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

Mathilde Mechling, Brice Vincent, Pierre Baptiste, David Bourgarit

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Résumé

Des statues en bronze de divinités bouddhiques et hindoues furent produites dans l'archipel indonésien entre le VIIe et le XIe siècle environ. À ce jour, les études techniques consacrées à ces images restent rares et limitées à des pièces isolées. Afin de compléter nos connaissances sur les techniques de fonte du bronze en Indonésie, des examens techniques et des analyses ont été réalisés sur la collection du Musée national des arts asiatiques – Guimet à Paris. Une large gamme de méthodes analytiques a été utilisée, nous permettant d'obtenir une caractérisation préliminaire des procédés de fonte, des compositions d'alliages et des techniques de décoration. Les dépôts encore conservés à l'intérieur de quatre statues fournissent par ailleurs des informations importantes sur leur consécration rituelle.

Abstract

Bronze statues of Buddhist and Hindu deities were produced in the Indonesian archipelago approximately between the 7th and 11th centuries. To date, technical studies on these images are scarce and restricted to isolated pieces. To fill the gaps in our knowledge of Indonesian bronze-casting technologies, technical examinations and analyses have been carried out on the collection of the Musée national des arts asiatiques – Guimet in Paris. A wide range of analytical methods was employed, leading to a preliminary characterisation of casting processes, alloy compositions and decorative techniques. Deposits still preserved inside four statues also provide important information on their ritual consecration.

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Keywords: Hindu-Buddhist bronze statuary; Indonesia; lost-wax casting; high-tin bronzes; engraving; consecration deposit; technical know-how; regional exchanges.

Résumé

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Mots-clés : statuaire en bronze hindo-bouddhique ; Indonésie ; fonte à la cire perdue ; bronzes à forte teneur en étain ; gravure ; dépôt de consécration ; savoir-faire techniques ; échanges régionaux.

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1. Introduction

Bronze statues of Buddhist and Hindu deities were produced in the Indonesian archipelago approximately between the 7th and 11th centuries. To date, publications on bronze statuary from Sumatra, Java, Kalimantan, and Sulawesi refer mainly to iconography, while stylistic studies are still in their infancy.[1] As far as bronze working techniques are concerned, technical studies are scarce and restricted to isolated items (Schnitger 1937: 3 [6. 'A bronze Buddha head'], pl. 7 [lower left]; Huyser 1939; Werner 1972). One previous study was devoted to the analysis of a consecration deposit still left inside a bronze Buddha statue (Domela Nieuwenhuis 1983). To fill the gaps in our knowledge of Indonesian bronze-casting technologies, in-depth technical examinations and analyses have been carried out on the Indonesian bronze statues in the collection of the Musée national des arts asiatiques – Guimet in Paris. This comprehensive technical study was conducted by Mathilde Mechling as part of her ongoing Ph.D. project on Indonesian bronze sculpture,[2] in collaboration with David

* Mathilde Mechling, Ph.D. Candidate at Leiden University and Sorbonne Nouvelle – Paris 3, mathilde.mechling@gmail.com; Brice Vincent, École française d'Extrême-Orient, brice.vincent@efeo.net; Pierre Baptiste, curator of the Southeast Asian collections at the Musée national des arts asiatiques – Guimet, pierre.baptiste@guimet.fr; David Bourgarit, Centre de recherche et de restauration des musées de France, david.bourgarit@culture.gouv.fr. Mathilde Mechling presented a summarised version of this paper at the 9th International Conference on the Beginnings of the Use of Metals and Alloys (BUMA), Busan, Korea, in October 2017, while the part on the consecration deposits was presented at the 16th International Conference of the European Association of Southeast Asian Archaeologists (EURASEAA), Poznan, Poland, in July 2017. The authors' deepest gratitude goes to Mathilde Mechling's Ph.D. supervisors, Marijke Klokke and Vincent Lefèvre, for supporting this project. Many thanks also to all our colleagues who have contributed to the accomplishment of this study: at the Musée Guimet, Thierry Zéphir for his precious advice; at the C2RMF, Elsa Lambert (radiographs and neutron tomographic images reconstruction), Anne Maigret (photographs), Juliette Langlois (analysis of organic material), and Dominique Robcis for teaching the use of the digital microscope; at the Laboratoire Léon Brillouin (UMR12 CEA–CNRS), Frédéric Ott for doing the neutron tomographic images and their reconstructions.

1. See mainly Le Bonheur 1971 as well as Lunsingh Scheurleer & Klokke 1988.

2. Given our focus on sculpture, the ritual objects present in the Guimet collection have thus been excluded, as well as the 'Kediri bronzes' produced around the 19th century, see Le Bonheur 1971: 351–357, appendix 3.

Bourgarit from the Centre de recherche et de restauration des musées de France (C2RMF, Centre for Research and Restoration of Museums of France) and Brice Vincent from the École française d'Extrême-Orient (EFEO, French School of Asian Studies), with the generous support of Pierre Baptiste from the Musée national des arts asiatiques – Guimet.

A wide range of investigative methods was employed. X-ray radiography and tomography reveal the casting processes used, bulk and surface metal analyses (ICP-AES and XRF) give the alloy compositions as well as impurity patterns, and digital microscopy has allowed us to determine the decorative techniques employed.[3] In addition, neutron radiography and tomography were used to investigate the consecration deposits sealed by a dense metal within some of the statues and which are, at the present moment, unique to Southeast Asian bronze statuary.

This large-scale technical study, the first ever conducted on Indonesian bronze artefacts, is intended as a starting point in determining a preliminary characterisation of the Indonesian bronze-casting tradition. Utilising a readily accessible collection, it hopes to pave the way for further technical studies on other collections. Although it is difficult to classify and date Indonesian bronze statues, this study tries to see how stylistic and chronological groups intersect with metal composition. It also aims to address issues on possible intra- and interregional exchanges of technical know-how, although this type of research is still in a very preliminary stage. As portable objects, bronze statues provide direct religious, artistic, and technical information on multiple intercultural interactions between the Indonesian islands and other regions in the Indian Ocean and South China Sea. They constitute an invaluable source of information for understanding cultural transfers, and especially the nature as well as directions of artisanal and religious exchange within the Buddhist and Hindu world.

2. History of the collection

Since the publication in 1971 of Albert Le Bonheur's (1938–1996)[4] *La sculpture indonésienne au Musée Guimet*, very little research has been conducted on a collection which can nevertheless be considered "one of the jewels of the Musée Guimet."[5] In his work, Le Bonheur performed essential studies on the stylistic and iconographic aspects of the stone and bronze material. Questions of provenance and the history of the collection remain more difficult to address because of gaps in the museum's documentation. As Jeannine Auboyer (1912–1990), then senior curator and head of the museum, pointed out in her preface to the 1971 catalogue, "the collection of Indonesian art

3. As we will see later, there is no trace of clay core on the current corpus since all the statues are solid cast. It was thus impossible to employ petrography to trace the material to specific workshops or regions and help in the geographical grouping of the artefacts in order to define their origin of casting.

4. Le Bonheur 1971. On this scholar who was in charge of the Southeast Asian Department of the Musée Guimet for almost 30 years, see Filliozat 1996: 139–140.

5. Monod 1966: 217.

preserved in the Musée Guimet is far from being homogenous; it was constituted by various steps in the early years of the institution, at a time when, for various reasons, the exact provenances of the objects were neither inscribed in the Inventory catalogue, nor mentioned verbally to the new generation of curators. This is the reason why any identification seems nowadays so problematic. It forces anyone to remain particularly careful." Le Bonheur's catalogue can still be considered today one of the most complete studies on the subject, going far beyond his focus on a single museum collection.

The thirty-five Buddhist and Hindu bronze deities from Indonesia included in the 1971 publication came to the museum from various collections. Le Bonheur elaborated on this as follows: "as it is for the rest of the collection, we ignore the initial provenance of the piece. What is more, here [the study is on MG 3475, fig. 16], we ignore the exact date when the object entered the museum. The earliest date we can find in our archives is given by the inscription to the *Catalogue général des Objets d'art du Musée Guimet* [General inventory catalogue of the Musée Guimet works of art]. The first one on this list seems to have been written around 1910. The inauguration year of the Musée Guimet in Lyon being 1879, the date of its transfer to Paris 1888, it is obvious that this inscription is much subsequent to the real entry date of the collections in the museum. On the other hand, one cannot rely on the numerical order of the artefacts to approximately date their entry" (Le Bonheur 1971: 121, n. 2). In spite of these unfortunate gaps, it is still possible to further clarify these remarks. The 1971 study showed clearly that twenty-five of the thirty-five bronze deities included in the catalogue once belonged to the same collection, mentioned as a "Don de J. J. Meijer" [J.J. Meijer gift].[6] The designation "Don J.J. Meye" or "Don Mejer" is also found periodically in the Inventory Catalogue between the numbers MG 3466 (a cow-bell not studied here) and MG 3831 (a Śiva [?] bust, fig. 19). No dates were given for these gifts.

In a 1917 article, Nicolas Johannes Krom (1883–1945) followed the wishes of the editors of the magazine *Nederlandsch Indië Oud en Nieuw* in studying a collection of Javanese bronzes which was "stored in the Musée Guimet of Paris, on loan from Mr J.J. Meyer of The Hague, waiting for a generous patron who will buy it as a gift to the museum" (Krom 1917: 386). Deploring the fact that private collections retained little information on the provenance of the works and the circumstances which sent them to Europe, Krom expressed the hope that these important bronzes would at least be acquired by the Musée Guimet, where they would be accessible to all. Before accepting J.J. Meijer's collection of bronzes for his museum, Émile Guimet (1836–1918) organised a committee of experts to confirm the authenticity of the pieces. The members of this committee were director of EFEO Louis Finot (1864–1935), Alfred Foucher (1865–1952), recognised internationally as a major authority in Gandharan "Greco-Buddhist" art and in the Buddhist iconography of India, and Antoine Cabaton (1863–1942), a Malay teacher at the École des Langues orientales [School of Oriental Languages] in Paris

6. In spite of our research, we remained unable to find J.J. Meijer's first names (1857–1926).

since 1906. Cabaton had in 1899 worked in Java as an assistant to Louis Finot as they began to conceptualise the EFEO, learning from the colonial authorities of the Dutch East Indies in the management of local heritage (Lombard 1983). At the same time, Krom highlighted his own expertise, gained through studying the hundreds of Javanese bronzes he had selected for the Museum of Batavia (nowadays the National Museum of Indonesia, Jakarta). Therefore, Krom insisted on the exceptional quality of some of Meijer's pieces, such as the Avalokiteśvara with ten arms (MG 3816, fig. 1a–b) and the Jambhala figure (MG 3814, fig. 2a–b). In any case, Krom's article testified to the way that the Musée Guimet in 1917 was trying to enlarge and diversify its collections. Before this time, few objects in the galleries could testify to the richness and beauty of the Indonesian arts. Only two Javanese bronzes were exhibited in the museum in Lyon before 1883 (Le Bonheur 1971: 121, n. 3), one being MG 5179 (Le Bonheur 1971: 136–137) (fig. 48a–b), first identified in the *Inventory Catalogue* as an "Indian Jain *tīrthaṅkara*" and later reidentified as "Śākyamuni, Java". However, it appears to be a fake, dating to the second half of the 19th century. The second one is the Vajrasattva MG 2173 (fig. 14a–b). Three other bronze deities, though mentioned by Le Bonheur as "registered around 1912?", seem to us convincingly belonging to the same Meijer ensemble, if one looks carefully at their position in the *Inventory Catalogue*.[7]

The Musée Guimet archives contain letters dated from March 1912, which were sent by a Dutchman named J.J. Meijer to Joseph Hackin (1886–1941), Émile Guimet's secretary and later assistant curator from 1913.[8] These letters explicitly mention the deposit by Meijer of a collection of Indonesian bronzes. They also highlight a new piece of information – Meijer was acting only as an intermediary. Deeply impressed by Émile Guimet, whom he met in Paris at the "Congrès de Madagascar"[9] and whom he called "grand maître vénéré", Meijer became close to Joseph Hackin and Léon de Milloué (1842–1930?), then curator at the Musée Guimet. As can be seen from his letterhead, Meijer was "Oud assistent resident, Beëdigd vertaler voor de maleische-, javaansche- en soendaneesche Talen" [Former assistant-resident, certified translator of Malay, Javanese and Sundanese], living in The Hague (then named s'Gravenhage) in the Netherlands, and published articles and books on the languages and the ethnic groups of the Dutch East Indies (Meijer 1890a and b, 1891a and b, 1893; Meijer, Jacobs & van Tricht 1891). His obituary, published on 3rd December 1926 in the newspaper *De Indische Courant*,[10] recorded that he was born in Batavia on 17th April 1857 and spent his entire administrative career in the

7. These are the Buddha Vairocana MG 3475 (fig. 16), Avalokiteśvara MG 3480 (fig. 20), and Viṣṇu MG 2328 (see Le Bonheur 1971: 214–217).

8. The Musée Guimet archives are preserved in the museum storage, under the responsibility of the curator in charge of the Library. Pierre Baptiste wishes to express here his warmest thanks to Mrs Cristina Cramerotti who kindly allowed him to do this research in the storage.

9. This is probably the *Congrès de l'Afrique orientale (Madagascar et dépendances – Côtes françaises des Somalis)* [Congress of Oriental Africa], which was held in Paris from the 9th to the 14th October 1911. Meijer mentions this meeting in his letter of the 3rd August 1913 (Musée Guimet archives).

10. This information was kindly given by our colleague from Leiden University, Marijke Klokke.

Dutch East Indies, acting as controller, assistant-resident and then as resident in Tegal, Banyumas and Banten (Central and West Java), Wonogiri (Southeast Central Java) and Amuntai (South Kalimantan), before retiring in 1908. He was a member of the Instituut voor Taal-, Land- en Volkenkunde van Nederlandsch-Indië [Institute of linguistic, geographical and ethnographical studies of the Dutch East Indies],[11] and appeared in at least one old photograph preserved in the Tropenmuseum (Amsterdam), where he is described as an "assistent-resident van Amoentai" [Assistant-resident of Amuntai].[12] In his letters to Joseph Hackin, Meijer expressed his deepest wish to see the bronze collection exhibited in the Musée Guimet. In one dated 3rd August 1913, Meijer wrote, "until now, I have been able to keep the collection for your museum [we have seen it was on loan in the Musée Guimet at least for 16 months, and that some objects were probably inscribed on the *Inventory Catalogue* at the time of their arrival], but the owner becomes impatient and my means are exhausted to give her a new payment in advance." He added, "the Indo-Dutch government is more and more severe towards antiquities. Recently, they created an Official Commission fighting against illegal exportation of statues, whether in stone or in metal, and it has been proposed to prosecute those who have recently brought Javanese antiquities of any date. This collection was for more than 50 years in the hands of an Indo-European family, so this is not a stolen collection. Your museum will have the possibility to accept the gift, particularly because the immense ensemble of the Musée Guimet lacks these specific types of statues." The upheavals of World War I postponed many aspects of the scientific activity of the museum and it was only in 1919, a short time after Hackin was demobilised from the Russian front that the business with Meijer resumed and was, at last, concluded. On 1st July 1919, Meijer announced triumphantly to his very good friend Hackin: "I am happy that this collection of Javanese deities will belong for ever to your museum. After a couple of days, I shall give you more information on the fellow who did the gift." It took more than seven years for Meijer to be able to do it. The identity of the patron who obviously reimbursed Meijer for the value of the collection remains unfortunately obscure. We find no trace of any more letters on this subject in our archives. Posterity has retained the name of this zealous Francophile intermediary and we shall now keep the mention: "J.J. Meijer gift, 1912–1919" as the origin reference of these important pieces. Some of them were quickly recognised internationally as great masterpieces, such as the Jambhala figures MG 3814 (fig. 2a–b) and MG 3813 (fig. 3), the ten-armed Avalokiteśvara MG 3816 (fig. 1a–b), and the male deity MG 3818 (see Le Bonheur 1971: 162–163), for instance, which were included in the great Cologne Exhibition of 1926 devoted to Asian Art (Salmony 1929: pl. 10, no. 2).

11. "Bijlage I. Naamlijst der leden van het Instituut (Maart 1888)" [List of the members of the Institute (March 1888)], *Bijdragen tot de Taal-, Land- en Volkenkunde (van Nederlandsch-Indië)* [hereafter *BKI*] 37, 1888, pp. 73–84. See p. 82: "J.J. Meijer, Controleur 2e klasse bij het Binnenlandsch Bestuur te Rangkas Betoeng, Bantam" [Controller 2nd class of the inner administration in Rangkasbitung (Banten Province, Java, Indonesia)].

12. Tropenmuseum, inv. no. TM-10001594, 9 × 12 cm (accessible online at: https://collectie.wereldculturen.nl using the inventory number [last accessed on 1st October 2018]). See also Boomgaard & van Dijk 2001: 339.

A few more pieces were later added to the collection. In 1932, the Sūrya image MG 18315, of a much later period, was part of the important Kœchlin legacy (Le Bonheur 1971: 226–228). In 1933, another piece was bought on auction at the *Collection de M. de Frey* sale of the gallery Jean Charpentier, in Paris, on 12th–14th June 1933. Interestingly, this image of Vairocana MG 18290 (fig. 15) was part of the objects studied in 1917 by Krom, while they were on loan in the Musée Guimet (Krom 1917: 388, no. 11; Le Bonheur 1971: 125). It is unknown how this piece was put back on the art market after Krom's study, but it is clear that before 1919, the exact ownership of these bronzes was not resolved. Three other bronzes entered the collections after World War II. The bodhisattva MA 507 (fig. 4) was part of Miss A. Getty's legacy that was accepted in January 1949 (Le Bonheur 1971: 146–147). A customs seizure in 1976 added a small image of Akṣobhya (?) MA 3790 to the Javanese ensemble. Finally, the Vairocana MA 6936 was given to the museum by Jean Lapresle in 2001.

3. Presentation of the corpus

Thirty-seven metal statues and two separate pedestals[13] in the Indonesian collection of the Musée Guimet were thoroughly analysed (table 1) in order to establish a preliminary characterisation and to highlight general trends. All of them are religious statues of Buddhist and Hindu – Śaivaite or Vaiṣṇavite – deities. As is the case of most Indonesian collections, the Buddhist images are far more numerous (twenty-four artefacts) than Hindu images (four artefacts).[14] The collection also counts deities associated with wealth such as Kubera-Jambhala (six artefacts) and Vasudhārā (two artefacts), whose iconographies are identical in both Buddhism and Hinduism.[15]

3.1. Previous studies

As the majority of the archaeological remains in Indonesia has to date been found in Java, ancient Indonesian art has been divided roughly into two styles which correspond to two periods: the Central Javanese period (8th–early 10th centuries), when the political and cultural centre of Java was located in Central Java, and the East Javanese period (early 10th–early 16th centuries) when it moved to East Java. The use of these geographic

13. Although they bear the same inventory numbers as the bodhisattvas MG 3824 (fig. 13b) and MG 3827 (fig. 13c), which were originally part of a triad together with MG 3820 (fig. 13a), these pedestals are stylistically different from one another and depart clearly from the style of the triad. It is thus likely that they were originally not associated to the statues, but have been added later. They have been studied separately using the inventory number of the museum and adding the letter 'b' to differentiate them from the statues (hence, MG 3824 b and MG 3827 b in the tables 1 and 2).

14. MG 3831 (fig. 19) can be identified as Śiva because he wears a skull set above a crescent in his hair, but it is shaped as a bust, a type of representation highly unusual in Indonesian, and more broadly in Asian religious sculpture, be it in stone or metal.

15. Only MG 3814 (fig. 2a) is unmistakably the Buddhist Jambhala since it bears the Buddhist creed *ye dharmāḥ* inscribed at the back of the pedestal (fig. 2b).

terms implies a chronological distinction and not a regional one, since some remains in Central Javanese style have also been found in East Java and *vice versa* (Lunsingh Scheurleer & Klokke 1988: 3, n. 4 and 6). A proper reconstruction of the chronology of the bronze statues is prevented by the absence of secure elements, such as inscribed dates, that can be used in their dating.[16] A few attempts have nonetheless been made to divide them between Central and East Javanese periods. Relying on provenance, some have assumed that an image found in Central Java likely dates from the Central Javanese period and an image found in East Java is from the East Javanese period (e.g. Fontein, Soekmono & Suleiman 1971: 143). However, this assumption does not account for the inherent mobile nature of such objects and the possibility that their find spot does not necessarily indicate the place where they were cast. Such could be the case for two groups of bronze statues sharing the same style and thus probably dating from the same period, although one was found in East Java and the other in Central Java. The first find occurred in 1913 in the hamlet of Candirejo, Nganjuk district, Berbek department, Kediri residency in East Java (Lunsingh Scheurleer & Klokke 1988: 32–35) and the second in 1976 in the village of Surocolo, Bantul district, Yogyakarta residency in Central Java (Fontein 1990: cat. 66, A–T). The statues share characteristics (slim bodies, long arms and legs, spiky ornamentation of the jewels and curls on the shoulders) of the style commonly called "Nganjuk style" after the district where the first group was found. This group of statues can be dated at the latest to the first half of the 11th century,[17] and seems to be one of the last groups of bronze statues produced in Java.[18]

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16. In only one instance, on a triad depicting a standing Avalokiteśvara flanked by two (one now lost) seated Tārās the craftsman has inscribed his name (Sūrya), the name of the deity represented (Bhaṭāra Lokanātha, i.e. Avalokiteśvara) and the date (961 śaka, i.e. 30 March 1039 AD) of manufacture in Old Malay followed by a closing Sanskrit phrase in Palaeo-Sumatran script (see reading by Kern 1917: 142–144; calculation of the date by Damais 1955: 207–208; and recent translation and commentary by Griffiths 2014b: 217–219). It is now in the National Museum of Indonesia, Jakarta (inv. no. 3309 or 626 d) and was found in the 1880s in the *pusaka* [family heirloom] of the *raja* of Gunung Tua (Padang Lawas district, North Sumatra province), but its exact findspot is not known (Schnitger 1937: 32, 44, pl. XL [lower image]; Brinkgreve & Sulistianingsih 2009: 62, fig. 4.5; Perret 2014: cat. no. 156, pl. 10 [with references to earlier publications]).

17. This dating is applied for two reasons: 1) the images represent deities of the *vajradhātu maṇḍala* composed by Ānandagarbha who lived in the last quarter of the 10th century at the earliest; 2) the main figure of the *maṇḍala* is seated on a throne whose stylistic features are still part of the Central Javanese artistic repertoire, while only some elements can be assigned to the East Javanese style and betray the probable early East Javanese date of this group of bronze statues (Lunsingh Scheurleer & Klokke 1988: 35).

18. Their exact place of manufacture remains however an open question since artefacts in a similar style have been found in Sathing Phra District, Songkhla Province, Peninsular Thailand (Krairiksh 1980: pl. 43; unidentified deity, Songkhla National Museum; H. 10.3 cm, bronze), and in the cargo of the Cirebon shipwreck found in 2003 off the coast of West Java, Indonesia (Vajrarāga, Musée royal de Mariemont, Belgium, ref. 112537; H. 8 cm, bronze; accessible online at: http://cirebon.musee-mariemont.be/la-cargaison/cargaison-d-accompagnement/objets-metalliques/objets-rituels-bouddhiques.htm?lng=fr [last accessed on 1st October 2018]). The composition of the cargo seems to indicate that the vessel was sailing from the Straits of Malacca to Java (Liebner 2014: 295), so the artefacts could not have been made in Java. However, the statue itself would not have been part of the cargo but maybe of the "ceremonial requirements of a travelling Buddhist monk" (Liebner 2014: 192), which does not completely rule out the possibility that it was made in Java.

In addition, a periodisation based on provenance supposes that the findspots of the bronze statues are known, which is quite rare for those not preserved in Indonesian collections. The findspots of the sculptures in the present study were not recorded at the time of their discovery, and so cannot be associated with any archaeological contexts. The distinction between the Central and East Javanese groups can therefore rely only on stylistic aspects and not on provenance. Yet, this classification is not entirely suitable for bronze statues, as it excludes archaeological remains that do not fit into this chronological framework, do not belong to the Central or East Javanese stylistic groups, and which come from Indonesian islands other than Java.

In his 1971 catalogue, Albert Le Bonheur followed a classic approach in classifying the artefacts by materials, subdividing them by iconographic forms[19] and suggesting a rough Central or East Javanese dating for each one of them. But the innovative part of his work was to attempt a preliminary stylistic grouping using comparative materials in other Dutch and Indonesian collections.[20] In 1988, Pauline Lunsingh Scheurleer carried on with the formation of stylistic groups broadly assigned to periods spanning around two centuries each, with possible overlaps. Based on the collections available in the Netherlands, she formed seven broad groups. Images from Sumatra constituted 'Group Six' and those from other Indonesian islands 'Group Seven,' but their small number in the Dutch collections did not help to establish a more detailed classification. The majority of the Indonesian bronze statues known nowadays come from Java – or when their provenance is unknown they are attributed to Java – so more groups were constituted for objects from (or supposedly from) this island ('Groups One to Five') to illustrate a chronological evolution of stylistic groups.[21] In subsequent articles, Lunsingh Scheurleer presented a further division of 'Groups One and Two' into sub-groups and a more general evolution of bronze production which, as she suggested, developed in three phases.[22]

Although pioneering, this classification was nevertheless not entirely accurate, as a large number of artefacts still do not fit into the stylistic groups. A detailed typology of bronze statues including not only those from Java, but also those from Sumatra, Kalimantan, and Sulawesi, is thus highly desirable to classify their stylistic, iconographic and technical aspects, and to eventually determine a historical evolution of production.

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19. In accordance with the classification first established by the earliest scientific catalogues compiled for Indonesian artefacts (Groeneveldt 1887; Juynboll 1909).

20. He was able to examine the collection of the Museum Volkenkunde in Leiden providing first-hand observations and he used the photographs (named "OD" photos) of the former Oudheidkundige Dienst in Nederlandsch-Indië [Archaeological Service of the Netherlands Indies] depicting collections kept in Indonesia.

21. Lunsingh Scheurleer & Klokke 1988: 23–39; Lunsingh Scheurleer 1994: 76–77. 'Group One': images related to South India (8th–9th century); 'Group Two': images related to Northeast India (8th–9th century); 'Group Three': images in a Javanese style of the Central Javanese period (2nd half of 9th–early 10th century); 'Group Four': transition group between 'Groups Three and Five' (late 9th–11th century); 'Group Five': images of the Nganjuk *maṇḍala* of the early East Javanese period (10th–mid-11th century).

22. Lunsingh Scheurleer 1992 and 1994; for the development in three phases, see pp. 77–81 of the latter.

3.2. Classification of the Musée Guimet corpus used in the current study

Our ongoing Ph.D. research analyses a larger corpus of artefacts than before, from virtually all Indonesian, European, and American collections accessible in person or through publications. The Musée Guimet collection represents only a sample of the total corpus included in our Ph.D. research. The thirty-nine statues constituting the corpus of the present technical study were visually analysed to produce a preliminary categorisation based on stylistic grounds. But the stylistic diversity in the corpus prevented us from forming well-defined ensembles, so we had to keep to broad groups. The corpus is divided into four main categories, each corresponding to tentative temporal markers given in centuries (table 1). We have not attempted a further division of the corpus between "major" or "minor" artefacts on the basis of their aesthetic quality and size to envisage issues on patronage and commission. It is still premature as most of the sculptures in the present study are relatively small (between 6.5 and 34 cm).[23]

- *Category 1*: Four statues in the present corpus display early iconographic forms and foreign styles associated with Bangladesh (MA 507 [fig. 4] and MG 3628 [fig. 5]), South India (MG 3627 [fig. 6]), and Peninsular Southeast Asia (MG 3620 [fig. 7]). We have tentatively dated them to between the 8th and early 9th centuries, but they might overlap with the pieces attributed to the 9th century (Category 2) even more. As they show stylistic features also found on bronzes from other Asian regions, it is not clear whether they were made in Indonesia or brought from another place. It has been suggested that at first bronzes images were imported from India and Javanese bronze craftsmen used them as models, but quickly developed their own style (Lunsingh Scheurleer 1994: 77). Scholars have debated for decades on the origins of these so-called imported bronze statues based on their stylistic features only (for a summary see Lunsingh Scheurleer & Klokke 1988: 24–30; Lunsingh Scheurleer 1994: 77–79). However, style can be misleading, as it is not only associated with a particular place of manufacture, but also with the hand of a craftsman trained in a specific workshop. For this reason, determining the place of manufacture remains problematic, because there are a variety of possible scenarios. Movements of craftsmen between South and Southeast Asia are now well attested and have to be taken into account (Bellina 2006; Manguin, Mani & Wade 2011: xix; Manguin 2017: 32). Thus, artefacts made according to Indian styles could have been made in Southeast Asia, either because South Asian craftsmen moved to Southeast Asia or because Southeast

23. However, a number of larger images are known: Fontein 1990: cat. 52, Śiva (Museum Nasional Indonesia, inv. no. 6050; H. 107 cm, bronze with gold and silver inlays); cat. 56, Avalokiteśvara from Tekaran, Central Java (Museum Nasional Indonesia, inv. no. 509; H. 98 cm, silvered and gilded bronze); cat. 57, fragmentary arm (Museum Nasional Indonesia, inv. no. 5746; H. 26 cm, bronze). To date, the largest image is the Śiva discovered in 2001 in Karangnongko, Central Java, which is 107 cm without the head (now missing), see Sri Hardiati 2006.

Asian craftsmen were trained in South Asian workshops. It is notable that bronze statues inspired by Indian styles have been found not only in the Indonesian archipelago but also in other regions of Southeast Asia.[24] However, until technical aspects have been fully investigated to complement stylistic and iconographic observations, it seems premature to try to differentiate imported bronzes from those which were locally made or even to assume that the earliest bronze images found in Southeast Asia are necessarily Indian imports.

- *Category 2*: Around the 9th century it seems that several Indonesian styles developed and coexisted. A homogeneous stylistic group (corresponding to Lunsingh Scheurleer's 'Group Three'; Lunsingh Scheurleer & Klokke 1988: 30–31; Lunsingh Scheurleer 1994: 79–80) with recurrent stylistic features found only in Java and stereotyped iconographic forms emerged in Central Java, and was apparently produced in great numbers, given the large number of extant artefacts. MA 3540 (fig. 8), MA 3790, MA 5936 (fig. 10), MG 2255 (fig. 9), MG 3624 (fig. 21a), MG 3823, MG 3824 b, MG 12895, and MG 18402 correspond to this stylistic group that we have here designated 'Central Java B'. MG 3619 (fig. 11) is a later development of this style and probably overlaps the early 10th century. MG 3479 (fig. 35a), MG 3630 (fig. 28a), and MG 3826 have been designated as the 'Central Java A' stylistic group because they seem to display Central Javanese stylistic features, but they differ from the group 'Central Java B'. MG 3626, MG 3629 (fig. 32a), MG 3813 (fig. 3), MG 3815 (fig. 12), MG 3816 (fig. 1), MG 3820, MG 3824, and MG 3827 (figs. 13a–c) bear the mention 'Not identified' (NI) because they do not display any specific stylistic features and it is impossible to classify them in a specific stylistic group for the time being. It is as yet difficult to know if their marked divergence accounts for a manufacture in other Javanese workshops or maybe on other Indonesian islands. Since stylistic evolutions are visible within these stylistic groups, especially 'Central Java B', a further sub-periodisation into three periods – first half, second half and late 9th century – has been applied.
- *Category 3*: Our third category contains artefacts possibly dated no later than the first half of the 10th century (MG 2173 [fig. 14], MG 3475 [fig. 16], MG 3625 [fig. 17], MG 3822 [fig. 18], and MG 18290 [fig. 15]). They display late Central Javanese characteristics but also signs of the later Nganjuk style (first half of the 11th century at the latest). Important political changes occurred in the early 10th century with the movement of the political centre to East Java. Only a few architectural and sculptural remains have survived for the early

24. It is thus difficult to pinpoint which precise artistic and religious centres inspired some of the bronze statues found in Southeast Asia since it is now clear that stylistic inspirations are more diverse than previously assumed and their exact sources are not always clear. Just as Pan-Southeast Asian styles of sculpture were identified earlier in stone (e.g. Dalsheimer & Manguin 1998 for the so-called "mitred Viṣṇus"), even more can be identified in bronze sculpture.

part of the East Javanese period, although inscriptions and works of Old Javanese literature are known. The bronze statues and ritual objects are thus precious specimens. Decorative motifs on the bronze ritual objects do not depart completely from the Central Javanese style in the beginning. The same seems to occur with bronze statues, where stylistic features of the late Central Javanese style are still visible, though ornamentation tends to increase and the body shapes are more elongated (Lunsingh Scheurleer 1994: 80–81).

- *Category 4*: Objects that could not be clearly assigned to stylistic traditions and a period of time were classified into the category 'uncertain dating'.

4. Operating conditions

4.1. Radiography and tomography

4.1.1. X-ray

All the X-ray radiographic images – face and profile views for each object, as well as 45° top-down views for MG 2173, MG 3625 (fig. 45a), and MG 18290 – were made using one of the two Seifert Isovolt 420 kV X-ray tubes at the C2RMF, with a 1.4 mm focus, on MX125PB Kodak films. Parameters for voltage, intensity, exposure time, and thickness of copper filters were adapted given the thickness of the objects to be examined and the density of their material. For thin-walled objects, and for those with a cavity, exposure conditions were 300 kV, 4 mA, 8 minutes exposure time, source-to-film distance of 2.5 m, with a 3 mm copper filter. For thicker-walled objects, a higher voltage was necessary up to 410 kV, 4 mA, 13 minutes exposure time with an 8 mm copper filter.

In addition, X-ray tomography was performed on three objects (MG 3619, MG 3815, and MG 3822). The sensor used was a Flatpanel, type Flashscan Thalès of 110 µm resolution. For each one of them, 720 projections were taken, at intervals of a half-degree rotation. Exposure conditions were 410 kV, 10 mA, 1.4 seconds exposure time, source-to-film distance of 2.5 m, with a 5 mm copper filter. Data acquisition and 3D reconstructions were made using DigiACQ and DigiXCT softwares.

4.1.2. Neutron

The energy used at the C2RMF was too low to transmit the X-rays through the dense material sealing the consecration deposit still in place inside the internal cavity of four statues (MG 2173, MG 3619, MG 3625, and MG 18290 [figs. 44, 45a–c]).[25] Therefore neutron radiography and tomography were used to further examine the consecration deposits (figs. 46a–b

25. At first we had suspected that MG 3822 (figs. 18, 27b) also had part of its consecration deposit still in place deep inside its internal cavity, but some preliminary neutron radiography images revealed that the statue is now completely empty. Tomographic measurements were thus abandoned for this object.

and 47a–b). Already applied to Tibetan bronzes (Lehmann, Hartmann & Speidel 2010; Henss & Lehmann 2016), neutron imaging provides a useful non-invasive approach, as it penetrates the metal in depth and reveals organic materials. The tomographic measurements were performed on the IMAGINE spectrometer at the Laboratory Léon Brillouin (UMR12 CEA–CNRS, CEA Saclay, France) installed on the cold neutron beam G3bis (peak flux around 4A°) (Ott *et al.* 2015). The transmission measurements were measured with a lithium enriched ZnS scintillator of thickness 100 µm coupled to an ANDOR NEO sCMOS camera. The L/D ratio used was 250, providing an effective spatial resolution of 150 µm. The reconstructions were performed using the software Octopus[26] and VGStudio Max.

4.2. Surface examinations

4.2.1. Digital microscopy

A selection of nine statues (MA 3540 [fig. 8], MG 3475 [fig. 16], MG 3625 [fig. 17], MG 3813 [fig. 3], MG 3814 [fig. 2], MG 3816 [fig. 1], MG 3820 [fig. 13a], MG 3822 [fig. 18], and MG 3824 [fig. 13b]) presenting incised decorative patterns (figs. 36a–c, 37a–d, 41), were examined by digital microscopy (Hirox KH-8700 Ver 1.40) at the C2RMF, in order to characterise the tool marks and to identify the technique employed, i.e. decoration made into the wax model before casting, or into the metal – by engraving or chasing – after casting. 3D profiles of the tool marks gave insight into the shape of the tools used, and allowed us to measure the dimensions of their active part (figs. 38, 39, 40, 41, 42). At this stage of the research, statistical analysis of the data thus obtained was not possible, given the lack of comparative data and the difficulty of seeing some of the tool marks because of corrosion or dust. For this reason, quantitative data is not reported in the present paper.

4.3. Bulk and surface metal analyses

4.3.1. Atomic spectrometry (ICP-AES)

Circa 20 mg of metal was drilled (HSS steel drills, 1 mm diameter, 10 mm deep) after eliminating most surface corrosion products by removing the surface layer on the location sampled. If the artefact was visibly made of separately cast sections, or in the case of doubt, all the sections of interest were sampled where possible (see the locations of the forty-six samples in table 2). The samples were carefully screened under binocular lens to remove any corrosion product and/or dust. Circa 10 mg of each drilling was precisely weighed and dissolved in 5 ml aqua regia solution (hydrochloric and nitric acids) following a methodology developed specifically for copper-alloy artefacts that are objects of cultural heritage (Bourgarit & Mille 2003). The solution was then analysed by inductively coupled plasma atomic emission spectrometry (ICP-AES) at the C2RMF, with thirty-one chemical elements characterised.

26. Accessible online at: https://octopusimaging.eu/ [last accessed on 1st October 2018].

4.3.2. X-ray fluorescence (XRF)

XRF[27] was used to analyse the silver statuette MA 3540 (fig. 8), and to try to find assembled parts for those that could not be sampled. It was also used in an attempt to determine why some objects (MG 3479 [figs. 35a–b], MG 3630 [fig. 28a], and MG 3827 [figs. 13c, 34]) had black, slightly cracked surfaces. Although some Indonesian bronzes are gilded, none of the statues in the Musée Guimet collection showed visible traces of gilding. Finally, XRF was employed to analyse the material – used to seal a consecration deposit still in place or now lost – present inside the pedestal of seven statues.

5. Results

5.1. Fabrication techniques

5.1.1. Lost-wax processes

On all the statues, several elements, such as pedestals and decorative items, were clearly made separately in wax and assembled during the modelling of the wax model. These represent the clearest evidence of the use of the lost-wax technique (*cire perdue*), as opposed to sand casting. All the statues consist of a number of elements inherent to their divine nature. All the possible elements which make up an image are listed below, even though simpler configurations do not exhibit them all:

- A quadrangular pedestal with mouldings. The shape and regular thickness suggest that slabs of wax were assembled together. MG 18290 still has incised lines parallel to the edge of the angles that could be remains of assembly marks (fig. 22, detail of fig. 15).
- A lotus flower and/or a cushion – that might be now lost or broken – supporting the divine figures either in a standing or seated position. The lotus was apparently made of two bands of wax modelled to form the upper and lower rows of petals. Traces show that the two bands were sealed together in the wax (MA 507, MG 3625, MG 3628, MG 3629, MG 3814, and MG 3822) (e.g. fig. 23, detail of fig. 18).
- The divine figure with, in some cases, a halo attached at the nape of the neck to surround its head.
- The backpiece attached to the rear of the pedestal, topped by a parasol to surround the deities' bodies and to shelter their heads. Although the assembly of the backpiece during the modelling of the wax model seems the most logical, an irregular and uneven mark where the backpiece meets the pedestal at the back of some artefacts raises questions (e.g. MG 3619 and MG 2255 [figs. 24a–b]). It suggests two

27. Niton GOLDD XL3T, Ag anode, quantification by using Niton software, certified reference materials (silver and copper alloys) analysed under the same conditions. For the silver statue MA 3540 (fig. 8), the analysis was carried out on drillings sampled in the tang under the legs of the statue (table 3). For the other statues, the analysis was performed directly on the surface without any cleaning. As expected in the latter case, because of surface alteration, XRF results proved to be very different from the ICP-AES results carried out on drillings (table 4).

> possibilities. The uneven mark could simply be due to the join in the wax elements (the backpiece and the pedestal), which were assembled prior to casting. Since it is located at the back of the image, a side that is not visible, it would not have been completely hidden. The second possibility is that the backpiece was cast separately prior to being inserted into the pedestal of the wax model, then cast with the entire image, or that it was assembled by secondary casting. The radiographic and tomographic examinations do not give a clear idea of the exact process, but welding seems unlikely. Regarding MG 3619 (fig. 24a) for which this uneven line is particularly visible and the backpiece is unusually thin (one millimetre), it has been possible to take only one sample (pedestal), and surface analyses of the different parts do not enable us to confirm one or the other hypotheses (table 4).

In general, all the constituting elements of the statues (pedestal, lotus, deity, backpiece) were assembled into the wax model, to cast the entire image in one unique piece. Nonetheless, some statues have elements that were separately cast and then mechanically attached. Specifically, the pedestal (MA 3540 [fig. 8], MG 3816 [fig. 1], MG 3820, MG 3824, and MG 3827 [figs. 13a–c] [original pedestal now lost]; MG 3624 [original pedestal still in place] [figs. 21a–b]), the backpiece and halo (MG 2173 [figs. 14 a–b]) or only the halo (MG 3816 [fig. 1b]). It seems that mechanical assemblies are more common for earlier statues than later ones, even though some earlier statues are also cast in one piece.

5.1.2. Solid casts with cavities

All the statues under study are solid cast, even the two largest ones (MG 3814: H. 28 cm and MG 3816: H. 34 cm, figs. 25a–b).[28] However, when the lotus flowers or the cushions supporting the figures are still in place they are always hollow, as is the quadrangular pedestal open at the bottom. In some cases, the cavity under the pedestal goes further up into the legs or the abdomen (figs. 26–27). As most of the statue is solid, the presence of this cavity does not result from a technical choice in the casting process, but has a specific function for the consecration of the divine image after casting, as we will see later (section 6.4.).

For statues with a cavity extending into the legs and abdomen, this cavity was obviously made during the manufacture of the wax model. It is, however, difficult to identify the technique employed. One possibility is to

28. This clarifies the description of the lost-wax process often used in the literature about Indonesian bronze statues. The process is generally described as including the use of an internal clay core (van Lohuizen-de Leeuw 1984: 14; Lunsingh Scheurleer & Klokke 1988: 12), but it is clear from the present study that this is not the rule for Indonesian bronze statuary. Based on visual examinations of bronze images in European and Indonesian collections, it seems that most of them are solid cast. However, some large images with missing elements (e.g. Fontein 1990: cat. 56, Avalokiteśvara with the broken arms visibly hollow and an iron armature still in place in the lower left arm; Museum Nasional Indonesia, inv. no. 509), or core pins visible at the surface (Brinkgreve & Sulistianingsih 2009: fig. 4.9, Śiva; Museum Nasional Indonesia, inv. no. 6031), reveal that they are hollow cast and that this process was also known and used by Indonesian founders.

prepare the cavity in advance by forming the wax model around a structure (e.g. in wood) or a clay core that once removed would form the cavity. The second option is to dig a cavity into the block of wax after the figure is already modelled. The dissymmetric axis of the cavities, not centred inside the abdomen of the figures, and the irregular contours of the internal volume (e.g. MG 3475 and MG 3822, figs. 27a–b), tend to suggest that the second hypothesis is more likely.

5.1.3. Direct or indirect lost-wax process?

No physical evidence points conclusively to the use of either the direct or the indirect process to form the wax model.[29] It is generally believed that in India and Southeast Asia, only the direct process was used in ancient times because the statues appear to be unique pieces and not series of copies. However, one shall keep in mind that a unique piece may also be created by using the indirect process.[30] Such a situation is easily understandable in the case of a model made in another material than wax (e.g. wood, clay, stone) and then moulded.

Lunsingh Scheurleer has suggested that at first local craftsmen would have taken moulds from foreign-made statues, giving examples of this based on visual observations (Lunsingh Scheurleer & Klokke 1988: 29, cat. 18 and 20). However, this remains rather subjective as long as we do not possess the foreign statue and its local copy. A similar process could have been used not only to copy foreign images, but also to replicate images with the same basic composition. Once the general composition was copied by moulding, minor elements could have easily been modified on the wax model obtained from this mould. Successive castings made from the same original mould may thus differ only in detail. The 9th century apparently marks a boom in the production of bronze images in a very stereotyped style in Java (Lunsingh Scheurleer & Klokke 1988: 30–31). Such standardisation could have easily been promoted by an indirect casting process. Moreover, such process would have been particularly suited to the apparent high demand for this type of images. The use of the indirect process was also suggested by Maria Lulius van Goor after her observations of the Nganjuk hoard in 1920 as she wrote "for some of the groups the same mould was used and these statuettes were completed by the addition of various separately cast attributes."[31] It should be noted, however, that the shapes and compositions are relatively simple in the small statues, so that a skilled craftsman would have been able to reproduce them without using a mould. More evidence is necessary to confirm the use of the indirect technique.

29. In the direct process, the wax is modelled directly to form the model. In the indirect process, the wax is applied in a mould to replicate the model.

30. The use of indirect casting to make original bronze statues is evidenced for a number of periods and regions including ancient Greece and Rome (Mille 2017), as well as Early Modern France (Bewer, Bourgarit & Bassett 2008). In the case of Southeast Asia, this issue of indirect lost-wax process has also been discussed for Khmer bronzes (Bourgarit *et al.* 2003; Vincent 2012).

31. Quoted by Fontein 1990: 231.

5.1.4. Casting direction

For two objects (MA 3540 and MG 3816 [fig. 25b]), the porosity is more concentrated at the bottom of the images (pedestal, feet). This tends to show that these statues were cast upside down. Yet, such clear concentration of porosity is rarely observed among the few statues showing porosity.[32] Moreover, this is the only feature supporting this hypothesis because the numerous remaining traces of gating systems do not enable us to assess the casting direction. Metal pouring channels or vents for the gases to escape can be seen on numerous statues at the bottom, either around or at the corners of the pedestal (MG 2173, MG 3479, MG 3629, MG 3630 [fig. 28b], and MG 3813 [fig. 28c]), or as a tang that was used as the main pouring channel and not removed to be used for mechanical assembly of a pedestal (MA 3540 [fig. 8], MG 3816, MG 3820, MG 3824, and MG 3827 [figs. 13a–c]).

That said, most of the statues were probably cast vertically, except for MG 3620 (figs. 7, 29a–b) that may have been cast horizontally, face down.[33] The loop at the back of the head was intended to fix a halo now lost, but could also have served as a pouring channel cut after casting, as indicated by its flat extremity. A second lump is located at the rear of the round pedestal and could have been another pouring channel. Although these two lumps of metal are visible only at the back of the image and not at its bottom, the more common upside down casting cannot be completely excluded if these pouring channels were bent upwards and connected to a main pouring gate located at the bottom of the statue. Nonetheless, the very flat morphology of the back supports a horizontal casting as well. Unfortunately, the statue's thickness is not sufficient to see whether porosity is concentrated around these spots at the back on the radiography of the profile. This would have indicated the points of entrance of the metal and definitely confirmed a horizontal casting.

5.1.5. Casting defects, repairs and alterations

Casting defects are rarely observed in this corpus, although this may not be surprising given both the small size of the objects and the fact that they are solid cast. Repairs by secondary casting (in order to fill areas where the metal failed to flow) were observed only on three statues, namely MG 3475 (upper part of the backpiece [fig. 30a]), MG 3625 (lower part of the backpiece [fig. 30b]) and MG 3814 (front face and corresponding interior part of the pedestal [figs. 31a–b]). The thick black material at the rear of the backslab of MG 3629 (figs. 32a–b) has been sampled and analysed. Although at first sight it seemed to be organic, this material proved to be mainly made of metal corrosion products. It is most likely a secondary casting repair.[34]

32. Slightly porous images are: MA 3540, MG 2328, and MG 3818; moderately porous: MG 3620, MG 3630, MG 3813, MG 3820, MG 3824, MG 3827, and MG 18402; highly porous: MG 3480 and MG 3816.

33. MG 3822 (figs. 18a–b) also bears a series of round symmetrical traces at the rear of the backpiece which could indicate that pouring channels were placed at the back, but it is difficult to ascertain that they were used for a horizontal casting.

34. First, the statue was examined with natural and UV light to localise the possible presence of adhesive or varnish, which are fluorescent substances, but no fluorescence was observed. Second,

Quadrangular patches (probably inserted mechanically) to hide porosity holes are only visible on MG 3816 (around its ankles [fig. 33]), the largest figure of the corpus (H. 34 cm).

Although unmistakably part of the same ensemble with MG 3820 (fig. 13a) and MG 3824 (fig. 13b), MG 3827 (fig. 13c) displays the distinctive cracked black surface (fig. 34) which is notably observed on copper-based objects exposed to fire. This is also the case for MG 3479 (figs. 35a–b) and MG 3630 (fig. 28a). Unfortunately no X-ray diffraction could be carried out to track the presence of tenorite CuO (Scott 1997). XRF surface analyses have not allowed for any definite conclusions.

5.1.6. Finishing

There is no evidence that the surfaces were intentionally patinated. As mentioned earlier, gilding is attested for artefacts preserved in other collections,[35] but no traces could be detected in the current corpus. It is thus difficult to determine if these statues were originally gilded or not. A discontinuous thin organic surface layer has been revealed by neutron radiography and tomography around some of the objects (MG 2173 [fig. 14] and MG 3619 [fig. 11]). It is probably a varnish as shown by some shiny areas and it was very probably applied in recent periods.

Nine chased and/or engraved statues (MA 3540 [fig. 8], MG 3475 [fig. 16], MG 3625 [fig. 17], MG 3813 [fig. 3], MG 3814 [fig. 2], MG 3816 [fig. 1], MG 3820 [fig. 13a], MG 3822 [fig. 18], and MG 3824 [fig. 13b]) were examined by digital microscopy (table 5, figs. 36–42). Among these, only seven statues had tool marks in good condition for proper investigation.[36]

First, three objects (MG 3475 [fig. 16], MG 3625 [fig. 17], and MG 3822 [fig. 18]) from the early 10th century (Category 3) show that work in the wax is restricted to parts not accessible once the object is cast. This is the case for the horizontal lines decorating the backpiece behind the divine figure, where the narrow space between these two elements prevents tooling after casting (figs. 36a–c). On the contrary, the more accessible top part of the lotus, its petals, and the cushion supporting it are decorated – or at least

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samples of the supposedly organic material at the back of the statue were examined with an optical microscope, first with natural light and then through a blue filter (B2/A), to check again the fluorescence of the materials, but none was detected and they had a metallic aspect under microscope. They were then chemically treated (trimethylsilylation) and analysed by gas chromatography-mass spectrometry (GC-MS) on a 15m column to identify their molecular constituents and the possible presence of natural components (wax, diterpenic and triterpenic resins, fat materials from animal or vegetal origin). No organic material was detected in the samples.

35. See a published example in Fontein 1990: cat. 38, seated Buddha (Museum of Fine Arts, Boston, inv. no. 1988.151; H. 30.5 cm, gilded bronze). More gilded statues are also kept, for example, in the Museum Volkenkunde, Leiden (inv. no. RV-1403-2391, RV-1403-3050, and RV-1403-2842), in the Victoria & Albert Museum, London (inv. no. 459.IS), and in the Weltmuseum, Vienna (inv. no. VO_68756, VO_68769, VO_68788, and VO_68790).

36. Corrosion, wear and/or dust filling the marks prevented correct examinations. In most cases, not all the decorated parts of these seven statues could be examined, either because some marks were also encrusted, or because the shape of the statue did not allow access to the digital microscope, which was designed to observe flat and not 3D objects.

enhanced – after casting (figs. 37a–b, 39, 40, 41b). Possibly because their decorated parts are all easily accessible (features of the face, hair/headdress, costume), the earlier objects observed (Category 2) show only cold working in the metal (figs. 37c–d, 41c–d).[37]

MG 3814 (fig. 2) is a special case. There is a repair by secondary casting on the front part of the pedestal, located on the element depicting a piece of cloth (fig. 31). Two kinds of decorative lines, running almost parallel to each other, were observed on the primary cast part. The smooth and shallow ones are interpreted as having been made in the wax. The deeper and sharper ones are clearly the result of metal cold working (fig. 38). This suggests that this element representing a piece of cloth hanging from the pedestal had initially been decorated in the wax by lines depicting pleats, but after the secondary casting, one section was lacking decoration. This latter part repaired by secondary casting was thus entirely decorated in the metal, and the primary cast part, which had been decorated in the wax before casting, was reworked in the metal as well. The lines made in the wax and in the metal do not superimpose well enabling us to see the initial decoration in the wax and the cold working decoration after casting.[38]

Second, five objects (MG 3814 [fig. 2], MG 3816 [fig. 1], and MG 3824 [fig. 13b] from the 9th century [Category 2]; MG 3625 [fig. 17] and MG 3822 [fig. 18] from the early 10th century [Category 3])[39] show that engraving was used, at least for the decorated parts accessible to microscopic examinations (figs. 41a–b). Both raking light photography by reflectance transforming imaging (RTI)[40] and digital microscopy clearly reveal striations inside the motifs, which are the successive marks of the tool as it removes slivers of metal. This is particularly visible for the hexagonal patterns – their lines and central circles – made to recreate the pericarp of the lotus on MG 3822 (fig. 40). In addition, three-dimensional modelling of the tool mark profiles shows the characteristic 'V' shape of the engraver and slightly raised edges along the engraved line (fig. 39). The pointed ends of the engraved lines are also characteristic and due to the quick movement made by the tool in cutting slivers of metal (fig. 40).

Finally, some motifs have been punch-marked very probably into the metal, as seen on the garments or the cushion supporting the lotus of MA 3540, MG 3475 (fig. 37a), MG 3625 (fig. 37b), and MG 3824 (fig. 41d).

37. Their iconographic compositions and ornamentations are also very different from the objects of the later periods and bear no direct comparisons.

38. Such duplicated lines were only observed in the repaired part. Elsewhere on the statue, the lines examined display only the features of metal cold working. It seems therefore that they were not based on a preparatory drawing of the decoration in the wax.

39. As for the other two statues, only the decorative dots on MG 3475 could be observed because the lines are too corroded and MA 3540 has only dots on the costume.

40. RTI was carried out using a Nikon D750 camera with a macro focus of 60mm. Around 64 photographs (NEFF format) illuminated with a flash Nikon SB-910 were taken with different angles of incidence. After developing the photographs in JPEG format using Photoshop, the final image was assembled with RTI Builder using two black spherical markers placed on each side of the photographed object during the shot.

MG 3814 also bears a motif of circles, but these are not concave and only their outline is visible (figs. 37d, 41c). Interestingly, the 3D reconstruction of the dots on MG 3475 (fig. 42a) and MG 3625 (fig. 42b), and consequently of the active part of the punch, shows a systematic defect in the sphere, thus clearly testifying to the use of the same tool for all the motifs investigated.

5.2. Metal compositions

Forty-six samples stemming from thirty-eight statues or statue fragments were analysed by ICP-AES. Samples have been duplicated for statues made of parts cast separately (especially for the halos) or suspected to be made of several parts. Similarly, several samples were taken from statues showing repairs by secondary casting. As mentioned earlier, the silver statuette MA 3540 (fig. 8) was analysed by XRF (table 3). All the results are reported in table 2 and summarised hereafter.

5.2.1. Alloys

Most of the statues analysed are unleaded bronzes, that is, copper-tin alloys with less than 2 to 3 wt.% lead.[41] Three ranges of bronze compositions may be distinguished depending on the tin content (table 2), although a continuum of compositions is observed between the lowest and highest tin contents (fig. 43). The alloy names applied here do not refer to any specific normative nomenclature:

- Low-tin bronzes (five objects) with tin contents ranging from 2 to 5 wt.%.
- Medium-tin bronzes (nineteen objects) with tin contents ranging from 6 to 11 wt.%.
- High-tin bronzes (fifteen objects) with tin contents ranging from 12 to 20 wt.%.

The variation in bronze composition may be related to chronological aspects, as a progressive increase in tin content is observed through time, especially from the 9th century onwards, although it is not clear-cut at the beginning of the period due to the small number of objects (table 2). Thus, the four statues of the 8th and early 9th century are divided between two high-tin and two medium-tin bronzes. Then, three low-tin bronzes are reported in the early 9th century (MG 3819 is also a low-tin bronze, but it could not be dated). Three medium-tin and two high-tin bronzes also exist for this period. Twelve medium-tin bronzes with more uniform levels of tin content appear in the second half of the 9th century and persist into the late 9th century (except MA 3790 and MG 3826 which are two high-tin bronzes). In the early 10th century, all statues are made of high-tin bronze.

41. Chemical elements will be designated by their symbol, as follows (sorted by alphabetical order): Ag (silver), As (arsenic), Au (gold), Bi (bismuth), Co (cobalt), Fe (iron), Ni (nickel), Pb (lead), S (sulphur), Sb (antimony), Se (selenium), Sn (tin), and Zn (zinc).

In addition, bronze compositions may also be related to iconographic aspects. Although the corpus contains only four Hindu deities, it is noteworthy that all but one (MG 2328: 8 wt.% Sn) are high-tin bronzes (MG 3626 and MG 3627 [fig. 6]: 14 wt.% Sn, MG 3831 [fig. 19]: 20 wt.% Sn). That said, a number of Buddhist deities show large tin contents as well (MA 3790: 12 wt.% Sn, MG 3620 [fig. 7]: 19 wt.% Sn, MG 3815 [fig. 12]: 18 wt.% Sn, MG 3826: 13 wt.% Sn, etc.).

Two artefacts, MG 2173 (fig. 14) and MG 3627 (fig. 6), diverge from the rest of the analysed objects given their higher lead content ranging from 5 to 7 wt.%. They are thus made of a different type of alloy: MG 2173 is a low-lead bronze and MG 3627 is a low-lead/high-tin bronze (14 wt.% Sn). As will be seen later, their impurity patterns are also atypical. MG 2173 indeed shows high gold content (1000 wt. ppm Au) and relatively high bismuth content (558 wt. ppm Bi).[42] MG 3627 exhibits much higher zinc content than average (1.5 wt.% Zn). In addition, MA 3540 (fig. 8) is made of silver, corresponding to a type of small silver statues made in a style commonly found in Indonesia.[43]

The Buddha MG 3819 (Le Bonheur 1971: 134–135) is even more unusual. It is not made of bronze but leaded brass (8 wt.% Zn and 12 wt.% Pb) with low tin content (2 wt.% Sn).

5.2.2. Impurities

In addition to lead and tin, nine other chemical elements have been detected in most metals. When cumulated, those elements including zinc represent less than 0.5 wt.% of the metal composition. If lead is added, the total amount does not exceed 1 wt.% in most cases (fig. 43). These elements (including zinc and lead) may easily be considered as impurities, as opposed to the unique alloying element here, namely tin.[44] Thus, the large majority of the analysed metals in this corpus prove to be relatively pure. However, the impurity contents vary greatly within the corpus. In an attempt to group together objects with similar impurity patterns, a statistical treatment has been carried out on the impurity contents, thus leading to a partition into seven composition groups (table 2).[45] The relationships between these groups and stylistic associations are not straightforward, but some interesting trends may be pointed out when gathering information on impurities, tin contents and chronological aspects.

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42. 'ppm' means part per million. 1% equals 10 000 ppm.

43. See e.g. van Lohuizen-de Leeuw 1984: cat. 20, Mañjuśrī (Lindenmuseum, Stuttgart, inv. no. SA 35 244 L; H. 6 cm, silver) and Fontein 1990: cat. 49, Avalokiteśvara and consort (Asian Art Museum, San Francisco, inv. no. B86B1; H. 12 cm, silver and bronze pedestal).

44. Except for the aforementioned low-lead (MG 2173) and low-lead/high-tin bronzes (MG 3627), as well as the leaded brass (MG 3819) for which lead, and in the latter case zinc, are alloying elements as well.

45. A cluster analysis has been performed on seven chemical elements (Ag, As, Bi, Co, Ni, S, and Sb), after standardisation of the values (Ward's method). Two objects have been withdrawn from the analysis, namely the Buddha MG 3819 (leaded brass) and the Viṣṇu MG 2328 (unusual high bismuth content). This enables to group objects with similar compositions.

The four earliest objects (Category 1) show among the highest levels of impurities (As, Fe, Ni, S, and Pb between 1 and 3 wt.%, instead of 0.5 wt.% in general for more recent objects). All of them belong to atypical composition groups (groups #1 and #4), except Brahmā MG 3627 (group #3 [fig. 6]). MG 3628 (fig. 5) and MG 3620 (fig. 7) are particularly similar with their relatively high levels of lead and nickel content (2–3 wt.% Pb, 0.35 wt.% Ni). Both are supposed to date between the 8th to early 9th centuries and to show foreign characteristics.

In the first half of the 9th century (Category 2), four statues (MG 3626, MG 3629 [fig. 32], MG 3630 [fig. 28a], and MG 3814 [fig. 2]) belong to the group #5, whereas three others (MG 3813 [fig. 3], MG 3815 [fig. 12], and MG 3816 [fig. 1]) are gathered in a quite different composition group with very high composition similarities (group #6). However, in both groups arsenic is low and nickel medium. Only Kubera MG 3823 stands out (group #7).

In the second half of the 9th century (Category 2), a rather homogeneous composition group of objects is observed (group #5), except for one object (MG 3826, group #6). Group #5 was already mentioned for some objects of the first half of the 9th century. It is marked by low impurity levels (in particular low As, S, Ni, and medium Co), as well as medium tin content. Within this group, six objects stand out by their particular compositional resemblance, namely MG 2255 (fig. 9), MG 3479 (fig. 35a), MG 3790, MG 3820 (fig. 13a), MG 3824 (fig. 13b), and MG 3827 (fig. 13c).

In the late 9th century (Category 2), levels of tin content remain consistent at medium levels (between 7 and 11 wt.%). All the statues belong to group #3, except for MA 5936 (fig. 10) in the atypical group #2. Three objects in particular, namely MG 3624 (fig. 21), MG 12895, and MG 18402 show very similar compositions.

The first half of the 10th century (Category 3) is marked by a very consistent tin content of around 13 to 14 wt.%. In addition, four out of five statues in this category (MG 3475 [fig. 16], MG 3625 [fig. 17], MG 3822 [fig. 18], and MG 18290 [fig. 15]) show remarkably similar impurity contents (high arsenic and nickel contents). They belong to group #6. Only MG 2173 (fig. 14) is part of group #3, a composition group more or less related to the previous period.

Interestingly, most atypical compositions relate to unusual styles. Hence, the unusually high zinc and selenium contents in MG 5179 (fig. 48) echo the doubtful authenticity of this object, as will be discussed later. The atypical alloy of MG 3819 (a leaded brass) pertains to a similar view on authenticity. MG 2328 bears unusually high bismuth contents (2085 wt. ppm Bi) and also has unusual iconographic aspects.[46]

46. The upper left hand of this Viṣṇu image seems broken but it is in fact shaped as if the hand was removable. This feature is highly unusual, in particular because the three other hands have been cast in one piece with the rest of the image. The two flying figures in front of the pedestal are also difficult to identify and depart from the representation of Viṣṇu's mount, Garuḍa, usually depicted on the pedestal. Despite these suspicious features, the style of the image is close to a Viṣṇu image

Finally, particularly high gold contents have been measured in a number of statues: around 100 wt. ppm Au in MA 5936 (fig. 10), MG 2328, MG 3620 (fig. 7), MG 3629 (fig. 32), MG 3630 (fig. 28a), and MG 3823; up to 1000 wt. ppm Au in MG 2173 (fig. 14) and 851 wt. ppm Au in MG 3831 (fig. 19). Some of these statues show among the highest silver contents as well (MA 5936: 0.81 wt.% Ag, MG 2173: 0.11 wt.% Ag, MG 2328: 0.17 wt.% Ag, MG 3823: 0.24 wt.% Ag, MG 3831: 0.4 wt.% Ag).

5.2.3. Ensembles and assemblies

In all statues investigated, separately cast parts systematically show slight differences in composition for both alloying element (Sn) and impurities (table 2). This tends to show that for most cases the different parts were cast in the same workshop but using different batches of metal. The particular case of MG 3624 (figs. 21a–b) should be mentioned – a similar composition between the pedestal and the figure is observed, except for specific impurities such as cobalt (which seems to be correlated to Fe), zinc, and to a lesser degree lead.

In some cases, large differences in tin contents may reveal later associations. Hence, the figure (18 wt.% Sn) and the halo (10 wt.% Sn) of Kubera MG 3815 (fig. 12) are stylistically quite different. Moreover, the front side of the halo, with a decorative flower pattern on the edge, is mistakenly reversed suggesting that it may not have been originally associated with this image.

That said, Avalokiteśvara MG 3816 (fig. 1) also displays a difference in the percentage of tin between the figure (4 wt.% Sn) and the halo (9 wt.% Sn), although both pieces do not show any marked stylistic divergence. One may thus wonder whether different amounts of tin might have been controlled in order to create an effect of polychromy, with the flaming halo slightly more silvery and shiny with its higher tin content. At least, these differences in tin contents for the same object in the same workshop tend to show that alloying – that is, addition of tin to copper – took place in the workshop.

A similar control of metal composition for aesthetic purposes might have occurred for MG 3475 (fig. 16). A crack is visible at the base of the backpiece and it was probably repaired by secondary casting (fig. 30a). However, the backpiece (sampled in the fragment of the parasol shaft at the top of the backpiece) is almost ten times richer in gold than the pedestal (13 and 98 wt. ppm Au).

The only case of perfect homogeneity of compositions is observed in the bodhisattvas MG 3820, MG 3824, and MG 3827 (figs. 13a–c). This, together with the fact these statues display a remarkable stylistic consistency, shows without any doubt that all three were cast simultaneously using the same metal batch in order to integrate them in a same ensemble, maybe originally fixed to a unique pedestal as a triad or associated to more statues as a *maṇḍala*.

in the Museum Volkenkunde, Leiden (inv. no. RV-1403-1867) and it is too soon to settle on its authenticity (see also Le Bonheur 1971: 214–217).

5.3. Consecration deposits

During preliminary visual examinations of the Musée Guimet collection, a consecration deposit was noticed inside the pedestal of MG 3625 (fig. 17). The statue had been damaged earlier, and some of the objects in the deposit were visible to the naked eye (a coin, a white stone bead, a folded metal sheet, and a separate metal sheet [fig. 44a]). Later on, three more statues with consecration deposits still in place were found (MG 2173 [fig. 44c], MG 3619, and MG 18290 [fig. 44b]). Their pedestals differed from the empty pedestals of most of the statues, as their bottoms were filled with a material, and some tiny objects sealed inside were partially visible at the surface.

The contents of the deposits, as partly revealed by neutron tomography, are listed below:

- MG 3625: a rolled-up metal foil, a metal foil, a possibly silver-alloy coin, a white stone bead, other unidentified objects.
- MG 18290: a rolled-up metal foil, two metal foils, one possibly silver-alloy coin, an unidentified triangular object, other unidentified objects (figs. 46a–b).
- MG 2173: a rolled-up metal foil, two possibly silver-alloy coins, two roughly square objects with rounded corners which look like 'piloncito'-type coins in gold (Christie 1998: 166–167, fig. 1), a black stone bead, a white flattened bead pierced in the centre, an unidentified triangular object, other unidentified objects (figs. 47a–b).
- MG 3619: a roughly square object with rounded corners, which looks like a 'piloncito'-type coin in gold.

The sealing material[47] in the cavities hosting – or which were supposed to have hosted – consecration deposits was sampled by drilling on seven statues (MG 3475 [fig. 16], MG 3479 [fig. 35], MG 3480 [fig. 20], MG 3619 [fig. 11], MG 3624 [fig. 21], MG 3630 [fig. 28a], and MG 18290 [fig. 15]).[48] The sealing material of MG 18290 exhibited a brown colour on the surface (fig. 44b) but proved to be metallic inside. It has been analysed by XRF, revealing a tin-based alloy with small amounts of lead (90 to 95 wt.% Sn, 5 to 10 wt.% Pb).[49] Under the microscope, all the material in the other statues proved to be metal corrosion products with a dark greyish colour. XRF analyses systematically revealed a compound dominated by tin, very probably a tin oxide, with small amounts of lead. One may argue that this material used to be a tin-based alloy, as consistent with the sealing material of MG 18290.

47. This material apparently replaces the metal plates usually hammered over the base of other Buddhist statues, notably Tibetan metallic statues, to seal their consecration deposit (Reedy 1991: 17, fig. 1), as no traces of plates were found on our Indonesian corpus. Lehmann, Hartmann & Speidel (2010: 423, sample A) also mention a sealing plate in wax, resin or gemstone.

48. The sealing material of MG 2173 (fig. 14) and MG 3625 (fig. 17) was not sampled, as to not damage the objects of the deposit, which were too close to the surface.

49. The only reference material at disposal was the Solder NIST 1131 (60 wt.% Pb and 40 wt.% Sn), with which our XRF analyses showed some discrepancies (36 wt.% Sn). Therefore, we assume a quite large margin of error for the analytical results of MG 18290's sealing material.

6. Discussion

6.1. Distinctive features of the production

The making of divine images in Buddhist and Hindu traditions is codified by specific rules prescribed in craft manuals (*śilpaśāstra*) from India, which were originally written in Sanskrit. The textual sources used in Indonesia to explain the technical rules followed for casting Indonesian statues are now unknown. Nonetheless, our study has brought to light for the first time several technical features distinctive of Indonesian bronze statuary.

All the Indonesian statues investigated are solid cast, even the largest ones. However, they all have a hollow part necessary for inserting a consecration deposit after casting. This hollow part is constituted by the lotus flower or cushion supporting the figure – for some statues (MA 3540 [fig. 8], MG 3816 [fig. 1], MG 3820, MG 3824, and MG 3827 [figs. 13a–c]) these elements, once mechanically attached, are now missing – as well as by the quadrangular pedestal where one is found.

The marked presence of tin in most Indonesian statues constitutes another distinctive technical feature. The present study has shown that thirty-five out of the thirty-nine artefacts analysed are made of copper alloyed with only one element, namely tin. Most of them contain relatively high amounts of this element, even given the variability in its exact percentage in the alloy. In any case, any amount of tin in an alloy qualifies it as a bronze. No brass artefacts were found in the current study (except the Buddha MG 3819 whose authenticity is questionable). This does not come as a surprise, as the Indonesian production of bronze statues probably stopped in the 11th century and zinc came into common use in Southeast Asia only later (see e.g. Woodward 1997: 186–187; for regional comparisons, see also section 6.3.).[50] The importance of tin in Indonesian bronze statuary is even more significant when one considers that the material used to seal the consecration deposits – as demonstrated for seven out of the nine statues which still have their sealing material – is almost pure tin.

In addition, low impurity levels in the bronzes are a distinctive feature of the Indonesian production.

Finally, most surface decoration on the seven statues examined by digital microscopy was carried out by cold working in the metal, and mostly by engraving. That said, given the limited corpus under study, neither clear trends nor evolution of the practice could be drawn.

6.2. Towards a chronological, stylistic, and technical serialisation

Despite the common technical features mentioned above, some aspects clearly evolved during the almost three centuries of production studied

50. Our results are also consistent with earlier results obtained by Otto Werner (1972: 141), even though the latter should be treated with caution because the analytical techniques used then did not have the accuracy that can now be reached.

here. The size and depth of the cavity for consecration deposits increased with time. Moreover, metal compositions vary more or less closely with style and chronology.

The four objects dated to the 8th or early 9th centuries (Category 1) display different compositions including medium and high-tin bronzes (from 7 to 19 wt.% Sn). Moreover, MG 3627 (fig. 6) is one of the rare low-lead bronzes, with higher zinc content than other objects (1.5 wt.% Zn). These discrepancies are not surprising since the images display diverse stylistic connections (Peninsular Southeast Asia, Bangladesh and South India). It might well be assumed that they were manufactured in different places, but it is as yet difficult to trace their exact origin. Only MG 3628 (fig. 5) and MG 3620 (fig. 7) show the same impurity patterns, in particular for lead (2–3 wt.% Pb) and nickel (0.35 wt.% Ni). Regarding the manufacturing process, MG 3620 seems to have been cast horizontally (fig. 29), and not vertically as with the majority of the other artefacts.

During the 9th century (Category 2), the coexistence of at least two styles, 'Central Java A' and 'Central Java B', with other objects in as yet undefined styles which developed for a century, renders the picture quite complex. Nonetheless, in juxtaposing stylistic groups with chronological sub-periodisation – first half, second half, and late 9th century – some interesting trends can be pointed out (table 2).

Most statues of the first half of the 9th century, except MG 3630 ('Central Java A') (fig. 28a) and MG 3823 ('Central Java B'), cannot be linked to any specific style. Yet, this period exhibits several interesting features regarding both metal compositions and fabrication techniques. First, all pieces with the lowest levels of tin content of the corpus (less than 6 wt.% Sn) belong to this period, though an equal number of objects bear medium and high-tin levels. Moreover, the impurity patterns can be sorted into two composition groups (#5 and #6), which are not specific to the period. Composition group #5 is also observed in the second half of the 9th century, whereas composition group #6 characterises objects from the early 10th century. Pieces with low-tin content are found in both groups. Regarding fabrication techniques during the first half of the 9th century, it seems that more statues show separately cast parts.

In the second half of the 9th century and in the late 9th century, chronological, stylistic, and technical aspects are more closely connected. The 'Central Java B' stylistic group is the most homogeneous and well-defined one, both in terms of distinctive stylistic features, and also in their alloy compositions, with medium-tin contents (around 10 wt.% Sn) as well as mostly low and consistent impurity levels. All objects belong to the composition group #5. The late 9th century does not witness any change regarding the alloy compositions of the 'Central Java B' stylistic group, but the impurities of the metal in use switch entirely to another signature, namely the composition group #3 (except MA 5936 [fig. 10] in the atypical composition group #2). Moreover, all statues display consistent technical features. In particular, the cavity hosting a consecration deposit is small (limited to the pedestal and folded legs of the deity [fig. 26]), and images have been cast in one piece (except for MA 3540 [fig. 8] and MG 3624 [fig. 21] with mechanically assembled pedestals [now lost for MA 3540]).

The 'Central Java A' stylistic group, represented by only three objects of the corpus, is not homogeneous, with wide variations in tin levels (from 3 to 13 wt.% Sn). Nonetheless, two statues (MA 3790 and MG 3630 [fig. 28a]) have impurity patterns related to the 'Central Java B' stylistic group of the second half of the 9th century (composition group #5).

As for the other objects whose artistic source has not been identified, five of them (MG 3626, MG 3629 [fig. 32], MG 3814 [fig. 2], MG 3820, MG 3824, and MG 3827 [figs. 13a–c]) have impurity patterns coherent with the composition group #5 of the 'Central Java A' and 'Central Java B' stylistic groups of the second half of the 9th century.

Finally, the stylistic and technical similarities of the objects from the early 10th century (Category 3) are striking (MG 2173 [fig. 14], MG 3625 [fig. 17], MG 3822 [fig. 18], and MG 18290 [fig. 15]). They share stylistic characteristics related to their iconographic forms. High, elaborate thrones, which bear a seated deity, indicate that they were probably part of ensembles of statues arranged as *maṇḍala*s.[51] In technical terms, all statues were cast in one piece and have a large internal cavity (fig. 27). High-tin contents (13–14 wt.% Sn) are also the rule, and impurity patterns are very consistent but not entirely specific to the period. They belong to the composition group #6, which also includes three much earlier objects assumed to date to around the first half of the 9th century (MG 3813 [fig. 3]; MG 3815 [fig. 12]; and MG 3816 [fig. 1]). Despite these compositional similarities, stylistic considerations seem to support our dating of these two groups of statues to different periods. Another possibility is that, in the early 10th century, older bronze statues were melted down and recycled for new creations. It has frequently been assumed that, during this specific period, when the political and cultural centre moved to East Java, the sanctuaries were deserted and the bronze statuary was melted down (Fontein, Soekmono & Suleiman 1971: 40). More evidence is needed to fully ascertain this assumption.

To sum up our observations on the technical developments in Indonesian bronze statuary, tin content clearly increases slowly in the alloy composition from the early 9th to the early 10th centuries, despite several exceptions to the rule. The technical motivations for such an increase are not straightforward. The quest for particular colorations of the surface might have played a role, but it is not clear whether the statues were originally gilded or not and if natural metal colorations were thus hidden (see also section 6.3.).

51. Such as the statues that form part of the so-called Nganjuk *maṇḍala* for example. Its main deities are seated on lotuses, placed on high quadrangular bases decorated with upright ornaments at the corners and on the sides of the upper moulding, indicating a higher hierarchy in the *maṇḍala* (Lunsingh Scheurleer & Klokke 1988: 33–34). In addition, MG 3822 [fig. 18] was probably part of the same *maṇḍala* as a Vairocana and a Prajñāpāramitā kept in Museum Volkenkunde, Leiden (RV-1403-2847 and RV-1403-1697; Lunsingh Scheurleer & Klokke 1988: cat. nos. 43 and 44), since the decorative elements of their thrones are almost identical.

Economical aspects, and particularly the cost of tin versus copper, may also have played a role. The systematic use of tin-based alloy as sealing material for the consecration deposit of the seven statues investigated, all dated from the late 9th to the early 10th centuries, may partly reflect the low cost of tin in a region very close to rich tin resources, as we will see later (section 6.3.). In addition, tin melts at 230° C and would have been easier to use than the alternative method of hammering a metal plate over the base (see n. 47).

Differences in impurity patterns point mainly to variations in sources of metal ore. These sources may have changed with time, as has clearly been shown here despite the still-limited size of the corpus under study. Besides time, geographical differences might also explain variations occurring contemporaneously. Because of the large scale of production, the numerous artefacts that have come down to us might point to several workshops being active simultaneously. It has indeed been assumed that Java was the main production centre because the majority of the Indonesian bronzes excavated so far have come from this island. However, one cannot exclude the possibility of other production sites on other Indonesian islands. If the islands of the archipelago exchanged manufactured products like statuary, it would explain the presence of statues produced by other Indonesian workshops in Java. Variations in metal compositions would then testify to different regional provenances, although it is too premature to identify any precise regional bronze workshops. At the least, a number of small groups of objects show very similar compositions, which may testify to their origins in particular workshops. This is the case for the triad MG 3820, MG 3824, and MG 3827 (figs. 13a–c), but also for three objects (MG 3624 [fig. 21], MG 12895, and MG 18402), and for another group of three objects (MA 3790, MG 2255 [fig. 9], and MG 3824 b).

6.3. Searching for regional connections

Now that some of the main features of the Indonesian bronze-casting tradition have been preliminarily characterised – at least for the corpus of bronze statues under study – , it might be possible to go one step further and attempt to address the nature of regional exchanges involving technical know-how. For methodological reasons, only lost-wax casting and Hindu-Buddhist copper-based sculptures will be discussed hereafter. Priority will be given to contemporary metallurgical traditions in Peninsular and Mainland Southeast Asia, although comparative data from the Indian subcontinent will be considered as well. To narrow the scope of this still emerging debate, however, the focus will be on three specific technical features identified within the corpus which we consider potentially significant, that is, images cast face down, high-tin bronze alloys and high gold contents.

6.3.1. Casting face down at a slight angle

One or possibly two statues of the corpus have very probably been cast lying face down: a standing two-armed bodhisattva Avalokiteśvara dated to the 8th or early 9th centuries (MG 3620 [Category 1] [figs. 7, 29]) and a seated bodhisattva dated to the first half of the 10th century (MG 3822 [Category 3] [fig. 18]). Both are small Buddhist images of around 15 to 20 cm in height that are solid cast, with MG 3822 also having an internal cavity under its pedestal [fig. 27b].

As mentioned earlier, the first statue shares a stylistic affinity with images from Peninsular Southeast Asia. Moreover, other Buddhist images cast face down are attested in this region from the 8th century onwards, especially for large statuary commonly associated with Śrīvijayan shrines and royal commissions. The first example is a standing eight-armed Avalokiteśvara from Wat Phra Borommathat (Chaiya district, Surat Thani province, South Thailand), dated to the late 8th or early 9th centuries (Bangkok National Museum, inv. no. S.V.24; H. 76.5 cm; Guy 2014: 258–260 [cat. 166]). The statue is hollow cast in one piece leaving remains of cut-off gates or vents and excess metal on the back, with an additional quadrangular tenon behind the head, which was intended to fix a halo now lost but also probably used as a pouring channel.[52] The second example is a more complete image of standing eight-armed Avalokiteśvara from a Bidor tin mine (Batang Padang district, Perak, Malaysia), dated to the second half of the 8th century (Muzium Negara, Kuala Lumpur, inv. no. MN.BALAIB.40.2008; H. 93 cm; Guy 2014: 258–260 [cat. 157]). Also hollow cast in one piece, the statue reveals a much more porous metal surface on the back, which is another indication of a casting face down.[53]

The main advantage of this method applied to standing images seems to be that casting defects caused by the incomplete flow of molten metal, by porosity holes due to gases within the mould, or by the shrinkage of metal on cooling, are more likely to occur on the back of the sculpture, that is, on a hidden part. This technological interpretation has already been proposed for large bronze statues from South India and Tibet, respectively Hindu and Buddhist images. Among the few pieces studied are: a miscast and unfinished Balakr̥ṣṇa from Tamil Nadu, which is solid cast and dated to the 11th century (Victoria and Albert Museum, London, inv. no. IS.177-1993; H. 39 cm; Johnson 1972: 46, figs. 19–20, 22–23, 26); a 13th-century Viṣṇu from Tamil Nadu, also solid and unfinished (Chhatrapati Shivaji Maharaj Vastu Sangrahalaya Museum, Mumbai; Srinivasan 2015: 214, figs. 10–11); and a hollow-cast Avalokiteśvara from Tibet dated to the 12th or 13th centuries (Museum of Fine Arts, Boston, inv. no. 2003.339; H. 93.5 cm; Hykin,

52. Technical examination of the following pieces was conducted in person by Brice Vincent in April 2014, at the occasion of the international exhibition *Lost Kingdoms: Hindu-Buddhist Sculpture of Early Southeast Asia* organised by the Metropolitan Museum of Art in New York (14th April–27th July 2014).

53. Although their provenance is unknown, two other Southeast Asian examples of hollow-cast statues face down have to be mentioned: the first one is a four-armed Avalokiteśvara from South Thailand or Sumatra, dated to the 8th or early 9th centuries (Metropolitan Museum of Art, inv. 1982.64; H. 56.5 cm; Guy 2014: 251–252 [cat. 158]); the second is an exceptionally large four-armed Durgā from Cambodia or Champa, dated to the 7th century and rather linked to Cham artistic tradition (private collection; H. 191 cm; Bunker & Latchford 2011: 54, 63, 473–480 [Appendix 1], figs. 4.6a–e, 4.8a).

Newman & Cummins 2007: 94–95, fig. 10; see also Reedy 1997: 62). In all cases, it has been argued that the statue was cast face down, approximately horizontally but with the head slightly lower than the feet and the gate-vent system on the back. More precisely, pouring channels were located on the lower rear part of the figure and vents probably at the other end, so that the largest volume in the mould first received the molten metal, thus forcing escaping gases to the upper rear part.[54] In other words, this method allows the founder to achieve adequate risering and more directional solidification, and in the case of solid casting, avoiding the problems of the metallostatic pressure created by a great weight of molten metal (Srinivasan 2015: 214).

In Sri Lanka, a similar casting method has been tentatively proposed, but only for small Hindu statues of around 10 to 35 cm in height – all standing images – that are solid cast. The earliest known example, possibly dated to the 2nd century BCE, is a group of eight *yakṣa* found in 2011 as part of a sacred deposit at the Deegavapi *stūpa*, Ampara district (Archaeology Department of Sri Lanka; H. 9 cm; Kasthuri 2016a: 8, fig. 1; Kasthuri 2016b: 42). Two later groups of Brahmā surrounded by four *lokapāla* (Yama, Indra, Kubera, Varuṇa), both dated to the 9th century, have been cast lying face down as well: the first group was also part of a sacred deposit, associated with the colossal Avukana Buddha image, Anuradhapura district (Archaeological Museum, Anuradhapura, inv. no. 424–428; H. 16.5 to 27 cm; Kasthuri 2016a: 8, fig. 11; Kasthuri 2016b: 42, fig. 7; see also Von Schroeder 1990: 158–159, 302–303, Phs. 86A–F); the provenance of the second group is unknown (Metropolitan Museum of Art, inv. no. 2003.548.1–2, 2004.465, 2005.468.1–2; H. 23.5 to 33 cm; Kasthuri 2016a: 8, figs. 9–10; Kasthuri 2016b: 42, fig. 6). In the latter group, each *lokapāla* reveals more than five pouring channels or vents on the back, a gate-vent system that is comparable to what has been observed on the backpiece of MG 3822 (fig. 18), although the deity is seated and no slight angle is evidenced.

In the case of MG 3620 (figs. 7, 29), both stylistic and technical affinities with the Peninsular bronze-casting tradition have been argued. It thus appears as a largely peripheral production within the corpus under study, especially considering that it was cast face down – upside-down casting being the rule in our corpus. Nevertheless, when considered as part of a small group of Southeast Asian copper-based statues cast face down – further technical investigations are definitely needed to identify more examples –, the Avalokiteśvara MG 3620 appears to be of greater significance. This set of images, with likely counterparts in Tamil Nadu, Tibet and Sri Lanka, would indeed offer a new argument for the transfer to Southeast Asia of Indian bronze-casting technologies, potentially from one or more metallurgical traditions.

54. Ethnoarchaeological study of modern foundries in India, where this casting position is still employed helped to develop the latter technological reconstruction (Chamba in Himachal Pradesh: Reedy 1987; Swamimalai in Tamil Nadu: Craddock & Hook 2007).

The idea of technological transfer, especially in terms of the lost-wax casting technique from India being employed locally in Southeast Asia for the production of new metal icons, is often raised in the long-standing debate over the introduction of Indian religions into Southeast Asia. More recently, this claim has been repeated in the literature dedicated to the early Hindu-Buddhist copper-based sculptures appearing in both Peninsular and Maritime Southeast Asia (from the 6th c. onwards).[55] To date, however, the directions (direct or indirect with single or multiple sources), vectors (Indian and local founders, Brahmans, portable images, religious texts) and mechanisms (innovation, adaptation, adoption) of exchange have been largely understudied and are poorly understood.

6.3.2. High-tin bronze alloy, tin-surface enrichment and silver imitation

Fifteen statues in our corpus have been identified as high-tin bronzes, with tin content ranging from 12 to 20 wt.%.[56] All are unleaded bronzes, that is, with lead content lower than 2–3 wt.%, except for one statue (MG 3627 [fig. 6]: Pb 4.8 wt.%). All are also solid cast. As mentioned earlier, the use of high-tin bronze alloys for both Buddhist and Hindu images is attested from the 8th or early 9th centuries onwards, but seems more common from the second half of the 9th century.

The technical choice of a high-tin bronze alloy, that is, the decision to add high amounts of tin to copper, has no direct benefits on casting as far as we know, but primarily allows creating a silvery and reflective lustre on the surface of the finished statue, be it solid or hollow. The side-effect of this intended external aspect, however, is a very brittle and hard alloy, which makes the repairing and finishing work after casting more difficult, or even impossible (Becker, Strahan & O'Connor 2014: 268–269).

Although the precise meaning and importance of silvery surfaces is not defined in any textual source, the production of high-tin bronze alloys has been observed in various regions of Southeast Asia and beyond. According to the sparse available analytical data, mainly obtained from scattered and sometimes unpublished technical studies of copper-based statues – and for this reason, reproduced in full in footnotes hereafter –, high-tin bronzes are evidenced in a series of metallurgical traditions associated with local polities of Southeast Asia.

Among the bronze-casting traditions of Mainland Southeast Asia that have been studied, one should mention the Buddhist statuary produced during the 7th and 8th centuries by the Mon culture of Dvāravatī in Central Thailand. Although represented only by a few sculptures, primarily small Buddha images, it is characterised by a large variety of alloy compositions

55. See e.g. Brown 2014a, 2014b.

56. According to David Scott (1991: 25), the usual limit of solubility of tin in copper is about 14 wt.% – the theoretical limit is around 17 wt.% – , which might form another tin-content frontier between low-tin and high-tin alloys (e.g. Bourgarit *et al.* 2003 for Khmer bronzes). Other metallurgical studies even choose to define high-tin bronze as an alloy of copper with 15 wt.% or more tin (e.g. Woodward 1997 for Mon, Khmer and Thai bronzes).

including unleaded high-tin bronze, that is, with tin content ranging from 16 to 26 wt.% and lead content lower than 3 wt.% (Becker, Strahan & O'Connor 2014: 268–269).[57]

One neighbouring bronze-casting tradition has received relatively more analytical attention, that is, the so-called 'Prasat Hin Khao Plai Bat II bronzes'. This cache of bronze sculptures was discovered in 1964 in Buriram province, Northeast Thailand, and consists of an extended series of Buddhist statues, primarily images of the bodhisattvas Avalokiteśvara and Maitreya, which are supposed to have come from different places and periods (late 7th–first half of the 9th c.). In addition to large dimensions (up to 140 cm in height), one of their striking technical features is a silvery or grey coloration of the surface, resulting from levels of tin content that often approach and sometimes exceed 15 wt.%, while lead levels are variable ranging from trace amounts to 10 wt.% or more (Becker, Strahan & O'Connor 2014: 269).[58] At least three of these sculptures also show considerably greater tin enrichment near the surface, which may be interpreted either as a deliberate technical choice or as the consequence of a natural selective corrosion, such as the copper depletion from burial.[59] Note also the existence of 10th-century Dvāravatī Buddha images

57. Hereafter is a non-exhaustive list of the high-tin bronzes identified thus far: Buddha in *vitarkamudrā* (Metropolitan Museum of Art, inv. no. 1982.220.5; H. 83.5 cm; Sn 26 wt.% [SEM-EDS]; Becker, Strahan & O'Connor 2014: 268 [cat. 142]); Buddha in *vitarkamudrā* (Walters Art Museum, Baltimore, inv. no. 54.2708; H. 39.5 cm; Sn 22.5 wt.%, Pb 0.1 wt.% [ICP-AES]; Woodward 1997: 62–63 [cat. 9]); Buddha in *vitarkamudrā* (Musée Guimet, inv. no. MA 3785; H. 19 cm; Sn 16 wt.%, Pb 0.4 wt.% [ICP-AES]; Bourgarit *et al.* 2003: appendix 2); two Buddha in *vitarkamudrā* (National Museum of Cambodia, Phnom Penh, inv. no. *ga* 6937–6938; H. 10 to 20 cm; *ga* 6937: Sn 17 wt.%, Pb 2.6 wt.% and *ga* 6938: Sn 16 wt.%, Pb 1.5 wt.% [ICP-AES]; Bourgarit 2009). Two small images of bodhisattvas made of a high-tin bronze alloy may also be related to the metallurgical tradition of Central Thailand: Maitreya? (Walters Art Museum, inv. no. 54.2714; H. 21 cm; Sn 20 wt.%, Pb 2.1 wt.% [ICP-AES]; Woodward 1997: 57–58 [cat. 5]); Maitreya (Philadelphia Museum of Art, inv. no. 1965-133-1; H. 19.5 cm; Cu 60.7–65.7 wt.%, Sn 27.8–31.6 wt.%, Pb 4.1–5.5 wt.% [XRF]; Woodward 1997: 57, n. 54).

58. Hereafter is a non-exhaustive list of the unleaded and leaded high-tin bronzes identified thus far, including three statues of related style also found in Buriram province, more precisely in the village of Ban Fai (50 km northwest of Khao Plai Bat):
1) *Prasat Hin Khao Plai Bat II (?)*: Avalokiteśvara (Metropolitan Museum of Art, inv. no. 67.234; H. 142 cm; Cu 77.9–80.5 wt.%, Sn 18.8–18.9 wt.%, Pb 0.05–2.4 wt.% [SEM-EDS]; Becker, Strahan & O'Connor 2014: 269 [cat. 141]; see also Woodward 1997: 66, n. 92); Maitreya (Asia Society, New York, inv. no. 1979.63; H. 96.5 cm; Cu 74–75 wt.%, Sn 13–15 wt.%, Pb 9–12 wt.% [EMP]; Jett 1998: 6–7); bodhisattva? (Walters Art Museum, inv. no. 54.2688; H. 22 cm; Sn 18.7 wt.%, Pb 3.3 wt.% [ICP-AES]; Woodward 1997: 66–67 [cat. 12]); Avalokiteśvara? (National Gallery of Australia, Canberra [?]; H. 30 cm; Sn 19.3%, Pb 0.9% [wet chemical analysis]; Barnard 1978: 21–25); Avalokiteśvara (Musée Guimet, inv. no. MA 3321; H. 46 cm; Sn 11 wt.%, Pb 0.6 wt.% [ICP-AES]; Bourgarit *et al.* 2003: appendix 2); Avalokiteśvara (Musée Guimet, inv. no. MA 4985; H. 64 cm; Sn 13 wt.%, Pb 0.9 wt.% [ICP-AES]; Bourgarit *et al.* 2003: appendix 2).
2) *Ban Fai*: Maitreya (Bangkok National Museum, inv. no. 343/2516; H. 137 cm; Cu 80.2–82.5 wt.%, Sn 14.1–15.3 wt.%, Pb 2.8–3.8 wt.% [AAS]; Janposri 1993: 66); Maitreya (Bangkok National Museum, inv. no. 344/2516; H. 70 cm; Cu 82.5 wt.%, Sn 13.6 wt.%, Pb 0.4 wt.% [AAS]; Janposri 1993: 66); Buddha in *vitarkamudrā* (Bangkok National Museum, inv. no. 345/2516; H. 110 cm; Cu 81 wt.%, Sn 13.6 wt.%, Pb 5.1 wt.% [AAS]; Janposri 1993: 66).

59. The three known examples are: the Metropolitan Avalokiteśvara 67.934, with tin levels ranging from about 19 wt.% in the alloy to more than 30 wt.% on the surface (Becker, Strahan & O'Connor 2014: 269 [SEM-EDS]); the Guimet Maitreya MA 3321, with tin levels ranging from 11 wt.% in the alloy to about 20 wt.% on the surface (Bourgarit *et al.* 2003: 115–116, 118, table 5, appendix 2 [ICP-AES and PIXE]); and the Walters bodhisattva 54.2688, although the analytical data are less precise (Sn 18.7 wt.% [ICP-AES: alloy], Sn 27.5–47 wt.% [XRF: surface]; Woodward 1997: 67, appendix C [cat. 12]).

characterised by similar tin-surface enrichment.[60] Metallographic study would be of some help in that case and, if intentional, would also help to distinguish if the tin-enriched surface has been produced by inverse segregation during cooling ('tin sweat'), or by a variety of different tinning processes after casting (see e.g. Meeks 1993). The use of high-tin bronze alloys and/or tin-surface enrichment in the Buriram tradition seems to achieve the same aim: to imitate silver by employing tin as a less expensive substitute, especially in the case of large castings, while the precious metal, either pure or alloyed, is reserved for smaller statues, as attested by a few surviving images.[61]

The same conclusion would be applicable to the Khmer bronze-casting tradition, where the use of high-tin bronze alloy is attested from the Funan period (1st–6th c.). Evidence comes from a series of statues and objects, probably for ritual purposes, which have been found in the Óc Eo region (An Giang and Kiên Giang provinces, southern Vietnam) and made of both unleaded and leaded high-tin bronze.[62] Additionally, Khmer founders certainly employed tin-surface enrichment, at least from the 7th or 8th centuries onwards.[63] The intent of obtaining a silvery appearance would also explain the atypical tin-based alloy of a Lokeśvara image from Angkor Borei (Takeo province, South Cambodia), with around 84 wt.% tin and 8.5 wt.% lead (National Museum of Cambodia, inv. no. *ga* 5330; H. 18 cm; Bourgarit *et al.* 2003: appendix 2 [ICP-AES]). Although not much analytical information is available for copper-based statues produced during the early Angkor period (9th–11th c.), at least one high-tin bronze is attested for the second quarter of the 10th century, that is, a large but fragmentary image of male deity, possibly Śiva (Metropolitan Museum of Art, inv. no. 1998.320a–f; H. 110–115 cm; Sn 10–16 wt.%, Pb 0.2–1.1 wt.% [ICP-AES]; Vincent 2014: 6–23 [cat. 2.1]).

60. Two examples have been identified at the Walters through both ICP-AES and XRF: standing Buddha? (inv. no. 54.2705; H. 25 cm; Cu 88.9 wt.%, Sn 10.9 wt.% [ICP-AES: alloy], Sn 15.5–21.5 wt.% [XRF: surface]; Woodward 1997: 70–71, appendix C [cat. 15]); Buddha on *nāga* (inv. no. 54.2707; H. 16 cm; Cu 83 wt.%, Sn 7.9 wt.% [ICP-AES: alloy], Sn 17–32 wt.% [XRF: surface]; Woodward 1997: 71–73, appendix C [cat. 16]).

61. The only available analytical data comes from three Metropolitan bodhisattvas made of almost pure silver or a silver alloy with around 20 wt.% copper (inv. no. 1989.237.2, 1994.51, and 1995.570.8; H. 9.5 to 25 cm; Becker, Strahan & O'Connor 2014: 269 [SEM-EDS]). They can directly be compared to two Buddha in *vitarkamudrā* from Central Thailand, which are both kept in the same collection and cast in silver alloy, with silver levels ranging from 5.3 to 12.5 wt.% (inv. no. 1993.387.6 and 2004.142.1; H. 28.5 to 39.5 cm; Becker, Strahan & O'Connor 2014: 269 [SEM-EDS]).

62. Most of these artefacts are now kept in the National Museum of Vietnamese History, Ho Chi Minh City: porcine head (inv. no. BTLS 1594; L. 7.5 cm; Cu 70.9%, Sn 14.3%, Pb 8.4%); small bell (inv. no. BTLS? [MBB 4459]; D. 2 cm; Cu 65%, Sn 14.4%, Pb 13.9%); bell or cymbal? (inv. no. BTLS? [MBB 3879]; D. 3 cm; Cu 70.4%, Sn 19.2%, Pb 6.1%); fragment of mirror? (inv. no. BTLS? [MBB 4028]; th. 3 mm; Cu 63.2%, Sn 29.3%, Pb 5.7%; Zn 1.7%); rim of vessel (inv. no. BTLS 1595; D. 8.5 cm; Cu 72.6%, Sn 26%); fragment of bracelet (inv. no. BTLS? [MBB 4677]; D. 6 mm; Cu 71.1%, Sn 27.2%) (Malleret 1960: tables 2–6 [wet chemical analysis]).

63. The two supposedly tin-enriched bronze statues identified thus far are: a Viṣṇu, also from Óc Eo, showing a thin layer of tin on its surface (National Museum of Vietnamese History, inv. no. BTLS 1585; H. 25 cm; Cu 74.4%, Sn 9.9%, Pb 14.5%; Malleret 1960: table 2 [wet chemical analysis]); and an exceptionally lifesize bull of Śiva from Tuol Kuhea (Kandal province, South Cambodia), usually said to be made of a silver-bronze alloy but whose metal and surface have not been analysed yet (Royal Palace, Phnom Penh; H. 80 cm, L. 130 cm).

More generally, the production of high-tin bronzes, and the additional practice of tin-surface enrichment, as evidenced in Central and Northeast Thailand, South Vietnam, and Cambodia, may not be surprising given the vast and accessible resources of the Southeast Asian Tin Belt, running from Central Burma down through the Thai-Malay Peninsula (Bronson 1992: 83–84, fig. 3). Even though the available analytical data for the Peninsular bronze-casting tradition is too scarce to allow for any general conclusions – only one image of the corpus has been identified as an unleaded high-tin bronze (MG 3620; for other analyses, see e.g. Barnard 1978 and Bourgarit *et al.* 2003) –, tin may be presumed to be a major alloying element in casting copper-based statues and, for the same geographic and economic reasons, to have a similar origin.[64]

The proximity and availability of the rich peninsular tin ores may also have influenced the alloying practices of the Indonesian bronze-casting tradition. It would obviously explain the use of high-tin bronze alloys and, more generally, the marked presence of tin in most of the copper-based statues studied. Additionally, one should remember the complementary employment of tin as a sealing material for consecration deposits. The practice of tin-surface enrichment may be reasonably presumed, though it has yet to be investigated, as can be seen in, for instance, the Tekaran Avalokiteśvara cited above which is usually said to be made of silvered and gilded bronze. Consequently, another observation previously made would be applicable to the Indonesian metallurgical tradition, that is, the employment of silver imitation for large statues, whereas pure or alloyed silver has been reserved for smaller ones, such as the silver statuette of the corpus (MA 3540 [fig. 8]).

The last question would be to ask if the omnipresence of tin is only proper to Southeast Asia or also common to other contemporary metallurgical traditions, particularly on the Indian subcontinent. Analyses of hundreds of copper-based statues from across the whole North Indian and Himalayan region (i.e. Rajasthan–Gujarat, Kashmir, Swat, Ladakh, Tibet, and Nepal) show quite the opposite, since the prevalence of brass and the zinc content of alloy compositions increased through the centuries, the main exception being mercury-gilded images, which were usually made of copper (Craddock 2015: 72–73). In the Northeast Indian bronze-casting tradition, however, rare examples of high-tin bronzes are attested among the few images analysed thus far. One should mention the Pāla Buddhist centre of Nālandā in Bihar (8th–12th c.), where unleaded high-tin bronze statues have been produced, with tin contents ranging from around 14.5% to 23.5% and lead contents lower than 3% (Santra *et al.* 2008: 29, table 1b, citing Lal 1956 and Sahai 1977). Finally, regarding early South Indian and Sri Lankan copper-based statues (8th–13th c.), which have also received relatively little analytical attention, they appear to be very similar to each other, being made of copper or more frequently of leaded bronze, with a variable but overall quite low tin content (Craddock 2015: 57, 66; see also Craddock & Hook 2007: 76). An

64. As an illustration, one may refer to the Bidor Avalokiteśvara cited above, which, as with other Buddhist bronze images, has been recovered from a Perak tin mine.

exception exists for the Sri Lankan bronze-casting tradition, where high-tin bronze is employed in the Polonnaruwa period, but only for Buddhist images (9th–11th c.) – not for Hindu ones (11th–13th c.) –, before becoming much common during the Divided Kingdoms and Kandy periods (14th–18th c.) (Thantilage 2008: 92–94).

What emerges from this overview is bits and pieces that help to characterise a Southeast Asian tradition of high-tin bronze statues – now also including Indonesian bronzes –, whose development seems to be related to the exploitation by local polities of one of the world's largest tin deposits. At this stage, however, it is still premature to propose the influence or precedence of one Southeast Asian bronze-casting tradition over another, especially given that technological transfers from the Indian subcontinent are not to be excluded as well. Although comparative analytical data is not equally available for all regions, the use of high-tin bronze alloy is at least attested for Nālandā Buddhist bronzes (Northeast India) and Polonnaruwa Buddhist bronzes (Sri Lanka), both contemporary to the period of bronze production in the Indonesian islands. A new opportunity is thus offered to reconsider transregional exchanges in terms of religious, stylistic and technical aspects, in particular the Nālandā / Java connections often cited in the literature on Indonesian bronze statuary (e.g. Bernet Kempers 1933; Lunsingh Scheurleer 1992; Huntington 1994; Mechling 2013).

6.3.3. High gold contents, ritual offerings and auspicious alloy formulae

The gold-rich Vajrasattva MG 2173 (figs. 14, 44c, 45b, 47) is one of the four statues of the corpus with consecration deposits. Dated to the late 9th or early 10th centuries (Category 3), it is made of low-lead bronze, with high gold as well as relatively high bismuth contents (1000 wt. ppm Au and 558 wt. ppm Bi). As for the second gold-rich statue identified, the male deity MG 3831 (fig. 19), it is uncertainly dated (Category 4) and, above all, raises questions about its authenticity: firstly because of its unusual iconography, although it is not certain that it was originally conceived as a bust, and also because of its atypical impurities, being a high-tin bronze bearing both high gold and high silver contents (800 wt. ppm Au and 4000 wt. ppm Ag).

The high gold levels observed cannot be explained through the use of particular copper ores naturally rich in gold or by the re-melting of gilded statues. A third possibility is a deliberate addition of gold in the melt, maybe for ritual purposes. In that case, small amounts of gold would have been added through devotional offerings made in casting ceremonies. Such ritual practices have been tentatively proposed for the Khmer bronze-casting tradition, to explain the supposedly continuous production from the 7th to the 14th centuries of gold-rich leaded and unleaded bronzes (Bourgarit *et al.* 2003: 118; Vincent 2012: 329–332, figs. 4.76–4.77). This hypothesis has been based on the observation in Cambodia and neighbouring countries of modern castings of Buddha images, where various metal artefacts are commonly offered as meritorious actions and then melted down, including personal gold and silver ornaments usually reserved by devotees for the statue's head. Note that the same explanation was given for the high gold content identified for one of the Metropolitan silver Buddhas from Central Thailand cited above (inv. no. 2004.142.1, Au 0.4 wt.% [SEM-EDS]; Becker, Strahan & O'Connor 2014: 269).[65] Similarly, devotional offerings may also explain the high silver content observed for three pieces of the corpus: in addition to MG 3831(fig. 19), MA 5936 (0.81 wt.% Ag [fig. 10]) and MG 3823 (0.24 wt.% Ag).

Following this hypothesis of the deliberate addition of gold and silver by devotees, another tentative suggestion is that the founders added themselves the precious metals in the melt, in an attempt to obtain auspicious alloy formulae made of a combination of metals. This would suppose another type of transfer to Southeast Asia, that is of speculative beliefs in metals, which are well attested on the Indian subcontinent. An intense alchemical interest in magical numbers had indeed existed there, being the foundation of a series of theoretical metallurgical recipes containing five, seven, eight or even nine metals (Lo Bue 1981: 33). At least for the modern period, both written and oral traditions confirm the presence of quite similar speculations in Mainland Southeast Asia (for Cambodia and Thailand, see e.g. Vincent 2012: 297–311). Further research in this field would be necessary in the case of the Indonesian islands. Finally, small additions of gold and silver by founders may also have a more specific aim, as, for example, evidenced by modern foundries of Tamil Nadu. For the casting of *pañcaloha* or five-metal images, the pouring channel at the back of the head is indeed used to add small quantities of gold and silver, as it is thought to give a special lustre to the face of the statue (Srinivasan 2015: 214).

6.4. Consecration and sacred deposits

There are no extant ritual texts describing how divine images were consecrated in the Indonesian archipelago and the rules to be followed, but gold and silver foils engraved with Buddhist *mantra*s have been found by chance in some Indonesian bronze statues.[66] These thin metal sheets were

65. In that case, however, gold may also have come from the silver ore source.

66. Although this list is not exhaustive, we may refer to Stutterheim 1934: no. A 2, Stutterheim 1937: 13, 22, no. A 12, and Krom 1913: 66, describing folded foils inserted into the pedestals of bronze statues. Fontein, Soekmono & Suleiman 1971: 151 mention in reference to cat. 45–49 that: "inside one of the pedestals a small gold plate (I 3/16 by 11/16 in.) was discovered. It bears an undecipherable inscription. As a few other statuettes contained similar gold plates, it is possible that all were once provided with such pieces." Arlo Griffiths (2014a: 142) also refers to "a rolled-up silver foil [which] had been hidden in the base of the largest sculpture of the Sambas hoard." Unfortunately, the documentation he mentions about the extraction process of the silver foil, currently kept at the British Museum, London (inv. no. 1956,0725.8.b; L. 15.5 cm), is no longer available on the online museum database. In the same publication, Griffiths (2014a: 150, n. 47) gives other useful references which are worth citing here in full: "*OV* [*Oudheidkundig Verslag*] *1948*, p. 30 (about Candi Plaosan Lor): 'A small bronze statue of a two-armed Bodhisattva, presumably representing Padmapāṇi, was found during the excavation of the floor of the northern cella of the principal shrine on the South, with the folded silver foil with a *dhāraṇī* still visible in the bottom of its base.' Another interesting find is the fragment of silver foil extracted from the silver Mañjuśrī statue from Ngemplan Semongan, discussed by Bosch 1929: 45. Quite a number of further references to finds of the colonial period are cited in the article by F.J. Domela Nieuwenhuis (1983). For some more recent finds, see also Nugrahani *et al.* (1998: 18 and photos 27–8); for some cases from Campā, not yet properly published, see John Guy 2011: 318–9."

likely part of a deposit of sacred objects inserted after casting inside the statues in order to consecrate them and to render them suitable for use in religious practices. Few examples are apparently known from India,[67] but there is ample evidence that this practice was widespread in Indonesia. These deposits are important archaeological artefacts that help document further the ritual use of the bronze statues, and may even help to date them more precisely. From a study carried out in 1983 on a bronze statue of Vairocana from the Domela Nieuwenhuis collection, it appears that other types of objects, such as coins, were also contained in these consecration deposits (Domela Nieuwenhuis 1983).

Four statues in the Musée Guimet collection (MG 2173 [fig. 14], MG 3619 [fig. 11], MG 3625 [fig. 17], and MG 18290 [fig. 15]) have consecration deposits inside their pedestals (figs. 44–47). The deposits have been sealed with a tin-based alloy, either corroded or not. The same observation was made of the Domela Nieuwenhuis Vairocana (Domela Nieuwenhuis 1983: 204; sample no. 1 [liquid metal from the entrance]: Sn 61.2 wt.%, Pb 36.8 wt.%; sample no. 2 [metal content]: Sn 93.4 wt.%, Pb 6.7 wt.% [XRF]).

Further research will be necessary to identify every element contained in the consecration deposits of the Indonesian statues, but a number of them have already been securely characterised and show some uniformity. This uniformity is consistent with the similarities in style (late Central Javanese/early East Javanese for MG 3619 [fig. 11] as well as early East Javanese for MG 2173 [fig. 14], MG 3625 [fig. 17], and MG 18290 [fig. 15]), dating (late 9th–early 10th c.), as well as with the alloy composition and impurity patterns of the four statues. All of them contain a folded metal sheet, but the exact nature of the metal is not yet certain. Coins are also part of the deposit, as with the Vairocana in the Domela Nieuwenhuis collection. Since we did not extract the coins, we do not know if they are of exactly the same type, but their concave shape visible in the neutron tomography is similar (figs. 46–47). Those extracted from the Domela Nieuwenhuis Vairocana are silver-alloy coins of the 'sandalwood flower' type, bearing the *akṣara* '*mā*' for *māṣa* in *nāgarī* script, which circulated in Java between the late 8th or early 9th to the 11th centuries (Christie 1998: 167–169). Even though they are all very worn and the character is not clear on all of them, those still legible can be cautiously dated to the early 10th century. Although this dating appears to correspond roughly to the stylistic dating of the statues, we cannot exclude the possibility that these coins "were in circulation for years, or perhaps decades, before they were deposited in the base of the statue."[68] Neutron imaging on the statues of the Musée Guimet collection also reveals that some of them contain another type of coin, cubic and in gold ("piloncito" type), which was also used in Java (Christie 1998: 166–167, fig. 1). Apart from the white stone bead visible under the pedestal of MG 3625 (fig. 44a), MG 2173 (fig. 44c) also has a round black bead and a

67. Only two examples from India are cited by Yael Bentor (1995: 254).

68. This is directly quoted from a personal communication by email in February 2017 with Jan Wisseman Christie. We are grateful for her tentative dating and explanations.

white flattened perforated bead. Other objects with variable shapes remain to be securely identified.

Since all the statues in the current corpus have a cavity, it is likely that all of them were originally consecrated with precious objects, but these were probably taken out for their value later when the images were no longer in use. Remains of the tin sealing material inside five statues (MG 3624 [fig. 21], MG 3475 [fig. 16], MG 3480 [fig. 20], MG 3479 [fig. 35a], and MG 3630 [fig. 28a]), which are now empty, confirm that they once held a deposit. The absence of a cavity in bronze statues thus seems to be an important element in their authenticity, and such is the case with MG 3819 and MG 5179 (figs. 48a–b), whose metal compositions are also unusual. It might also be the case with MG 3831 (fig. 19), if it was indeed originally conceived as a bust.

7. Conclusion

Based on updated stylistic and chronological classifications, these preliminary technical investigations on thirty-nine artefacts have allowed us to undertake an initial comprehensive characterisation of the Indonesian bronze-casting tradition. Through the study of the fabrication techniques employed, several features specific to Indonesian bronze statues have been brought to light for the first time. Thus, solid casting dominates the production, and levels of tin content increase progressively in time towards remarkably high concentration levels, while impurity levels remain low. Alloy compositions and impurity patterns intersect with stylistic and chronological features. Supplementing these observations, manufacturing features have confirmed the attribution of objects to specific groups, helping in their categorisation. Questions related to the identification of regional workshops and metal supply require further study to understand relationships between the Indonesian islands and with other Asian regions as well. Nonetheless, we have already seen that three specific technical features bear intra- and possibly interregional connections. The method of casting images face down identified for two objects in our corpus is attested in Peninsular Thailand, and also in Tamil Nadu, Tibet and Sri Lanka. Although it suggests transfers of technical know-how between these regions, the directions, vectors and mechanisms of exchange are not yet clear and, more generally, will need further studies by specialists of both South and Southeast Asian bronze-casting technologies. Additionally, the use of high-tin bronze alloys and high-gold content integrates the Indonesian bronze production with a broader Southeast Asian tradition where such practices are well attested – at least in the first case; more sporadically in the latter. Meanwhile, transregional interactions with the Indian Nālandā bronzes or the Sri Lanka Polonnaruwa bronzes should also be reconsidered in terms of their technical aspects. Finally, further research on consecration deposits would greatly enhance our understanding of the ritual rules supervising the creation of these religious images. In order to advance our understanding of these issues, technical investigations on an enlarged corpus of Indonesian bronze sculpture are already underway in collaboration with the Museum

Volkenkunde in Leiden and Marijke Klokke of Leiden University.[69] This new study will help us to further develop our hypotheses, and to see whether the features observed in the course of this preliminary study are recurrent in a broader corpus of objects.

Abbreviations

AAS	Atomic absorption spectrometry
BKI	*Bijdragen Koninklijk Instituut voor de Taal-, Land- en Volkenkunde*
EMP	Electron microprobe
GC-MS	Gas chromatography-mass spectrometry
H.	Height
ICP-AES	Inductively coupled plasma atomic emission spectrometry
L.	Length
PIXE	Proton induced x-ray emission
RTI	Reflectance transforming imaging
SEM-EDS	Scanning electron microscopy with energy dispersive spectrometry
th.	thickness
wt.	weight
XRF	X-ray fluorescence

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Categories used for current corpus	Designation	Inv. no.	Height (cm)	Artistic group	Date	Consecration deposit
Category 1 (8th to early 9th c.)	Avalokiteśvara	MG 3620	17	Peninsular Southeast Asia	8th–early 9th c.	N
	Vasudhārā	MG 3628	12	Bangladesh	8th–early 9th c.	N
	Avalokiteśvara (?)	MA 507	8.5	Bangladesh	8th–early 9th c.	N
	Brahmā	MG 3627	15	South India	8th–early 9th c.	N
Category 2 (9th c.)	Jambhala	MG 3814	28	Bangladesh	1st half 9th c.	N
	Kubera / Jambhala	MG 3815	13	NI	1st half 9th c.	N
	Kubera / Jambhala	MG 3813	17	NI	1st half 9th c.	N
	Viṣṇu	MG 3626	13	NI	1st half 9th c.	N
	Six-armed Avalokiteśvara	MG 3630	8.4	Central Java A	1st half 9th c.	N
	Ten-armed Avalokiteśvara	MG 3816	34	NI	1st half 9th c.	N
	Kubera / Jambhala	MG 3823	9.5	Central Java B	1st half 9th c.	N
	Kubera / Jambhala	MG 3629	16	NI	1st half 9th c.	N
	Bodhisattva	MG 3479	10.5	Central Java A	2nd half 9th c.	N
	Bodhisattva	MA 3540	6.5	Central Java B	2nd half 9th c.	N
	Bodhisattva	MG 3826	8.5	Central Java A	2nd half 9th c.	N
	Buddha	MA 3790	9	Central Java B	2nd half 9th c.	N
	Vasudhārā	MG 2255	13	Central Java B	2nd half 9th c.	N
	Throne	MG 3824 b	11.5	Central Java B	2nd half 9th c.	N
	Bodhisattva	MG 3820	9.5	NI	2nd half 9th c.	N
	Bodhisattva	MG 3824	11	NI	2nd half 9th c.	N
	Bodhisattva	MG 3827	11	NI	2nd half 9th c.	N
	Bodhisattva	MG 12895	10	Central Java B	late 9th c.	N
	Vairocana (crowned)	MG 18402	8	Central Java B	late 9th c.	N
	Vairocana	MA 5936	10.5	Central Java B	late 9th c.	N
	Mahāpratisarā	MG 3624	18	Central Java B	late 9th c.	N
	Kubera / Jambhala	MG 3619	17	Late Central/ Early East Java	late 9th c.	Y
Category 3 (First half of the 10th c.)	Vajrasattva	MG 2173	12	Early East Java	late 9th–early 10th c.	Y
	Vairocana	MG 18290	15.5	Early East Java	1st half 10th c.	Y
	Vairocana	MG 3475	12	Early East Java	1st half 10th c.	N
	Kubera / Jambhala	MG 3625	18	Early East Java	1st half 10th c.	Y
	Bodhisattva	MG 3822	17.5	Early East Java	1st half 10th c.	N
Category 4 (Uncertain dating)	Akṣobhya	MG 3825	13	NI	9th c. ?	N
	Akṣobhya	MG 3819	10	NI	?	N
	Buddha	MG 5179	15	Bangladesh	?	N
	Avalokiteśvara (?)	MG 3480	13.5	Central Java B	?	N
	Unidentified divinity	MG 3818	23	NI	?	N
	Lotus pedestal	MG 3827 b	4	NI	?	N
	Viṣṇu	MG 2328	18	NI	?	N
	Bust of divinity (Śiva?)	MG 3831	13	NI	?	N

ICP-AES = inductively coupled plasma-atomic emission spectrometry; N = no; NI = not identified; XRF = X-ray fluorescence; Y = yes

Table 1. — The thirty-nine Indonesian bronze statues studied.

	Metal / Surface anal.	RTI	XR Radiography	XR Tomography	Neutron Tomography	3D Scan	Digital microscopy
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	Y
	ICP-AES	N	Y	Y	N	N	N
	ICP-AES	N	Y	N	N	Y	Y
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	Y	Y
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	XRF	N	Y	N	N	N	Y
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	Y
	ICP-AES	N	Y	N	N	N	Y
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	Y	Y	N	N
	ICP-AES	N	Y	N	Y	N	N
	ICP-AES	N	Y	N	Y	N	N
	ICP-AES	N	Y	N	N	N	Y
	ICP-AES	N	Y	N	Y	Y	Y
	ICP-AES	Y	Y	Y	N	Y	Y
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N
	ICP-AES	N	Y	N	N	N	N

Categories used for current corpus	Designation	Inv. no.	Artistic group	Date	Bronze type	Impurity metal group	Sample localisation	Results in wt% Ag	As	Fe	Ni	Pb
Category 1 (8th to early 9th c.)	Avalokiteśvara	MG 3620	Peninsular Southeast Asia	8th–early 9th c.	High-tin	#4	Right arm	0.079 ±0.008	0.38 ±0.04	0.29 ±0.03	0.35 ±0.04	2.8 ±0.3
	Vasudhārā	MG 3628	Bangladesh	8th–early 9th c.	Medium-tin	#4	Inside the base, under the legs	0.041 ±0.004	0.2 ±0.02	0.84 ±0.08	0.34 ±0.03	1.7 ±0.2
	Avalokiteśvara (?)	MA 507	Bangladesh	8th–early 9th c.	Medium-tin	#1	Inside the base, under the legs	0.07 ±0.007	0.29 ±0.03	0.15 ±0.02	0.091 ±0.009	0.8 ±0.08
	Brahmā	MG 3627	South India	8th–early 9th c.	High-tin	#3	Right leg, bottom	0.11 ±0.01	0.57 ±0.06	0.49 ±0.05	0.068 ±0.007	4.8 ±0.5
Category 2 (9th c.)	Jambhala	MG 3814	Bangladesh	1st half 9th c.	Medium-tin	#5	Base, back-left corner	0.03 ±0.003	0.052 ±0.005	0.52 ±0.05	0.063 ±0.006	0.089 ±0.009
							Base, secondary casting, front side	0.035 ±0.003	0.078 ±0.008	0.47 ±0.05	0.083 ±0.008	0.33 ±0.03
	Kubera / Jambhala	MG 3815	NI	1st half 9th c.	High-tin	#6	Base, front side, bottom edge	0.04 ±0.004	0.11 ±0.01	0.43 ±0.04	0.14 ±0.01	0.28 ±0.03
							Backpiece, tang	0.099 ±0.010	0.078 ±0.008	0.23 ±0.02	0.11 ±0.01	0.3 ±0.03
	Kubera / Jambhala	MG 3813	NI	1st half 9th c.	Low-tin	#6	Under the buttocks	0.065 ±0.006	0.17 ±0.02	2.3 ±0.2	0.083 ±0.008	0.61 ±0.06
	Viṣṇu	MG 3626	NI	1st half 9th c.	High-tin	#5	Base, bottom edge	0.05 ±0.005	0.051 ±0.005	0.016	0.029 ±0.003	0.78 ±0.08
	Six-armed Avalokiteśvara	MG 3630	Central Java A	1st half 9th c.	Low-tin	#5	Under the right foot	0.09 ±0.009	0.12 ±0.01	0.0036 ±0.0004	0.093 ±0.009	1.3 ±0.1
	Ten-armed Avalokiteśvara	MG 3816	NI	1st half 9th c.	Low-tin	#6	Figure, tang under the feet	0.047 ±0.005	0.11 ±0.01	0.5 ±0.05	0.089 ±0.009	0.28 ±0.03
							Halo, bottom edge	0.039 ±0.004	0.16 ±0.02	0.81 ±0.08	0.069 ±0.007	0.9 ±0.09
	Kubera / Jambhala	MG 3823	Central Java B	1st half 9th c.	Medium-tin	#7	Base, front-left corner	0.24 ±0.02	0.37 ±0.04	0.61 ±0.06	0.087 ±0.009	1.5 ±0.1
	Kubera / Jambhala	MG 3629	NI	1st half 9th c.	Medium-tin	#5	Inside the base, under the legs	0.073 ±0.007	0.083 ±0.008	0.46 ±0.05	0.045 ±0.004	0.15 ±0.01
	Bodhisattva	MG 3479	Central Java A	2nd half 9th c.	Medium-tin	#5	Base, bottom edge	0.054 ±0.005	0.22 ±0.02	0.12 ±0.01	0.075 ±0.007	0.74 ±0.07
	Bodhisattva	MG 3826	Central Java A	2nd half 9th c.	High-tin	#6	Base, bottom edge	0.056 ±0.006	0.094 ±0.009	0.024 ±0.002	0.1 ±0.01	0.081 ±0.008
	Buddha	MA 3790	Central Java B	2nd half 9th c.	High-tin	#5	Base, front side, bottom edge	0.084 ±0.008	0.17 ±0.02	0.11 ±0.01	0.066 ±0.007	0.089 ±0.009
	Vasudhārā	MG 2255	Central Java B	2nd half 9th c.	Medium-tin	#5	Inside the base, under the lotus	0.057 ±0.006	0.12 ±0.01	0.11 ±0.01	0.059 ±0.006	0.09 ±0.009
	Throne	MG 3824 b	Central Java B	2nd half 9th c.	Medium-tin	#5	Back-right corner	0.046 ±0.005	0.2 ±0.02	0.13 ±0.01	0.074 ±0.007	0.45 ±0.04

Table 2. — The analytical results for thirty-eight Indonesian statues (46 samples).

RESULTS IN WT%				RESULTS IN WT PPM															
S	**Sb**	**Sn**	**Zn**	**Al**	**Au**	**Ba**	**Bi**	**Cd**	**Co**	**Cr**	**In**	**Mg**	**Mn**	**Mo**	**P**	**Se**	**Ti**	**V**	**W**
0.15 ±0.02	0.074 ±0.007	19 ±2	0.013 ±0.001	nd <4.3	118 ±12	nd <0.1	60 ±11	nd <0.2	441 ±44	nd <1.7	13 ±3	nd <0.3	nd <0.1	nd <1.1	nd <13	19 ±2	nd <0.2	nd <0.3	nd <8.3
0.21 ±0.02	0.14 ±0.01	10 ±1	0.25 ±0.03	nd <4.2	21 ±2	nd <0.1	77 ±8	nd <0.2	1 036 ±104	nd <1.7	17 ±2	nd <0.3	nd <0.1	nd <1.1	nd <13	24 ±2	nd <0.2	nd <0.3	nd <8.2
0.13 ±0.01	0.45 ±0.05	6.9 ±0.7	0.049 ±0.005	nd <4.1	38 ±4	nd <0.1	64 ±6	nd <0.2	570 ±57	nd <1.6	14 ±4	nd <0.3	nd <0.1	nd <1.1	nd <13	32 ±4	nd <0.2	nd <0.3	nd <8.0
0.056 ±0.006	0.13 ±0.01	14 ±1	1.5 ±0.2	nd <4.6	43 ±4	nd <0.1	60 ±6	nd <0.2	486 ±49	nd <1.8	19 ±2	nd <0.3	nd <0.1	nd <1.2	nd <14	24 ±2	nd <0.2	nd <0.3	nd <8.9
0.07 ±0.007	0.01 ±0.001	9.6 ±1.0	0.019 ±0.002	34 ±3	15 ±2	nd <0.1	32 ±6	nd <0.2	459 ±46	nd <1.7	13 ±2	1.7 ±0.2	nd <0.1	nd <1.1	21° <44 >13	45 ±4	23 ±2	nd <0.3	nd <8.2
0.083 ±0.008	0.022 ±0.002	12 ±1	0.021 ±0.002	8.4° <15.3 >4.6	21 ±2	nd <0.1	56 ±6	nd <0.2	450 ±45	nd <1.8	7.9 ±5.2	nd <0.3	nd <0.1	nd <1.2	20° <48 >14	49 ±5	nd <0.2	nd <0.3	nd <8.9
0.081 ±0.008	0.025 ±0.003	18 ±2	0.04 ±0.004	nd <4.4	20 ±2	nd <0.1	86 ±9	nd <0.2	365 ±36	nd <1.7	11 ±4	nd <0.3	nd <0.1	nd <1.1	nd <14	30 ±3	nd <0.2	nd <0.3	nd <8.5
0.054 ±0.005	0.027 ±0.003	9.5 ±0.9	0.12 ±0.01	nd <4.1	82 ±8	nd <0.1	72 ±7	nd <0.2	240 ±24	nd <1.6	11 ±1	nd <0.3	nd <0.1	nd <1.0	nd <13	20 ±5	nd <0.2	nd <0.3	nd <7.9
0.28 ±0.03	0.024 ±0.002	5.3 ±0.5	1.5 ±0.1	nd <4.3	30 ±3	nd <0.1	412 ±41	nd <0.2	257 ±26	nd <1.7	22 ±3	nd <0.3	nd <0.1	70 ±7	25° <44 >13	32 ±3	nd <0.2	nd <0.3	nd <8.3
0.02 ±0.002	0.039 ±0.004	14 ±1	0.026 ±0.003	nd <4.2	10 ±1	nd <0.1	33 ±10	nd <0.2	68 ±7	nd <1.6	5.8 ±0.6	nd <0.3	nd <0.1	nd <1.1	nd <13	20 ±2	nd <0.2	nd <0.3	nd <8.1
0.047 ±0.005	0.064 ±0.006	2.9 ±0.3	0.083 ±0.008	nd <4.3	100 ±10	nd <0.1	142 ±14	nd <0.2	30 ±3	nd <1.7	4.1° <5.7 >1.7	nd <0.3	nd <0.1	nd <1.1	nd <13	44 ±4	nd <0.2	nd <0.3	nd <8.4
0.14 ±0.01	0.018 ±0.002	4.4 ±0.4	0.64 ±0.06	nd <4.3	22 ±2	nd <0.1	63 ±6	nd <0.2	267 ±27	nd <1.7	15 ±5	nd <0.3	nd <0.1	nd <1.1	nd <13	66 ±7	nd <0.2	nd <0.3	nd <8.4
0.095 ±0.010	0.053 ±0.005	8.8 ±0.9	1 ±0.1	23 ±4	37 ±4	nd <0.1	85 ±9	nd <0.2	329 ±33	nd <1.7	24 ±4	nd <0.3	nd <0.1	4 ±0.8	26° <44 >13	15 ±4	nd <0.2	nd <0.3	nd <8.3
0.18 ±0.02	0.12 ±0.01	8.7 ±0.9	0.53 ±0.05	nd <4.5	109 ±11	nd <0.1	118 ±12	nd <0.2	1 289 ±129	nd <1.8	20 ±2	nd <0.3	nd <0.1	nd <1.2	nd <14	14 ±2	nd <0.2	nd <0.3	nd <8.8
0.057 ±0.006	0.0073 ±0.0007	6.2 ±0.6	0.11 ±0.01	nd <4.7	229 ±23	nd <0.1	24° <25 >7	nd <0.2	378 ±38	nd <1.8	11 ±1	nd <0.4	nd <0.1	nd <1.2	nd <15	17 ±6	nd <0.2	nd <0.4	nd <9.1
0.062 ±0.006	0.047 ±0.005	9.7 ±1.0	0.032 ±0.003	nd <4.1	46 ±5	nd <0.1	104 ±10	nd <0.2	220 ±22	nd <1.6	9.4 ±3.0	nd <0.3	nd <0.1	nd <1.1	nd <13	18 ±4	nd <0.2	nd <0.3	nd <8.0
0.15 ±0.01	0.022 ±0.002	13 ±1	0.0032 ±0.0003	17 ±4	19 ±2	nd <0.1	66 ±8	nd <0.2	336 ±34	nd <1.5	9.4 ±2.7	1.5 ±0.2	nd <0.1	2.1° <3.4 >1.0	nd <12	9.8 ±1.0	nd <0.2	nd <0.3	nd <7.7
0.072 ±0.007	0.032 ±0.003	12 ±1	0.022 ±0.002	nd <4.3	74 ±7	nd <0.1	56 ±6	nd <0.2	466 ±47	nd <1.7	11 ±1	nd <0.3	nd <0.1	nd <1.1	nd <13	16 ±3	nd <0.2	nd <0.3	nd <8.4
0.044 ±0.004	0.034 ±0.003	8.9 ±0.9	0.018 ±0.002	54 ±5	20 ±2	nd <0.1	64 ±6	nd <0.2	400 ±40	nd <1.8	9.3 ±0.9	16 ±2	nd <0.1	nd <1.2	nd <14	14 ±1	nd <0.2	nd <0.3	nd <8.8
0.045 ±0.004	0.039 ±0.004	8.7 ±0.9	0.034 ±0.003	49 ±5	45 ±4	nd <0.1	80 ±8	nd <0.2	226 ±23	nd <1.6	10 ±3	nd <0.3	nd <0.1	nd <1.1	nd <13	9.3 ±3.1	nd <0.2	nd <0.3	nd <8.2

Categories used for current corpus	Designation	Inv. no.	Artistic group	Date	Bronze type	Impurity metal group	Sample localisation	Results in wt%				
								Ag	As	Fe	Ni	Pb
Category 2 (9th c.)	Bodhisattva	MG 3820	NI	2nd half 9th c.	Medium-tin	#5	Tang under the legs	0.057 ±0.006	0.044 ±0.004	0.2 ±0.02	0.11 ±0.01	0.35 ±0.03
	Bodhisattva	MG 3824	NI	2nd half 9th c.	Medium-tin	#5	Tang under the legs	0.052 ±0.005	0.04 ±0.004	0.19 ±0.02	0.099 ±0.010	0.31 ±0.03
	Bodhisattva	MG 3827	NI	2nd half 9th c.	Medium-tin	#5	Tang under the legs	0.054 ±0.005	0.042 ±0.004	0.18 ±0.02	0.1 ±0.01	0.33 ±0.03
	Bodhisattva	MG 12895	Central Java B	late 9th c.	Medium-tin	#3	Inside the base, under the legs	0.068 ±0.007	0.34 ±0.03	0.036 ±0.004	0.02 ±0.002	0.33 ±0.03
	Vairocana (crowned)	MG 18402	Central Java B	late 9th c.	Medium-tin	#3	Base, front side, bottom edge	0.087 ±0.009	0.32 ±0.03	0.065 ±0.007	0.072 ±0.007	0.37 ±0.04
	Vairocana	MA 5936	Central Java B	late 9th c.	Medium-tin	#2	Base, back side, bottom edge	0.81 ±0.08	0.12 ±0.01	0.083 ±0.008	0.16 ±0.02	2 ±0.2
	Mahāpratisarā	MG 3624	Central Java B	late 9th c.	Medium-tin	#3	Base, front-left corner	0.1 ±0.01	0.32 ±0.03	0.015 ±0.002	0.041 ±0.004	1.5 ±0.1
							Figure, tang under the legs	0.073 ±0.007	0.36 ±0.04	0.096 ±0.010	0.044 ±0.004	0.66 ±0.07
	Kubera / Jambhala	MG 3619	Late Central Java B	late 9th c.	Medium-tin	#3	Base, front side, bottom edge	0.085 ±0.008	0.37 ±0.04	0.011 ±0.001	0.073 ±0.007	1.1 ±0.1
Category 3 (First half of the 10th c.)	Vajrasattva	MG 2173	Early East Java	late 9th–early 10th c.	Medium-tin	#3	Base, front-right corner	0.11 ±0.01	0.42 ±0.04	0.066 ±0.007	0.13 ±0.01	7.2 ±0.7
	Vairocana	MG 18290	Early East Java	1st half 10th c.	High-tin	#6	Back-right corner	0.033 ±0.003	0.14 ±0.01	0.11 ±0.01	0.18 ±0.02	0.18 ±0.02
	Vairocana	MG 3475	Early East Java	1st half 10th c.	High-tin	#6	Base, back-left corner	0.022 ±0.002	0.18 ±0.02	0.087 ±0.009	0.17 ±0.02	0.038 ±0.004
							Backpiece, parasol shaft	0.039 ±0.004	0.17 ±0.02	0.027 ±0.003	0.16 ±0.02	0.1 ±0.01
	Kubera / Jambhala	MG 3625	Early East Java	1st half 10th c.	High-tin	#6	Base, back side, bottom edge, middle	0.033 ±0.003	0.17 ±0.02	0.12 ±0.01	0.18 ±0.02	0.2 ±0.02
							Base, front-left corner	0.035 ±0.004	0.18 ±0.02	0.039 ±0.004	0.2 ±0.02	0.17 ±0.02
							Backpiece, parasol shaft	0.032 ±0.003	0.16 ±0.02	0.042 ±0.004	0.19 ±0.02	0.14 ±0.01
	Bodhisattva	MG 3822	Early East Java	1st half 10th c.	Hight-tin	#6	Inside the base, back side of the lotus	0.033 ±0.003	0.15 ±0.01	0.16 ±0.02	0.17 ±0.02	0.07 ±0.007
Category 4 (Uncertain dating)	Akṣobhya	MG 3825	NI	9th c.?	High-tin	#5	Base, bottom edge	0.041 ±0.004	0.11 ±0.01	0.27 ±0.03	0.095 ±0.009	0.11 ±0.01
	Akṣobhya	MG 3819	NI	?	Low-tin		Base, back-left corner	0.059 ±0.006	0.29 ±0.03	0.2 ±0.02	0.037 ±0.004	12 ±1
	Buddha	MG 5179	Bangladesh	?	High-tin	#5	Under the base	0.03 ±0.003	0.066 ±0.007	0.084 ±0.008	0.029 ±0.003	1.5 ±0.2
	Avalokiteśvara (?)	MG 3480	Central Java B	?	Medium-tin	#3	Inside the base, under the lotus	0.12 ±0.01	0.47 ±0.05	0.11 ±0.01	0.033 ±0.003	0.36 ±0.04

Table 2. — *Continued.*

RESULTS IN WT%				RESULTS IN WT PPM															
S	**Sb**	**Sn**	**Zn**	**Al**	**Au**	**Ba**	**Bi**	**Cd**	**Co**	**Cr**	**In**	**Mg**	**Mn**	**Mo**	**P**	**Se**	**Ti**	**V**	**W**
0.053 ±0.005	0.024 ±0.002	6.9 ±0.7	0.16 ±0.02	nd <4.5	28 ±3	nd <0.1	162 ±16	nd <0.2	70 ±7	nd <1.8	7.6 ±2.0	nd <0.3	nd <0.1	nd <1.2	nd <14	63 ±6	nd <0.2	nd <0.3	nd <8.8
0.049 ±0.005	0.022 ±0.002	6.2 ±0.6	0.14 ±0.01	nd <4.1	27 ±3	nd <0.1	142 ±14	nd <0.2	65 ±7	nd <1.6	8.4 ±2.0	nd <0.3	nd <0.1	nd <1.1	nd <13	57 ±6	nd <0.2	nd <0.3	nd <8.0
0.053 ±0.005	0.023 ±0.002	6.4 ±0.6	0.15 ±0.01	nd <4.3	27 ±3	nd <0.1	152 ±15	nd <0.2	66 ±7	nd <1.7	9.1 ±6.1	nd <0.3	nd <0.1	nd <1.1	nd <13	63 ±6	nd <0.2	nd <0.3	nd <8.4
0.02 ±0.002	0.067 ±0.007	11 ±1	nd <0.00083	164 ±16	19 ±2	nd <0.1	51 ±10	nd <0.2	nd <0.2	nd <1.7	5.6° <5.8 >1.7	5.5 ±0.5	nd <0.1	1.5° <3.7 >1.1	34° <45 >14	6.0° <7.8 >2.3	nd <0.2	nd <0.3	nd <8.5
0.028 ±0.003	0.053 ±0.005	6.8 ±0.7	0.014 ±0.001	nd <4.4	61 ±6	nd <0.1	64 ±8	nd <0.2	283 ±28	nd <1.7	7.5 ±4.3	nd <0.3	nd <0.1	nd <1.1	nd <14	16 ±2	nd <0.2	nd <0.3	nd <8.6
0.058 ±0.006	0.024 ±0.002	8.5 ±0.8	0.0073 ±0.0007	nd <4.6	196 ±20	nd <0.1	57 ±12	nd <0.2	436 ±44	nd <1.8	5.3° <6.1 >1.8	nd <0.3	nd <0.1	nd <1.2	nd <14	21 ±2	nd <0.2	nd <0.3	nd <8.9
0.037 ±0.004	0.079 ±0.008	8.6 ±0.9	0.28 ±0.03	nd <4.6	66 ±7	nd <0.1	108 ±11	nd <0.2	165 ±17	nd <1.8	6.9 ±2.1	nd <0.3	nd <0.1	nd <1.2	nd <14	13 ±2	nd <0.2	nd <0.4	nd <9.0
0.038 ±0.004	0.064 ±0.006	7.9 ±0.8	0.032 ±0.003	nd <4.3	22 ±2	nd <0.1	72 ±8	nd <0.2	739 ±74	nd <1.7	10 ±2	nd <0.3	nd <0.1	nd <1.1	nd <13	11 ±2	nd <0.2	nd <0.3	nd <8.3
0.019 ±0.002	0.12 ±0.01	9.5 ±1.0	nd <0.00083	nd <4.4	21 ±2	nd <0.1	193 ±19	nd <0.2	19 ±2	nd <1.7	5.6° <5.8 >1.7	nd <0.3	nd <0.1	nd <1.1	nd <14	17 ±3	nd <0.2	nd <0.3	nd <8.5
0.11 ±0.01	0.17 ±0.02	7.6 ±0.8	0.007 ±0.0007	nd <4.4	1 000 ±100	nd <0.1	558 ±56	nd <0.2	376 ±38	nd <1.7	14 ±3	nd <0.3	nd <0.1	nd <1.1	nd <14	16 ±2	nd <0.2	nd <0.3	nd <8.6
0.087 ±0.009	0.018 ±0.002	14 ±1	0.0097 ±0.0010	25 ±2	17 ±2	nd <0.1	37 ±6	nd <0.2	701 ±70	nd <1.6	13 ±2	nd <0.3	nd <0.1	nd <1.1	nd <13	17 ±2	nd <0.2	nd <0.3	nd <8.1
0.13 ±0.01	0.016 ±0.002	15 ±2	0.0037 ±0.0004	98 ±10	13 ±1	nd <0.1	45 ±5	nd <0.2	825 ±83	nd <1.7	13 ±4	nd <0.3	nd <0.1	nd <1.1	nd <13	20 ±2	nd <0.2	nd <0.3	nd <8.2
0.089 ±0.009	0.014 ±0.001	13 ±1	0.0057 ±0.0006	nd <4.1	98 ±10	nd <0.1	33 ±6	nd <0.2	654 ±65	nd <1.6	13 ±2	nd <0.3	nd <0.1	nd <1.1	nd <13	22 ±3	nd <0.2	nd <0.3	nd <8.0
0.074 ±0.007	0.02 ±0.002	15 ±2	0.023 ±0.002	5.5° <14.7 >4.4	25 ±2	nd <0.1	43 ±6	nd <0.2	828 ±83	nd <1.7	12 ±1	nd <0.3	nd <0.1	nd <1.1	nd <14	22 ±3	nd <0.2	nd <0.3	nd <8.6
0.069 ±0.007	0.019 ±0.002	13 ±1	0.0071 ±0.0007	nd <4.3	20 ±2	nd <0.1	39 ±8	nd <0.2	634 ±63	nd <1.7	11 ±1	nd <0.3	nd <0.1	nd <1.1	nd <13	32 ±3	nd <0.2	nd <0.3	nd <8.3
0.068 ±0.007	0.016 ±0.002	12 ±1	0.0045 ±0.0004	nd <4.3	19 ±2	nd <0.1	36 ±5	nd <0.2	622 ±62	nd <1.7	7.5 ±0.7	nd <0.3	nd <0.1	nd <1.1	nd <13	32 ±3	nd <0.2	nd <0.3	nd <8.3
0.09 ±0.009	0.017 ±0.002	14 ±1	0.0072 ±0.0007	36 ±4	18 ±2	nd <0.1	33 ±5	nd <0.2	908 ±91	nd <1.8	12 ±3	nd <0.3	nd <0.1	nd <1.2	nd <14	16 ±4	nd <0.2	nd <0.3	nd <8.9
0.09 ±0.009	0.025 ±0.002	12 ±1	0.025 ±0.002	nd <4.5	61 ±6	nd <0.1	56 ±6	nd <0.2	365 ±36	nd <1.8	11 ±4	nd <0.3	nd <0.1	nd <1.2	nd <14	25 ±2	nd <0.2	nd <0.3	nd <8.7
0.054 ±0.005	0.15 ±0.01	2.3 ±0.2	8.3 ±0.8	nd <4.4	54 ±5	nd <0.1	38 ±4	nd <0.2	62 ±6	nd <1.7	8.2 ±4.5	nd <0.3	nd <0.1	nd <1.1	nd <14	13 ±5	nd <0.2	nd <0.3	nd <8.6
0.057 ±0.006	0.025 ±0.003	15 ±1	1.9 ±0.2	nd <4.2	2 ±0.2	nd <0.1	61 ±14	0.2° <0.6 >0.2	102 ±10	nd <1.7	36 ±4	nd <0.3	nd <0.1	nd <1.1	nd <13	251 ±25	nd <0.2	nd <0.3	nd <8.2
0.045 ±0.005	0.14 ±0.01	7.1 ±0.7	0.16 ±0.02	nd <4.3	36 ±4	0.9 ±0.2	146 ±15	nd <0.2	77 ±8	nd <1.7	12 ±1	nd <0.3	nd <0.1	nd <1.1	nd <13	5.6° <7.7 >2.3	nd <0.2	nd <0.3	nd <8.4

Categories used for current corpus	Designation	Inv. no.	Artistic group	Date	Bronze type	Impurity metal group	Sample localisation	RESULTS IN WT% Ag	As	Fe	Ni	Pb
Category 4 (Uncertain dating)	Unidentified divinity	MG 3818	NI	?	High-tin	#5	Garment, right sash	0.093 ±0.009	0.11 ±0.01	0.055 ±0.005	0.12 ±0.01	0.32 ±0.03
	Lotus pedestal	MG 3827 b	NI	?	High-tin	#5	Bottom edge	0.033 ±0.003	0.12 ±0.01	0.17 ±0.02	0.088 ±0.009	0.06 ±0.006
	Viṣṇu	MG 2328	NI	?	Medium-tin		Loop inside the base	0.17 ±0.02	0.35 ±0.04	0.52 ±0.05	0.098 ±0.010	1.4 ±0.1
	Bust of divinity (Śiva?)	MG 3831	NI	?	High-tin	#7	Left arm	0.4 ±0.04	0.18 ±0.02	0.33 ±0.03	0.074 ±0.007	1.1 ±0.1

Table 2. — *Continued.*

Ag	Pb	Au	Cu	Sn	Zn	Ni	Co	Fe	Sb	As
94	0.4	0.5	4.2	0.5	<LOD	<LOD	<LOD	0.4	<LOD	<LOD

Table 3. — The silver statuette MA 3540.

Designation	Inv. no.	Technique	Sample localisation	Fe	Pb	Sn	Zn
Kubera / Jambhala	MG 3619	XRF	Base, back side	0.5	1.4	13	< 0.1
		ICP-AES	Base, front side, bottom edge	0.011	1.1	9.5	< 0.0009
Bodhisattva	MG 3820	XRF	Abdomen	2.0	1.2	28	0.07
Bodhisattva	MG 3820/24/27	ICP-AES	Tang under the legs	0.19	0.31	6.2	0.14
Avalokiteśvara (?)	MG 3479	XRF	Lotus seat, front side	3.3	2.9	49	0.1
		ICP-AES	Base, bottom edge	0.12	0.74	9.7	0.032

Table 4. — Comparison of the analyses performed by X-ray fluorescence (XRF) and inductively coupled plasma atomic emission spectrometry (ICP-AES).

	RESULTS IN WT%				RESULTS IN WT PPM															
	S	**Sb**	**Sn**	**Zn**	**Al**	**Au**	**Ba**	**Bi**	**Cd**	**Co**	**Cr**	**In**	**Mg**	**Mn**	**Mo**	**P**	**Se**	**Ti**	**V**	**W**
	0.047 ±0.005	0.033 ±0.003	14 ±1	0.042 ±0.004	nd <4.1	30 ±3	8.8 ±0.9	54 ±5	nd <0.2	526 ±53	nd <1.6	14 ±3	nd <0.3	nd <0.1	1.6° <3.5 >1.1	nd <13	27 ±3	nd <0.2	nd <0.3	nd <8.0
	0.084 ±0.008	0.017 ±0.002	20 ±2	0.029 ±0.003	nd <4.1	10 ±1	nd <0.1	77 ±9	nd <0.2	555 ±56	nd <1.6	24 ±3	nd <0.3	nd <0.1	nd <1.0	nd <13	24 ±2	nd <0.2	nd <0.3	nd <7.9
	0.11 ±0.01	0.051 ±0.005	7.9 ±0.8	1 ±0.1	nd <4.2	126 ±13	nd <0.1	2085 ±209	nd <0.2	639 ±64	nd <1.7	15 ±6	nd <0.3	nd <0.1	nd <1.1	nd <13	40 ±4	nd <0.2	nd <0.3	nd <8.2
	0.081 ±0.008	0.034 ±0.003	20 ±2	0.046 ±0.005	nd <4.3	851 ±85	nd <0.1	62 ±6	nd <0.2	833 ±83	nd <1.7	19 ±2	nd <0.3	nd <0.1	nd <1.1	nd <13	16 ±2	nd <0.2	nd <0.3	nd <8.3

Categories used for current corpus	Statue	Decorated parts	Types of decoration	Could be examined	Could not be examined
Category 2 (9th c.)	Jambhala MG 3814	Features of the face Costume (fig. 37d) Cushion Pedestal (piece of cloth hanging in front [fig. 38] and eyes of the animals [fig. 41a])	Lines Circles and lines Lines Lines	- X X X	X (not accessible to microscope) - - -
	Kubera / Jambhala MG 3813	Costume (fig. 37c) Attribute in left hand	Circles and lines Lines	- -	X (dust) X (dust)
	Ten-armed Avalokiteśvara MG 3816	Halo Features of the face / hair Costume / belt	Lines Lines Lines	- X -	X (not accessible to microscope) - X (corrosion/dust)
	Bodhisattva MA 3540	Costume	Dots	X	-
	Bodhisattva MG 3820	Features of the face / headdress Costume	Lines and dots Lines and dots	- -	X (corrosion/dust) X (corrosion/dust)
	Bodhisattva MG 3824	Features of the face / hair Costume (fig. 41d)	Lines Lines and dots	- X	X (not accessible to microscope) -
Category 3 (First half of the 10th c.)	Vairocana MG 3475	Backpiece (fig. 36a) Costume (fig. 37a) Lotus (petals) and cushion	Lines Lines Dots and lines	- - X	X (not accessible to microscope) X (not accessible to microscope) -
	Kubera / Jambhala MG 3625	Backpiece (fig. 36b) Costume Lotus (petals) and cushion (figs. 37b, 41b)	Lines Dots and lines Dots and lines	- - X	X (not accessible to microscope) X (not accessible to microscope) -
	Bodhisattva MG 3822	Backpiece (fig. 36c) Costume (fig. 39a) Lotus (petals and stamens) and cushion (figs. 39, 40)	Lines Circles and lines Circles and lines	- - X	X (not accessible to microscope) X (not accessible to microscope) -

Table 5. — The nine statues examined by digital microscopy.


cm
5
a.

Fig. 1 — Ten-armed Avalokiteśvara, first half of 9th c., unknown provenance. Bronze, H. 34 cm. Musée Guimet, inv. no. MG 3816, front view (a.) and back view (b.). Photo: © C2RMF/Anne Maigret.

Fig. 2 — Jambhala, first half of 9th c., unknown provenance. Bronze, H. 28 cm. Musée Guimet, inv. no. MG 3814, front view (a.) and back view (b.). Photo: © C2RMF/Anne Maigret.

Fig. 3 — Kubera / Jambhala, first half of 9th c., unknown provenance. Bronze, H. 17 cm. Musée Guimet, inv. no. MG 3813, front view. Photo: © C2RMF/ Anne Maigret.

Fig. 4 — Avalokiteśvara (?), 8th–early 9th c., unknown provenance. Bronze, H. 8.5 cm. Musée Guimet, inv. no. MA 507, front view. Photo: © C2RMF/Anne Maigret.

Fig. 5 — Vasudhārā, 8th–early 9th c., unknown provenance. Bronze, H. 12 cm. Musée Guimet, inv. no. MG 3628, front view. Photo: © C2RMF/Anne Maigret.

Fig. 6 — Brahmā, 8th–early 9th c., unknown provenance. High-tin bronze, H. 15 cm. Musée Guimet, inv. no. MG 3627, front view. Photo: © C2RMF/Anne Maigret.

Fig. 7 — Avalokiteśvara, 8th–early 9th c., unknown provenance. High-tin bronze, H. 17 cm. Musée Guimet, inv. no. MG 3620, front view. Photo: © C2RMF/Anne Maigret.

Fig. 8 — Bodhisattva, second half of 9th c., unknown provenance. Silver, H. 6.5 cm. Musée Guimet, inv. no. MA 3540, front view. Photo: © C2RMF/Anne Maigret.

Fig. 9 — Vasudhārā, second half of 9th c., unknown provenance. Bronze, H. 13 cm. Musée Guimet, inv. no. MG 2255, front view. Photo: © C2RMF/Anne Maigret.

Fig. 10 — Vairocana, late 9th c., unknown provenance. Bronze, H. 10.5 cm. Musée Guimet, inv. no. MA 5936, front view. Photo: © C2RMF/Anne Maigret.

Fig. 11 — Kubera / Jambhala, late 9th c., unknown provenance. Bronze, H. 17 cm. Musée Guimet, inv. no. MG 3619, front view. Photo: © C2RMF/Anne Maigret.

Fig. 12 — Kubera / Jambhala, first half of 9th c., unknown provenance. High-tin bronze, H. 13 cm. Musée Guimet, inv. no. MG 3815, front view. Photo: © C2RMF/Anne Maigret.

Fig. 13 — Triad of bodhisattvas, second half of 9th c., unknown provenance. Bronze, H. 9.5 and 11 cm. Musée Guimet, inv. no. MG 3820 (a.), MG 3824 (b.), and MG 3827 (c.), front view. Photo: © C2RMF/Anne Maigret.

Fig. 14 — Vajrasattva, late 9th–early 10th c., unknown provenance. Bronze, H. 12 cm. Musée Guimet, inv. no. MG 2173, front view (a.) and back view (b.). Photo: © C2RMF/Anne Maigret.

Fig. 15 — Vairocana, first half of 10th c., unknown provenance. High-tin bronze, H. 15.5 cm. Musée Guimet, inv. no. MG 18290, front view. Photo: © C2RMF/Anne Maigret.

Fig. 16 — Vairocana, first half of 10th c., unknown provenance. High-tin bronze, H. 12 cm. Musée Guimet, inv. no. MG 3475, front view. Photo: © C2RMF/Anne Maigret.

Fig. 17 — Kubera / Jambhala, first half of 10th c., unknown provenance. High-tin bronze, H. 18 cm. Musée Guimet, inv. no. MG 3625, front view. Photo: © C2RMF/Anne Maigret.

Fig. 18 — Bodhisattva, first half of 10th c., unknown provenance. High-tin bronze, H. 17.5 cm. Musée Guimet, inv. no. MG 3822, front view (a.) and back view (b.). Photo: © C2RMF/Anne Maigret.

Fig. 19 — Bust of deity (Śiva?), uncertain dating, unknown provenance. High-tin bronze, H. 13 cm. Musée Guimet, inv. no. MG 3831, front view. Photo: M. Mechling.

Fig. 20 — Avalokiteśvara (?), uncertain dating, unknown provenance. Bronze, H. 13.5 cm. Musée Guimet, inv. no. MG 3480, front view. Photo: © C2RMF/Anne Maigret.

Fig. 21 — Mahāpratisarā, *ca.* late 9th c., unknown provenance. Bronze, H. 18 cm. Musée Guimet, inv. no. MG 3624, front view (a.) and bottom view (b.) showing the tang under the divine figure attached to the pedestal and protruding. Photo: © C2RMF/Anne Maigret.

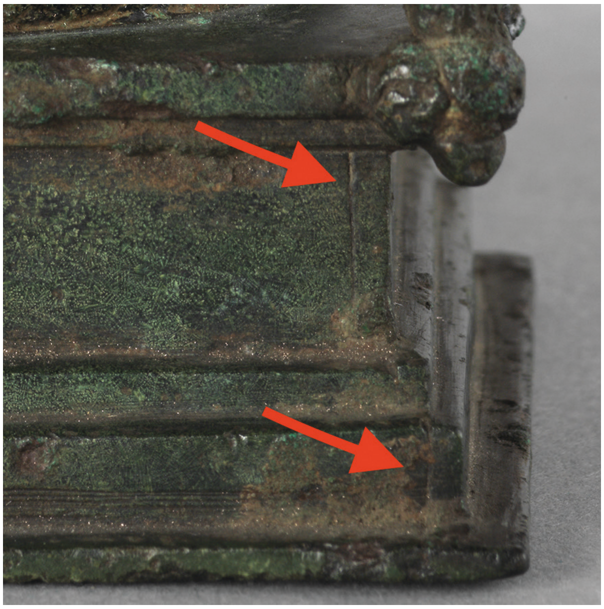


Fig. 22 — Detail of MG 18290 (fig. 15), showing incised lines on the edge of the pedestal, which could be remains of assembly marks in the wax model. Photo: © C2RMF/Anne Maigret.

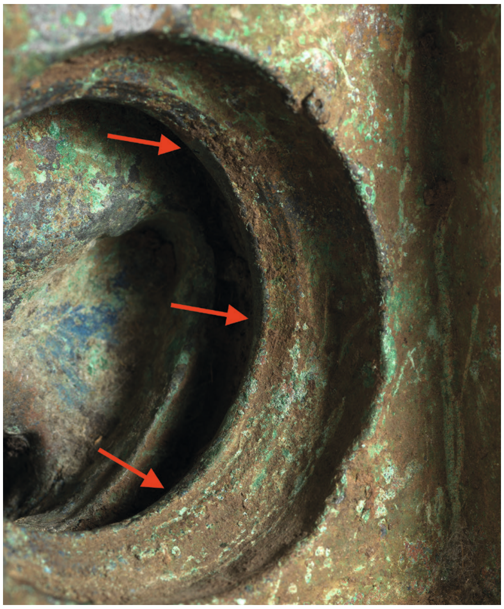
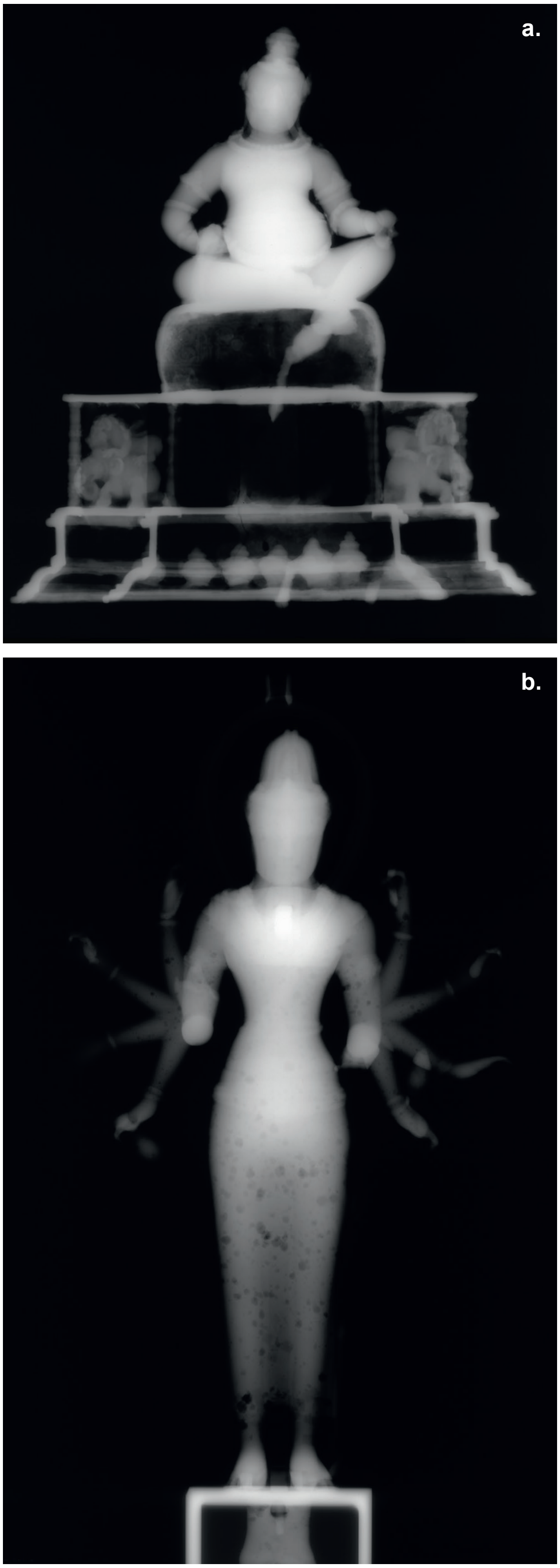


Fig. 23 — Detail of MG 3822 (fig. 18), showing the seam of two bands sealed together in the wax to model the lotus seat. Photo: © C2RMF/Anne Maigret.

Fig. 24 — Back views of MG 3619 (fig. 11) (a.) and MG 2255 (fig. 9) (b.), showing uneven marks where the back-pieces meet the pedestals. Photo: © C2RMF/Anne Maigret.

Fig. 25 — X-ray radiographs (front view) of MG 3814 (fig. 2) (a.) and MG 3816 (fig. 1) (b.), showing that the statues are solid cast. The concentration of porosity in the legs of MG 3816 (b.) supports the hypothesis of an upside down casting. Photo: © C2RMF/ Elsa Lambert.



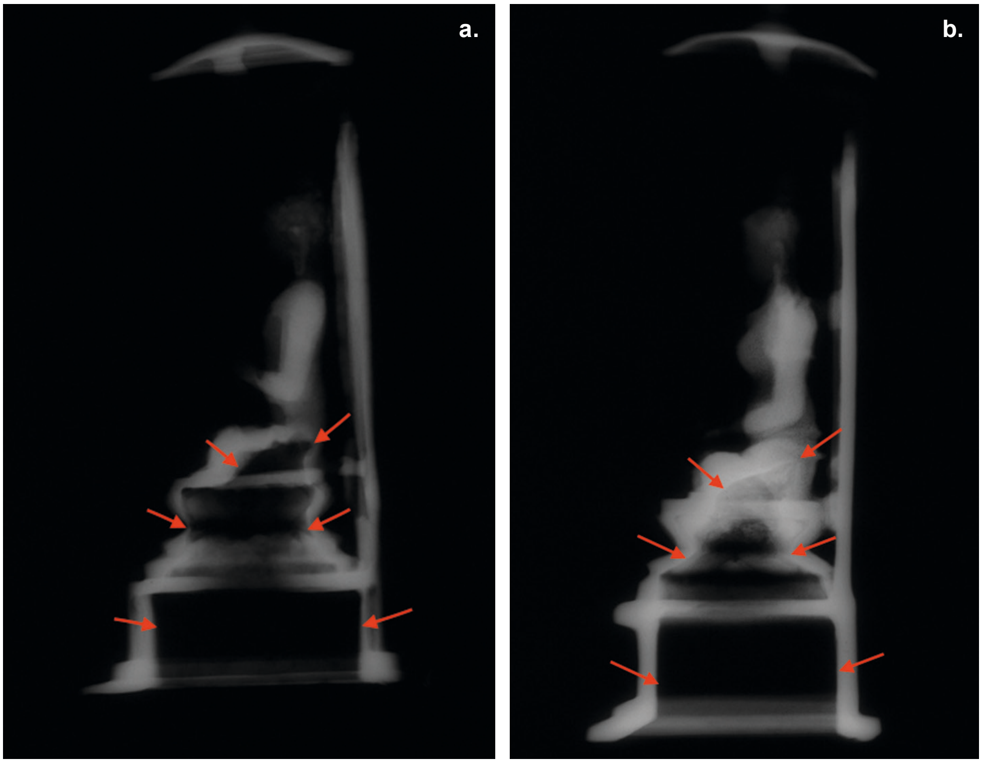


Fig. 26 — X-ray radiographs (left side view) of MA 5936 (fig. 10) (a.) and MG 2255 (fig. 9) (b.), showing the inner cavity in the pedestal, lotus and legs, as delimited by the red arrows. Photo: © C2RMF/Elsa Lambert.

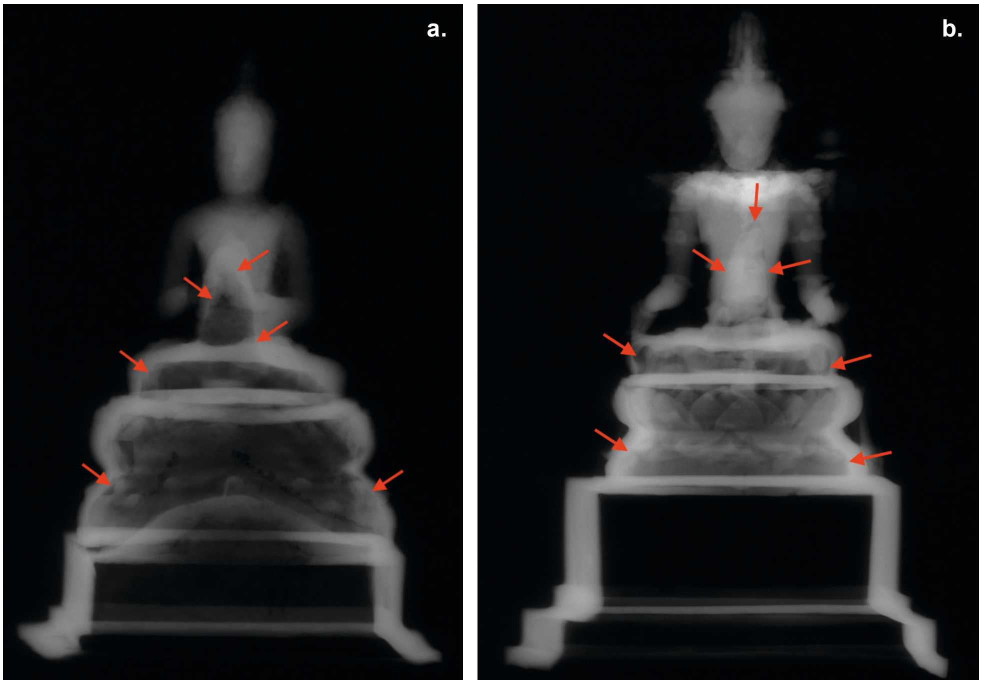


Fig. 27 — X-ray radiographs (front view) of MG 3475 (fig. 16) (a.) and MG 3822 (fig. 18) (b.), showing the inner cavity in the pedestal, lotus, legs and going up into the abdomen, as delimited by the red arrows. Photo: © C2RMF/Elsa Lambert.

Fig. 28 — Details of the pouring channels located at the bottom of MG 3630 (a. front view; b. bottom view) and MG 3813 (fig. 3) (c. bottom view). Photo: © C2RMF/Anne Maigret.

Fig. 29 — MG 3620 (fig. 7) (left side view) and corresponding radiograph showing possible remains of the gating system: the loop at the back of the head and the lump at the rear of the pedestal (as shown by the red arrows). Their location at the back of the image, together with the very flat morphology of the statue, suggest a horizontal casting. Photo: © C2RMF/Anne Maigret & Elsa Lambert.

Fig. 30 — Secondary castings on MG 3475 (fig. 16) (a. upper part of the back-piece, dark brown colour), and MG 3625 (fig. 17) (b. lower part of the pedestal, dark green colour). Photo: © C2RMF/Anne Maigret.

Fig. 31 — Secondary casting on the front part of the pedestal of MG 3814 (fig. 2) (a. darker green colour) as well as its corresponding interior face (b.) with the remains of two pouring channels used for the secondary casting (see arrows). Photo: © C2RMF/Anne Maigret.

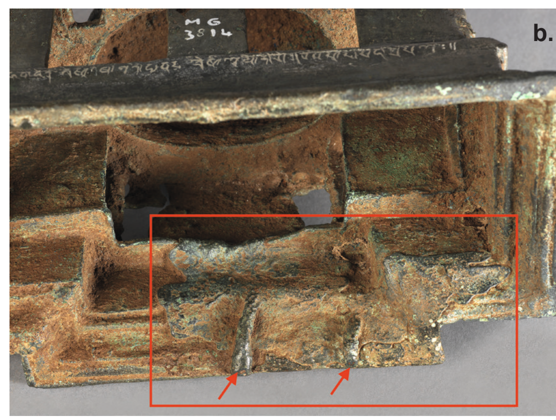


Fig. 32 — Kubera / Jambhala, first half of 9th c., unknown provenance. Bronze, H. 16 cm. Musée Guimet, inv. no. MG 3629, front view (a.) and back view (b.) showing the thick, black repairing material at the back. Photo: © C2RMF/Anne Maigret.

Fig. 33 — Detail of MG 3816 (fig. 1) showing the repair patches on the lower part of the garment. Photo: © C2RMF/Anne Maigret.

Fig. 34 — Detail of the face of MG 3827 (fig. 13c) showing the black cracked surface. Photo: © C2RMF/Anne Maigret.

Fig. 35 — Bodhisattva, second half of the 9th c., unknown provenance. Bronze, H. 10.5 cm. Musée Guimet, inv. no. MG 3479, front view (a.) and detail of the black cracked surface (b.). Photo: © C2RMF/Anne Maigret.

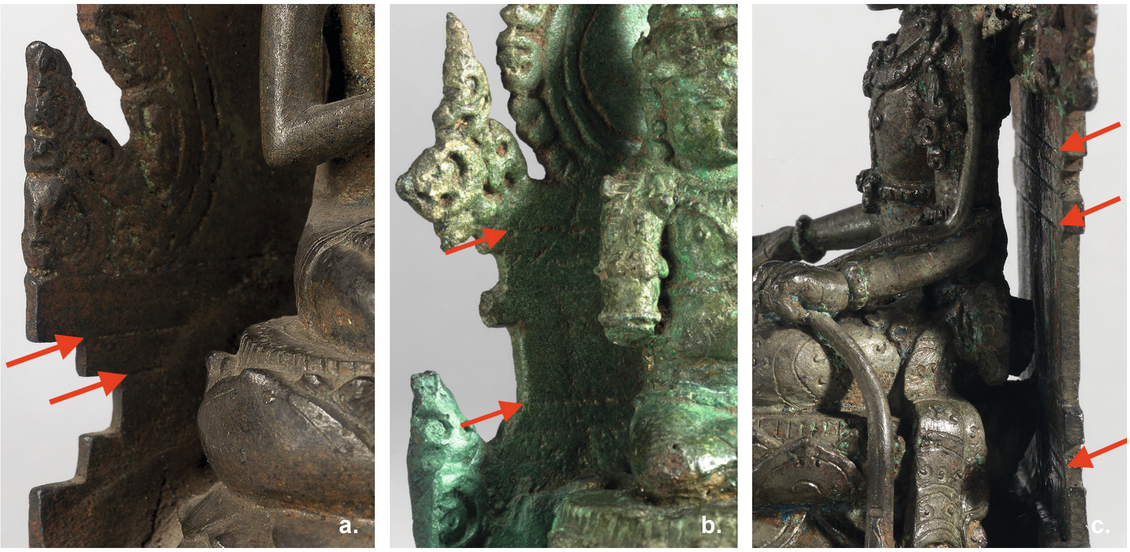
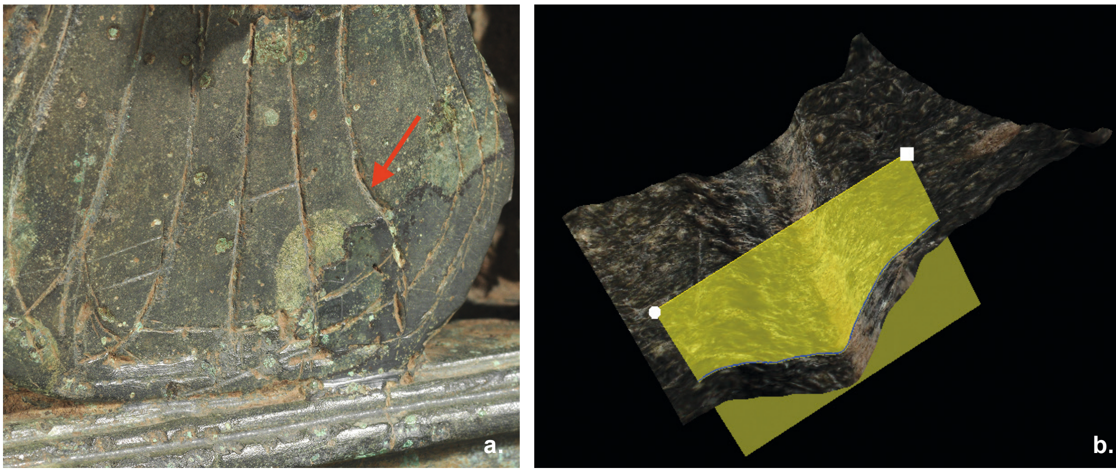
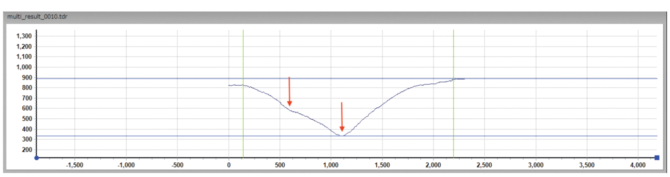


Fig. 36 — Details of MG 3475 (fig. 16) (a.), MG 3625 (fig. 17) (b.), and MG 3822 (fig. 18) (c.) showing the incised decorative lines traced on the backpiece in the wax before casting. Photo: © C2RMF/Anne Maigret.

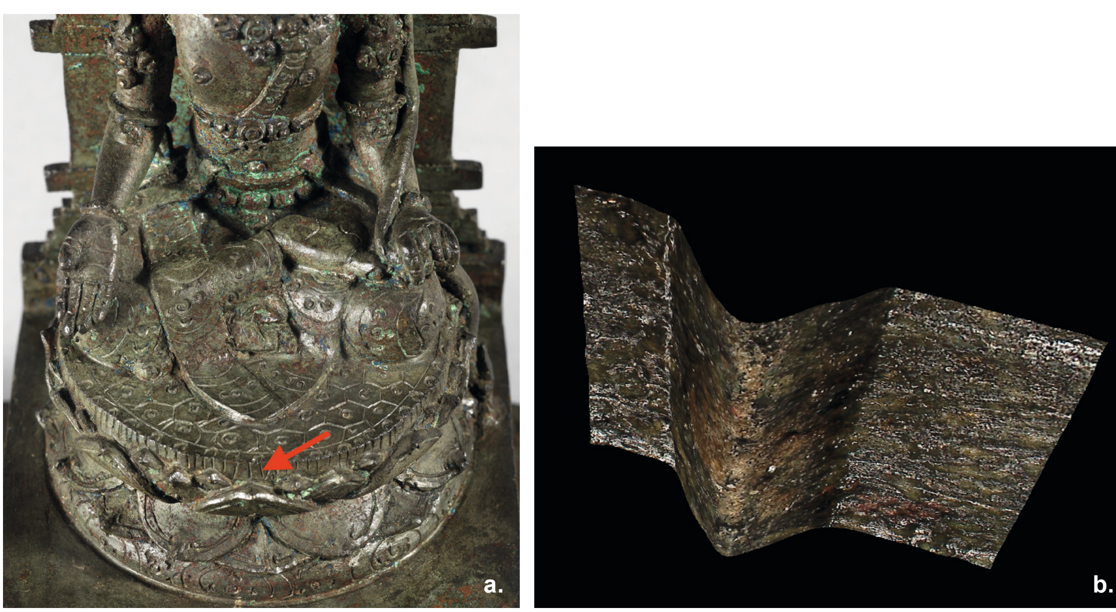
Fig. 37 — Details of incised decorative patterns (dots, lines, and circles) on the lotuses and cushions of MG 3475 (fig. 16) (a.), MG 3625 (fig. 17) (b.), as well as on the garment of MG 3813 (fig. 3) (c.), and MG 3814 (fig. 2) (d.). Photo: © C2RMF/Anne Maigret.

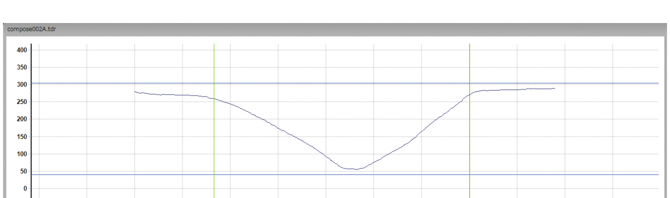




c.

Fig. 38 — Detail of MG 3814 (fig. 2), showing the decoration of the piece of cloth in front of the pedestal and the corresponding 3D reconstruction of an engraved line using digital microscopy (see the red arrow on the photograph), as well as its profile showing the parallel traces of two tools (red arrows). Photo: © C2RMF/Anne Maigret & Mathilde Mechling.





c.

Fig. 39 — Detail of MG 3822 (fig. 18), showing the decoration of the lotus and the 3D reconstruction of an engraved line using digital microscopy (see the red arrow on the photograph), as well as its profile showing the 'V' profile typical of engraving. Note that the angle of the groove, and thus of the tool, can be measured. Photo: © C2RMF/Anne Maigret & Mathilde Mechling.

Fig. 40 — Detail of MG 3822 (fig. 18) showing the engraved lines on the top of the lotus. Photo: © C2RMF/Mathilde Mechling.

Fig. 41 — Details of engraved lines on the right elephant's eye (on the pedestal) of MG 3814 (fig. 2) (a.), punch-marked dots on the cushion supporting the lotus of MG 3625 (fig. 17) (b.), punch-marked circles on the costume of MG 3814 (fig. 2) (c.), and punch-marked dots and engraved lines on the costume of MG 3824 (fig. 13b) (d.). Photo: © C2RMF/Mathilde Mechling.

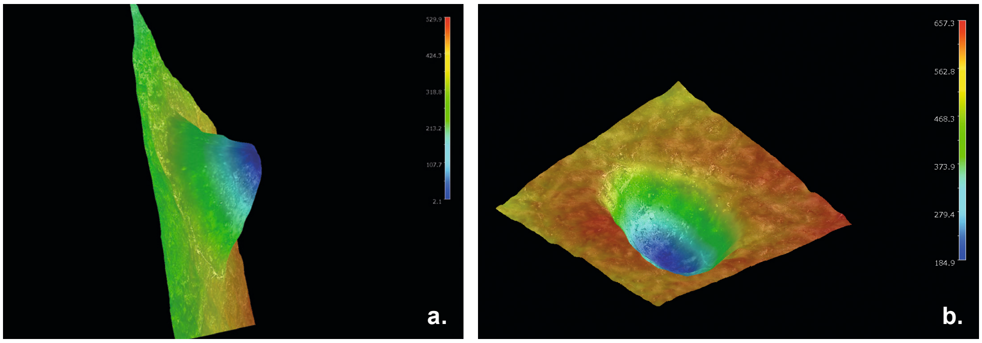


Fig. 42 — 3D reconstruction of a punch-marked dot on MG 3475 (fig. 16) (a.) and MG 3625 (fig. 17) (b.). Photo: © C2RMF/Mathilde Mechling.

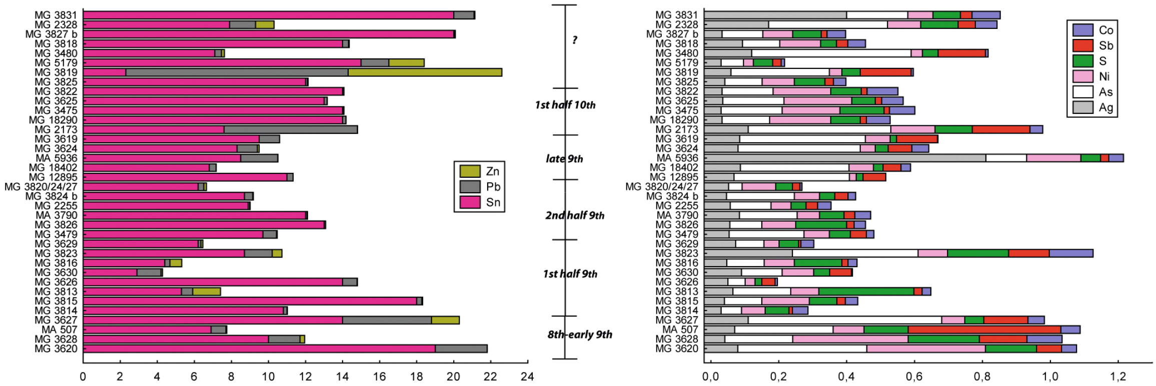


Fig. 43 — Elemental composition of the statues sorted by chronology. Inventory numbers are reported on the vertical axis of both graphs. On the left graph, tin (Sn), lead (Pb), and zinc (Zn) contents are reported for each objet. Contents are cumulated (for example, at the bottom MG 3620 shows around 19 wt.% Sn and about 3 wt.% Pb). On the right graph, main impurities are reported. All results in wt.%, ICP-AES analysis. Photo: © C2RMF/David Bourgarit.

Fig. 44 — View of the bottoms of the statues MG 3625 (fig. 17) (a.), MG 18290 (fig. 15) (b.), and MG 2173 (fig. 14) (c.), filled with the consecration deposits. Some objects (pointed by red arrows) are visible to the naked eye. Photo: © C2RMF/Anne Maigret.

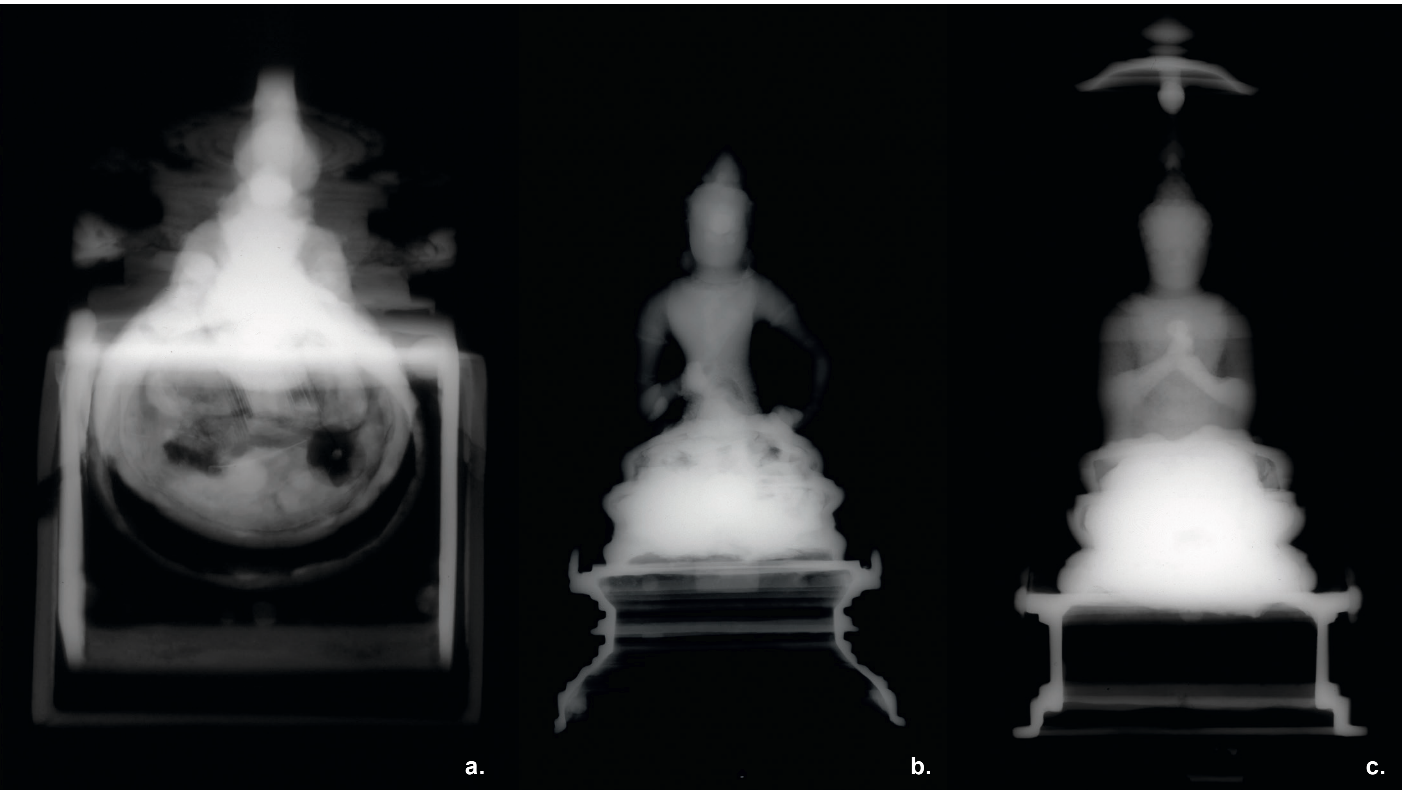


Fig. 45 — X-ray radiographs of MG 3625 (fig. 17) (a.), MG 2173 (fig. 14) (b.), and MG 18290 (fig. 15) (c.). The lead-tin material sealing the consecration deposits prevents the identification of the objects contained inside. Only for MG 3625 the white stone bead is visible (a black circle on the radiograph, see fig. 44a). Photo: © C2RMF/Elsa Lambert.

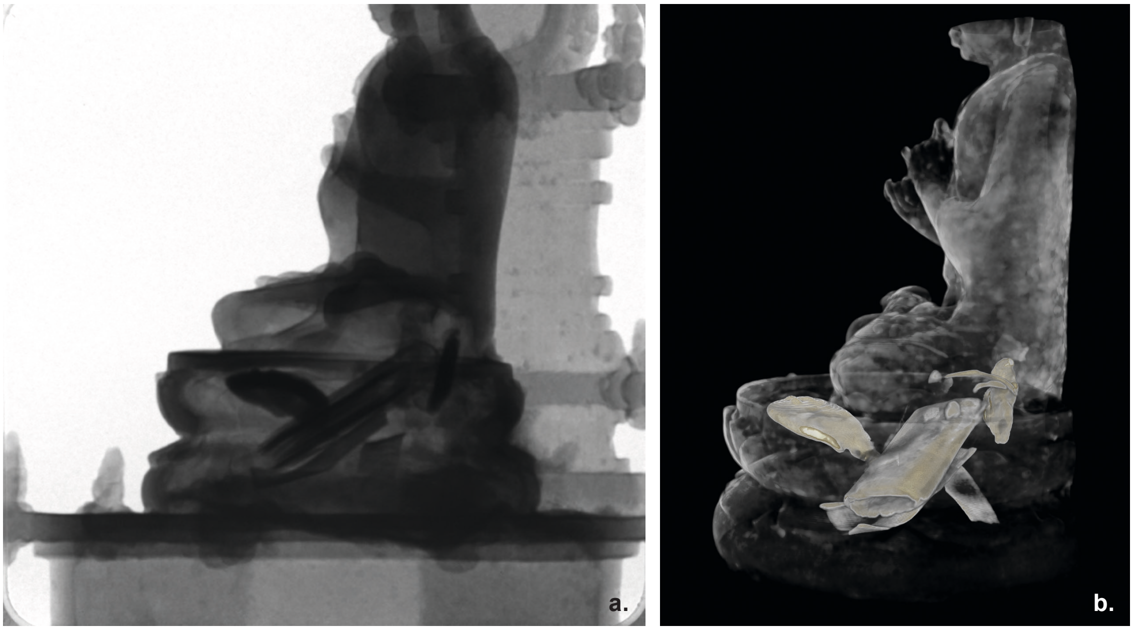


Fig. 46 — Neutron radiograph (a.) and tomography (b.) of MG 18290 (fig. 15) showing the objects of the consecration deposit inside the statue. Photo: © CEA–CNRS/Frédéric Ott (a.) & C2RMF/Elsa Lambert (b.).

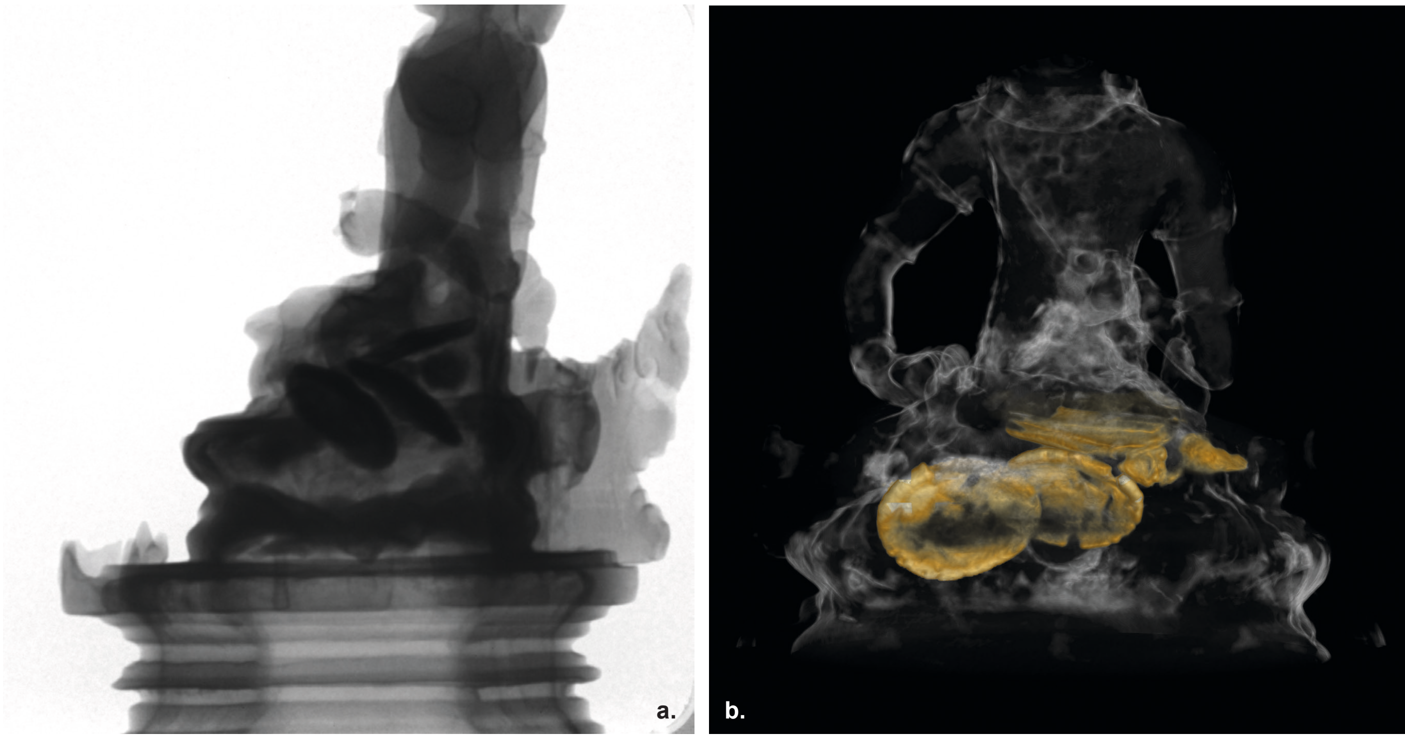


Fig. 47 — Neutron radiograph (a.) and tomography (b.) of MG 2173 (fig. 14) showing the objects of the consecration deposit inside the statue. Photo: © CEA–CNRS/Frédéric Ott (a.) & C2RMF/Elsa Lambert (b.).

Fig. 48 — Buddha, uncertain dating (modern period), unknown provenance. Bronze, H. 15 cm. Musée Guimet, inv. no. MG 5179, front view (a.) and bottom view (b.) showing the absence of cavity inside the pedestal proving that it is a forgery. Photo: © C2RMF/Anne Maigret.