number: "CS4"

title: Case Study 4

subtitle: The Technical Investigation of Eighth-, Ninth-, and Tenth-Century Statuettes from Indonesia

contributor:

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bio: Mathilde Mechling received her PhD in languages, civilizations, and Asian societies in 2020 from University Sorbonne Nouvelle and Leiden University. Her thesis focused on Hindu and Buddhist bronze statuary from the Indonesian archipelago, developing an interdisciplinary methodology combining stylistic and iconographic analysis, archaeometallurgy, archaeology, and religious aspects. She published “The Indonesian Bronze-Casting Tradition: Technical Investigations on Thirty-Nine Indonesian Bronze Statues (7th–11th c.) from the Musée national des arts asiatiques – Guimet, Paris” (2018) with David Bourgarit (C2RMF), Brice Vincent (EFEO), and Pierre Baptiste (Musée Guimet). She is adapting her PhD thesis into a book publication.

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bio: David Bourgarit (Archaeometallurgist, Centre de Recherche et de Restauration des Musées de France [C2RMF], Paris, and Laboratory TEMPS-CNRS-Nanterre University) has a background in physics, with a PhD on the physical metallurgy of a specific titanium alloy. Since 1996 he has been a researcher at the C2RMF, where he has been investigating metallic artifacts from almost all periods and regions. His primary research interests are in the technological approach to copper metallurgy, with a focus on the provenance of copper and fabrication techniques. He coedited *French Bronze Sculpture: Materials and Techniques 16th–18th Century* (2014).

abstract: The technical study of a group of thirty-nine statuettes in the collection of the Musée national des arts asiatiques – Guimet, Paris, was the first comprehensive examination undertaken of Hindu and Buddhist bronze statues from Indonesia. The wide array of visual and analytic methods utilized has provided a preliminary characterization of Indonesian bronze casting traditions. In addition, the study probed the possible exchange in technical know-how between the Indonesian islands and other regions of South and Southeast Asia, previously suggested on the grounds of stylistic connections. The research was part of a PhD project on Indonesian bronze sculpture combining traditional art historical research with technical studies.

short\_title: Case Study 4

## Slide 1: Introduction

The technical study of a group of thirty-nine statuettes in the collection of the Musée national des arts asiatiques – Guimet, Paris, was the first comprehensive examination undertaken of Hindu and Buddhist %%bronze%% statues from Indonesia. The wide array of visual and analytic methods utilized has provided a preliminary characterization of Indonesian bronze casting traditions. In addition, the study probed the possible exchange in technical know-how between the Indonesian islands and other regions of South and Southeast Asia, previously suggested on the grounds of stylistic connections. The research was part of a PhD project on Indonesian bronze sculpture combining traditional art historical research with technical studies.

**Figs. 67, 504, 505, 506, 507, 508, 509**

## Slide 2: The main questions

• Is there consistency in technical features such as the facture and alloy composition of Indonesian bronze statuary? If so, how distinctive are these features?

• Is it possible to refine the stylistic and chronological grouping of these objects by taking technical features into consideration?

• Given the stylistic connections found within bronze statuary across multiple regions of Asia, might there also be connections in their material and casting features?

**Figs. 67, 504, 505, 506, 507, 508, 509**

## Slide 3: Casting technique: Lost-wax casts with numerous wax assemblies

Naked-eye observation of the statuettes provides evidence that they were made by the %%lost-wax casting%%technique. This is evident in the general nature of the modeling, and in particular in the decorative elements on the outer surface, whose undercuts suggest direct modeling. And close examination of the hollow interior surfaces provides incontrovertible evidence that the figureswere affixed to their pedestals before casting and that the bases were constructed from separately assembled wax sections. The uneven ridges at the level of the lotus blossoms and base are wax-to-wax joints.

**Figs. 54, 67, 508, 509**

## Slide 4: Casting technique: Solid-cast figures

The X-ray radiographs confirm that the figurines, including the largest ones (30 cm tall) are mostly solid, with open, quadrangular pedestals.

**Figs. 126, 510**

## Slide 5: Visual evidence of extensive cold work

Naked-eye and microscopic observation of the outer surfaces of many of the statuettes found crisply defined decorative details and textures that are characteristic of cold working of the metal. (Exactly how much detail was already present in the wax %%model%% is hard to say.)

**Figs. 67, 276, 508, 511**

## Slide 6: Engraving, as suggested by reflectance transformation imaging (RTI)

Reflectance transformation imaging (RTI) (see [II.1§2.3](#II.1§2.3)) allowed for close documentation and study of the incised patterns. Under certain lighting conditions, the interrupted, stepped pattern along the interior walls of each incision was brought into relief. These are characteristic of %%engraving%%, formed by successive strikes on the graver as it is worked through the metal. The tapering ends of the incised lines are also consistent with engraving.

**Fig. 241**

## Slide 7: Metal punching confirmed by digital microscopy

Close examination of %%punch%% marks by digital microscopy (0.8 mm diameter) revealed that the smooth, compressed surface inflected by the punch and the dimple of displaced metal around the edge resulted from cold working. In addition, on one statue, a 3D reconstruction of the dots and consequently of the active part of the punch showed a systematic defect in the sphere, clearly testifying to the use of the same tool for all the motifs investigated.

**Figs. 285, 286**

## Slide 8: Metal engraving over preparatory drawing on wax confirmed by digital microscopy

Digital microscopy was used to map the topography of various tool marks. The indented lines on several statuettes showed the V profiles and slightly raised edges (or burrs) along the tops characteristic of engraved rather than punch marks. In some instances, the presence of two lines very close to each other may testify to a preparatory drawing on the wax model.

**Figs. 67, 273, 512**

## Slide 9: Cavities filled with dense material

Radiography has revealed in a number of statuettes a cavity extending from the top of the base up into the legs and the abdomen of the deity. This cavity is filled with a denser material than the metal of the statuette, making that area more radio-opaque (and whiter in the film) and effectively masking all structural details. Nondestructive X-ray fluorescence analysis (XRF) of the embedding alloy on several statuettes revealed them to be tin-based with smaller amounts of lead (90–95 wt.% tin, 5–10 wt.% lead). Such low-melting-temperature alloys are very radio opaque (difficult for X-rays to penetrate).

**Fig. 513**

## Slide 10: Consecration deposits revealed from below

In one of the statuettes, damage to the pedestal resulted in the partial loss of the metal fill. One can catch a glimpse of what remains embedded in the remaining metal matrix: several folded metal foils, the rim of a silver coin, a stone bead, and several more unidentified objects. These constitute a deposit to consecrate the statue before it could be used for worship. Such addition of a consecration deposit embedded in a metal matrix would have been a common feature within the group of statuettes studied, though today few of these objects preserve their interior contents. Might there be a way to learn more about these hidden contents without further disrupting them?

**Figs. 54, 508, 509, 514**

## Slides 11, 12: Consecration deposits revealed by neutron radiography and tomography

Access to a neutron reactor allowed for the neutron radiography and tomography (see [II.3§3](#II.3§3); {Bordenave and Mirebeau 2018}) of several Javanese sculptures that still preserved their consecration materials embedded in metal matrices. This works because metals such as copper, tin, and lead may be X-ray opaque, but they are relatively transparent to neutrons. The resulting images clarified the shape and location of the interior contents. Among other things, they enabled researchers to identify the typically Javanese *piloncito*-type cubic coins. Neutron radiography does not, however, allow for the precise characterization of materials that these consecration deposits were made of.

[Slide 11] **Figs. 400, 401, 515, 516**

[Slide 12] **Figs. 403, 404**

## Slide 13: Alloy composition

Inductively coupled plasma atomic emission spectrometry (ICP-AES; see [II.5§3.1](#II.5§3.1)) analysis of the bulk metal composition of the bronzes revealed that most of the thirty-nine statues analyzed are made of unleaded bronze alloys—copper-tin alloys with less than 2–3 wt.% lead. Zinc is present only in traces. With some variations, median values for each time period are higher than 8 wt.%. Nine statues have relatively high (12–20 wt.%) tin content.

**Fig. 517**

## Slide 14: Impurities in the metal

ICP-AES allowed us to determine that the main impurities found in these alloys are silver, arsenic, iron, nickel, sulfur, and antimony.

**Fig. 518**

## Slide 15: Summary of findings: Consistent features of Indonesian production

In all of the Indonesian statues investigated, even the largest ones, the figures themselves are mostly solid. All were made via lost-wax casting, with extensive modeling and assembling work on the wax. All were originally likely consecrated with sacred objects, and therefore have a cavity in the supporting pedestal or cushion.

The systematic use of a liquefied metal, namely a tin-based alloy, to seal the consecration deposits constitutes another consistent feature of Indonesian production. Copper-based sheets hammered over the base are often encountered for other Buddhist statues, notably in Tibet ({Reedy 1991a}) and China (**figs. 225, 226**).

Most statues are made of unleaded tin-bronze, with relatively high levels of tin. This is not very surprising given the vast and accessible resources of the Southeast Asian tin belt, running from central Burma down the Thai-Malay Peninsula to Bangka Island east of Sumatra, in the Indonesian archipelago.

**Figs. 67, 126, 510, 517**

## Slide 16: Summary of findings: Toward a chronological and stylistic serialization supported by metal composition

Despite the common technical features apparent in the whole study group, the lowest levels of tin were found exclusively in the statues attributed to the first half of the ninth century. Tin content increased markedly in the statues attributed to the early tenth century, despite several exceptions to the rule. Some periods are marked by very specific and homogeneous alloy composition and impurity patterns. This is particularly true for two groups, namely the group attributed to the second half of the ninth century and the group attributed to the early tenth century.

**Figs. 518, 519**

## Slide 17: Summary of findings: Alloy connections between Java and mainland Southeast Asia

The high tin content may pertain to technical connections with contemporaneous casting traditions in mainland Southeast Asia, namely the Mon culture of Dvāravatī in central and northeast Thailand (notably the Prasat Hin Khao Plai Bat II bronzes in Buriram province). High-tin bronze alloys are also found in the Khmer bronze-casting tradition for objects from various periods (the first to the tenth century). Conversely, coeval bronze statuary from the Indian subcontinent shows much lower tin content, except some examples from Sri Lanka (Polonnaruwa) and northeast India (Nalanda).

**Figs. 508, 520, 521, 522**

## Slide 18: Summary of findings: Characterization of consecration deposits thanks to neutron tomography

Neutron tomography has proven a successful nondestructive technique to learn more about the consecration deposits sealed inside the statuettes. Such deposits are important archaeological artifacts and indicators of the ritualistic rules overlaying the creation and use of these religious images. Few of the known contemporaneous statues from India or other parts of Southeast Asia retain their consecration deposits, but there is ample evidence that this practice was widespread in Indonesia. Bronzes such as these also form a crucial link with the later and better-documented Tibetan tradition of consecrating Buddhist images.

**Figs. 403, 404**

## Slide 19: Synopsis of technical parameters

This case study is based on a technical study carried out by Mathilde Mechling in collaboration with David Bourgarit and Brice Vincent as part of her PhD project on Indonesian bronze sculpture. The examinations and analyses were integrally carried out for free at the C2RMF as a service provided to French museums, in this case the Musée National des Arts Asiatiques – Guimet. Neutron tomography was also carried out for free at Reactor Orphée – Laboratoire Léon Brillouin, CEA-CNRS, Paris,as a service for public research*.* Main operating conditions are reported in {Mechling et al. 2018}. For more on the analytical techniques, please refer to volume II.

The approximate time required to carry out the whole study, excluding publication, was more than sixty days. The study involved:

* daylight and UV photography: Anne Maigret (C2RMF)
* digital microscopy: Mathilde Mechling (PhD candidate), David Bourgarit and Dominique Robcis (C2RMF)
* X-ray radiography: Elsa Lambert (C2RMF)
* neutron tomography: Frédéric Ott (CNRS-CEA)
* bulk metal analysis by ICP-AES: Nathalie Gandolfo and David Bourgarit (C2RMF)
* XRF: David Bourgarit (C2RMF)

## Slide 20: Further questions

• Would comparative data from either similar objects or copper and tin ore deposits make it possible to determine the provenance of the metal?

• Is there physical evidence pointing conclusively to the use of either the direct or indirect process to form the wax model?

• Can the fabrication of the hosting cavity be further elucidated?

• Can it be determined whether the statuettes were %%cast%% horizontally or vertically? Since horizontal casting is known to have been utilized in South India, Sri Lanka, and Tibet, is it a feature that might help to determine intercultural exchanges?

• Can a comprehensive quantification of tool marks (depth and angle of the grooves) by digital microscopy yield interesting clues regarding know-how in certain workshops?

• Can the identification of items in consecration deposits serve as a means of tracing the regional exchange of materials, and if so, can it be done nondestructively, avoiding the desecration of the religious image?

## Slide 21: Further resources

{Bordenave and Mirebeau 2018}

{Fontein, Soekmono, and Suleiman 1971}

{Fontein, Soekmono, and Suleiman 1990}

{Bonheur 1971}

{Lohuizen-de Leeuw 1984}

{Lunsingh Scheurleer and Klokke 1988}

{Mechling et al. 2018}

{Reedy 1991a}