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CONTENTS

10 From the General Editor's Desk

12 Of Buildings and Books: The Theory and Practice of the Architect Mandan*
Rima Hooja

28 Mandala by Design: The Courtyard of a Haveli Temple in Jaipur*
Vibhuti Sachdev

42 Palaces of the Rajput Kings*
Giles Tillotson

54 Dating the Nataraja Dance Icon: Technical Insights
Sharada Srinivasan

70 On the God-Mask in the Dionysia and Indra Jatra
Francois Pannier, translated by Christophe Roustan Delatour

80 Newsletters
From New Delhi – Kavita Singh
From Mumbai – Monisha Ahmed
From London – John Siudmak
From the USA – Donald M. Stadtner

93 Book Reviews
Kalighat Painting by Jyotindra Jain – Kavita Singh
Khajuraho by Devangana Desai and *Vijayanagara* by Anila Verghese – Pratapaditya Pal
Book Notices

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DATING THE NATARAJA DANCE ICON

Technical Insights

Sharada Srinivasan

One of the most quintessentially Indian of icons is the bronze Shiva Nataraja dancing the *anandatandava* or the cosmic dance of bliss, from Tamil Nadu. The mystique surrounding the concept of Nataraja or Shiva as cosmic dancer and the shrine to Nataraja at Chidambaram in Tamil Nadu embodying this concept has stirred the imagination in India and the West. The "cosmic" dimension to the dance of Shiva has rendered it one of the most modern of religious ideas and perhaps the most evocative 20th-century symbol of holism between science, art, and mysticism: succinctly described by Coomaraswamy as "poetry, but none the less science".[1]

There are problems in making attributions of date and provenance for south Indian icons on stylistic grounds and visual comparison alone. Few of them are datable by means such as inscriptions or archaeological contexts. This has complicated their authentication and the identification of forgeries, and there is a need for their forensic fingerprinting as a safeguard against theft. Thus it is relevant to technically fingerprint them, i.e. to look for unique technical features by which they may objectively and accurately be characterized and thereby stylistically dated, authenticated, or traced. In what is internationally recognized as the first and most comprehensive interdisciplinary study on the fingerprinting and stylistic authentication of south Indian metal icons, this writer undertook the technical fingerprinting of 130 art-historically important images in the collections of the Government Museum, Chennai, Victoria and Albert Museum, London, and British Museum, London, using lead isotope analysis and trace elemental analysis from bulk or interior composition as reported in her doctoral thesis,[2] which give the most powerful technical fingerprints, being dependent on intrinsic and unchanged geochemical factors. This study also touched upon dance iconography in relation to south Indian bronzes. Thus, characteristic analytical signatures were identified for different stylistic groups ranging from pre-Pallava, Pallava, early and high Chola, late and post Chola, to Vijayanagara and early and late Nayaka/Maratha periods, which assisted in the stylistic dating of bronzes of uncertain attributions and using which half the entire sampled collection was recatalogued.

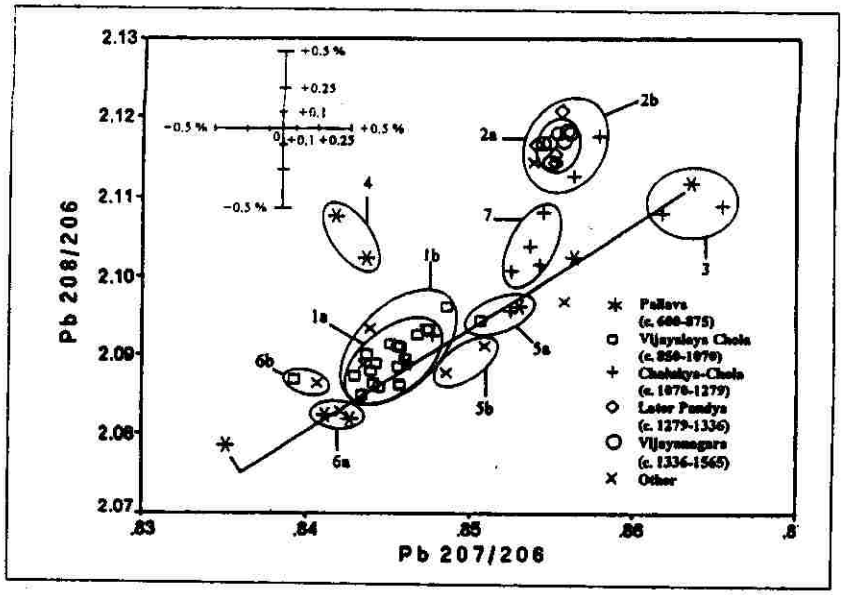
Some findings from such archaeometallurgical fingerprinting for the dating of Nataraja metal icons are discussed against the background of the development of dance iconography in south Indian art and sculpture, especially in temples such as at Chidambaram, where the worship of Nataraja – Shiva in the specific dance movement with the left leg extended, most often described as *bhujangatrasita karana* – is celebrated conceptually, sculpturally, and architecturally. It had previously been widely believed that the Nataraja bronze icon was an early Chola artistic accomplishment of the late 9th–10th century. However the archaeometallurgical study surprisingly indicates that the Nataraja bronze icon had already been formulated and cast under the Pallavas (circa 600–875) along with other depictions of Shiva's dance. This, together with finds of sculpture of *bhujangatrasita karana* suggests that the Pallava period was a crucible for wide-ranging iconographic development in stone and bronze, coinciding with the rise of the worship of Nataraja at Chidambaram. Nevertheless this study underscores the fact that the casting of Nataraja bronzes reached its zenith both in artistic excellence and output under the Imperial Cholas, described here as the Vijayalaya-Cholas (circa 850–1070) after the first ruler of this dynasty, including important patrons such as Queen Sembiyan Mahadevi, King Rajaraja, and King Rajendra Chola. The role of women patrons such as Sembiyan Mahadevi in the excellent

depictions of dance-related iconography in bronzes is highlighted. Under her patronage Nataraja images in stone seem to have really come into their own. In contrast to the ascendancy of the worship of Nataraja at Chidambaram in the late Chola period, the technical study suggests a slump in the production of Nataraja images in the late and post Chola periods classified here as the Chalukya-Chola (circa 1070–1279), and later Pandya (circa 1279–1336). No analysed Nataraja bronzes could be dated from their technical fingerprints to the Vijayanagara and early Nayaka period (circa 1336–1565), which fits the fact that these rulers were zealously Vaishnava in their religious affiliations.

CONCEPTS OF "NATARAJA" AND "CHIDAMBARAM": THE SCIENTIFIC DIMENSION

Fritjof Capra in his cult book *The Tao of Physics* indicates the manner in which the Nataraja icon has epitomized the romantic collusion between eastern mysticism and modern physics, stating that "modern physics has shown that every subatomic particle not only performs an energy dance but also is an energy dance...for modern physicists Siva's dance is the dance of subatomic matter."[3] While the interpretation of the Nataraja icon as Shiva's cosmic dance has permeated the modern understanding, it is intriguing to explore the scientific farsightedness of its creators.

Certainly the classic Nataraja icon can be seen as an anthropomorphic visualization of dynamic cosmic processes. The image metaphorically depicts the five actions of Shiva, *panchakritya*: creation suggested by the drum in the right rear hand, protection by the front right arm in *abhaya mudra*, the vanquishing of evil and ignorance being symbolized by the trampled demon *apasmara*, the giving of solace symbolized by the front left arm extended across in *danda hasta*, and destruction by the fire in the rear left arm, while the circular aureole or *prabhavali* depicts the cosmos in perpetual flux in cycles of creation and destruction. This cosmic activity is inspired by Parvati as consort Shivakami, the energizing female principle or Shakti. The dramatic cosmic effects of this dancing are poetically captured in various texts like the *Naishadhiyacharita*, which describe the scattering of myriad stars in the sky and splintering of rocks and crystals of Mount Kailash (*Naishadhiyacharita*, 22, 15), and of Shiva playing with crystal balls as if they were newly created planets[4] (the Vadnagar *prashasti* inscription in praise of Kumarapala).



1
Lead isotope ratio plots of Pb208/206 vs Pb207/206 and for sampled south Indian images with markers according to dynastic chronology. The ellipses indicate groups of objects with similar lead isotope ratios which relate to the metal coming from similar sources. The objects lying close to the line would have lead from two sources.

However, even more fascinating than this apparent sensitivity to the flux and motion of cosmic phenomena, are the philosophical implications of the concepts of Nataraja and Chidambaram: whereby Shiva is not just the cosmic dancer but is himself the sentient universe. These ideas hint at the intriguing paradoxes of quantum physics such as observer-influenced reality inherent in Heisenberg's uncertainty principle and wave-particle duality; or the notion propounded by eco-scientist James Lovelock of the Gaia or "earth mother" theory whereby the earth (or the universe by extension) may be seen as a self-regulatory or "live" system. Going back to metaphysical Upanishadic concepts, Shiva's cosmic dance weaves together the ideas of *anandatandava (ananda*: bliss; *tandava*: Shiva's dance) and *chidananda* (*chit*: mind; *ananda*: bliss), i.e. dance of bliss within the

consciousness, as captured in the hymn to Nataraja "*Kunchitanghrim Bhaje*" by the 13th-century poet Umapati Shivacharya of Chidambaram.[5] The shrine to Nataraja at Chidambaram (*chit*: consciousness; *ambaram*: cosmos) thus architecturally and conceptually links the cosmic realms and the inner consciousness through Shiva's dance. A verse in the *Tatvaryastava Strotra*[6] on Nataraja at Chidambaram elucidates this *akasha* or cosmic aspect, whereby not only is Shiva's dance cosmic, but Shiva is also identified with the cosmos itself: *hatakasabhanivasas satakatapannasakala-haridantah ghotakanigamo mayanatakasakshi jagatpatir jayati.* "In the verse following, the golden hall of Chidambaram, beautified over and over again by the Cholas and their successors is specially mentioned, and Shiva's dress composed of the quarters, is an attribute identifying him with the sky as the sky-clad and Chidambaram is the sacred spot for the element, sky. His special dance is one in which, as the Lord of the universe, he is the universal dancer and the witness of his own dance. There is special allusion to the illusion (maya) that he creates, which he removes before finally assuring emancipation." Chidambaram, the centre for the worship of Nataraja since the 7th century, is the only shrine where Shiva as cosmic dancer is worshipped in the inner sanctum or *garbhagriha*, instead of the aniconic lingam, whereas elsewhere metal Nataraja icons are processional images for festivals, the *utsava murti*. The *Chidambaram Rahasya* or secret of Chidambaram concerns the worship of Shiva as the *akasha* lingam or as an empty space.

DATING AND AUTHENTICATION FROM ARCHAEOMETALLURGICAL FINGERPRINTING

Unlike the radiocarbon methods which are used to date carbon-rich organic matter, there is no absolute method for dating metal objects. While thermoluminiscence analysis can be used for dating clay cores inside hollow cast bronzes, south Indian bronzes are nearly all solid cast with no clay cores. Hence, an archaeometallurgical approach based on metal analysis and chemical fingerprinting was explored, the usefulness of which stems from the possibility that metal artefacts may be grouped on the basis of chemical similarities resulting from shared sources of metal or methods of metal processing and alloying. Such studies can be a useful diagnostic tool in the typological classification or relative dating and/or identification of provenance of the artefacts, as has been attempted for Himalayan bronzes.[7] For this a statistically significant number of objects has to be investigated, while the sampling techniques should ensure that interior and uncorroded bulk composition is analysed, rather than surface corrosion which is variable. Although the composition of intentionally alloyed elements can vary randomly, the composition of trace elements in particular can provide useful fingerprints since they would be related to intrinsic geochemical factors of the source of copper. Thus the author sampled the 130 metal artefacts using portable equipment with internal drilling of up to 1 cm with minimal damage of less than 1 mm of surface area, barely visible to the eye. This technique also ensured that the analysis reflected the bulk or interior composition rather than surface corrosion. Then accurate compositional analysis for the 130 copper alloys was undertaken using inductively coupled plasma optical emission spectrometry for eighteen elements (copper, zinc, lead, tin, iron, nickel, arsenic, antimony, bismuth, cobalt, phosphorus, sulphur, chromium, manganese, vanadium, cadmium, silver, and gold) at Royal Holloway and Bedford New College, Egham.

More than elemental analysis, lead isotope ratio analysis provides the most powerful fingerprinting technique for metals[8] since isotopic composition, unlike elemental composition, is not affected by chemical processes so that it is unchanged from ore source to processed metal. This is because the isotopic composition of lead is measurably distinct and characteristic for different ore deposits due to geological factors such as the age of the deposit, the concentrations of parent isotopes of uranium and thorium at the time of formation of the deposit which decide the proportions of formation by their radioactive decay into the daughter isotopes of Pb206, Pb207, and Pb208, and the concentration of Pb204, i.e. the primary non-radiogenic isotope of lead. Thus the lead isotope ratios of artefacts with lead from the same source will tend to cluster together providing a unique fingerprint for that group and for the individual bronzes. Highly accurate lead isotope analyses were undertaken

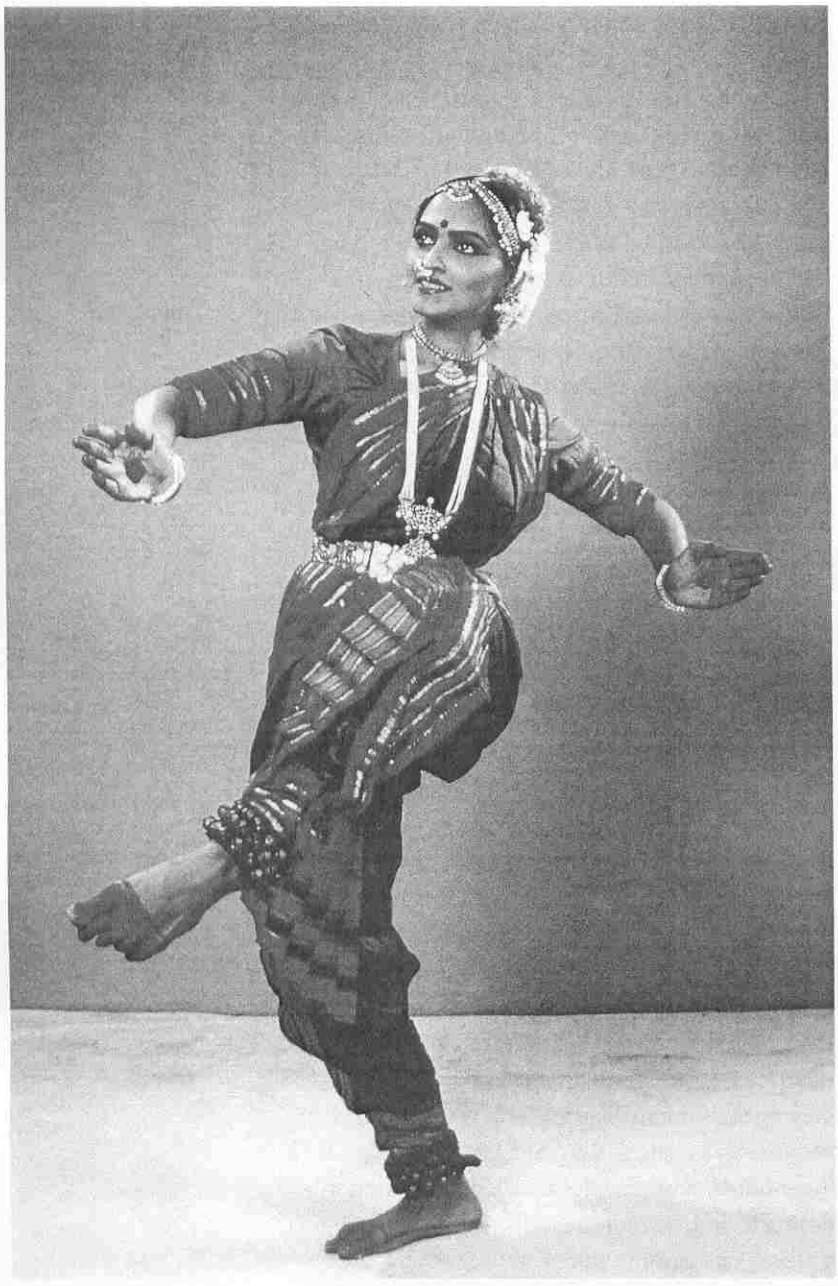
on sixty of the images and artefacts using thermal ionization mass spectrometry at the Oxford Research Laboratory for Archaeology and the History of Art. Ore, slag, and artefact correlations were also attempted by the author from studies on ancient mining debris from eight sites in south India, to aid in fingerprinting images by source of metal. The lead isotope approach has also been used on Chinese Buddhist images.[9]

Thus from technical analysis it was found that some fairly discrete lead isotope ratio and trace elemental patterns or analytical signatures could be identified for a significant number of archetypal images representing the different stylistic groups of south Indian bronzes. Images of uncertain dates and attributions could then be compared with these group characteristics, based on which the images could then be "dated", i.e. their stylistic attributions reassessed; thus for as much as half of the 130 sampled bronzes such attributions were modified using this approach. The major elements of copper, tin, zinc, and lead did not show very characteristic trends for different stylistic groups since these were intentionally added by the metal craftsmen and their concentrations may not have been too strictly controlled. However, significant patterns could be detected in the trace element concentrations due to their being inherent to the metal smelted from the ore source. For about half of the analysed collection (which was better dated by art historical consensus) trace element trends were detected which were found to relate well to groupings based on dynastic chronology, for the elements of arsenic (As), bismuth (Bi), nickel (Ni), cobalt (Co), and antimony (Sb). The lead isotope ratio plots such as of Pb208/206 vs Pb207/206 and Pb206/204 vs Pb207/206, also followed discrete trends for different artefacts when grouped by dynastic chronology (figure 1). In general the lead isotope trends were found to complement the trace element patterns: which suggests that to a fair extent distinct sources of metal were widely used at different periods. Thus from the framework of their lead isotope ratio and/or trace element composition (for As, Bi, Sb, Co, Ni) the images were stylistically resolved into the following groups: pre-Pallava, early Pallava and Andhra group (circa 200–600), middle Pallava (circa 600–850) and later Pallava (circa 850–875), early and high Vijayalaya Chola (circa 850–1070), early Chalukya-Chola (circa 1070–1125), later Chalukya-Chola (circa 1125–1279), later Pandya (circa 1279–1336), Vijayanagara and early Nayaka (circa 1336–1565), and later Nayaka and Maratha (circa 1565–1800).[10]

Methods in non-destructive testing (NDT) were experimented with in collaborative projects initiated by the author with atomic energy laboratories in India in attempting to fingerprint a few bronzes including five from the Prince of Wales Museum of Western India, Mumbai and three from Government Museum, Chennai[11] and these are currently being used by them for fingerprinting bronzes.[12] However, though interesting and significant in themselves, these methods do not give information on stylistic reassessment, which the author's approach has accomplished using lead isotope analysis and trace element analysis, and which is the crux of a successful authentication and fingerprinting exercise to provide a tracer method to tell apart a genuine antique from a modern forgery. Radiography is cumbersome, involving transport of large solid images and high-security objects, and it is not as useful for solid cast images which result in fairly opaque radiographs; radiographs and holograms serve as more advanced forms of archival retrieval, documentation, or indexing than photographs. X-ray fluorescence is a semi-quantitative surface analytical technique which only analyses corrosion products which are variable across the surface and give no unique fingerprints, while *in situ* metallographs are partly destructive apart from being variable over the surface. Furthermore the analyses in these studies were made from filings from pedestals which need not represent the main body of the image and could also be contaminated by surface corrosion.

EMERGENCE OF NATARAJA UNDER THE PALLAVAS

The link between dance and the plastic arts can be detected from the earliest art of the Indian subcontinent, such as the Mohenjodaro (circa 2500 BCE) statuette of the dancing girl and an enigmatic slightly twisted stone torso which may suggest the form of a male dancer with left leg lifted, not unlike the Nataraja icon. The interrelation between the fine arts and classical dance traditions of the *Natyashastra* (1st–2nd



2
Bhujangatrasita karana in Bharata Natyam, demonstrated by Sharada Srinivasan.

century CE) are described in the Gupta-period treatise *Vishnudharmottara Purana*. In the earliest sculpture, this link seems best exemplified in the limestone friezes from the great stupa at Amaravati in Andhra Pradesh of the Satavahana period (circa 1st–2nd century CE) where postures akin to Natyashastraic depictions are seen, including the twisted torso and lifted leg. With the rise of the worship of Shiva as cosmic dancer in the Deccan and south India, especially under the Cholas, dance movements such as *karanas* were precisely and profusely depicted.

While Shiva is seen in various *karanas*, the Nataraja brings to mind the pose with the left leg lifted at hip level and extended across the body, as seen in Bharata Natyam (figure 2). While this posture is generally described as *bhujangatrasita* (i.e. serpent fright) based on agamic texts, the *Tandava Lakshana* of the *Natyashastra* describes this as the *bhujanganchita karana* (i.e. serpent touch).[13] For clarity, all other depictions of the dancing Shiva are described here as *Natesa* images. Although the pose of Shiva as Nataraja in *bhujangatrasita karana* is best known, it is not seen much outside Tamil Nadu. The earliest, but isolated, example is reported in Gupta sculpture from Bhumara, Uttar Pradesh (circa 5th–6th century CE). An image of Shiva dancing in the *bhujangatrasita karana* is well delineated on a pilaster in the 7th-century Pallava cave temple of Sri Stambheshvara at Siyamangalam in Tamil Nadu (figure 3) although the front left hand is not crossed over but at the side in *gaja hasta*. A fine 8th-century Rashtrakuta cave painting[14] from Ellora, in Maharashtra, seems to be the first example of the typical Nataraja pose with leg and hand crossed over. Otherwise in Gupta and north Indian sculpture, Shiva in *chatura tandava* (i.e. rhombus posture) is more frequent, as also seen in a dynamic 6th-century Chalukyan sixteen-armed Natesa from Badami, Karnataka, while Shiva dancing in *urdhvajanu* pose, with lifted leg pointing down is often seen in Pallava sculpture such as the Dharmaraja Ratha at Mahabalipuram.

3
One of the earliest sculptures of Shiva in *bhujangatrasita karana*, 7th-century Pallava, Siyamangalam. Photograph courtesy Ecole Francaise d'Extreme-Orient, Pondicherry.

4
Lead isotope ratio analysis suggests that this Nataraja from the British Museum is Pallava (circa 800) and hence is the earliest known Nataraja image. Photograph courtesy of the Trustees of the British Museum.

5
Lead isotope ratios for this Nataraja from Kunniyur, now in the Government Museum, Chennai, are consistent with an attribution to the later Pallava period (circa 875). Photograph courtesy Government Museum, Chennai.

Hitherto, it has generally been believed that the Nataraja icon in bronze was developed by the early Cholas. However an unexpected finding from archaeometallurgical fingerprinting undertaken by this writer is that two Nataraja images of Shiva with leg extended in *bhujangatrasita karana*, which had previously been considered early Chola, actually fitted the lead isotope trends for the Pallava group. The first is a delicate Nataraja from the British Museum (figure 4) which may well be the earliest known Nataraja bronze image, datable to the Pallava period, circa 800. Indeed in aspects such as the looped waistband or *katisutra* it resembles the Natesa from Kuram[15] of Shiva dancing in *urdhvajanu* pose in the Government Museum, Chennai for which the lead isotope ratios fitted those for the Pallava group (indicated by the linear trend of the line on figure 1, from mixed lead from two sources). The second is the delightful Nataraja image from Kunniyur (figure 5) in the Government Museum, Chennai. Although it had been previously dated as a 10th-century Chola bronze, keeping in mind the indicators from technical analysis, it better fits the elegant idiom of some bronzes argued to belong to the later Pallava period (circa 875) such as the Tripurantaka from Ponvilaintanpatti.[16]

Thus these results indicate that the famed Nataraja bronze icon was in fact a Pallava innovation, predating its wide-ranging depiction under the Cholas. This is in fact consistent with the idea that the worship of Nataraja at Chidambaram goes back to at least the 7th century as indicated by the hymns of Sambandhar and Appar who were contemporaries of the Pallava king Mahendra Varman I, and with the Pallava sculpture of Shiva in *bhujangatrasita karana* from Siyamangalam. Indeed, Gaston's study[17] shows that of all regions it is in Pallava sculpture that all five types of images of dancing Shiva identified by her are found, with four on the Kailasanatha temple at Kanchipuram, indicating this to be a most experimental phase. A Pallava Nataraja sculpture is also reported in the Tirukkadaimudi Mahadeva temple, Tirucchinampundi, Tanjavur district.[18]

THE ROLE OF WOMEN PATRONS IN THE CHOLA PERIOD

Archaeometallurgical analysis supports the notion that the worship and iconographic depiction of Nataraja bronzes reached its artistic and technical apogee under the Imperial Cholas, referred to here as the Vijayalaya Chola dynasty, spanning the lineage of the direct descendants of the first ruler Vijayalaya Chola (circa 850–875) including the best known rulers and patrons of this dynasty such as Aditya Chola (circa 875–904), Sembiyan Mahadevi (circa 940–1006), Rajaraja Chola (circa 985–1014), and Rajendra Chola (circa 1014–1047). This is seen from the fact that seven out of twelve bronzes of the dancing Shiva investigated for this study had analytical signatures (of lead isotope ratios and/or trace element trends) which fitted those of the Vijayalaya Chola group. Figure 1 indicates this clustering of lead isotope ratios for bronzes of this group (indicated as Group 1a) which can be related to the fact that they come from a common source.

Certain important images which had been previously dated with some conviction from art-historical study fall in this group. They include the fine Velankanni Nataraja, Government Museum, Chennai, eulogized by Rodin[19] for its perfection in composition which has been attributed to the Rajaraja Chola period (circa 985)[20] and a fine Nataraja image in the Victoria and Albert Museum which has been attributed to the patronage of the distinguished widowed queen Sembiyan Mahadevi (circa 975).[21] Although at Chidambaram itself the earliest Chola records begin only from Rajendra Chola I and Kulottunga Chola I, a painted panel in Rajaraja's Brihadishvara temple in Tanjavur shows him worshipping the Nataraja at Chidambaram. The *bhujangatrasita karana* is depicted in Panel 35 at the Brihadishvara temple.

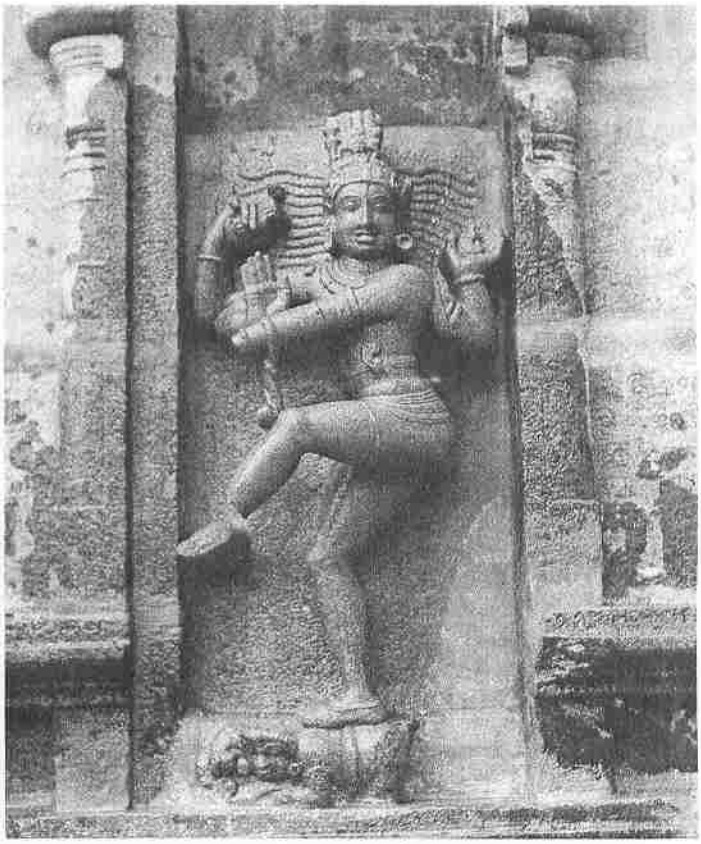
An interesting aspect of the finest Chola bronzes is the highly developed sensitivity to dance iconography and this could be linked to the fact that women, both royalty and laity, played a very active and even pivotal role in the patronage of art and bronzes in this period. Many queens were well-versed in art and dance, such as the princess Kundavai, sister of Rajaraja Chola and a munificent patron who trained in the Vazhuvur dance tradition which still survives. Indeed Nataraja images were invariably consecrated with Parvati as Shakti, the energizing female creative principle, and due to the notions of divine kingship this bestowed a high creative status on the queens and consorts of the king.

Temple dancers or *kuttans* were also accomplished patrons with several Chola records of endowments of bronzes and lamps by them and by attendants such as from the Shvetaranyeshvara temple at Tiruvenkadu. The image of the dancer Paravai Nachayar, consort of Shaiva saint Sundarar, is also worshipped and a splendid such bronze is in the Chidambaram temple. In fact the story of the creation of the *Natyashastra* as the fifth *veda*, suggests the manner in which dance as ritual created a space for spiritual release and precept for women who might have faced other restrictions in this sphere: "Indra approached Brahma and besought the Creator for a Veda which might be made accessible to those prohibited from studying the Vedas. Thereupon Brahma created the Natya Veda...certain aspects could only be expounded by women...hence the *apsaras* (or celestial dancers) were created."[22]

Arguably the most important patron who spearheaded high Chola artistic creativity with unprecedented expansion in temple building was the extraordinary widowed queen Sembiyan Mahadevi. As great grand-aunt, she also dominated the period of artistic achievement of Rajaraja Chola.[23] Indeed Harle[24] ranks her as amongst the great patrons of all time. A remarkable feature of the bronzes attributed to Sembiyan Mahadevi is the authoritative depiction of women together with the masterly execution of dance movements as best exemplified by the dancing Kali in a perfect and muscular *ardhamandala* posture in the Shiva temple in Tiruvalangadu, attributed to her by Nagaswamy.[25] A bronze for which the technical fingerprints fit the Vijayalaya Chola period is the dramatic eight-armed Mahishasuramardini (figure 6) from Turaikadu, now in the Government Museum, Chennai, which is similar in inspiration to this dancing Kali: with eight arms boldly executed in dance *mudras* including the *alapadma* (lotus) gesture of the rear upper right hand with fingers splayed. A promising trend for further dating of bronzes within this Vijayalaya Chola group is the fact that, in the Group 1a (figure 1) consisting of lead isotope ratios overwhelmingly of Vijayalaya Chola bronzes, the early Chola bronzes tend to group at the bottom, the high Chola bronzes along the middle, and the bronzes which may be counted amongst the latest of this group at the top of the ellipse, showing a chronological trend. This could perhaps be related to the progressive mining of ores of a deposit since the rocks deeper in a deposit would tend to be older, with higher Pb208/206 and Pb207/206 ratios. However to ratify this trend it would be useful to analyse many more bronzes in this way. Indeed this Turaikadu Mahishasuramardini falls somewhere in the middle of this group.

Remarkably, it seems that only in the temples related to Sembiyan Mahadevi's patronage do stone sculptures of Shiva as Nataraja in *bhujangatrasita karana* come prominently and consistently into vogue, with previous depictions having been sporadic. In earlier Chola temples, Shiva images seem more often featured in postures such as *urdhvajanu* as seen in the Koranganatha temple at Srinivasanallur of the Aditya Chola period (circa 875) next to an inscription, and in the Brahmanpurishvara temple (figure 7) in Pullamangai of the period of Parantaka I (905–955). A fine Nataraja sculpture

6
Mahishasuramardini, Government Museum, Chennai. Technical fingerprints for this bronze are consistent with an attribution to the high Vijayalaya Chola period, while the developed use of dance iconography is consistent with the style patronized by Queen Sembiyan Mahadevi (circa 975). Photograph courtesy Government Museum, Chennai.



7
Nataraja in *urdhvajanu* pose in the Brahmanpurishvara temple in Pullamangai of the Parantaka Chola I period (905–955). Photograph courtesy Ecole Francaise d'Extreme-Orient, Pondicherry.

8
Nataraja sculpture in the *mahamandapa* of the Manavaleshvarar temple, Tiruvelvikudi (circa 949–957), of a style attributable to Sembiyan Mahadevi, in whose temples this image in stone seems to come into its own much more than before. Photograph courtesy Ecole Francaise d'Extreme-Orient, Pondicherry.

of the Sembiyan school is seen in the *mahamandapa* of the Manavaleshvarar temple (figure 8), Tiruvelvikudi, attributed to the period of her son Uttama Chola (949–957). This and other stone Natarajas in temples, such as the one at the Kailasanatha temple (circa 980) built by her in the town of Sembiyan Mahadevi named after her, are marked by a consistency of style not really seen before.

LATE CHOLA PERIOD: DECLINE IN NATARAJA BRONZES AND THE RISE OF CHIDAMBARAM

The late Chola period is categorized here as (a) early Chalukya-Chola (circa 1070–1125) for clarity with the ascendancy of Kulottunga I, a prince of Eastern Chalukya lineage, to the Chola throne, and (b) later Chalukya-Chola (circa 1125–1279). This period is also the one where the celebration of Shiva's cosmic dance reached its pinnacle at Chidambaram. At this shrine which was mostly built from the time of Kulottunga Chola I to Vikrama Chola (12th–13th century), the 108 *karanas* associated with the *tandava* or dance of Shiva are dynamically represented in sculpture (figure 9) with explanatory verses from the *Natyashastra* on the east and west *gopuras*, which have been of vital importance to the reconstruction of Natyashastraic traditions. The temple at Tiruvannamalai is another important shrine with *karanas* sculpted on the *gopuras*. At the Chidambaram temple a prominent sculpture is of Shiva in *urdhvatandava* (figure 10), with leg pointing upwards, seen in the facade of a column in the Shivaganga tank. The *bhujanganchita karana* is demonstrated by a dancer on the lowest and the second of a set of eight panels on the east and north *gopuras*.

Paradoxically, despite this profusion of dance-related iconography in sculpture, from technical analysis the post Vijayalaya Chola period, i.e. after 1070, is not one from which a great number of Nataraja images can be identified; this may be due to a decline in technical skills in bronze casting. Only one Nataraja image from Melaperumbalam (figure 11) could be attributed to the period between later Chalukya-Chola and later Pandya, circa 1280, from its lead isotope ratios and trace element trends, with its lead isotope ratios falling in Group 2b in figure 1. Although this bronze had been thought to be of the 10th century, on reappraisal following technical analysis, this image can be seen to mark a departure from the classic Vijayalaya Chola

9
Sculpture of dancer in *chatura tandava* from a *gopura* in the Chidambaram temple. Photograph courtesy Ecole Francaise d'Extreme-Orient, Pondicherry.

10
Sculpture of Shiva in *urdhvatandava karana* beside the Shivaganga tank, Chidambaram temple. Photograph courtesy Ecole Francaise d'Extreme-Orient, Pondicherry.

11
Nataraja, Melaperumbalam, now in the Government Museum, Chennai. Technical fingerprints for this bronze suggest a late Chola date (circa 1280). Photograph courtesy Government Museum, Chennai.

12
Nataraja, Belur, now in the Government Museum, Chennai. Although the pedestal is inscribed to 1510, technical fingerprints for the image support a dating to the later phase of the Vijayalaya Chola period (circa 1040–1070).

idiom to the more provincial vigour of late Chola art as seen in the *ganas* or the dwarfs playing the pot and cymbals. The *bhujangatrasita karana* is not as well depicted here as in earlier Chola examples, with the leg slumping and not lifted high enough at hip level. It compares favourably to a Nataraja from the Valampuranadasvami temple also at Melaperumbalam; in this town too is the temple of Dakshinapurisvarar with an inscription of Vikrama Chola.[26]

Another interesting facet was that none of the analysed Nataraja images could be attributed to the Vijayanagara period from their technical fingerprints. As seen in figure 1 the lead isotope ratios of Vijayanagara bronzes cluster together in Group 2a, indicating they came from a similar source. Although the Belur Nataraja in the Government Museum, Chennai (figure 12), has a pedestal inscription of 1510 suggesting it was cast in the Vijayanagara period, the analysis from the main body fitted the technical fingerprint for the Vijayalaya Chola period. Indeed stylistically the image can be regarded as a decadent late Vijayalaya Chola bronze executed post-Rajendra Chola (i.e. circa 1040–1070), while the pedestal being separate could be later. Further, its lead isotope ratios falling to the top of the ellipse of Group 1a of Vijayalaya Chola bronzes rather than lower down with earlier pieces, supports such an attribution.

However the continuance of dance iconography in the Vijayanagara period is seen in Vaishnava images such as the Balasubramanium from Kodiakadu (figure 13), in *urdhvajanu* pose, now in the Government Museum, Chennai. This fitted trace element trends for the Vijayanagara and early Nayaka group (circa 1336–1565). Two analysed Nataraja images from the V&A could nevertheless be attributed to the later Nayaka and Maratha period, circa 1800, and indeed Shaivite worship is well known at temples of this period such as at Madurai.

13
Balasubramanium from Kodiakadu in *urdhvajanu*, now in the Government Museum, Chennai. This is representative of Vaishnava dancing images. Photograph courtesy Government Museum, Chennai.

CASTING NATARAJA: INSIGHTS INTO THE MAKING OF *PANCHA-LOHA* ICONS

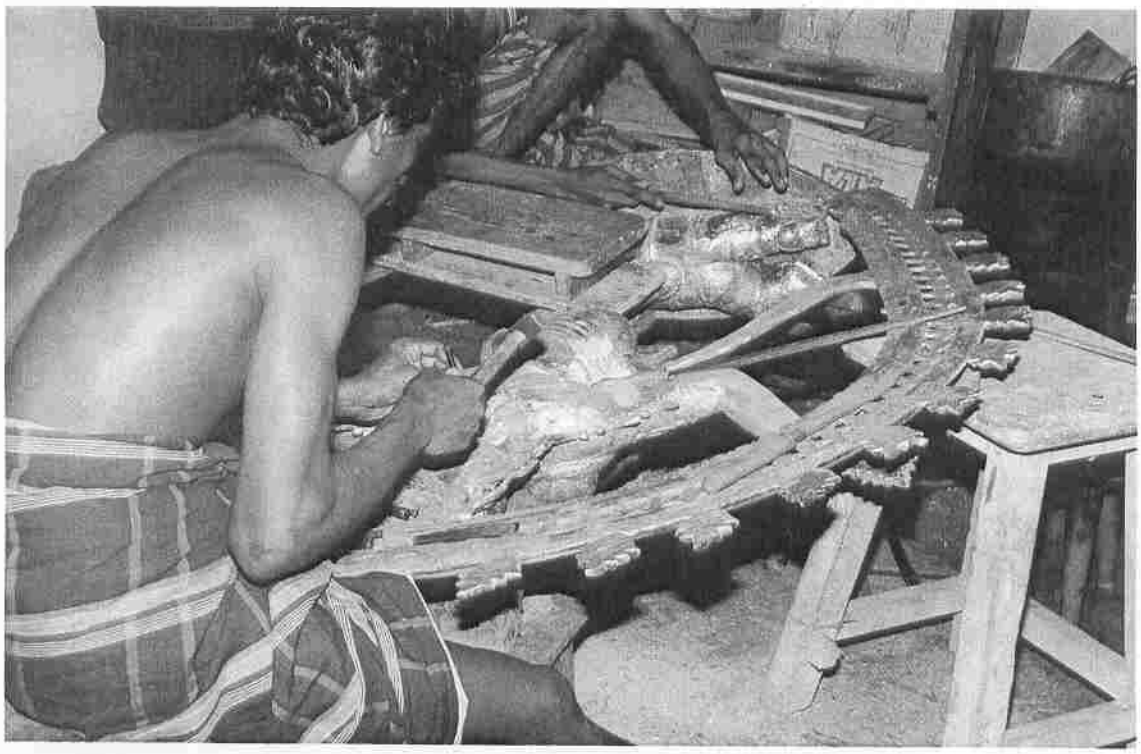
In the first detailed study of its kind reported in this writer's thesis, the salient metallurgical features of traditional image casting in south India were explored by putting together field investigations made in 1990–91 of foundry practices for lost-wax casting in Tamil Nadu (figure 14) and Kerala, observations of the macro-features and technical features of image casting, and comparisons with textual prescriptions in the 12th-century *Manasollasa*, the Gupta *Manasara* (5th century), and other *shilpashastras*. The lost-wax process or *madhuchehisthavidhana* as described in texts is one where a model was made of wax (of a solid piece of wax in the case of south Indian solid cast icons), which was then covered with a clay investment to form the mould. The wax was then melted out and metal poured into the cavity to take the shape of the icon.

About 80 per cent of the 130 sampled images analysed by the author were leaded bronzes with tin contents varying up to 15 per cent and with lead contents varying up to 25 per cent with the

rest being leaded brasses with zinc contents varying up to 25 per cent. However, while the images were deliberately made of more castable alloys such as these, the specialized manufacture of high-tin bronzes exploiting the properties of intermetallic compounds of beta (23 per cent tin) and delta (33 per cent tin) bronze to make articles such as vessels, cymbals, gongs, and mirrors is also seen over a long period in south India: the author's initial metallurgical and ethnographic studies made in 1991[27] were the first to establish links between surviving craft traditions in Kerala and finds from Indian prehistory, even going back to the Indus Valley to suggest that these techniques took root in the Indian subcontinent before spreading to other parts of Asia.

South Indian images are called *pancha-loha* or five-metalled icons in popular parlance. A *sthapati* interviewed by me in 1990 mentioned that this was because small amounts of gold and silver were also added together with the major elements of copper, tin, and lead. These were added more as a shastraic or as a ritual necessity, no more than about 100–200 mg for example, into the runner at the rear of the head as this was believed to improve lustre. Analyses on south Indian images by this writer support the likelihood of such small amounts of gold and silver having been added. However these would not be easily detectable in relation to the great weight of the castings; for instance a typical Nataraja image cast at Swamimalai could weigh up to 200 kg. What is particularly remarkable about the Nataraja icon is the manner in which the design elements, such as the circular aureole with the attached limbs and flying girdle or locks, would have enabled the even distribution of metal during pouring, in addition to the runners which would have been discarded after casting.

In Kerala some surviving lost-wax techniques for making lamps, vessels, and bells (apart from the making of wrought and quenched high-tin beta bronze vessels, gongs, cymbals, and high-tin delta bronze mirrors) were first documented by the author in 1991,[28] and with Dr I. Glover in 1998. These are techniques not much in vogue elsewhere and relate to prescriptions in shastraic texts. To obtain sound castings care was taken to make moulds of three grades of clay with the use of the finest layer next to the wax model consisting of lampblack and dung (figure 15): this would have resulted in the finest carbonaceous adsorbent layer also required in modern investment casting. Prescriptions in the *Manasollasa* for maintaining highly reducing conditions within the mould were followed with the use of a lighted wick at the mouth while pouring metal. Special furnaces were used for de-waxing the mould, and for preheating moulds to



14
Casting and finishing of a Nataraja at an image-casting workshop in Swamimalai, Tanjavur district. Photograph: Sharada Srinivasan.

15
The finest grade of clay mixed with lampblack and dung is applied on a wax model of a lamp in a workshop for lost-wax casting of lamps and bells in Kerala. Photograph: Sharada Srinivasan.

16
The pouring of molten metal into runners to a large mould buried under mud in the making of a cauldron or *urali* in Kerala. Photograph: Sharada Srinivasan.

the same temperature as the metal to be cast, to prevent bursting of the moulds and to ensure fluidity of the metal. Rope-turned hand lathes were used to excellent effect for polishing lamps. Figure 16 shows the casting of metal into a large mould for a cauldron or *urali* in Kerala.

CHOLAS: SKILLED BRONZE CASTERS OR SMELTERS?

Since the existence of chemical similarities in different artefacts (such as shared trace element patterns or lead isotope trends) can stem from their having come from similar ore sources, this writer surveyed and collected debris (such as slag and ore specimens) for technical investigation from eight sites in south India showing evidence of ancient mining of ores and metal processing activity or smelting. These included Mamandur in Tamil Nadu, Tintini, Kalyadi, and Ingaldhal in Karnataka, and Somalaragada, Nellore, Agnigundala, and Dhukonda in Andhra Pradesh. Slags refer to the metallurgical waste solidified from the molten state after smelting or extraction of metal from ore. Whereas it is very difficult to technically correlate ores to finished metals from the composition because of their inherent inhomogeneities, slags contain metal remnants trapped when molten after the metal has been retrieved as an ingot, and thus comparisons of trace elements in the metal remnants in slags

with the finished metal can more meaningfully indicate possible ore sources. The slag specimens were quantitatively investigated by scanning electron microscopy (SEM) followed by wavelength dispersive electron probe micro-analysis (EPMA) at the Institute of Archaeology, London.

From these, a few speculations could be made about likely ore sources; for instance the nickel versus cobalt ratios of copper slags from Tintini compared fairly well to that in images of the Vijayanagara period so that Tintini could have been a source of metal for them. Indeed Tintini is reasonably close to Hampi, the former capital of

17
Microstructure of slag from Kalyadi, Karnataka (400X) with remnants of bronze containing 7 per cent tin which, exceptionally, seems to have been made by co-smelting copper and tin ores. This and the nickel versus cobalt ratios match those of images of the Vijayalaya Chola period (circa 850–1070) suggesting it could have been a source for this period. Photograph: Sharada Srinivasan.

the Vijayanagara empire.[29] Investigations on slags (figure 17) from Kalyadi indicated that they appear to have been made by smelting together copper and tin ores to get a bronze composition with 7 per cent tin, rather than melting together copper and tin, which is an extraordinary finding scarcely reported elsewhere in the world.[30] The nickel versus cobalt ratios for these slags were similar to those for the Vijayalaya Chola bronzes, which also had an average of 6.8 per cent tin suggesting that this could have been a source for bronze. This may suggest that the Imperial Cholas were not only highly skilled at bronze casting, as widely recognized, but may also have been sophisticated bronze metallurgists.

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