapaty's nor by Raj et al (2000) and Levy et al (2008); and it might be that it was an earlier practice. In the author's experience however, the use of cowdung as an admixture especially in the final layer of clay was certainly noticed in other workshops such as at Irinjilakuda in Kerala in 1991, where bells were being made (Srinivasan 1997). This in fact makes a lot of scientific sense, since it would have helped to give a charred carbonaceous inner layer adjacent to the molten metal, which could better absorb the gases to give a better casting, as the prevalence of gases can result in a spongy casting. Both Raj et al (2000: 51), and Levy et al (2008: 56-8, 64) recorded the use of coarser clay from the paddy fields known as *padimunn* for the moulds. However, in a communication in 2014, Mr Shiva at Sri Jayam Industries, Swamimalai clarified that in recent



times, and only when they wanted to make larger moulds, they used such coarser clays which were also bound with iron bands. During the visits in the early 90s the researcher did not observe the making of such large moulds at the workshop of Sri Jayam Industries, while the workshop itself and its activities seem to have expanded very greatly in the years since then.

### De-waxing of the mould, risering and runners

The term 'de-waxing' is invoked in this paper to describe the process whereby the wax model, once it is encased within the clay mould, is then melted out to create a hollow cavity into which finally the molten metal would be poured. As practised in recent times, at the workshop of Radhakrishna Sthapaty, (as seen in 2006, 2008 and more recently in 2014), it was noted that a special hearth dug into the ground at a slight incline was designated for this activity. The hearth in which the mould is heated is generally known as *ulai*. Here, the mould was propped up over four inverted large graphite crucibles, laying it down and along a gradual incline, so that the end with the sprue for pouring was slightly lower than the other part of the mould, to ensure that the wax could flow out smoothly and steadily. The mould was heated from below using coconut husks as a combustible material and it was also packed on top with cowdung cakes (known as *raati*), as a fuel to ensure overall uniform heating of the mould so that the wax would drain out completely. A long tray below the mouth of the crucible was kept to collect the melting wax, with a bucket placed below it so that the wax could be collected for re-use as observed in 1990 (Fig. 7). As pointed out in Chandramouli (2004 :94) the hollowed mould is described as '*karuvu*'. This term also refers to the foetus or embryo so that there is almost a birthing connotation to the lost wax process. Metallurgy, ritual aspects and aesthetics were finely melded together in these traditional arts and crafts (Srinivasan and Ranganathan 2006).

Some finer details were however noted by the researcher during field visits made in 1990 concerning the de-waxing process at the workshop of Devasenasthapaty. After the wax had run out from the heated mould, the artisan further waited until the ground nut oil (which had been deliberately added to the prepared wax and which stained the mouth of the mould), had also been burnt off. He could tell this from the gases emanating from it and until the stain had disappeared. The purpose was to ensure that no wax residues remained which could cause problems during casting, and to ensure that the mould

was as dry as possible since trapped gases could result in faulty and spongy castings.



**Figure 7** Mould just having been dewaxed (1990) in Devasenasthapaty's workshop

### Risering and pouring practice and comparison with medieval bronzes

The moulds used at Swamimalai usually have two openings, one is the sprue through which the metal is poured in, and the other is called the riser, which is the channel through which the gases escape from the mould during casting and without which the trapped gases could result a spongy casting. Standard graphite crucibles of various sizes are used these days to melt the metals in a hearth provided with a blower. The moulds are often packed in rows into mud with only the mouth being exposed before pouring is undertaken (Fig. 8). In this way, should the mould burst and hot metal ooze out, the associated hazards are minimized. While the metal is poured the impurities or oxidized matter is pushed aside to allow a steady flow. A lighted wick is held at the mouth which made sense to prevent oxidation losses. Interestingly, the 12<sup>th</sup> century Chalukyan text of the *Manasollasa* which described the lost wax casting process (Saraswati 1936) also prescribes that before pouring metal into the mould, 'one should place a burning wick in the mouth of the tube of the heated mould'. The mould is allowed to cool for several hours before breaking it open. In 1990 a casting of a small Ganesa image was done for the author at the workshop of Devasenasthapaty's as a *panchaloha* icon. For this she and her husband Digvijay Mallah were asked to purchase a small amount of gold and silver of 100mg and 200 mg respectively. This was then heated in a ladle and then the Sthapaty held Mr Digvijay's hand to pour the mixture into the crucible for melting the metal for casting the image (Fig. 9).



**Figure 8** Pouring of molten metal into moulds packed in mud at Radhakrishna Sthapathy's workshop at Swamimalai in 2006



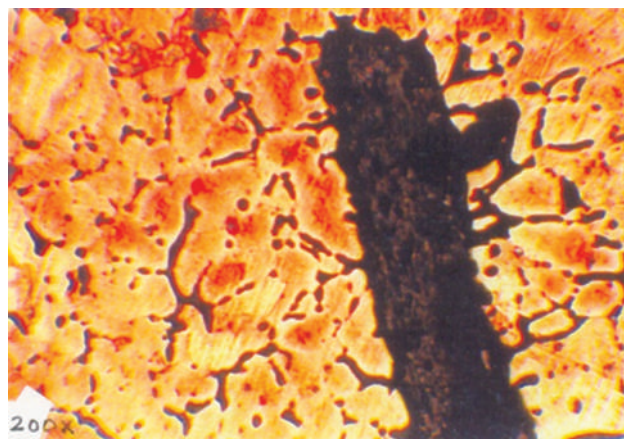
**Figure 9** Pouring of small amounts of gold and silver in a ladle into crucible for casting of panchaloha icon at Devasena Sthapathy's workshop in 1990

As mentioned by the late Devasenasthapati to the author in 1990 at Sri Jayam Industries, in the past the pouring practices differed, and more than one pouring sprue cups were used along the length of the rear of the image (Srinivasan 1996: 113). Indeed, a damaged and unfinished Vishnu which the author examined in 1989 from the Chhatrapati Shivaji Maharaj Vastu Sangrahalaya (CSMVS) Museum, Mumbai, (then Prince of Wales Museum of Western India), also indicated a similar gating design, of feeding the mould through sprues along the rear of the horizontally inclined mould. A long protruding irregular patch of metal at the rear of the torso indicated the use of a main sprue cup in this central region of the image (Fig. 10). Another sprue seems to have been at the back of the head. In addition, as still seen in images being made today, runners connected the attributes held in the arms to the main body which in most images are cut off after casting. The aim of this method appears to have been to achieve adequate risering, and more directional solidification. Furthermore, by pouring with the mould lying horizontal, the problems of the metallostatic pressure of a great weight of the metal used for the solid casting, which might break a vertical mould, would have also been avoided. Studies by Johnson (1972:45-53) on an unfinished 12<sup>th</sup> century Krishna image suggested a similar pouring practice. The *in-situ* metallograph

undertaken in 1989 with the author's collaboration with Dr S. Gorakshekar, then Director, Prince of Wales Museum / CSVMS Museum, Mumbai and BARC on the unfinished Vishnu from the same museum showed the heavy impregnation of mould material into the metal fireskin of this damaged image (Fig. 11). In fact late Devasenasthapathy in 1990 mentioned to the researcher that for the *panchaloha* images, the small additives of gold and silver would have been done through the runner at the back of the head, as it was thought to give lustre to the face of the image.



**Figure 10** Unfinished/damaged casting of Vishnu, 13<sup>th</sup> century, Prince of Wales Museum / CSVMS Museum, Mumbai showing sprue at the rear of the torso



**Figure 11** Surface *in situ* metallograph of the unfinished and damaged Vishnu, Prince of Wales Museum / CSVMS Museum, Mumbai showing impregnation of mould material into metallic areas



## Final finishing

A hammer is used to break open the mould and to remove the debris to retrieve the image. After breaking open the mould the present day *stapathis* finish the cast images by chasing and polishing the image and all the finer detailing nowadays is done by chiselling after casting (Fig. 12). This is possible because of the more brassy alloy they use these days. In more recent times, as observed by the author during a trip in 2014 to the workshop of Radhakrishna Sthapathy in Swamimalai, the use of dilute nitric acid was also seen for removing the thick fire-skin formed on the casting.



**Figure 12** Final finishing of cast image with intact runners by craftsman late Vadivelu at workshop of Devasena Sthapathy in 1990



**Figure 13** Pallava Somaskanda image, Government Museum, Chennai, 7<sup>th</sup> century, with runners still intact, copper alloy with 3 wt. % lead and 0.7 wt. % tin

Most early medieval bronzes (8<sup>th</sup>-10<sup>th</sup> century) seem to show much less apparent evidence of post-cast

tooling or working after casting. The miniature Pallava Somaskanda from Tiruvelangadu, in Government Museum, Madras (Fig 13) perhaps illustrates this point. That this bronze was probably not subjected to any post-cast tooling is indicated by the fact that two runners are still intact on the shoulders of the Siva image, connected to the weapons, while Siva's figure also shows a bit of metal drip at the base. These would have been trimmed off, if it had been finished. Moreover although intricately executed, the detailing of the ornaments and attire has a certain fluidity, smoothed contours and gentle relief, which suggest that they were executed in the wax rather than cut with files on metal. This image is a copper alloy with 3 wt. % lead and 0.7 wt. % tin. Another example, a superb 11<sup>th</sup> century Nataraja image from Kankoduvanithavam in Government Museum, Chennai, (the analyses carried out by the author showed it to contain 8% tin and 9% lead) has decorative features that stand up smoothly in high relief (Fig 14) in a way that suggests that minimal post-cast tooling was undertaken and the details were more or less as-cast.



**Figure 14** Chola Nataraja, Kankoduvanithavam, Tanjavur District, Government Museum, Chennai, with 8% tin and 9% lead showing details in high relief suggesting that not much post-cast tooling was done

## Conclusions

The above ethnometallurgical account provides insights into links between the past and present in the long and enduring tradition of image casting in the Tanjavur district, while also throwing some light on the points of departure with changing times. This paper also tries to more comprehensively string together observations of different scholars than it was previously attempted and to gain more insights into the recent trajectory of

this metal craft tradition in the Tanjavur district and in relation to other surviving craft traditions. Finally the aim of this paper was to place it better within the context of the archaeometallurgical studies of medieval bronzes.

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