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Metal Craft Heritage of Cauvery and Riverine Regions

National Institute of Advanced Studies
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Metal Crafts of the Cauvery Region and Beyond

Introduction

India has a rich repository of surviving crafts practices that hark back several centuries with unbroken traditions. The Cauvery basin occupies a large geographic region spanning three states across Karnataka, Tamil Nadu and parts of Kerala. This region has in its own way represented an inter-linked geographic and cultural ecosystem. The project has aimed to document and highlight this rich repository of artisanal technologies, particularly in the areas of metalworking and with respect to their connection to the local natural and cultural setting.

The metal crafts that have been nurtured in the Cauvery delta around the Thanjavur area are some of the best known of Indian crafts traditions. These range from the celebrated bronze images going back to Chola and Vijayanagara/Nayaka times, to lesser known ones such as the Swami repousse work and bell casting. Numerous crafts traditions have had a rich and diverse history along the stretch of the Cauvery region following the fortunes of major dynasties such as the Cholas, Hoysalas, Vijaynagara rulers, Tipu Sultan, the Mysore Wodeyars, Tanjavur Marathas and the Arcot Nawabs. This region has had longstanding trade and cultural interactions with other parts of the subcontinent and the world through overland and maritime networks.

The traditions from the Cauvery region also extended into or influenced other parts of southern India. Thus the project has also looked at a broader geographical area in southern India to understand the regional linkages. To give some examples, several of the metalworking Kammalar and Acharis of Kerala claim Tamil descent. The skilled crafts of making vessels and gongs of high-tin bronze in Parts of Kerala and Karnataka also seem to have had connections with the Thanjavur region. Riverine systems have also had a special bearing on some metal crafts that have depended on alluvial clays for the making of furnaces and moulds. Thus, the region evokes a rich historiography and continuing network of interconnected and mutually interdependent crafts traditions, including not only the 'Vishwakarma' or traditional Hindu artisan communities but also the non-Vishwakarma craft communities.

While this project has largely focused on base metal crafts, this is part of a broader initiative to understand the heritage of this region in totality in a way that integrates the tangible heritage (of historic sites) with the intangible heritage (of crafts and living traditions) and natural heritage. The use of technological approaches in enhancing such cultural understanding could particularly yield to bring fresh insights. This study also has a larger aim to explore facets of heritage in relation to ecological and environmental factors such as

riverine eco-systems which have some common features and inter-linked trajectories, since the metal crafts particularly thrived near riverine eco-systems due to the need for moulding clays drawn from river beds and alluvial sands.

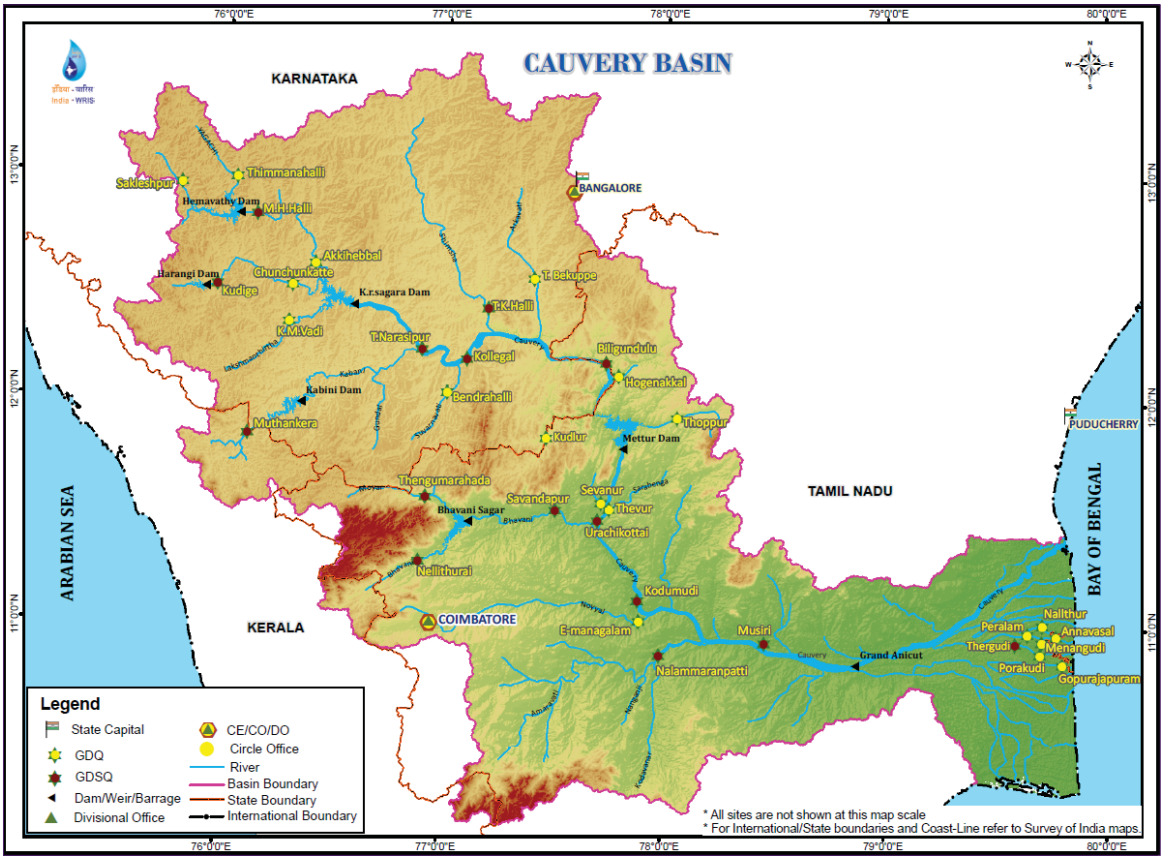
Some selected metal crafts have been explored which seem to have had distinctive and yet inter-linked cultural and technological trajectories and which are in their own ways declining rapidly in these regions. These include:

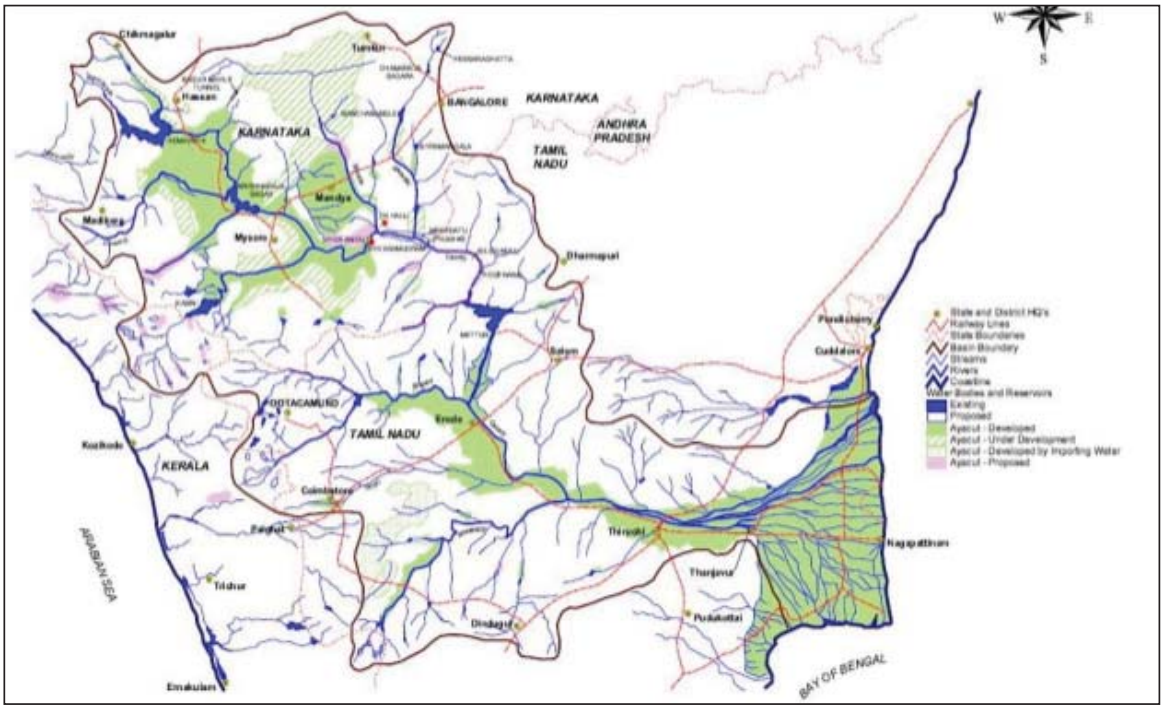
- Copper alloy image casting which is a tradition going back to the famous Chola bronzes of the Cauvery delta which flourished particularly around the world heritage site of the Brhadisvara temple in Thanjavur and which also flourished under the Vijayanagara rulers of Karnataka
- Bells and lamps which were part of the rich cultural milieu of ritual and performance in the Cauvery region
- Swami plate making which has been in vogue since the time of the Thanjavur Marathas
- Rare metal mirror making tradition near the Pampa river Kerala
- Ferrous metal practices of blacksmithy and iron and steel production

Crafts communities, metal crafts and related sites in nearly 50 locations covering some 200 members of artisan communities were identified and preliminary documentation from techno-cultural, socio-cultural and socio-economic perspectives were undertaken including Swamimalai, Thanjavur, Kumbakonam, Nacharkoil, Gangakondacholapuram, Tiruvannamalai, Chengum, Mylapore, Salem, Singarapettai, Mel-siruvalur, Nilgiris, Kotagiri, Srirangapatna, Onipenta, Konasamudram, Pochampalli, Dammanapet, Ibrahimpattinam, Nirmal, Chitvel, Kadappa, Amaravathi, Lepakshi, Hampi, Kamalapura, Kadibakele, Shivarapatna, Nagamangala, Tingallur, Maski, Shivamoga, Chitradurga, Gatihosahalli, Sankarapur, Udipi, Srirangapatna, Mysore, Aranmula, Pattanamthita, Mannar, Kalady, Trichur, Nadavarambu, Palakkad, Sholapur and Baroda.

Numerous stake holders who have been interacted with in the course of the project. These have variously included artisanal communities, cultural bodies such as Museums, Archaeological Survey of India, UNESCO (for building up dossiers for possible intangible heritage listings), bodies involved in training/promoting artisans such as Metal Co-operative Societies, Regional Design and Training Centres, the student and research community, historians, archaeologists, design institutes and the general public.

Even though there were teething problems due to the difficulties in being able to recruit staff in such niche areas, several of the milestones have been ably met. One of the important aspects of the study is that several families of artisans living on the margins who were not that well known before have been documented. Audio-visual documentation of the production processes and interviews with craftspeople has been undertaken. One of the successes has been the efforts at live demonstrations with craftspeople for documentation and popular outreach. The project has made significant strides towards creating an understanding of the current practices and in exploring their technological and cultural links with historic artefacts and heritage sites. Awareness of the intrinsic value of these traditional crafts has been generated as well as of some of the problems endangering their survival, and the need for the preservation and enhancement of the crafts.





View of Cauvery basin and its tributaries and neighbouring regions which have nurtured many artisanal centres and particularly for metal crafts and metals usages over the ages.

2

Chola legacy of icon making in Swamimalai

The Sthapatis of Swamimalai in Thanjavur are said to link their ancestry to the well known temple of Subramanya temple in Swamimalai which forms the hub of this town and which mainly dates to the late medieval Nayaka period. Currently, the most renowned hereditary family of Sthapatis of Swamimalai is of the lineage of late Devasenasthapati (whose son, Radhakrishna Sthapati and family have carried on the tradition) and with whom Prof Sharada Srinivasan first made contact with in1990 (Srinivasan 1996b). Whereas her earlier studies had comprised more of metallurgical studies on Chola bronzes with a few preliminary observations on bronze casting, during the course of the TCS project the scope of documentation related to traditional bronze casting and icon making was greatly expanded with more focused studies being undertaken on these aspects. Moreover, through fieldwork conducted with RA's many more families of Sthapatis and their networks were identified such as by Maniganda and Suresh and their spatial distribution was also explored. The techno-cultural aspects gleaned from Radhakrishna Sthapati's workshop are set out.

The Swamimalai sthapatis even today make the wax models model using the traditional 'talamana' system of measurement. To mark out the tala measurements to obtain the dimensions of the icon, they use a stiff strip of coconut palm frond or odiolai to mark out the proportions along its length. As pointed out by Radhakrishna Sthapati in 2007 (Fig 3), in the present day, the male figure was made by marking out 124 parts on the odiolai and the female figure of 120 parts. The Manasollasa a treatise by the 12th century Chalukyan king Someshwara mentions the lost wax process as Madhuchehisthavidhana in Sanskrit (Saraswati 1936:144).

The wax model was made from a mixture beeswax, powdered dammar resin (kunkuliyam) with a little ground nut oil or sesame/gingelly oil as observed in the 60's by Reeves (1962: 63) and also observed by Sgarada Srinivasan in the 90's. Beeswax or honey wax (tein melughu) is softer, while kunkuliyam is a harder resin collected from the sap of plants like sal. The Gupta era Manasara (Von Shroeder 1981: 18) also mentions the process of making the wax models with beeswax. However, as observed by the TCS team, in the present day the use of industrial paraffin wax is much more in vogue as an admixture.

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 solidify them. Then they 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. Sandalwood and steel spatulae seem to have been used for modelling the wax.

At Swamimalai, the mould or karu was built over the wax model using three successive layers of clay, leaving it to dry after each coat. The first coat was of very fine alluvial silt (kaliman) from the River Kaveri, carefully smoothed down with no coarse inclusions. The next layer was of slightly coarser clay from the river known as vandal mann. Finally, a coat of kaliman mixed with mannal, (i.e. coarser siliceous sand) was applied. Three layers of this clay, ground by a stone, were to be smeared over the model. The term 'de-waxing' is invoked 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 the finally the molten metal would be poured. At the workshop of Radhakrishnasthapathy, as practiced in recent times as seen in 2008 and more recently 2014, it was noted that a special hearth dug into the ground at a slight incline was designated for this activity. Here, the mould was propped up over four inverted large graphite crucibles, laying it down and along a gradual incline such 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. The mould was heated from below using coconut husks as a combustible material which would burn completely.

The hearth for heating the crucibles was known as ulai at the workshop of Swamimalai. The heated moulds were lifted by tongs and wedged inside trenches or pits at a slight incline before pouring. Soon after the heated crucibles were lifted by tongs and the molten metal which poured into the metal. It was also noted that behind the line of moulds packed in the trench, before pouring offerings had been made of a couple of coconuts along with flowers and lemons which was thought to ward off the evil eye, with these ritual elements invoked to ensure a successful casting.

The *Sthapatis* of Swamimalai seem to use an alloy for image casting which consisted of industrial ingots labelled '15% brass, 82% copper, 3% lead' (Srinivasan 1996: 101). Reeves (1962: 108) observed that alloys of '75 wt. % copper, 15 wt. % brass, and 5 wt. % tin' were used at Swamimalai for making icons. It is not clear in either case what 'brass' refers to, but it is presumed that it is an alloy of copper and zinc according to convention.

Analyses by Sharada Srinivasan of about 130 medieval south Indian bronzes, including several Chola masterpieces however (Srinivasan 1996) showed that they were overwhelmingly leaded bronze, i.e. copper alloyed with tin and lead with an average of about 5-10% each. It was found that 80% of them were leaded tin bronzes with the lead content varying up to 20% and the tin content from 5-15% tin, while only about 20% of the images were leaded brasses with a zinc content of up to 25%. However, compositional and trace element investigations by the author indicated that the *pancha-loha* prescriptions might relate to the random alloying of traces of gold and silver in addition to the alloys of copper, lead, tin or zinc (Srinivasan 1999). After breaking open the mould the present day Sthapathis finish the cast images by chasing and polishing the image and all the finer detailing nowadays is done by chiselling after casting, so it is fair to describe it equally as a work of sculpture as a casting. Of course, they are able to do all this extensive final finishing because these days they use a very brassy alloy which is rather malleable. Quite a thick fire skin forms as seen on the face of the icon, which is basically the

last metal to solidify consisting of the impurities which float on the surface of the molten metal and some impregnated mould material. This fire skin is removed by a lot of scraping. In more recent times the use of dilute nitric acid is also seen for removing the fire-skin. The refractory waste material from breaking open the mould is again re-used as powdered brick dust in the making of certain grades of clay. The runners provide an important function of channelling the viscous metal into the different parts of the casting. An important step during the finishing is that the superfluous runners are cut off and those parts chiselled down smoothly so that their impression is barely seen.

An important and dramatic ceremony performed at the icon making workshop is the 'opening of the eyes' of the icons, known in Tamil as *'kannatharakkarudu'* amongst the Sthapatis, which marks the transformation of the inanimate metal statue into a religious icon invested with divine power and pulsating with religious and ritual significance. Before the 'eye-opening' ceremony, the icon had been left unfinished in one aspect which is that the eyes are not yet delineated fully. Traditionally during the 'eye-opening' ceremony, which was common to both stone and bronze icon making, the chief Sthapati carved out the contours of the eyes with a chisel of gold or silver, although these days the chisel may be of steel or bronze (Ganapati Sthapati 2002, Raj et al. 2003, Srinivasan 1996). This ceremony would have been repeated by the poojari or priest at the temple as part of the installation ceremony. The priest also invokes the name of the deity that the icon will represent, praying for the particular god or goddess to reside in the icon. Thereafter the icon is fully installed and is ready to undergo various rituals as a processional icon where it would be clothed, decorated, garlanded and elaborately carried out in procession at specific festival times. The process of opening the eyes of the deity infuses it with divine grace. Even though elements of clothing are already delineated on the icons, they undergo another facet of ritual adornment before being taken out in procession which utterly transform their appearance, and even hide their true form from the devotees. Sometimes the face and arms are covered by a silver Kavacha or cladding and sometimes they are clothed in and heavily garlanded.

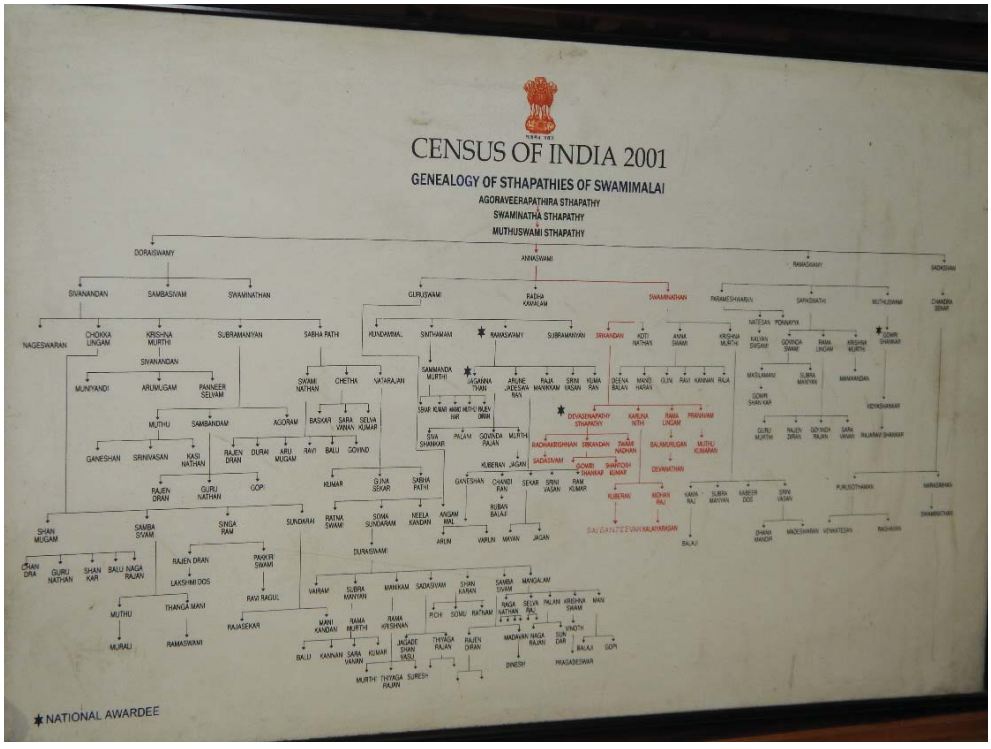
Swamimalai, Thanjavur icon making centre

Cast images of Vishnu with consorts

Workshop of Radhakrishna Sthapati of Swamimalai

Radhakrishna Sthapati's Brothers making wax model.

Master Craftsman Radhakrishna Sthapathi with Prof. Sharada.



Hereditory Geneology of Swamimalai Sthapatis

Making of the wax model

Completed wax model of the icon to be cast.

Sthapati family in Kumbakonam observed by Manigandan Ranganathan

Worskhop activities of icon making

Casting foundry area of Radhakrishna Sthapati's workshop

Wax model on large wooden table used as workshop area for icon making, late Mohanraj Sthapati's workshop

Mixing of clays to make the mould for the wax model.

Completed mould with orifice for pouring seen

Sthapati at a brazier making the model Swamimalai (Photo by Sharada Srinivasan)

Pouring of cast metal from crucible into mould.

Completion of pouring of metal into mould, Radhakrishna Sthapati workshop.

Final finishing of cast Nataraja icon (Photo: Sharada Srinivasan).

View of numerous artisans busy at final finishing of icons.

3

Bell and lamp making in Thanjavur district

Nacharkoil, a small village located four kilometres from Kumbakonam, has traditionally been renowned for the making of temple bells and temple lamps. In the past it had a sizeable community of Kammalar or bronze and bell metal workers with specially designated streets known as Kammalar Theru. The *Kammalar* community has been involved in making lost wax castings of large and medium sized temple bells or koil mani, the kuthu vilakku or temple lamps. Some workshops were first documented first by the author in 1990 (Srinivasan 1997). In recent visits during the course of the TCS project, Prof Sharada Srinivasan, and RAs Suresh and Maniganda made contact with a few more surviving artisans who still practice the traditional lost wax process of casting although this is steadily declining and giving way to sand casting.

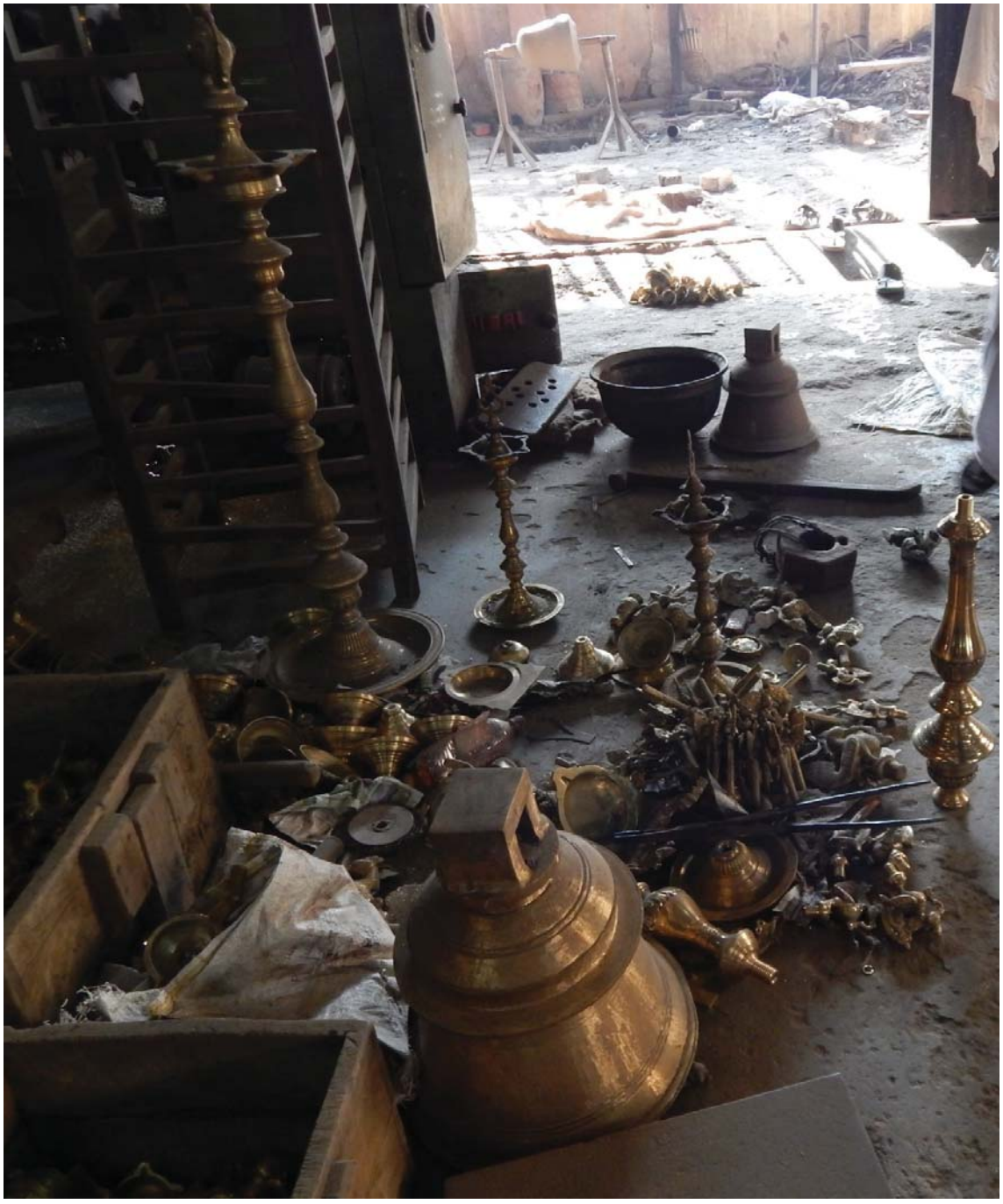
In the workshop of Govindrajan the making a large mould for the lost wax casting of a temple bell known as koil mani was observed. As a first step, an inner clay core mould was built up on a horizontal axle and then it was very finely moulded into a bell shape using a hand-turned lathe arrangement. For this, a horizontal wooden axle which was tapered at both ends was affixed within a trench. The axle had wheels at the ends which were embedded in grooves so that the axle could be held in place. The mould was built up, layer by layer around the axle, turning it at each stage by holding a spatula against the mud packed on the mould as it was hand turned to smoothen it. This was done until the mould was built up so that only a few centimeters were left clear at the edge, and finally the finished mould could be lifted out of the trench. This contraption of the bell mould was propped up an open yard so that the mould could dry out in the sunshine. Once dry the de-waxing and casting of metal into the mould would be undertaken. As such the team was not yet able to watch an entire casting since this would involve making visits at the appropriate time.

It was also noticed that a significant number of women are also involved in Nacharkoil in various steps of lamp making, being employed by Poompuhar as observed by Prof Sharada Srinivasan with Baalajee. In what could be described as a house hold activity several of them were lined up on the verandahs of their homes making various parts of the piece moulds going into making the lamps and they said that they were paid according to the number of pieces they made in a specified time. Several of them said they were from traditional Kammalar families. Lakshmi, who lived next to the bell maker Govindarajan described later had her own brazier inside the house. She first shaped the clay to the specification of previously cast pieces of the lamps and then heated the clay moulds she had prepared on the brazier to fire the pieces of lamp mould. After several were fired she handed them over to Poompuhar against payment for their commission.

Contemporary Perceptions of Crafts

Although the Swamimalai icon making tradition is seen as an unbroken and more 'pristine'version of tradition, there are however several changes towards mechanisation and speeding up of the proceses. There are also aspects of interest in the way the artefacts have transitioned from ritual objects to showpiece objects adorning mantleshelves as pointed out by Sharada Srinivasan in her paper 'From Temple to Mantlepiece: Changing paradigms in the art and craft of South Indian bronzes' (Srinivasan 2016a; Saffron Press London). With respect to growing concerns about the illicit trafficking of antiquities the methodologies described above of authenticating metal artefacts also have significance. The making of replicas of antiques was also driven by the taste for copies of masterpieces of bronzes.

Smriti Haricharan has also been exploring further in terms of the modern day perceptions of crafts people through the TCS project and with respect to exploring the modern day clientele with its network of retail showrooms and clients. As she points out, historic artifacts represent social contexts in time so that for archaeologists and historians, who are interested in understanding societies and practices of the past and their possible lingering temporality, objects become artifacts only through a mediation of the contexts. Campbell's ideas of the dichotomies between handmade and machine made are also significant in terms of such interrogations. An interesting observation was that some of the artisans from southern India expressed a concern that their artefacts were also being made in places like Moradabad, in a more mass produced way that held out unhealthy competition for them, which Sharada Srinivasan heard in a bell metal workshop in Kerala back in 1998. Interestingly Smriti Haricharan also heard a similar refrain in recent times, which is a phenomenon she described as 'Moradabad going Chinese' with the cheaper, machinemade imitations undercutting the value of the traditional or more 'authentic' handmade crafts. These are aspects for exploration going forward, the negotiations between tradition and modernity.



View of foundry for bell making and lamp making, Nacharkoil.

A semi-industrial workshop for lamp making in Thanjavur district.

Collection of waste filings for re-use.

Traditional bell making Kammalar Govindrajan in his house.

Trench inside Govindrajan's workshop for bell making.

Axle with wooden mount used to shape rough bell mould.

Final bell mould after it is covered with the final grade of wax and turned by hand lathe Govindrajan seen with former NIAS RA Pallavi.

Suresh at the workshop of another bell maker in Nacharkoil seen with final bell mould.

Govindrajan with mount for drying bell mould with Prof Sharada.

Figure 3.10. Lakshmi neighbour of Govindrajan who makes lamp moulds.

Lakshmi, lady artisan of Kammalar family with brazier (Photos by Sharada Srinivasan)

4

Swami work: The art of Thanjavur plate

Thanjavur is a veritable repository of the arts and crafts of Tamilnadu with numerous surviving communities of artisans still carrying on traditional metal crafts. The Thanjavur art plate is an exquisite art form of repousse metalwork . The Swami plate as it is known consists of a wrought base of brass which supports intricate patterns and encrustations in silver and copper. The designs in repousse can include and array of lively motifs ranging from those of gods, goddesses, birds, and animals to flowers fruits, leaves and floral decorations The repousse patterns are executed in low and high relief in softer materials of silver and copper, creating something of a more three dimensional effect.

The Thanjavur Art Plate, or Kalai thattu also known as Swami work making is one of the major surviving craft traditions of the Thanjavur region. The traditional art of the Swami plate is thought to have been handed over from generation to generation. It seems to have been in vogue for about the past 300 years as it is believed that the tradition was greatly encouraged by the Maratha ruler of Thanjavur, Serfoji (1797-1832) and his successors. Serjoji is known to have richly patronized the development of arts and crafts in the Thanjavur region. Thus the Thanjavur Art Plate or Swami plate resembling a medallion has its own distinctive baroque appeal. Typically the central motif in the past may have mainly represented a deity, with known examples such as of Murugan, the popular Tamil deity, Lakshmi seated with elephants, or Shiva Nataraja. Lately central motifs of the swan (hamsa), peacock, the lotus motif and the temple tower or gopuram have become increasingly popular.

The Kammalar community as a hereditary group of metal artisans have been traditionally associated with this craft. However, in recent times through the efforts of the handicraft showrooms such as Poompuhar, this art form is being practiced by members of other

communities as well. Traditionally, the metal artisans involved in the making of Swami plates were called Tampalakarar. Ie one who makes the *tambulam* or *tambalam* (i.e. plate often used also in rituals) and considered themselves to be part of of the five-fold Viswakarma social division of craftspeople.

However, there are still a handful of traditional practices who follow the art as a cottage industry. One of the prominent families of traditional Swami art plate makers is of Rajamanikam Loganathan, who live in Selvam Nagar, about one km northwest of the Tanjore Big Temple near the old neighbourhood or settlement of Sr. Research Associate at NIAS, Mr Suresh learnt about this family through Mr. Ramesh, an owner of a showroom for the Thanjavur Art Plate on V.R. Arts Eallaiyam Street. Mr Suresh was able to interact with Mr Rajamanikam in 2016 and to gain insights into their craft practices which they said

they had been engaged in for three generations and going back to the Maratha period. Mr Loganathan is seen in Fig 5.5.1.3 at work, attired in a dhoti and sportings the sacred thread as well as three lines of vibhuti or sacred ash on his arms, marking out his stature as a Vishwabrahmin. In particular two types of design are popular, one the medallion type of design with a central motif and surrounding radiating patterns known as Swami work and the other where a traditional pot shaped like a *kumbha* is decorated

Art and craft of Swami plate

The making of the Thanjavur art plate had been recognized as a small scale cottage industry which took place at the level of households itself. As seen quite often elsewhere in the Thanjavur district, such as at Swamimalai, a part of the house itself was designated as the workshop area and was known by the general terms of *pattarai* referring to the workshop space. Traditionally, this craft was passed on as a hereditary skill from generation to generation. The youth of the community learnt the trade by apprenticing with their extended family members, while traditionally women were not given any role in the processes of manufacturing. The craft over several generations has been the monopoly of the few members of this community who strove to ensure that the craft technique was not imparted to members outside these communities and to other sects of the community. However this situation has changed in recent times and in the larger interest of the survival of traditional crafts, the knowhow has been communicated with other communities.

There is a division of labour in the various stages of the manufacture of the Thanjavur Art Plate. In fact there are several units of families who specialize in the various manufacturing stages. For example, the first stage of the process which involves preparing the base plate in the past had dedicated smiths such as the Kammalar for this heavy forging. In the present day however, the artisans get a circular brass plate readymade ordered to size from foundry in Kumbakonam. As to the finer detailing of the embossings, this is undertaken by an artisan who has had experience as a jewellery maker or a diamond setter or is himself a silversmith/goldsmith. Thus, sometimes as required by the client, the central circular repousse motif is done in gold by a goldsmith or more commonly in silver by the silversmith, such as the naga motifs. Then these motifs are soldered on the base plate. Thus the endeavor is like a co-operative assembly line production effort by numerous artisans.

It is interesting that the aspect of having specialized groups of artisans working on each stage of the craft, which brings to mind the notion of chaine operatoire, is something which is not unique to this craft. In the icon making traditions of Swamimalai as well, there is a certain division of labour where the most qualified chief sthapathi undertakes the more artistic and important task of the carving and modelling of the wax model, while other extended family members or junior family members may take on the other tasks including final finishing or brazing. The actual casting and pouring of metal these days may be undertaken by other labour.

The artistic components of the art plate were varied. A first step concerned the procurement or the manufacture of the circular brass plate which would form a base. The primary central relief is encrusted in the central hollow portion of the plate. This can be of gold or silver. Usually this circular motif is of silver and is larger than the subsidiary relief works and is worked heavily in repousse such that it gives a more of a three

dimensional effects. Traditionally, the motifs included gods and goddesses, flowers, birds such as the mythical hamsa, floral decorations, the temple gopura and other such. These days the artisans cater to the needs of the clients so that various new secular or non-traditional motifs have also come in such as the logos or institutions, organisations, busts of personalities and so on.

Subsidiary repousse motifs are encrusted on the rim of the brass plate all around the primary relief, which are usually made of alternating reliefs of silver and copper or with silver lying between two copper reliefs and such like. In the area between the concentric rings separating the central medallion from the outer radial motifs, floral motifs may be made and also a signature design element of the Thanjavur Art Plate, ie patterns of raised circular punch marks.

The raw materials used to make the art plates thus consist of brass for the base plate, silver and copper sheets. The dye and mould against which the repousse hammering of the copper sheet is done is made of lead. The plate is fixed onto a base board for working it which is made of asphalt, a by-product of petroleum over which a mixture of resin is applied. This resin is a mix of kunkuliyam or dammar resin, gingili oil and brick powder. The plate is heated and fixed onto this resin base. The finer silver and copper sheets are hammered against the lead dye which they can purchase as standard dyes with patterns or motifs that they can reuse. They hammer the sheet against this, skillfully using a thick wadge of rubber to soften and moderate the hammer blows. Brass is obtained from Punjab and Haryana in northern India and copper is procured from the local market in Mumbai. Other specific materials are obtained from Kumbakonam or Chennai.

Finally, a vast array of tools are skillfully used for a versatile range of metalworking activities. Many of these are locally available while some forging and hammering and fine tuning is also undertaken to sharpen and shape the tools in the Pattarai. The tools included hammers, punches and chisels of various shapes. As many as 300 tools are said to have been in vogue by the artisan. This is an aspect that also needs further documentation. Mr Loganathan undertaks final finishing work on the Swami plate, for which the anvil consists of a cylindrical wooden member with a flat circular wooden top on to which the Swami plate is kept and hammered. He was working with the traditional hamsa design as central motif.

As such, the number of members from traditional families engaged in the art of Swami plate making from the Kammalar community have greatly declined. The Census of India (Chandramouli 2004) reported only four such families left. The Kammalar interviewed by us through Mr Suresh, Mr Manikam Loganathan also pointed to the declining fortunes of the trade. As far as remunerations are concerned, for some of the members, it is a struggle since they earn only daily wages for this work of about 150 to 350 rupees and that too only when they get orders. In recent years, the Government of Tamilnadu through its outlet Poompuhar for the production of handicrafts and training and marketing, and the Office of the Development Commissioner (Handicrafts Board), Government of India have initiated steps for providing structured training programmes and organised marketing of the products since 1980s. The training concentrates on the technical skills associated with the production of the Thanjavur art plates. While this has of course democratized the craft, and ensured its wider visibility, it has also paradoxically contributed to the decline of the craft amongst the traditional practitioners due to the competition.

Recently the Thanjavur Art Plate craft has also been awarded a Geographical Indicator status.

This registration also accords it protection under the Trade Related Intellectual Property Rights (TRIPS) agreement, whereby it is recognized as a unique craft tradition of that particular geographical area, in this case Thanjavur. A listing has been made of the Thanjavur Art Plate under item 63 of the GI Act 1999 of the Government of India, with its registration duly undertaken by the Controller General of Patents Designs and Trademarks. The GI status also implies that there is a standardization of the metal compositions and design techniques, so that only the size of the artefact is allowed to be different across different objects (Lakshmanam 2010, The Hindu Jan 2016).

Swami plate with Murugan motif (Swami plate work).

Showroom, Thanjavur town, Kasikadai Ther (Street).

Swami Plate with Nataraja motif.

Craftsman working for Mr Loganathan, Swami plate maker.

Master craftsman, Manikkiam (65 yrs), father of Mr. Loganathan observed by Suresh

Wooden base plate with resin to hold it in place.

Cut brass pieces being hammered for use.

Loganathan, owner of the brass plate foundry working on the lotus medallion base

Large Swami plate made on a larger wooden octagonal mount.

5

Copper alloy working centres in Karnataka

There are a few surviving icon making centres in Karnataka which were of significance in the past. Nagamangala in the Mandya district of Karnataka was an important historical town in the Cauvery region which at various times passed under the overall control of the dynasties of the Western Gangas, Cholas, Hoysalas, Vijayanagara, and Mysore Wodeyars. At the same time, Nagamangala retained a measure of independence at it was generally looked after by the local chieftains who also built the fort inside the town. The remnants of numerous important temples are found. Nagamangala can also be ascertained to have been a significant historical place connected to the settlement of Vishvakarma craftspeople.

An important local landmark is the Vishwakarma temple at Nagamangala dedicated to the goddess Kalikammateshwara. The Kalamma-kammateshwara temple is located near the main entrance to the inner fort of the town. It is built in Tamil Dravidian style with has a huge shikhara and a tower or Gopura. Kali is the main deity of this temple. There is also shrine to the god Kammateshwara. The inner sanctum or *garbhagriha* houses a powerful image in black stone of the Goddess Kali, as seen in the photograph, clad in fine silks. The inner portions of the temple hark back to the early medieval period probably of the 9th century Ganga period as seen in the pillars and columns. Near the patalankana of the temple are sculptures of Ganapathi and Bhairava. The temple is also said to house several 'panchaloha' sculptures such as of Nataraja, Suryanarayana, Vinayaka.

Enquiries were made to gain insights into the Vishwakarma community and to understand the significance of the temple they worshipped at and the related rituals connected to the place with fieldwork especially undertaken by Uma Krithika and Baalaji. Members of the Vishvakarma community were interviewed in the Nagamangala town. These included the priest of the Kalikammateshwara temple, the temple of the Vishwakarma community in the Nagamangala, and two craftspeople. The following information was gleaned. According to Raghu, the priest of the Kali Kammateshwara temple, who is also a Vishvakarma traditional craftsman, there are numerous distinctive customs and ritual practices concerning the temple and its community of worshippers.

Traditionally there are two sub castes of Vishwakarma were living in the town Nagamangala. These included the Kulachar, or the sub caste consisting of blacksmiths, goldsmiths and carpenters and the Matachars or the sub caste consisting mainly coppersmiths. At present, it is found that the Kulachar families have completely disappeared from the Nagamangala town, and there are only a few Matachar families still surviving there. In the present times they felt that there is no distinction between the sub castes as all of them would undertake all kinds of works. One of the interesting observations about the master craftsman Raghu's workshop was that whereas many other craftspeople did not seem to have much of a sense of historicity in terms

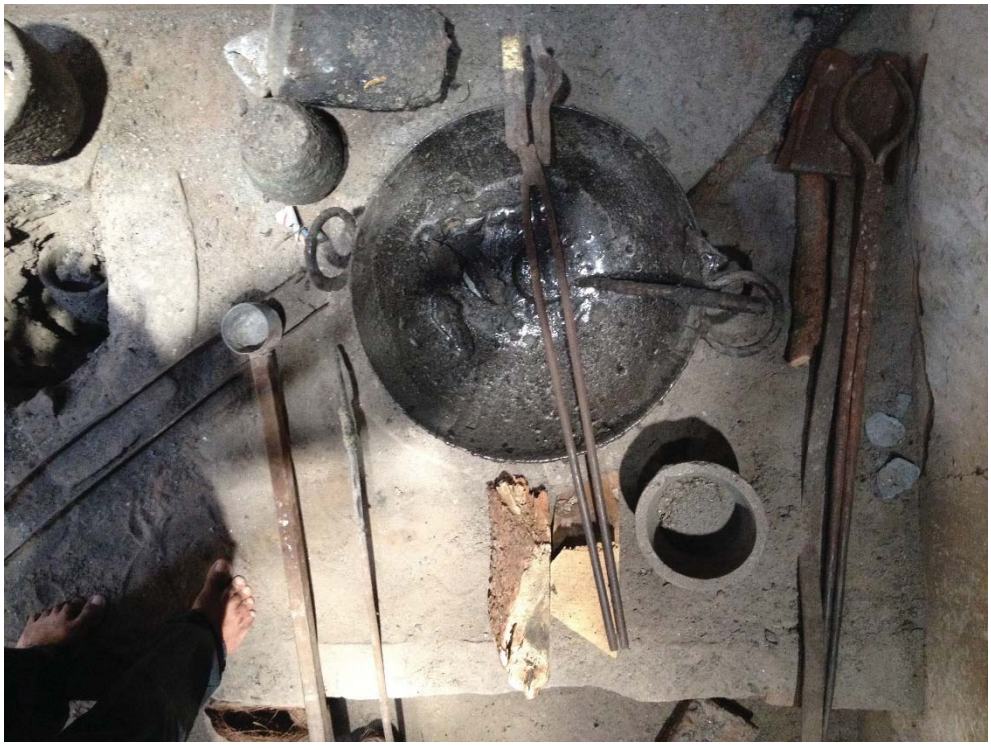
of artefacts or heritage, Raghu had kept and collected a rich old tools that had been used over time in undertaking post-cast tooling of icons both in steel. At his workshop an unfinished and outstanding cast icon of an image of Vishwakarma, the deity worshipped by the five communities of craftspeople is seen which was made at Nagamangala, Karnataka. He is depicted standing with four heads in one level and a fifth on top, and with eight arms, also holding a veena, and wearing the sacred thread. The metal caster Mr. Raghu was also the chief priest of local Vishwakarma temple of Kalikamma and wore angavastra, dhoti and the sacred thread signifying his stature as a Vishwabrahmin and Vishwakarm priest. Repousse work was also undertaken by the craftspeople at Nagamangala in softer materials such as silver. This technique involved working with a ductile material of brass or silver by hammering it against a background mount made of a hard material such as hardened dammar raisin. By this method the portions of the metal were raised in relief to give the decorative pattern.

It was also interesting to observe at Nagamangala the close association of the artisanal community to the local temple. Icons were also taken out in procession as utsava murti from the Nagamangala Kali temple in a rather elaborate way. A lot of community participation could also be seen with members joining in taking the image out in procession and holding the poles used to hold up the processional utsava murti and such like. Thus, a lively lived tradition is seen in Nagamangala connecting the community of icon makers to their local temple rituals and festivities.

Bronze icons made at Nagamangala

Vishwakarma priest and bronze caster Mr Raghu at Nagamangala

Foundry and hearth for melting crucibles.



Tools of the foundry.

Hearth for crucibles.

Tools for final polishing.

6

Iron and Steel Traditions of Telangana Kammaris Techno-cultural ethos of former wootz steel makers

The Indian subcontinent has a vibrant iron and steel working tradition of yore. The fame of Indian iron and steel is also reflected in numerous accounts from various parts of the world which suggest that it was a prized item of export over the ages, ranging from Mediterranean to Arab accounts. The legendary Indian wootz steel, or ukku in south Indian languages, is found to be a high-grade high-carbon crucible steel that was especially produced in the southern part of India (Bronson 1986, Srinivasan 1994, Srinivasan and Griffiths 1998, Srinivasan and Ranganathan 2004). The Damascus steel blade, believed to have been forged of Indian wootz steel of a high carbon content of 1.5-2%, was reputed for its cutting edge. It had a typical damask or 'watered silk' pattern obtained from the etching of a forged wootz ingot. This pattern is poetically described as 'ten thousand meandering lines' by Sir Walter Scott, in the Talisman which fictionalized the episode reported in the 13th century Crusades when King Saladin (Salahuddin) of Egypt is said to have sliced a handkerchief with a Damascus sword during the truce with King Richard of England.

Tavernier's 17th century writings indicate that Golconda wootz from the Telangana region in southern India was the most prized by Persian artists for making Damascus swords (Bronson 1986), suggesting it was ranked amongst the best steels. The watered silk pattern synonymous with the Damascus blades emerged from the forging and etching of a wootz ingot with 1.2 to 1.5% carbon resulting in alternating striations of the darkly etched pearlite phase and the whitish cementite carbide phase which resists etching with a higher carbon content.

The word ukku from which the term wootz steel, the crucible steel encountered by European travelers such Voysey and Buchanan is still used in popular parlance in many parts of southern India as found by the author although its manufacture has died out. Investigations of the 19th and 20th centuries have shown wootz to be a high carbon hypereutectoid steel of 1.5% carbon made by carburising iron in crucibles. The use of high-carbon steels may go back to early antiquity with some examples from at least the early historic period in southern India, as seen in a nail investigated by the author from Pattinam which shows the classic structure of hyper-eutectoid 1.5% high carbon steel structure of wootz (Srinivasan 2007). In many parts of southern India there has been evidence until recent times of archaeometallurgical debris of crucibles and slag from wootz steel making (Srinivasan 1994, Srinivasan and Griffiths 1997, Lowe 1990).

Crucibles found at Mel-Siruvalur near Tiruvannamalai in Tamil Nadu studied by Sharada Srinivasan in the 90's contained metallic remnants that corresponded astonishingly well with modern hyper-eutectoid ultra-high carbon steel structures (Srinivasan 1994, 2007, 2017), suggesting that highly reducing and high temperature pyro-metallurgical conditions were reached. The region of Salem, also near Coimbatore was renowned for its iron and steel works as seen in the 19th century accounts of Walhouse who mentioned the renown all over India of the bladesmith, Arunachalam.

By the medieval period, the best-quality wootz Deccani process was said to have come from the Hyderabad/Golconda region. By the late 1600s, shipments of tens of thousands of wootz ingots were said to have reached Persia from the Coromandel coast from ports such as Masulipattinam . Tavernier in 1679 wrote that steel from Golconda was the only kind that Persian artists to make the fabled Damascus blades indicates its great demand and specialized properties, as 'it was the only sort that could be damascened by Persian artists by etching with vitriol (Bronson 1986). Voysey observed the making of crucible steel in the Godavari and Telangana region. This Deccani process was studied 1980's by Thelma Lowe (1990) who extensively surveyed sites in the Nizamabad area and undertook investigations on the debris of steel making crucibles from surface survey. In this process, steel of an intermediate composition was thought to be obtained by fusing together a piece of low-carbon iron bloom with cast iron in a crucible. Under the past UKIERI supported Pioneering Metallurgy project, which had Prof Sharada Srinivasan as a lead investigator with Dr Gill Juleff and in collaboration with Dr Jaikishan, historian from Telangana, preliminary surveys were made of sites in northern Telangana for iron and steel production. Analyses on crucibles from some of the sites confirmed the Deccani co-fusion process of wootz production with cast iron prills with 4% iron found in the crucible shards from the co-fusion production of higher carbon steel (Srinivasan et al 2011). In the further studies made under the NIAS TCS Heritage Project, an attempt has been made to better understand the cultural ecosystem that these leading iron and steel production traditions emerged under through studies on the blacksmithing communities, and their cultural and technological landscapes.

Kammaris: the blacksmiths and wootz steel makers of Telangana

The region of northern Telangana seems to have been particularly a hub of wootz steel making, especially the former provinces around Golconda as mentioned by the traveller Tavernier (Srinivasan 1994; Jaikishan; Juleff, Srinivasan and Ranganathan 2013). Till recently there were enormous slag heaps with crucibles in various places like Konasamudram for wootz steel making. Many of which have been whittled away over time having been used as local building material due to the impervious nature and for filling ditches. The specimens collected from field surveys and slag heaps included numerous bases of broken crucibles that would have been charged to produce crucible steel. There has also been a vibrant blacksmithing tradition in Telangana of Vishwakarma communities, known as Kammaris, some of whom also have memories of working wootz steel in their youth. Their identity as Vishwakarma and related ritual aspects such as the worship of Veerabrahmendra Swamy is touched upon. Amongst the surviving blacksmiths, one of the interesting aspects of the intangible heritage was the worship of the Goddess Mamayee, or Goddess of iron the temples as indicated in publications by Dr Jaikishan. There are several such intangible heritage aspects enmeshed with technologies aspects to be documented.

The blacksmiths in the Telangana region were known as Kammaris and traditionally included both the Mudda Kammari who were iron smelters, which is no longer practiced, as well as the actual forger of iron implements or blacksmiths. The mudda Kammari thus would procure the banded ferruginous magnetite ores from the forested areas. Several veins of banded ferruginous quartzite ores are seen along the bed of the Godavari river itself on the way to Adilabad, making for a spectacular sight. As seen in most of Southern India (Ramaswamy 2004, Brouwer, 1995a, 1995b), in the region of Telangana, the iron-working communities were traditionally grouped under the Viswabrahmin/Viswakarma caste, along with four sets of craft specialists of the carpenter, goldsmith and silversmith, bronzesmith/bronze worker and the sculptor (Jaikishan). As seen from the surface, there is a sense that the Viswabrahmin caste identity seems to be homogenous and somewhat universally accepted throughout peninsular or southern India. However, insightful investigations by a team led by Dr Tathagatha Neogi, NIAS-Exeter doctoral student and the author indicate that this apparent homogeneity is in fact underscored by numerous tussles for symbolic dominance within the Viswakarma/Viswabrahmin fold which the highly hierarchic groups of craft specialists were caught in. Furthermore, as elegantly argued from field studies by Tathagata Neogi, the emergence of a more dominant Vishwakarma narrative in the Telangana region is of more recent vintage. Interviews with artisans indicate that the Viswabrahmin caste identity in northern Telangana, seemed to have emerged through a coalescing of various crafts groups who were laterally placed in terms of caste hierarchies. The socio-economic and political contexts in which such a homogenization process took place provide for a complex narrative.

Mandalogi Gangaram was one of the last of the blacksmiths or Kammaris who had memories of the making of wootz steel and was interviewed by the team of S. Jaikishan with Prof Sharada Srinivasan and Baalaji. He had childhood memories of the making of ukku steel which his ancestors and grandfather (thatha) he said were very proficient at. He also had recollections of his father working wootz or ukku steel and his own memories of working with wootz in his heydays. He also mentioned that they prized the older tools and toddy tapping knives etc since they were made of wootz steel and blacksmiths did not like to easily part with them for newer tools. His workshop made of a solid wooden framework still survived in his backyard. Various interesting facets of the intangible heritage of the Kammari blacksmiths of the Vishwakarma community of the Telangana region came to light through interviews and interactions with Kammari blacksmiths of Dammanapet village conducted by the author and team in collaboration with Dr. Jaikishan. It was found that one of the elderly blacksmiths still recollected some of the songs which were dedicated to the goddess Mamayee, the local goddess worshipped by some of the Vishwakarma and blacksmiths of the Telangana region. The etymology of Mamayee suggests it could be translated as goddess of steel, if the term ayas for iron is kept in mind, although the terms could also be derived from Mahamayee, a name for the great mother goddess. There are numerous temples to Mammayee dotting the landscape such as a famous one in the weaver's village of Pochampalli, indicating the popularity of the goddess amongst the broader Vishwakarma community. This temple also has a black stone image of Veerabrahmendra Swamy, a saint who is said to hail from the Kadapah region and is venerated by blacksmiths.

The view overlooking banks of Godavari where iron rich ores are found in Telangana.

Mammayee temple in Pochampalli, Goddess of craftspeople and blacksmiths.

The country side and roads leading to the blacksmith village in Konasamudram.

Blacksmith Bhimanna from Telangana fixing the anvil, Dammanapet (Interviewed by Profs Sharada Srinivasan with Dr S. Jaikishan, Telangana historian)

Mandolji Gangaram who had a living memory of wootz sword making.

Mandolji Gangaram in an interview with NIAS team (Dr Jaikishan, Prof Sharada and Baalaji) describing the wootz steel making process in his home in Konasamudram and the extent of swords he made.

Heap of archaeometallurgical and steel making debris in Konasamudram in Telangana.

Archaeometallurgical debris showing tuyeres, slag and crucibles embedded with soil.

Crucible fragment with remnants of slag fused with ingot.

Crucible fragment with steel ingot.

Iron implements for everyday use.

7

Traditional Blacksmithy in Tamil Nadu and Karnataka

Tiruvannamalai: Arasampattu and Mel-siruvalur

Blacksmithy communities in Karnataka and Tamil Nadu were studied to explore the techno-cultural aspects at places such as around Tiruvannamalai area, in Tamil Nadu which was also an area where iron and steel making seems to have thrived in antiquity as indicated by past studies by Srinivasan (1994, 2016) on crucible steel making in Mel-siruvalur. Hence ethnoarchaeological comparisons were made with blacksmiths who were identified in the region of Tiruvannamalai. of the Karuman Vishwakarman communities.

The foundries of three blacksmiths in Arasampattu in Sankarapuram district of Tamil Nadu were explored with the help of NIAS research assistants Maniganda Ranganathan and Meghna Desai. One of the blacksmiths Temburaja mentioned that they were practising blacksmithy for the past four or five generations and still preferred to make products with their hands rather than work with machinery. Temburaja, as a Karuman Vishwakarman wore the sacred thread or punal marking himself out as a traditional Vishwabrahmins As in Tingallur, the use of the votive stepped pyramidal wall to mark the bifurcation of the foundry into two parts was seen, the rear having the blower set up and the frontal portion the hearth with the forging anvil. At the back of the stepped pyramidal wall was a blower which was powered by one of the juniors peddling a bicycle wheel. This was also an innovation observed by Jan Brouwer (1995) in his account of blacksmithy workshops in southern Karnataka. It may be surmised that in earlier times a wooden wheel, akin to a bullock cart wheel, could have been used for the purpose with ropes which may have given way to the bicycle wheel.

As observed by Maniganda Ranganathan and Meghna Desai, the blacksmiths around Tiruvannamalai region worshipped a range of deities as Kuladevas or family deities ranging from Pacheamma, the goddess Kamakshiamman and Vinayagar of Ganesa. Another diety reported as being worshipped is Periyakarupannaswami, a rural male deity of Tamil Nadu, whose priests are not Brahmins and with the entire village as a community contributing to the maintenance of the temple.

Suburbs of Bangalore: Tingalur, Sanjaynagar

Certain technical and cultural similarities were noted with blacksmith communities in northern Tamil Nadu with those in southern Karnataka. There were similarities to the workshop of a blacksmith also from the Andhra region in the

Sanjaynagar suburb of north Bangalore from the Kammari community of Andhra Pradesh identified by Prof Sharada Srinivasan. Here too a pyramidal wall with seven steps was seen with a terracotta face on top representing the deity. A large upright anvil in the shape of a cuboid with a surface of nearly a 12 inches by 12 inches and 1 foot height was embedded in the ground and supported on all sides by thick timber stakes also embedded in the ground and bound by iron wire. The advantage of the height was that he could comfortably sit on a stool next to the anvil and undertake hammering. A lot of the work he did was mainly of tempering and sharpening tools.

The migration of blacksmiths from rural areas into the urban peripheries is a recent phenomenon. Makeshift sheds of blacksmiths may be observed in parts of suburban Bangalore over empty patches along the roadside. Some of these in north Bangalore were found to have migrated from bordering parts of Telangana and Andhra Pradesh. One such family of blacksmiths identified by Dr Smriti Haricharan, Assistant Professor, NIAS, was documented in the neighbourhood of Tingallur near Jakkur. Mangamma along with her husband Nagaraja, practice blacksmithy in Thingalur, Bangalore. The duo migrated from Chittoor and settled in Kolar, Karnataka. From Kolar about a few decades back they relocated to Bangalore. They made hoes, sickles and knives that seem to be used in gardening and urban landscaping. The working unit consisted of a husband and wife team, Nagaraja and Mangamma. They were from the Kammari community of blacksmiths. The NIAS team documented these workshops.

The hearth area was bowl-shaped and was fashioned on a bed of charcoal where wood was used as fuel. This was waste wood which was procured from a carpenter's shop across the street in the forms of chips and shavings. Just in front of the hearth was a solid iron anvil in the shape of a cuboid with a flat square surface on which the hammering was done. It had been re-inforced by fixing it within a sectioned tree trunk, providing a stable foundation. In addition, just in front of the anvil was a lower rectangular stone platform as documented by Dr Udaya Kumar which was used to beat out the fire skin and impurities on the iron implement as it was initially heated to red heat. It was only after this step that the implement was then forged extensively at red heat. A trench kept next to it was used for quenching the tempered or forged implement for improving its strength. Forging was done by one of the smiths with a heavy hammer, while the other sat near the anvil held the red hot implement with tongs for shaping. A hand held blower was used with one of two women sitting at the back and cranking it continuously. This particular workshop being in a semi-open space did not have electricity for an electric blower.

Ritual Aspects: Worship of Kalikamata

Their male and female relations also contributed to the blacksmithy activities. They worshipped the deity of Kalkamata or Kalikamata, a form of the goddess Kali. Kalikamata was also venerated by itinerant blacksmiths such as the Rajput Lohar of Rajasthan as reported by Dr Udaya Kumar, Post-doctoral Associate at NIAS. A typical feature of several blacksmiths foundries observed in southern Karnataka and northern Tamil Nadu is the partitioning by a stepped-pyramidal brick wall of the foundry into two areas. The area behind the brick wall was where the blower was affixed, going under the wall, into the hearth area in front of the brick wall where the iron implement was heated and forged on the anvil. This partitioning

served to minimise the fire hazards for the people working on the bellows. The stepped brick wall had a series of nine courses with one on top of the other. On top was a fired terracotta lump representing their family deity, the goddess Kali/ Kalikamata, with a trident embossed within, the emblem of Shiva. Thus, the brick wall served both a functional as well as intrinsic ritualistic purpose. Mangamma also mentioned that they also revered Munishwara, a deity who was a form of Shiva with the matted locks, and whose worship is popular in southern Karnataka and offered the hair of their firstborn child to the deity.

Connection of Muneshwara cult to blacksmiths

Muneshwara is considered to be the holiest man by all the Vishwakarmas of the northern Karnataka region. His temples are found in many parts of the northern Karnataka. The temple of Muneshwara at Tintini is located on the northern bank of Krishna River. It is also called by Vishwakarmas as the Muneshwara Matha. It dates back to the 16th century and is built in Islamic style architecture during the time of the Adil Shahis. Prior to Muneshwara settling in Tintani, the village which was mostly covered in forests had a temple of Isvara. All the members of northern Karnataka's Vishwakarma sub-castes are known to the life history of Muneshwara but unfortunately during the Jan Brouwer's survey no one had a detailed and complete knowledge of the history. He is considered to be holy, from the community of goldsmiths (which Brouwer does not mention) and historical, but Brouwer analysis him and his Vishwakarma connections as a myth. Muneshwara is depicted as a Vishwakarma striving for recognition and position. His career which desire independence has allegorically place goddess Kali in the sphere of conflict and dependence. Muneshwara has manifested in forms of Siva, Vishnu and Muslim through his myths.

The extent of Muneshwara cult, its impact and its socio-religious fundamentals explored in Bangalore amidst the urban-rural setting by Meghna Desai and Madan Sundarraj. The key idea was to understand whether it is the same Muneshwara from Northern Karnataka, who is worshipped by both Hindus and Muslim blacksmiths alike as had been previously recorded at a crucible steel site of Tintini in north Karnataka by Sharada Srinivasan (1996). The blacksmith couple Mangamma and Nagaraj also followed some observances of the cult of Muneshwara. The extensive survey at the major Muneshwaran temples and an examination of the worship practices corresponded to its Tamil counterpart from where the cult seemed to have spread (based on oral accounts). While some temples of Muneshwaran were worshipped by Gowdas and Reddys there were others worshipped by different Tamil communities. The temples of Muneshwaran were generally paired with those of Mariamma and Ayyannar. The temples were located in narrow by lanes deep inside the urban jungle. The annual procession or '*jatra'* only takes place in the Jadamuneshwar Temple amongst the others documented. A lot of these temples are known for animal sacrifices or offering '*bali'* on no moon days. A questionnaire was used as a template and the questions were asked to the temple priest or the person in charge. The survey was interrupted as the priestess; wife of Ramaiyya (who was answering) went into trance. Among the owners and other land details, Ramaiyya mentioned one aspect which deserves a crucial attention that the worship of Muneshwara was not associated with any other village gods and goddesses in Karnataka.

View of the Rautnallur iron rich hills near Tiruvannamalai, Tamil Nadu.

Blacksmith Chinnappa at his foundry in Arasampattu.

Blacksmith Chinnappa in his foundry with a display of tools he has forged from scrap iron in Arasampattu.

Temburaja, who gave a very informative interview owns the adjacent foundry to Chinnappa in Arasampattu.

Taking a break from forging.

Two young brothers from Melsiruvalur lending a hand at their father's workshop.

The photo of an evening market where tools are displayed for sale. The display is set up right outside the foundry at Melsiruvalur.

The displayed items for sale include not just iron but aluminium, plastic and wood as well.

RAs Meghna and Manigandan at the blacksmith's market.

Meghna and Manigandan with elderly blacksmith.

Shri Nagaraja and Smt Mangamma, family of blacksmiths at Tingalur.

Anvil with square top, Tingalur.

Lady at the manual blower and with Mangamma tending fire.

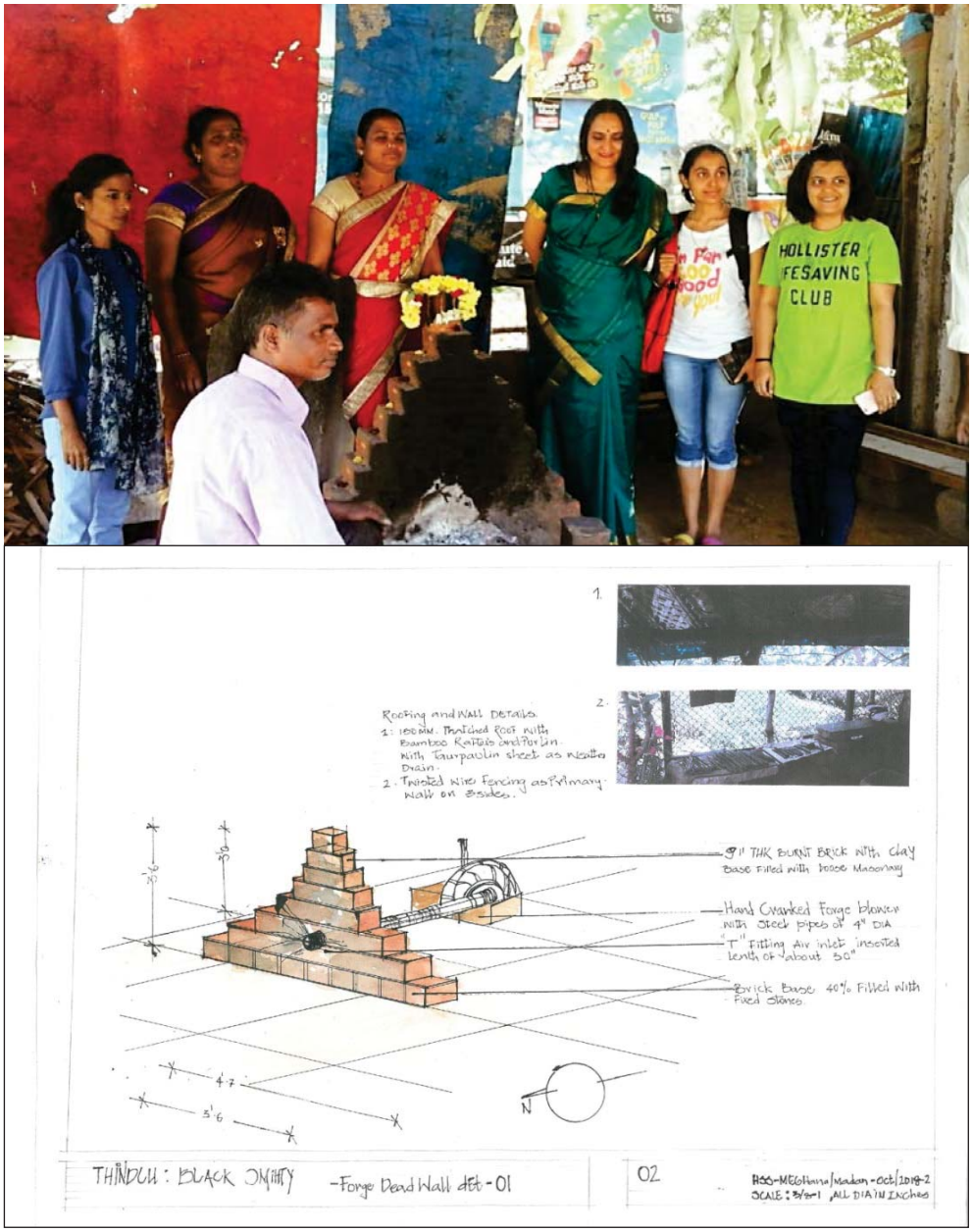
Tools fashioned at Tingalur workshop.

Festival of Ayudhapuja worshipping furnace in Tingalur,Nov 2018.

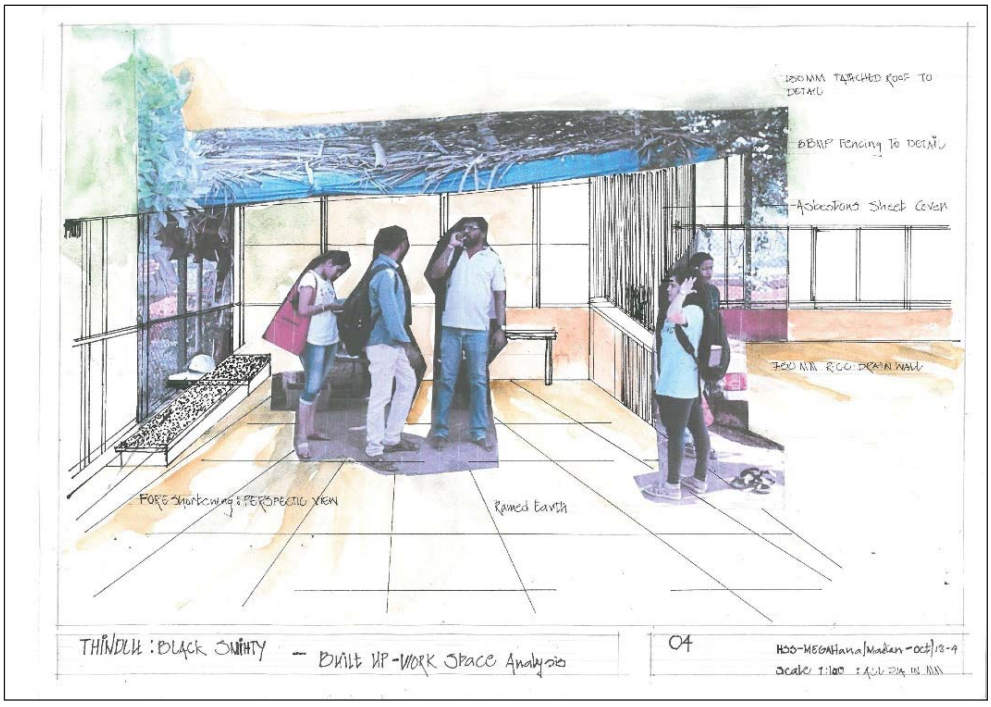
Jadamuneshwara temple and the priestess (w/o Ramaiyya).

Image worship of Katerri Mariamman and Muneshwaran Jadamuneshwar icon in silver and silver frame surrounding him.

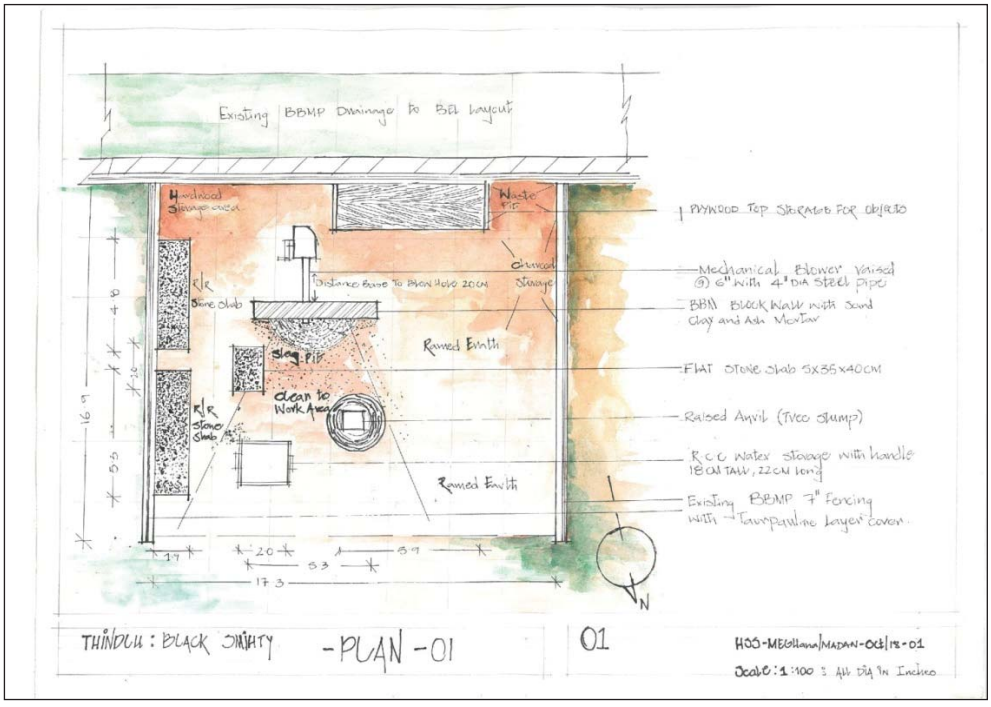
View outside the Muneshwaran temple. The horses of Ayyannar on a hillock overlooking the city amidst the urban landscape of Bangalore.



The sketch of blacksmithy at Thingalur including the electric blower and brick partition between the hearth and the blower. Inset is the picture of fragile boundary of the foundry over looking civic waste (sketches by Madan Sundarraj)



The team of NIAS-TCS from HSS department documenting the Thingalur workshop led by project PI Prof. Sharada Srinivasan (sketches by Madan Sunderraj).



Floor plan of Thingalur blacksmithy for documenting heredity blacksmiths in an urban space and their integration with their environment. (Sketches by Madan Sundarraj).

8

High-tin bronze metal mirror craft from Aranmula, Kerala

Mirrors have held long held a fascination as indicated by finds going back to hoary antiquity from various parts of the Old World and Asia. The production of metal mirrors has been a longstanding tradition in various parts of the Old World and Asia. In India, mirrors have been held in considerable significance. In Sanskrit, mirrors are known as *darpana* and as *kannadi* in South Indian languages of Tamil, Malayalam and Kannada . One of the most beautiful and enduring sculptures to be found in Indian iconography is that of the celestial maiden, deity or dancer admiring herself in a mirror. Although the art and craft of mirror making has all but died out around the world, it is remarkable that a marvelous tradition of mirror making still survives in a small village in the southern Indian state of Kerala. There are numerous fascinating vignettes concerning metal mirrors ranging from the historical trajectory, to the sculptural representations and the archaeometallurgical insights as pointed out further. Previous preliminary ethnometallurgical findings by the author suggested that it is made of specular bronze of 30-34% tin, and which can be more precisely described as delta bronze (Srinivasan 2008, Srinivasan and Glover 2007, Srinivasan and Glover 1995). However, more detailed investigations into the foundry practices and the socio-cultural milieu of the crafts tradition had not been well understand which was attempted during the period of this project. The study of this landmark, technologically discrete, tradition constitutes an important aspect of history of science and technology.

The verdant village of Aranmula in Kerala in southern India is best known for the spectacular snake boat races which are held at the time of Onam, the most prominent Malayali religious festival. Nestled in this humble abode along the meandering banks of the Pampa river, a unique mirror making tradition has thrived over centuries. Using low-cost methods and organic materials, the skilled manufacture of a cast high-tin bronze mirror of 33% tin with highly specular or reflective properties has been undertaken. Its reflective properties can be compared very favourably with those of the glass mirrors that are manufactured in modern day factories with mercury coating. This ancient tradition with its technological and ritualistic significance is, however, greatly in decline.

The traditional weddings of the upper castes of the Nambuthri Brahmin community and the Nairs, the matrilineal warrior clan, included the ashtamangalyam comprising of eight auspicious articles that to be part of the wedding trousseau the brides. These included the Aranmula mirror (valkannadi in Tamil and Malayalam) as reported even from the early 20th century by Thurston and Rangachari (1909).

The details of the manufacture of the Aranmula Kannadi had for many years been zealously guarded as secret by a small group of surviving master craftsmen who consider themselves to be of the status of acharis or gurus. Such crafts also did not apparently have any written records or treatises associated with them but were passed on empirically through practice in a hereditary fashion, which also became a way to safeguard the exclusivity or patent of their traditional knowledge.

One of the families that Prof Sharada Srinivasan interacted with since late 1990's was of late Janardhan Achari in Pattanamthita, master craftsperson who has made some of the largest of Aranmula mirrors of upto a foot large. During the duration of the project fieldvisits were made particularly to the workshop of his daughter Suddhammal Aranmula as an example also of a woman who has taken up the metal crafts profession and has been keeping the craft going with her mother who used to assist in the workshop and son. In recent times, the Aranmula metal mirror makers have been undergoing some difficulties with the floods of 2018 along the river Pampa which inundated their workshops, leading to damages. Efforts have been under way to rehabilitate them and to revive the crafts.

Mirror composition of delta bronze

Fragments of the mirror alloys have collected from more than one metal mirror making workshop in Aranmula by the author over the past couple of decades and subjected to metallurgical investigation. These have comprehensively established that the Aranmula Kannadi mirrors were intentionally made of a binary unleaded alloy of copper with 33% tin. This alloy has a close match with the composition of the pure delta phase of bronze which is an intermetallic compound (Cu 31Sn 8) comprising of 32.6% tin and the rest copper. The extraordinary reflective properties of the alloy also owes itself to this composition, approximating to the pure delta phase. This predominant delta phase composition yields properties ideally suited for a mirror, as it is a hard, stable and silvery compound, and can be polished with great reflectance and highly specular properties.

In fact, the entire mirror manufacturing process seems skilfully geared towards optimising the presence of this delta phase which is not trivial. This is because, as the copper-tin phase diagram indicates, the delta phase forms only within a narrow composition range of bronze of 32–34% tin at non-equilibrium room temperatures (Scott 1991: 95). Yet another technological challenge that the Aranmula craftspeople seem to have offset well is that of the high brittleness of the alloy. While this silvery metallic alloy shatters quite easily like glass, this brittleness is offset not by adding lead (which was added for this reason generally to copper-tin alloys) but by casting a very thin blank, no more than 3 mm thick, which would thus cool quickly with fewer heterogeneities. Then the blank is reinforced by mounting it with resin on a wooden mount for the polishing process. A finished mirror from Aranmula consisted of 32.5% tin, approximating the composition of the pure delta compound of 32.6% tin. Thus, it is remarkable that merely by using traditional 'low-tech' methods and materials a rather sophisticated 'high-tech' metallurgical end product is achieved.

Aranmula mirror makers

Family of Suddamal Aranmula, Aranmula metal mirror makers with Prof Sharada Srinivasan's family, husband and daughter.

Prof Sharada Srinivasan with master craftsman Janardhan Achary, Sudhamal Aranmula's father during a fieldtrip made by her in 1998, who passed away in early 2000's.

Foot long high-tin bronze mirror made by late Janardhan Achary.
(Photography by Digvijay Mallah, husband of Dr Sharada Srinivasan)

Wife of late Janardhan Achary making the crucible-mould for casting mirror blank.

Hearth for melting the crucible-cum-mould for casting the mirror blank.

Hearth for firing the crucible for casting mirror.

Niranjan Achary lifting the closed crucible-mould with tongs; the bottom sealed cup has the metal to be melted.

Niranjan Achary lifting the closed crucible-mould with tongs; the bottom sealed cup has the metal to be melted. The closed mould is then tipped over for the molten metal to flow into the encased two-piece mould to cast the blank. Photographs by Digvijay Mallah (Prof Srinivasan's husband).

View of the workshop which has been in place since Janardhan Achary's time (Photo by Sharada Srinivasan)

Polishing of cast blank by Niranjan Achary (Photograph: Sharada Srinivasan)

Polishing of cast blank by Niranjan Achary

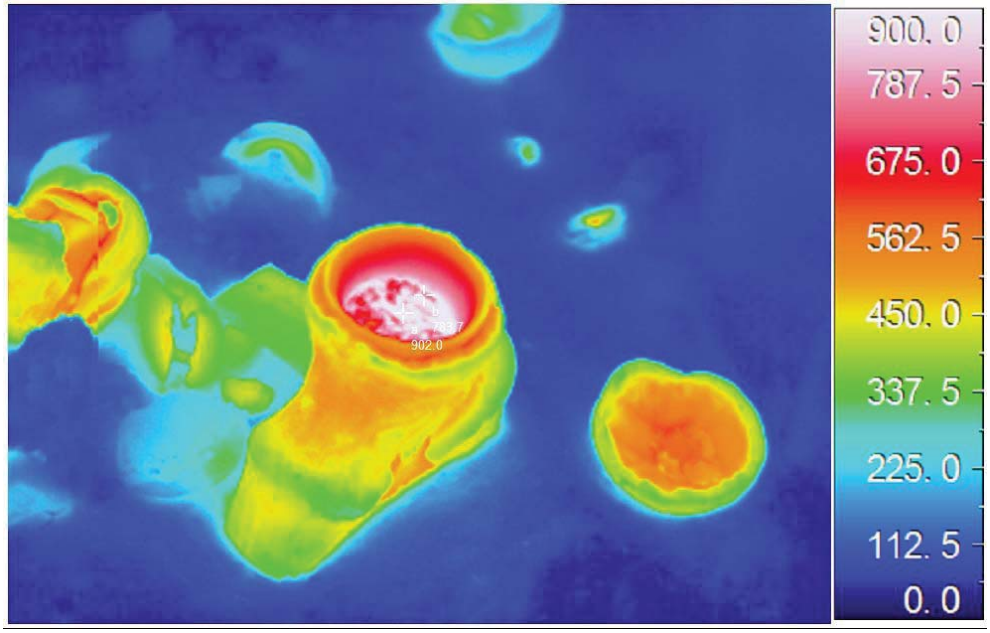
Polishing of cast blank by Niranjan Achary. (Photography by Sharada Srinivasan)

Silver cast blank of delta high-tin bronze mounted on resin for polishing
(Photograph Digvijay Mallah)

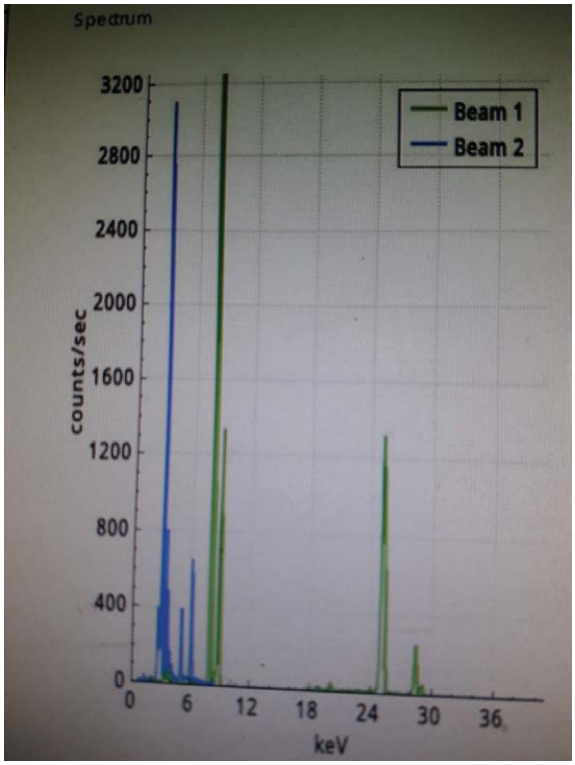
Mirror handles and finished Aranmula mirror
(Photo: Dr Srikumar Menon, Associate Professor, NIAS)

Reflection in Aranmula mirror of Professor Sharada Srinivasan, NIAS

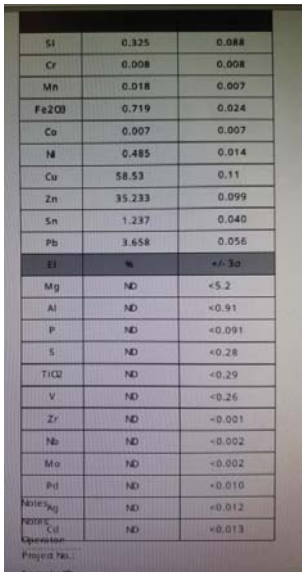
Aranmula mirror was purchased from Sudhammal, Lady Mastercraftswoman, daughter of late master-craftsman Janardhan Achary for analysis



Thermal Camera analysis by Sharada Srinivasan with Nagae, Mifune, Ranganathan et al showed temperatures reaching at least 700 degrees inside the crucible to the point of solidification of delta bronze.

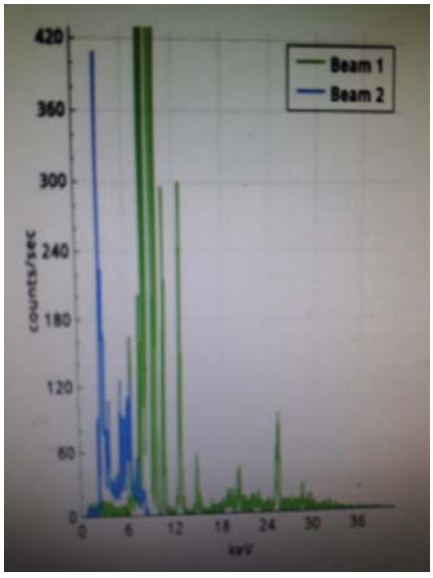


XRF Spectrum of mirror sample as above from Sudhhamal Aranmula showing presence of only copper and tin as major elements with the mirror having few other impurities with other elements only in very trace amounts.

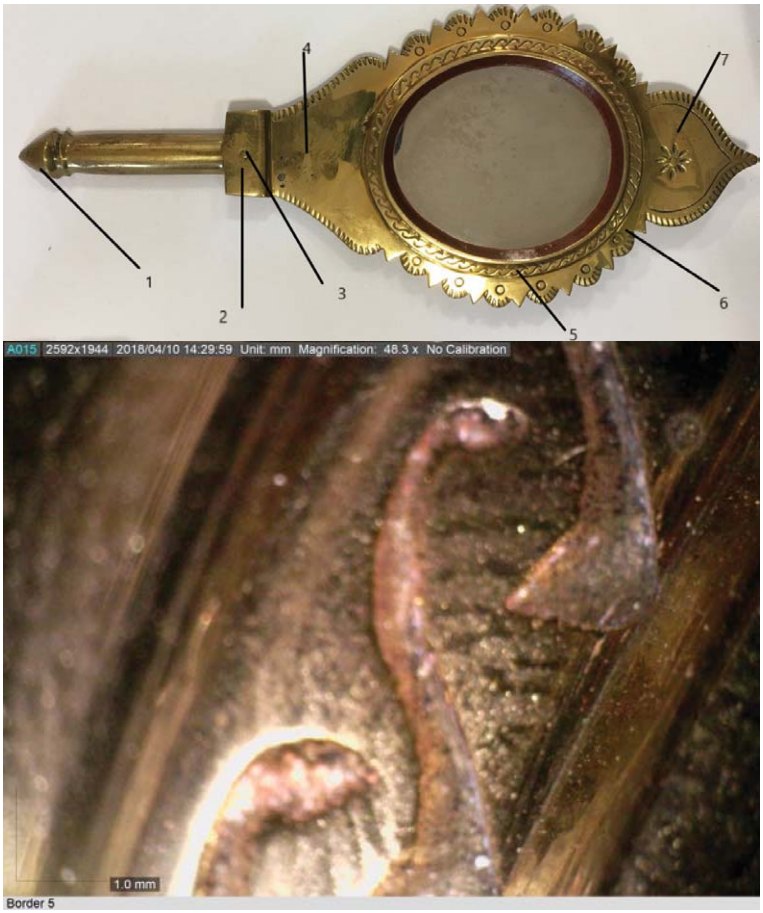


Si	0.325	0.088
Cr	0.008	0.008
Mn	0.018	0.007
Fe2O3	0.719	0.024
Co	0.007	0.007
Ni	0.485	0.014
Cu	58.53	0.11
Zn	35.233	0.099
Sn	1.237	0.040
Pb	3.658	0.056
El	%	+/- 3σ
Mg	ND	<5.2
Al	ND	<0.91
P	ND	<0.091
S	ND	<0.28
TiO2	ND	<0.29
V	ND	<0.26
Zr	ND	<0.001
Nb	ND	<0.002
Mo	ND	<0.002
Pd	ND	<0.010
Ag	ND	<0.012
Cd	ND	<0.013

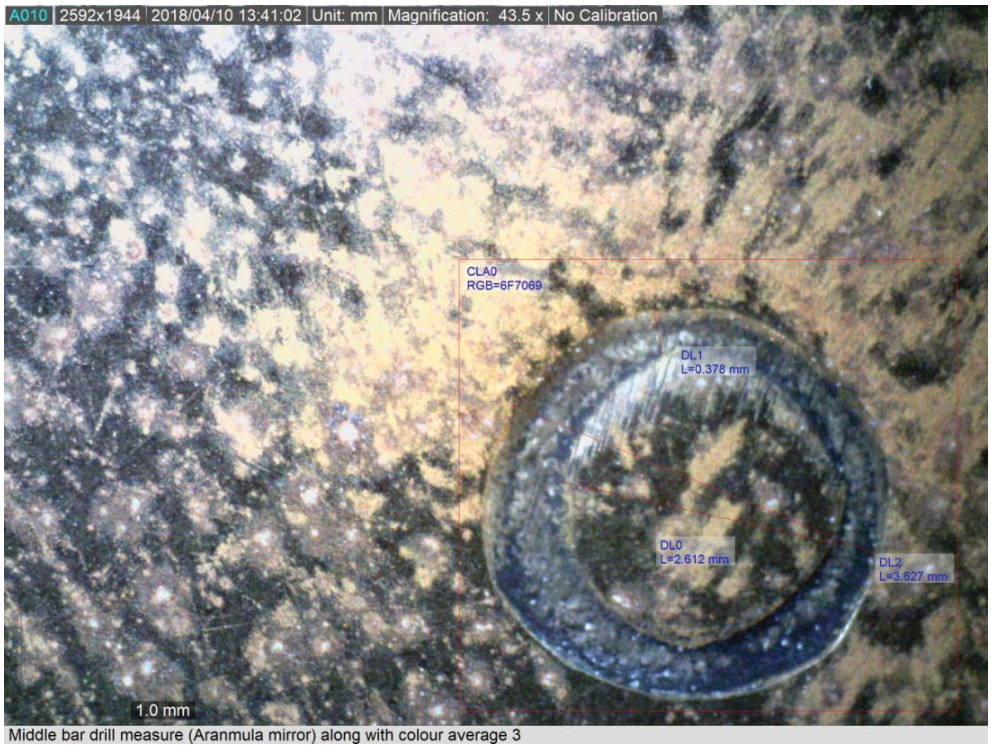
Analysis of the brass handle of the mirror procurd from Suddhamal Aranmula

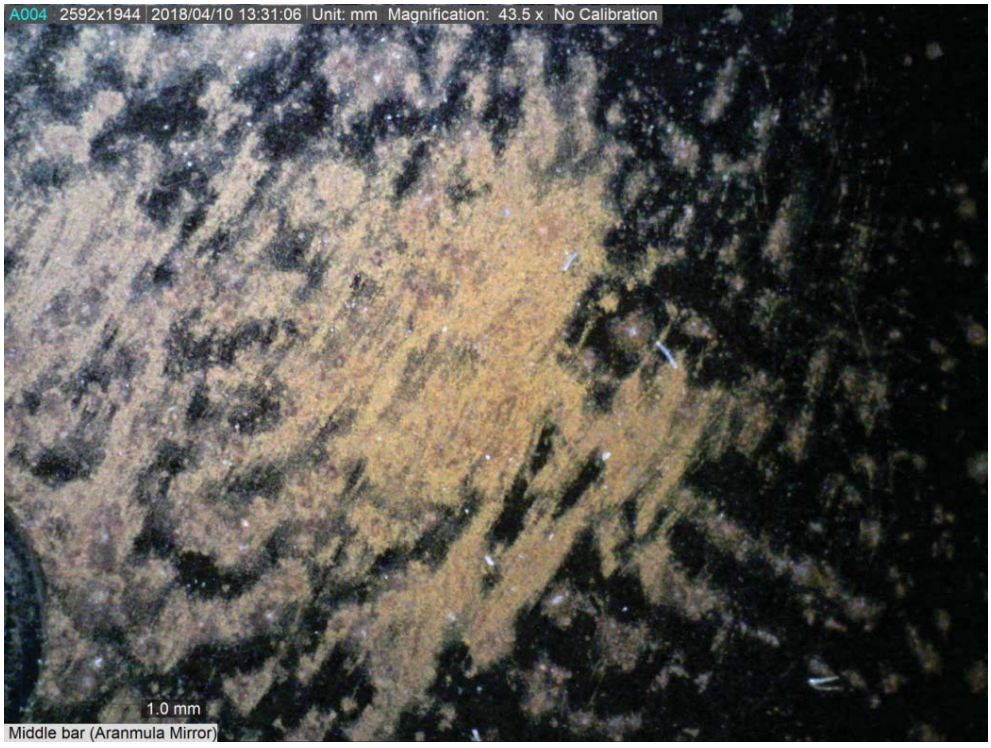


XRF Spectrum of the brass handle indicating the elemental peaks for the brass alloy with some impurities

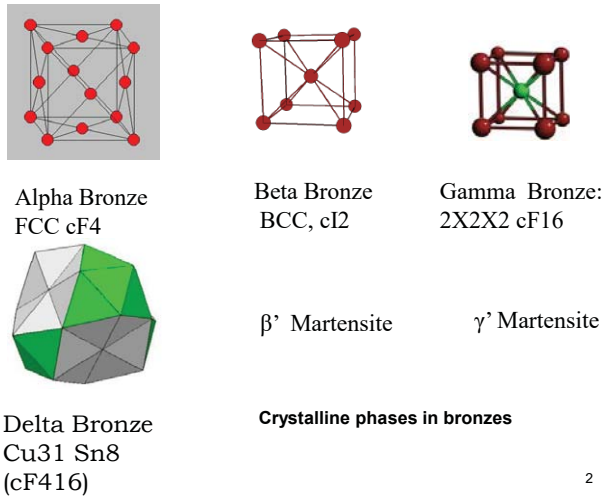


Dinolite Photography and Non-destructive Metallography on above Aranmula mirror obtained from Sudhammal Aranmula





Dendritic micro-structure of two-phase cast beta brass revealed in the brass frame (undertaken by Meghna Desai)



Crystal structures of alpha, beta and delta bronze

Submerged home of Sudhamal Aranmula, mirror maker and view of her damaged workshop in the aftermath in Aranmula in Aug 2018. Efforts have been made to rehabilitate such metal artisans affected by Kerala floods

9

Experimental Iron and Steel Smelting Workshops

Phase I (16th-22nd Aug 2017): Firing of Experimental Wootz Steel Furnace

India has been famed for its traditional iron and steel, as testified by the Delhi Iron Pillar, with several legends of the making of the high-grade wootz steel or ukku steel abound. Many of these traditional practices have died out, particularly of wootz steel making, while iron smelting has also greatly declined. The Heritage, Science and Society Programme of NIA held an exciting workshop under the NIAS-TCS Heritage Initiative between 16th-22th Aug 2017, on 'Experimental smelting of iron and wootz steel', co-ordinated by Prof Sharada Srinivasan, NIAS and in collaboration with Prof Mark Kenoyer, University of Wisconsin Madison. It aimed to towards gaining a more scientific and empirical understanding of processes of traditional practices The NIAS campus came alive for a week with spectacular and unusual scenes of fired furnaces for iron and steel smelting which students and staff worked enthusiastically hands on build amidst blustery monsoon weather.

The NIAS Heritage Programme has been actively involved in studies on production landscapes for wootz making from antiquity from various parts of southern India for some decades. In the west, where experimental archaeology is emerging as a major sub-discipline of archaeology, substantial experimental work has been done on the re-construction of high-carbon wootz steel and on the forging of Damascus blades of wootz. The iron and wootz steel making experiment that was set up in NIAS, Bangalore was a unique one for various reasons. It took such smelting trials further by attempting to incorporate more traditional or authentic local materials, also drawing from actual findings on the compositions of pre-industrial wootz making crucibles from southern India, such as those made by the NIAS researchers (eg Sharada Srinivasan 1994, 2007, Juleff, Srinivasan, Ranganathan et al 2013). Furthermore, it aimed to follow in the footsteps of Francis Buchanan who gave a most lucid account of wootz steel production by crucible processes during his travels in the regions of Mysore around the 1800's with a sketch of the furnace. The experimental workshop thus had two furnaces built, one an iron smelting furnace, and the other a wootz steel smelting furnace wherein crucibles filled with appropriate ingredients could be packed in the manner illustrated by Buchanan and fired to produce wootz steel, although of course using modern blowers in place of hand bellows that were used in the past. Prof Mark Kenoyer, eminent South Asian archaeologist who has excavated in Harappa in Pakistan on the Indus Civilisation for several decades, has had an abiding interest in crafts anthropology and also conducted well received experimental archaeology workshops elsewhere in India and Pakistan.

Another highlight was that the workshop aimed to interface with local crafts community to draw upon their skills and knowhow too. Thus, potters from the Nandi Hills area were co-opted to get local clays, plasters and mud bricks to make the furnaces and the crucibles, with the NIAS team working closely with them. Fieldtrips to potters and blacksmiths in the Nandi hills and around Bangalore were made by assistants of Meghna Desai, Maniganda and Uma Kritika. The iron smelting furnace was charged for several hours with ore mixed with gobar or manure to form balls. A family of blacksmiths from Tingallur including a lady blacksmith Mangamma, who were sourced by Dr Smriti Haricharan, temporarily set up their smithing foundry and anvil at NIAS.Their task was to work on the smelted iron bloom to extract those iron-rich portions which could be fired and carburized in the steel making furnace and then on forging the steels produced.

The steel making furnace underwent two firing trials, one whereby modern graphite crucibles were used, and the second with crucibles made by the potters according to the specifications of the team. Both trials also charged wrought iron with cast iron along the lines of the Deccani wootz process with the the furnaces withstanding upto 1300-1400^0 C. NIAS team enthusiastically took the lead in various activities of breaking charcoal and bricks, mixing plasters and clays, and assisting in firing and tending the furnaces. Faculty, staff, cholars and students from around NIAS and IISc took considerable interest to attend and take photographs and videos of this spectacular event. Workshop participants included Dr S.K. Aruni of Indian Council of Historical Research and Dr Tathagatha Neogi, who during his PhD under the NIAS-Exeter UKIERI scheme also worked with one of the last iron smelting communities of the Asur tribals of the Jharkhand. Further scientific investigations are under way by the collaborative team on the retrieved ingots and fired crucibles and furnace remains to make archaeometallurgical comparisons.

Phase I (16th-22nd Aug): Firing of Agaria Iron Smelting Furnace

The Experimental Smelting Workshop Phase II of the NIAS-TCS Heritage Initiative held on 23rd April involved experimentation with iron smelting drawing more directly upon traditional iron smelting practices. This time the furnace was modelled along the lines of the traditional Agaria iron smelting shaft furnace of Central India. Here the charcoal is fed by a feeder at regular intervals into the central shaft. The workshop was co-ordinated by Prof Sharada Srinivasan and Dr Uday Kumar, with the furnace was inaugurated in the presence of Prof Shailesh Nayak and Prof Shiv Vishwanathan, OP Jindal University with the participation of a family of blacksmiths as well from Tingallur. The furnace was well plastered, dried and then fired with alternate layers of charcoal and iron ore following the technique of the traditional Agarias, with a continuous draft through a blower. The furnace was fired all night continuing into the wee hours of dawn tended diligently by the team members. The bottom of the furnace was broken a bit to retrieve the bloom and charcoal before it totally cooled and congealed. They proceeded to successfully retrieve the semi-solid iron bloom from the furnace while it was still hot by mid-day resulting in a successful smelt.

Iron and Steel smelting and blacksmithy workshop at NIAS (Aug 2017). co-ordinated by Prof Mark Kenoyer, University of Wisconsin-Madison and Prof Sharada Srinivasan, NIAS; seen with late Prof Baldev Raj, Director, NIAS

Iron and Steel smelting and blacksmithy workshop at NIAS (Aug 2017) co-ordinated by Prof Mark Kenoyer, University of Wisconsin-Madison and Prof Sharada Srinivasan, NIAS

Blacksmith family of Mangamma seen at NIAS workshop with Prof Mark Kenoyer, Prof Sharada Srinivasan, Prof Atul Choksi, IISc and Prof S Ranganathan

Iron and Steel smelting and blacksmithy workshop at NIAS (Aug 2017) co-ordinated by Prof Mark Kenoyer, University of Wisconsin-Madison and Prof Sharada Srinivasan, with fully fired furnace for steel making loaded with crucibles

Traditional furnace modelled after the Agaria furnace at NIAS built and fired during Experimental Iron Smelting Workshop Phase II (Seen in photograph are Prof Shiv Vishwanathan, OP Jindal University, and from NIAS, Prof S. Ranganathan, Dr MB Rajani, Dr Srikumar Menon, Dr Smriti Haricharan, and workshop co-ordinators Prof Sharada Srinivasan and Dr Udaya Kumar with the team of Sheela Karunakaran, Meghna Desai, Maniganda Ranganathan, Suresh and Bhargavi)

Traditional furnace modelled after the Agaria furnace at NIAS built and fired during Experimental Iron Smelting Workshop Phase II co-ordinated by Prof Sharada Srinivasan and Dr Udaya Kumar, Post-doctoral Fellow, NIAS

Experimental Iron smelting following the traditional Agaria process Phase II.

10

Bronze Making Demonstrations and exhibitions

Outreach and Exhibitions

The NIAS-TCS Metal Crafts Initiative co-organised a five day public exhibition of **Indian Metal Crafts Demonstration** held alongside the prestigious international **ICOM-Metals 2016 conference at IGCNA, New Delhi between 26th-30th Sept 2016** partnering IGNCA in the same. Apart from about 100 international delegates, the exposition was also open to the public. Entitled 'Exotic Metal Crafts of India', about ten metal crafts were showcased, with crafts groups setting up stalls and, including live demonstrations including Swamimalai bronze icon casting, Aranmula metal mirror making, Tatheras vessel makers of Jandial Guru, Panjab, Dhokra making. The exhibition was co-curated by Prof Sharada Srinivasan, Head, NIAS HSS Programme who also gave keynote address at the inauguration.

The family of Radhakrishna Sthapati who are a traditional family of bronze casters and icon makers from the Thanjavur area who had a stall and display with numerous icons also made a live demonstration. They built a bronze casting kiln on site and showed the various steps of pouring and casting of the molten metal into the mould which had been prepared previously and brought to the site. They also demonstrated the processes of final finishing and polishing. The demonstration was much appreciated. They also displayed the numerous tools, moulds nad other materials used in casting along with icons of well known eities such as Ardhanarishwara, Parvati, Nataraja, Ganesa and others. The family of Sudhhamal Aranmula and her son Niranjan Achari who made the exotic Aranmula mirror displayed the finished and polished mirrors made of this unusual high tin bronze alloy as well as the materials used in the processes of making and polishing the cast blank. It was interesting to see the image making craftspeople mingle for example with muslim artisans from Moradabad or the folk dhokra artisans cutting across regional and community lines. Also on display was a live demonstration by the Tathera vessel makers from Jandial-Guru, Punjab who were listed on the Intangible Heritage List of UNESCO.

Chairperson of ICOM-Metals 2016 Claudio Camillo with Veena Joshi, IGNCA, TCS Representative and Prof Sharada.

Swamimalai metal icon makers stall, seen with well made Ardhanarishwara image.

Aranmula mirror makers from Kerala, at ICOM-Metals 2016, Sudhammal Aranmula and family with Prof Sharada Srinivasan, NIAS.

Suddhamal Aranmula demonstrating polishing of Aranmular specular bronze mirror.

Tatheras or vessel makers from Jandial-Guru Punjab who have been listed in Intangible Heritage list of UNESCO, seen in photo with Prof Sharada Srinivasan and Joint Secretary IGNCA, Smt Veena Joshi.

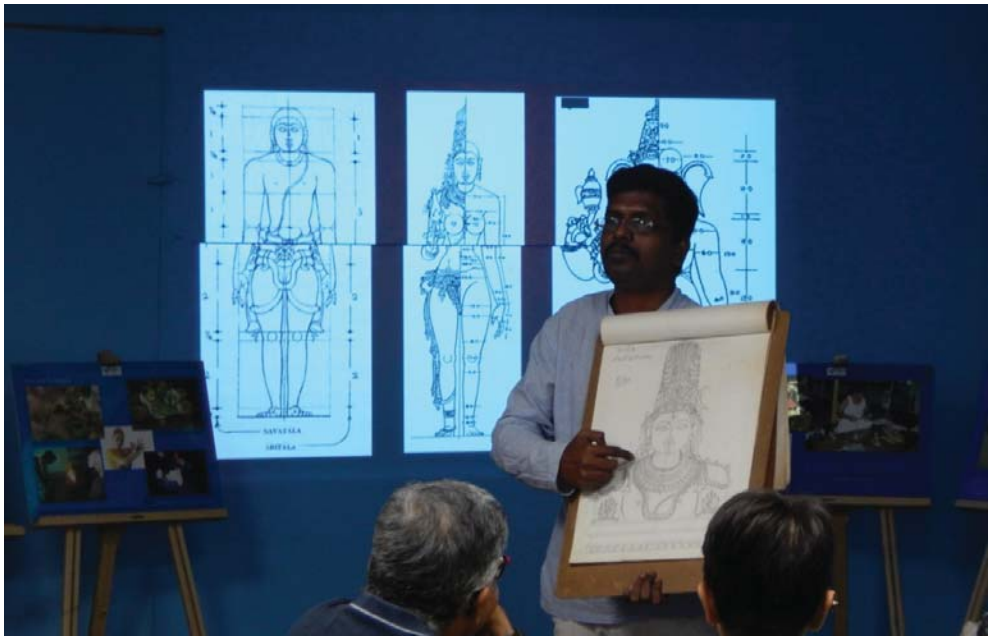
Brass vessel makers from Moradabad.

Furnace for casting of bronze icon made by Sthapatis from Swamimalai.

Final polishing of cast bronze icon made by Sthapatis from Swamimalai.

Outreach and Exhibitions

As part of the outreach of the important international exhibition at the **National Museum, New Delhi**, members of the NIAS TCS Heritage were invited to conduct a **Traditional Bronze Casting Workshop between 1st to 3rd June 2018.** This activity coincided with their major exhibition 'India and the World' including artefacts from international collections such as British Museum. The aim of the workshop was to disseminate wider awareness of the traditional methods of making metal icons through the lost wax casting methods used in making South Indian bronze and particularly drawing from the traditional knowledge of Sthapatis or icon makers in Thanjavur area, among children, students and the general public. Through lectures and actual hands on experience various aspects of drawing, wax preparation, wax model, wax moulding and casting were demonstrated with good enthusiasm and hands on participation of the workshop participants in various aspects including wax modelling. About a 25 members of the public including students participated while about a 100 visited the venue during the course of the workshop. Curated by Prof. Sharada Srinivasan, and conducted by Dr Uday Kumar, with the support of Maniganda, the workshop was hugely successful with enthusiastic participation by the general public and students, while the Sectretary for Culture and DG- National Museum also took time to drop in and observe the workshop and photo-exhibition to commend both. A photo-exhibition on bronzes, technology, art and dance by Prof Sharada Srinivasan was also on display. The NIAS team has been invited to run the workshop at National Museum in 2019 June as well.



Dr Uday explains iconographic aspects through his original drawings.

Students engage with photo-exhibition by Prof Sharada Srinivasan.

Demonstration of wax modelling.

Dr B.R.S. Mani Director General National Museum with Dr Uday, NIAS Post-doc, TCS Project.

Dr Uday at National Museum bronze gallery.

Melting wax at workshop.

Interaction on bronze casting Maniganda Ranganathan, NIAS.

Casting furnace setup for demonstration at National Museum

Dr Uday with crucible for melting metal at workshop.

Photo-exhibit on bronze casting by Prof Sharada.

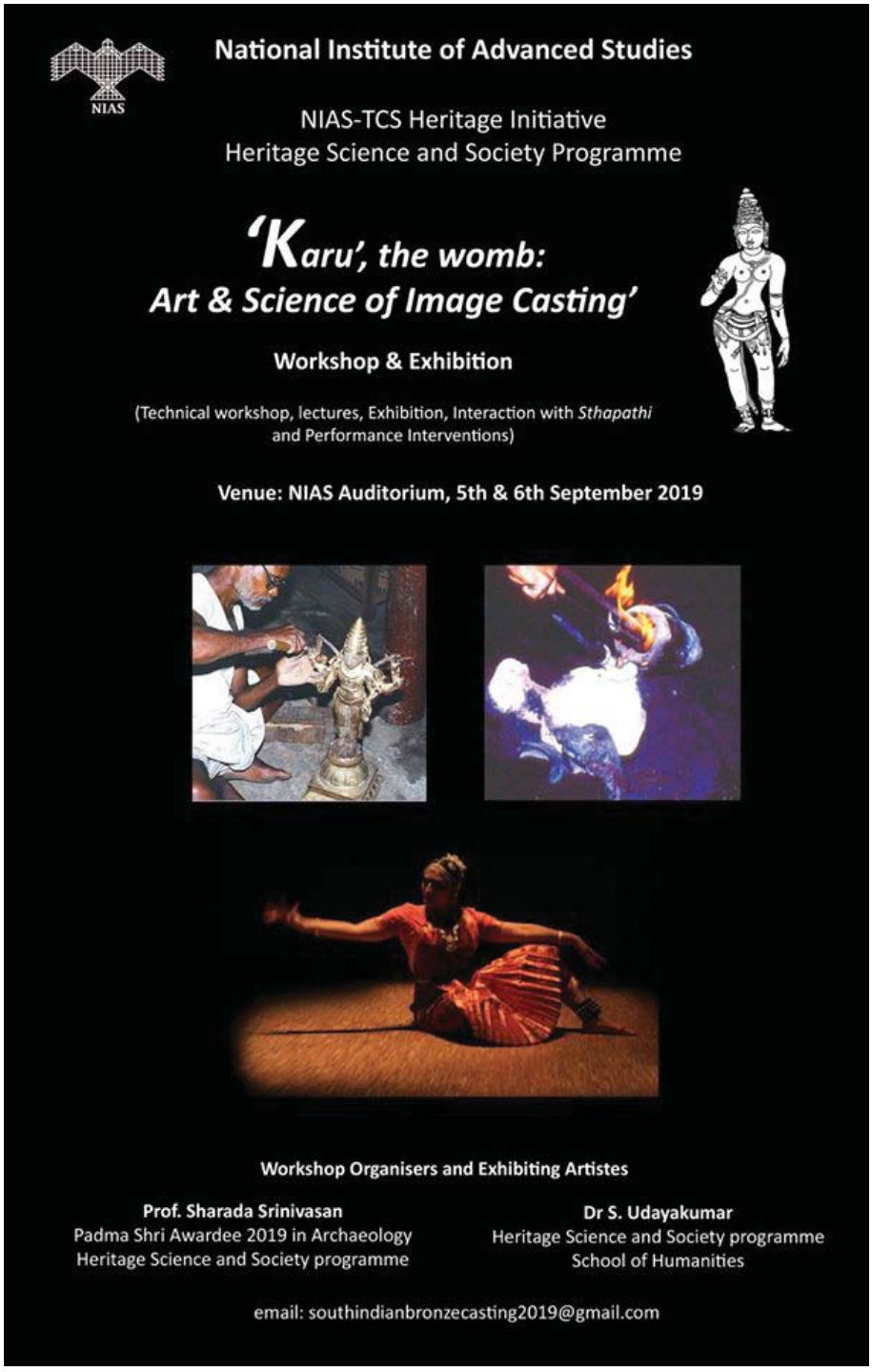
The NIAS-TCS Heritage initiative participated actively in the conference on Relevance of Archaeology for the 21st Century (23rd-25th July) organized by Dr Smriti Haricharan and the coinciding Exhibition 'Field Experiences', which was an innovative and artistic way of bringing alive numerous fascinating facets of archaeological and field research through multi-media installations, videos, photography as well as actual samples collected from fieldwork. Participants included archaeologists, landscape architects and artists who exhibited works related to their experience of the field. This juxtaposition provided a meaningful exploration into the various ways in which one negotiates the archaeological or ethnographic 'field' which may connote a process, a distilled experience an undefined space or a freedom of expression. The exhibits touched upon materials in heritage and image casting by master craftsmen at Swamimalai and studies on resonant rocks in monuments by Prof Sharada Srinivasan and materials related to the iron and steel making smelting experiment by Prof Sharada Srinivasan and Dr Uday Kumar, while Dr Smriti had an exhibit retracing the photographic memories of her master's dissertation and Vijayashree Kashyap on the Bhuta cult of Karnataka.

'The Field within Us': Exhibit on NIAS iron smelting experiments conducted by Prof Sharada Srinivasan and Dr Uday Kumar, seen with Manigandan Ranganathan and Uma Krithika.

Exhibit on Archaeology, Materiality and Performance by Prof Sharada Srinivasan, for exhibition curated by Dr Smriti Haricharan on 'Experiencing the Field' showing links between metal casting, bronzes and performance.

Prof Shailesh Nayak, Director, NIAS looking at 'Field Experiences' exhibits.

BRONZE CASTING WORKSHOP AT NIAS (Sept 2019)



The workshop on image casting, 'Karu, the mould: Art and Science of Image Casting' was held at NIAS co-ordinated by Prof Sharada Srinivasan with Dr Udaya Kumar, with hands-on bronze casting demonstrations of mould making and image casting by the family of late Dr Mohanraj Sthapati from Swamimalai, and with expert lectures and a multi-media exhibition curated by Sharada Srinivasan and Uday Kumar (Sept 5th-7th 2019)

Late Dr Mohanraj Sthapati of Swamimalai, sculptor and poet with Prof Sharada Srinivasan seen with his bronze casting of Nataraja

Karu exhibition inaugurated by Shri Chiranjiv Singh (IAS)

Family of Dr Mohanraj Sthapati demonstrating the making of the lost wax furnace and casting process at NIAS, Shri Sendilkumar and Shri Kalai Arasan and Shri Arumugam

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Appendix I

NIAS-TCS Heritage Initiative Impact

The impact of the NIAS-TCS Heritage Initiative in the past three years has been very wide ranging and remarkable, reaching multiple stakeholders across the socio-economic, educational and policy spectrum, from crafts communities, governmental cultural bodies, museums and institutions to educational institutions both at the level of higher education, college and school education, and international cultural organisations as well. Crafts communities, metal crafts and related sites in nearly 50 locations covering some 200 members of artisan communities were identified and preliminary documentation from techno-cultural, socio-cultural and socio-economic perspectives were undertaken including Swamimalai, Thanjavur, Kumbakonam, Nacharkoil, Gangakondacholapuram, Tiruvannamalai, Chengum, Mylapore, Salem, Singarapettai, Mel-siruvalur, Nilgiris, Kotagiri, Srirangapatna, Onipenta, Konasamudram, Pochampalli, Dammanapet, Ibrahimpattinam, Nirmal, Chitvel, Kadappa, Amaravathi, Lepakshi, Hampi, Kamalapura, Kadibakele, Shivarapatna, Nagamangala, Tingallur, Maski, Shivamoga, Chitradurga, Gatihosahalli, Sankarapur, Udipi, Srirangapatna, Mysore, Aranmula, Pattanamthita, Mannar, Kalady, Trichur, Nadavarambu, Palakkad, Sholapur, Baroda. In addition about 7 workshops/ exhibitions outreach activities were held at NIAS involving crafts which reached out to over 200 members of the public and students and some 200 school children [for eg Experimental Iron & Steel Smelting Workshops Phase 1 & 2 (2017, 2018) with hands on building of furnaces with craftspeople, and as part of NIAS-INTACH Public Outreach Demonstrations 2017, Disseminating Archaeology for school children 2017, Relevance of Archaeology 2018 with Art Exhibition, Performing the Periphery Workshops and Exhibition with role of metal crafts in performance 2018]. The NIAS TCS Heritage Programme also collaborated with IGNCA ICOM-CC Metals 2016 for a major public Indian metal crafts exposition with live demonstrations in New Delhi and a workshop on Bronze Casting for the India and World Exhibition at National Museum, New Delhi 2018 with 30 students, Traditional Furnaces Workshop Deccan College (2018), Crafts and Artisan Demo, India International Science Festival (2018) a mega event, Conference on Science-Society Dialogues at IIT-M, (2018), and others which attracted scores of students and public of at least 300. Thirty high impact publications including 6 book monographs were generated covering important journals such as Transactions of the Indian Institute of Metals, Journal of Metals, Materials and Manufacturing Processes, Indian Journal of History of Science, Current Science, RILEM, ICOM-CC and others. The NIAS-TCS Heritage Initiative has engaged with policy by working with Governmental bodies such as Indira Gandhi National Centre for Arts towards making documentaries on declining metalcrafts of the Viswakarma and Kammalar communities for wider dissemination and Archaeological Survey of India in the area of illicit trafficking of antiquities and bronzes, National Museum, CSVMS Museum, Government Museum, Chennai for understanding craft technologies of metal antiquites and bronzes. Following the disastrous floods in Kerala, many metal foundries which

lie along the river banks for the use of alluvial clay such as Pampa Bharatapuzha were affected as found by NIAS-TCS Heritage Intitiative which had been in touch with several of these communities such as the Aranmula metal mirror makers and metalworkers in Palakkad etc and since then members of the initiative have been requested to take part in several national and international missions through UNESCO, ICCROM and Kerala Government and so on for rescuing and reviving the heritage such as the recently formed Institute of Aranmula Heritage, Rescue Kerala and others.

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Appendix II

Research Team

Prof Sharada Srinivasan, PI of the NIAS-TCS Metal Crafts Heritage Initiative is Head, Heritage, Science and Society Programme and a recipient of Padhma Shri, India's fourth highest civilian award in Archaeology and a recipient of the Dr Kalpana Chawla Young Women Scientists'Award. She has undertaken pioneering research on numerous aspects of archaeotechnology, archaeometallurgy and materials characterization and had a background in archaeometallurgy and exposure to the study the Thanjavur region with its celebrated legacy of Chola bronzes and numerous bronze and bell metal working traditions. She contributed to a catalogue of Indian bronzes and bronze casting for National Museum, New Delhi and has completed two documentary films on declining wootz making and high-tin bronze traditions for IGNCA for INSA. The book Metals and Civilisations edited by herself Prof Ranganathan and Alessandra Giumlia under the BUMA series draws together several facets of research on Asian metallurgical heritage and she is also co-author of the book India's Legendary Wootz Steel. She was featured amongst India's top ten women scientists by Condi Nast magazine in 2018.

The TCS project was also ably supported and complemented by the research interests and inputs of the dynamic younger faculty including **Dr Smriti Haricharan**, Assistant Professor, NIAS and former Fulbright Scholar who has been interested in the aspect of circulation, usage and exchange of artefacts in relation to the Tamil region. **Dr MB Rajani, Assistant Professor** and Homi Bhabha Fellow has been looking at Srirangapatna, as another major cultural and technological hub along the Cauvery in terms of Tipu era sites, while this project has also touched upon the legacy of Tipu Sultan in terms of metals heritage. **Dr Srikumar Menon, Associate Professor** and Achuta Raya Fellow has been looking at the Iron Age and megalithic cultures such as of the Coorg at the source of the Cauvery to understand its early trajectory, while the project has also had an interest in ethnoarchaeology related to metal finds in relation to megaliths. **Dr Uday Kumar, Post-doctoral Associate, NIAS**, has undertaken significant research in experimental approaches in archaeology and in the study of iron smelting, also initiated at NIAS and received the prestigious Tylecote Prize from the Historical Metallurgical Society, UK for studies related to the use of traditional bellows. The encouragement of **Visiting Professors S Ranganathan**, NIAS and Indian Institute of Science, materials scientist with contributions in heritage, **Prof S Settar**, NIAS and former Director, IGNCA Bangalore Centre expert in Kannada and art history of Karnataka has been very valuable. The project has also been kindly supported by late Prof Baldev Raj, Prof Ramamurthy and late Prof BV Sreekantan. The Project has also had a very committed group of Research Associates and Project Assistants including **Meghna Desai** who has an interest in technical investigations on ferrous metallurgy and craft, **Madan Sundarraj**, who had a background in civil engineering before getting into conservation studies, **Maniganda Ranganathan** who has an interest in martial arts and swords and crafts traditions and iron smelting, **Mr Suresh**, from Thanjavur area

who had worked with Tamil University, **Sheela Karunakaran, Tallur Venkatesh, Pallavi Thakur, Uma Krithika and Bhargavi Ram**. The project benefitted a lot as well from the inputs of reputed consultants including **Dr S. Jaikishan**, Adjunct Faculyt, NIAS and expert on Telangana history and metalworking finds whose invaluable support in fieldwork and research in Telangana added great depth to the project, Baalaji, working on audio-visual documentation, **Dr Tathagatha Neogi**, **Adjunct Faculty,** who was a NIAS-Exeter doctoral student and who has worked on ethnoarchaeology of blacksmiths, Prof Subbaraman, former Head, INTACH, Chitrakala Parishat, Dr Choodamani Nandagopal, well known art historian, Chandra Jain, who has worked with craftspeople from Shivarapatna, Kandhan Raja of Chidambaram, Srinivasu Dokka, heritage collector and Kruthika Ganesh and the support of scholars including Prof Vijaya Ramaswamy, Dr Nagaswamy, Dr Venugopal, Aranmula Heritage Trust, Shri Chiranjeev Singh, Smt Gandhimati, Curator, Government Museum, Chennai, Dr Khened, Nehru Science Centre and others. **Digvijay Mallah**, husband of Prof Sharada Srinivasan contributed to some of the photographic content during a fieldtrip with her to Aranmula. During the course of the project some of the renowned master craftspeople very sadly passed away so that it is quite poignant that the project managed to capture some of the last vestiges of their great expertise and homage is paid to late Mandalogi Gangaram, Telangana blacksmith, late Govindrarajan, lost wax bell maker from Nacharkoil and last but not the least the extraordinarily gifted scholar, teacher and sculptor and metal icon maker and poet late **Dr Mohanraj Sthapati** of Swamimalai.

Prof Sharada Srinivasan was awarded Padmashri (India's 4th highest civilian award) by the **President of India in March 2019, in the category of Archaeology**. The citation also mentioned her work in archaeological science, the studies on history of alloys and metals covering bronze icons and wootz and preservation of rare metal craft traditions such as the Aranmula mirror, and also her contributions using Bharata Natyam dance to communicate art-science aspects. The researches on metalcrafts at NIAS also got highlighted in numerous press outlets due to the award of Padmashri to Prof Sharada Srinivasan such as in Asian Age, Deccan Herald, Hindu and other newspapers (https://www.asianage.com/age-on-sunday/100319/of-such-eloquent-metal.html), https://www.deccanherald.com/looking-and-down-answers-716212.html, https://researchmatters.in/news/two-bengaluru-scientists-shine-list-2019-padma-awardees

Dr Jaikishen, Adjunct Faculty and Telangana historian with Prof Sharada Srinivasan at iron smelting site

Dr. Uday Kumar, Post-graduate Associate under the NIAS-TCS Heritage Initiative won the **Tylecote Prize from Historical Metallurgy Society, UK**, to undertake further ethno-techno-archaeological research.

Mr Suresh with bell maker in Thanjavur area

Interview of Prof Sharada Srinivasan following award of Padmashri in Archaeology on her work on history of alloys through the ages and surviving crafts, for Asian Age newspaper, March 10th, 2019, 'Of such eloquent metal'

OF SUCH *ELOQUENT* METAL

The Padma Shri award winner with Swamimalai bronze icon maker Radhakrishna Sthapati

THE HISTORY OF ALLOYS THROUGH THE AGES HAS CONSUMED PADMA SHRI AWARD-WINNING SCIENTIST SHARADA SRINIVASAN. HER TRYST WITH DANCE WAS ALSO INSPIRED BY HER TIRELESS RESEARCH

SURUCHI KAPUR-GOMES

Deep in excavations, hands grimy from digging mine sites to unearth olden day metals with sweat on her brow, her body of work spans decades. Yet in the *mudras* and *varnams* she has practiced early in her life, science and dance have come together so beautifully. Ever questioning the nature of being, prying through what's the norm to unearth metallurgical explorations, she is inspired by alloys and bronze though the ages, with the famed *Cosmic Dance of Shiva* — Nataraja as her muse. Scientist, archaeologist, archaeometallurgist, culture explorer and danseuse Sharada Srinivasan has toiled over decades to experiment and understand metals through prehistoric era. The mother and wife who has spent years travelling to far off villages, mine trails and interacted with tribes that were once the brandishers of metal won the coveted Indian honour, the Padma Shri for her patient, determined and committed research. Sharada used archaeometric techniques to explore the classification of south Indian copper alloy metal icons. That lead to understanding the metallurgical finger-prints for bronzes of different periods such as Chola and Vijayanagara, which could be used as a diagnostic to categorise bronzes of uncertain dates and stylistic attributions.

Excited, and honoured, the scientist and dancer walks (limping slightly) in the lush IISC campus' National Institute of Advanced Studies where the 53-year-old academician supervises Phd students, continuing her research and analysis with the ASI and is now working on a project looking at bronze in Karnataka.

A fellow of the Royal Asiatic Society of Great Britain and World Academy of Art and Science, she was the recipient of the Kalpana Chawla State Award for Women Scientists 2011. Behind her calming and expressive eyes lies an acclaimed performer of Bharatanatyam whose *Danse e-toile: Nataraja and the Cosmos* was an original experiment of a cross-continental internet-streamed duet performance. The professor and alumni of Indian Institute of Technology (Mumbai), SOAS University of London and University College London (where she did her Phd) who comes from an august family of academicians, unearths the glint in her metal journey, and her life in this exclusive interview:

Q *Firstly, congratulations. How does it feel to win the Padma Shri for a lesser known subject like archaeometallurgy?*

It is indeed momentous when one's work over several decades gets such recognition at a national level, and in the subject area that I work in, of archaeological sciences which is a niche with less avenues for support. As a woman scientist and archaeometallurgist, I feel gratified that the award may serve as inspiration for more women to get into STEM disciplines, as well as into archaeology, which is inherently more challenging for women in terms of travel to remote areas, physically demanding surveys or excavation etc. It has also been overwhelming to receive so much goodwill and wishes, nothing prepares one for that.

Q *How would you describe your work and its relevance today? And what were your findings with the Chola Bronze?*

My work falls in the domain of what can largely be described as archaeometallurgy and ethnometallurgy — the technological study of metallic archaeological artefacts and art objects which helps us gain insights into the manufacturing techniques and history of technology, and the provenance and sources of metal. Some of my significant contributions are in 'technical art history.' For example, given the challenges in dating of south Indian bronze icons, I attemped to use archaeometric techniques to classify them by calibrating them against their metallurgical profiles since metals made of different sources could have different chemical profiles of lead isotope ratios and trace elements. One of the interesting finds was that the famous Nataraja icon had probably already been cast by the Pallava period since a couple of pieces had lead isotope ratios and chemical fingerprints that did not fit the 10th century Chola period but rather the 7th-8th Century Pallava period. This fits with the emergence of devotional Bhakti poetry by this period by saints such as Appar in praise of Kuttan or Nataraja worshipped at Tillai, the old name for Chidambaram. My studies have also demonstrated ancient skills in exploiting the alloys in bronze in Tamil Nadu and southern India going back to the Indian Iron Age and south Indian megaliths (such as Adichanallur and Nilgiris in Tamil Nadu).

I have also been studying iron and steel making traditions, for which India has been famed, particularly the high carbon wootz crucible steel made in southern India which was the first grade steel made in antiquity and was traded as far as Persia and west Asia to make the fables Damascus sword blades. Wootz steel attracted the scholarly attention of many European scientists going back to Michael Faraday. Most recently, I was involved in studies published in the *Journal of Arms and Armour*, UK on the Mysorean rocket of the Tipu era. The finding were the precursors to modern rocket technology!

Q *When does science stop, and dance begin? Uncannily, they find a meeting ground in your work too?*

As a Bharatanatyam dancer, the ways in which the mystique of the Nataraja icon has tended to meld together responses of artists, scientists and dancers alike has held a special place in my heart. An aspect that intrigued me was that given that the icon is often described as the 'cosmic dance' of Siva, the makers of the icons were probably inspired by celestial observances. To that effect, in a collaboration with late astrophysicist Nirupama Raghavan, former Director, Nehru Planetarium, we explored plausible links of the iconography to the star positions around the Orion constellation (since Nataraja is linked to the star Arudra or Betelgeuse in the Orion constellation). *Danse e-toile: Nataraja and the Cosmos* was an original experiment which I co-conceptualised with Jean-Marc and Anne Matos of France, and performed with Anusha Emrith — I was dancing in Bangalore and she was performing in Toulouse and we were interactively dancing via our internet images in a classical-contemporary fusion. The performance not only aimed to explore the interplay of the classical, Descartian and quantum mechanical world, but it also wove in the mystical insights from the Nataraja imagery. It was the most extraordinary and even humbling experience to dance with a virtual image, like an alter ego. So, if dance is poetry in motion, the most satisfying aspect for me has been the encounter of what Ananda Coomaraswamy (a Ceylonese Tamil philosopher and metaphysician), writing on the dance of Siva, succinctly described as 'poetry but nonetheless science'.

Sharada with her husband (third from left), brother and daughter at a Toda hut in Nilgiri

At the Hirebenkai megalithic site

Q *How were your growing years and the influences that saw you take to this profession?*

I have to say that I am indeed lucky that I had an upbringing which was very cosmopolitan, and yet very rooted in Indian ethos. My parents, uncles, aunts and family have made prominent contributions in scientific developments and teaching, as well engaged deeply with cultural studies, Indology, environmental issues and wildlife preservation. Of course, like many girls of a south Indian (Tamil-Kannadiga) background, I started learning Bharata Natyam as a child and this passion endured over the years, even though my academic inclinations in my teens was to study physics, which I was glad to have the opportunity to do through a B.Tech in Engineering Physics at IIT Mumbai. My father MR Srinivasan, who was involved with the nuclear power programme and eventually became Chairman of the Indian Atomic Energy Commission, was a big inspiration in my scientific pursuits having heard him lecture often on the peaceful uses of nuclear fission for energy. He used to take me to the power projects as a child and say, 'See this is the calandria, these are the zirconium tubes!' He encouraged me to excel at a time when women were not really seen in science. As children, my brother and I spent a lot of time rambling around the rock-cut Pallava monuments at Mahabalipuram (my father was then involved in the construction of the nearby Kalpakkam nuclear power plant where we lived). My uncle CV Seshadri always said, 'Don't be a lab scientist, go out there and get concerned in rural development.' I guess all this had an impact and I began to feel at some point during my studies at IIT that I would like to explore scientific applications in the study and conservation of art and archaeological objects. In fact, the lead isotope ratio analysis technique that I eventually used to study Chola bronzes also has links to uranium geo-chemistry. It was the allure of the Nataraja, that drew me to the study and the quest to understand and document the technology and metallurgical and crafts traditions.

Q *Who is Sharada, the dancer. Your limp, how has it affected your dance?*

My husband Digvijay Mallah and family have been huge pillars of support. Our 18-year-old daughter and I enjoy swimming together. At 14, she induced me to go scuba diving in the Andamans. My husband has a tea plantation in the Nilgiris, and also has interests in anthropological studies. His experience in photography and filming has enriched my work, for example, two documentary films I made on metal crafts also includes footage of Kota blacksmithy and remote Toda settlements; He was also a crucial part of *Danse e-toile*. I am very lucky to have a new-age husband, who has also been hugely supportive in running the household. In fact, my husband and daughter are both way better cooks than me! We all chill out to classical, Carnatic, Hindustani or western, jazz, African or even Korean BTS which is my daughter's pick! My husband now and then strums a guitar. Of course, the daily *sadhana* and rigour of Bharata Natyam sustained and gave me a lot of inner strength and physical equilibrium. I suffer from a birth condition called bilateral developmental hip dysplasia. I started noticing it during pregnancy, that I had this congenital problem, thus the limp (she smiles wryly). And yes, it has affected my dance. The hip bones are not properly aligned, and need surgery. I think my hanging on to dance as long as I did helped keep the symptoms at bay, and also added a certain philosophical character to my dancing, the aspect of creation emerging from destruction. To me, it symbolised overcoming your physical disabilities and that added a certain dimension, it makes you take life in a more philosophical manner, and not to take many things so seriously whether you fail or succeed. Now, I have to devise new ways to dance... I like swimming, so maybe something in water!

I also collaborated with a lithophonist, Sebastien Sauvage, who had been making musical instruments from stones from the Alps, and we performed themes inspired by the Hampi pillars and resonant rocks to his music, that too shortly after an attempt at skiing

I also collaborated with a lithophonist, Sebastien Sauvage, who had been making musical instruments from stones from the Alps, and we performed themes inspired by the Hampi pillars and resonant rocks to his music, that too shortly after an attempt at skiing

What motivates me is also the concern for the artisanal communities who are increasingly marginalised in the face of globalisation and industrialisation, and to highlight the need for more sustainable and inclusive ways of development that could also benefit them

The Padma Shri and beyond

It draws attention to less conventional subject areas that do not get much support. There will be increased exposure to the area, more support forthcoming, and it will also create more awareness that will have a beneficial effect.

On the mining Industry

A lot of what I do is tracing the places of mining in antiquity. One of the main problems with rampant mining is there is no sense of mining heritage... of protecting the sites. A very important way to preserve our heritage would be to create archaeometrological parks. If you go to a place like Kokkasamudram, the school children are not even aware that there was this steel making heritage that was so prized across the world. At least, in Kudremukh it is preserved as a reserve forest.

Tell us about Nuclear Winter, the film?

It was a low budget docudrama shot on the campus of IIT Mumbai in 1988 when the Cold War had not yet ended. In some ways, it was ahead of its time. It was brilliantly conceptualised by late Zul Vellani and produced by Homi Sethna. As a dancer, I tried to depict the sense of total annihilation. The Indian nuclear programme was envisioned for peaceful purposes of energy generation and nuclear disarmament, and it remains a critical goal globally.

The learning & discoveries

Some of the crafts and phenomenal techniques of making these high-tin bronze vessels are remarkable, but sadly, the tribes and metal craft communities don't get copper and tin to make freshly alloyed vessels, and it survives on recycling older ones. A community museum and giving such families remuneration is a good idea. This Toda man I encountered gave this beautiful vessel as a gift, innocently, without knowing the value and significance of it.

Document control sheet

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11. **Abstract:**
India has a rich repository of surviving crafts practices that hark back several centuries with unbroken traditions. The Cauvery basin occupies a large geographic region spanning three states across Karnataka, Tamil Nadu and parts of Kerala. This region has in its own way represented an inter-linked geographic and cultural ecosystem. This rich repository of artisanal technologies is explored, particularly in the areas of metalworking and with respect to their connection to the local natural and cultural setting. These include the copper alloy image casting tradition of the Thanjavur district and Swamimalai, following the famed medieval Chola legacy of metal icons; the making of bells and lamps in Nacharkoil and the tradition of Thanjavur Swami plate repousse work. The rare craft of making mirrors of high-tin delta bronze (33% tin) in the village Aranmula, Kerala, which was also affected in the 2018 floods around the Pampa river is also discussed. Surviving blacksmithy practices in the regions around the Godavari river in Telangana and Tiruvannamali region of Tamil Nadu are touched upon which also supported traditions of high-carbon wootz crucible steel making in antiquity. Thus, some insights into the survival status and glimpses into the rich techno-cultural milieu of senior master craftspeople following various artisanal traditions are obtained.

12. **Keywords:**
Metal Crafts, Cauvery region, Riverine regions, Lost wax, icon making, image casting, Swamimalai, Nacharkoil, Thanjavur, bell casting, wootz steel, blacksmith, Vishwakarma, swami plate, repousse, Aranmula mirror, high-tin bronze, metal mirror, smelting experiment, Karu bronze casting

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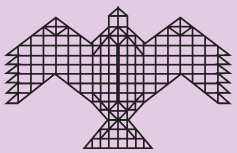

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