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Ceremonial helmet, Chinese, mid-18th century, steel, copper, gold, silk and metallic thread, height 55.2 cm.
Bequest of George C. Stone, 1935 (36.25.5a), The Metropolitan Museum of Art

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ENLIGHTENED TECHNOLOGY: CASTING DIVINITY IN THE GUPTA AGE

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"Inside the enclosure there was a temple…with stone steps and brick niches arranged in about a hundred tiers, each containing a golden image of the Buddha carved in intaglio. In the chamber there was a life-size bronze statue of the Buddha turning the Wheel of the Dharma." (Li, 1995, p. 85)

"To the south was the bronze temple built by King Śīlāditya, but the construction was unfinished. Otherwise it would have been more than a hundred feet in height, according to a careful study of its design. More than two hundred paces to the east of the city was a bronze standing image of the Buddha, more than eighty feet high…" (Li, 1995, p. 100)

Introduction

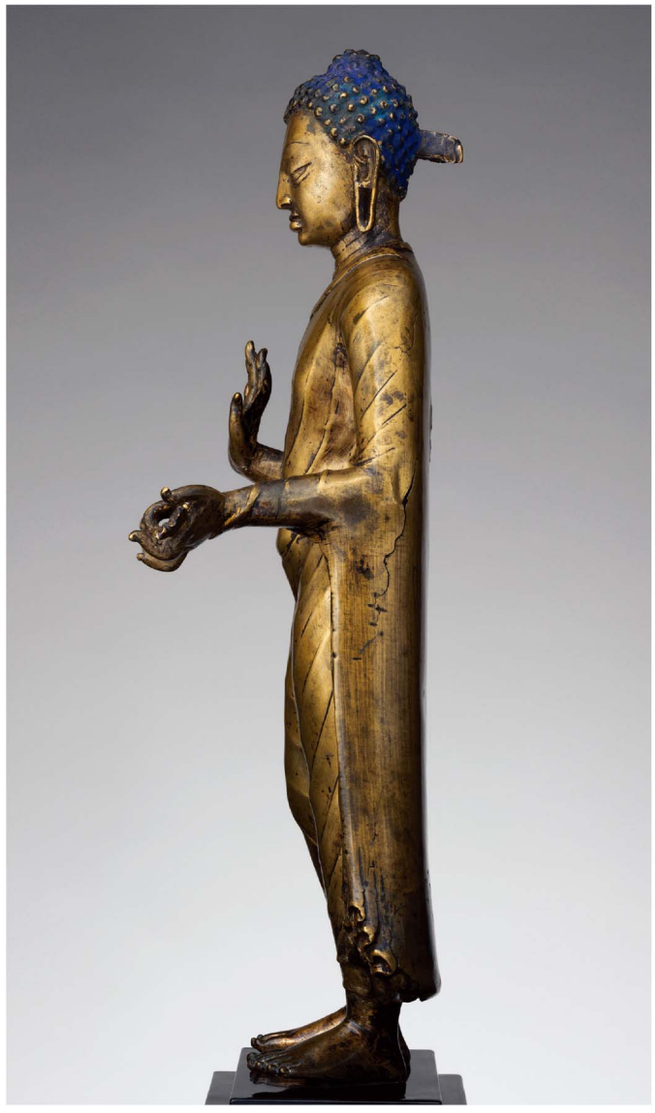
These and other observations reported by the Chinese monk Xuanzang from his travels in India during the first half of the 7th century hint at a wealth of metal statuary, in some cases monumental in scale, of which merely a small fraction has survived. Brown (2014, pp. 8–9), for example, cites Joshi's count of only thirty-two extant metal images from India that date to the 5th–6th century. Of these, twenty-seven are representations of the Buddha. Virtually no works in precious metals are known. The melting and recycling of metals, the decline of Buddhism, and the destruction of monasteries during the Muslim invasions combined to diminish the corpus of Buddhist images produced during the Gupta period (circa 320–550) and its aftermath into the 8th century. The extant images generally have come to light divorced from their original locations in temples or private devotional settings, and most survive because they were transported for safety to Himalayan monasteries or repurposed for veneration as Hindu deities (Guy, 2016). The Sultanganj Buddha, recovered from the ruins of a monastery during the 19th century excavation of a railway in Bihar (Harris, 1864), is an exception. Buddha images related in posture and gesture have also survived in regions that were outside Gupta political sovereignty: South India, the Himalayas, Sri Lanka, Cambodia and Thailand. Indeed, metal devotional images, being highly portable, are known to have played an important role in the dissemination of Buddhist thought, artistic style and iconography throughout Asia.

The most common surviving Gupta-style metal sculptures are representations of the standing Buddha. Following traditions developed in stone sculpture at Maratha and Sarnath (**1**), the Buddha is presented in a frontal pose with his right hand raised shoulder height in *abhaya mudra*, a gesture of protection. In his left hand, he holds the outer edge of his simple monastic robe (**2**). The weight of the figure rests mainly on the left leg, with the right leg slightly bent. His physical existence is secondary to his spiritual nature.

1 Buddha, Gupta period, about 475, India, Uttar Pradesh, Sarnath area, sandstone, height 86.7 cm, width 44.8 cm, depth 5.2 cm. Asia Society, New York: Mr and Mrs John D. Rockefeller 3rd Collection, 1979.5

While scholarship has focused on the Gupta age as the quintessential expression of classical Indian art, and on the key role of metal icons in the dissemination and development of Buddhist and Hindu practice, surprisingly little attention has been devoted to metalworking technology of

2 Buddha, India, probably Bihar, early 7th century, bronze, with later blue pigment, height 47 cm, width 15.6 cm, depth 14.3 cm. The Metropolitan Museum of Art, New York, Purchase, Florance Waterbury Bequest, 1969 (69.222). Image © The Metropolitan Museum of Art



3 Buddha (left profile view of 2). A tang for attaching a mandorla extends from the back of the head. Image © The Metropolitan Museum of Art

this period. Indeed, to the authors' knowledge, the distinctive, in some ways unique, casting method practised in Gupta and post-Gupta India described in this article has never been fully investigated. This relative neglect is particularly striking in view of the attention given to the casting traditions of South India, Thailand, Cambodia and the Himalayan Kingdoms. To some extent, the disparity probably derives from the limited number of surviving Gupta-style metal images, as well as to the appeal to scholars of the traditional casting industries surviving in places such as Tamil Nadu, Nepal and Thailand.

This article will examine bronze Gupta-style standing Buddha images from North India and consider how casting practice developed to meet the particular challenges of producing three-dimensional, but relatively shallow, figures with expansive draperies (3). All have a pronounced frontal orientation, and the backs of the figures, with the exception of their heads are summarily finished without detail (4). A total of four images in the collections of The Metropolitan Museum of Art (2), the Asia Society Museum (New York) (5, 6) and the Cleveland Museum of Art (7) were examined and radiographed. Spot analyses and line scans were carried out using X-ray fluorescence spectroscopy (XRF). Unpublished technical reports about the over life-size Sultanganj Buddha, now in the Birmingham Museum and Art Gallery, England (8), and a Buddha image owned jointly by the Victoria and Albert Museum and the British Museum, London (9), are sources of additional insights. A bronze standing Buddha image, currently on loan to The Metropolitan Museum, provides valuable visual clues relating to manufacture (Guy, 2016, figs 1, 11 and cover).[1] Buddha images from Thailand in The Metropolitan Museum (10) (Becker, Strahan and O'Connor, 2014) and the Rietberg Museum, Zurich (11) and an image from South India in the Museum of Fine Arts, Boston (12) (Gänsicke, 2016), attest to the transfer of innovations in North Indian casting technology to regions to the south and east. The ten figures range in size from approximately 36 to 230 cm.[2]

All of the sculptures discussed here were made using a direct hollow lost-wax casting technique. The production of each unique figure began with the modelling of a refractory core, generally a mixture of sand, clay and organic material. The core was clad with wax sheets and additional wax was applied to create solid details, such as the feet, hands or fingers and hair. A wax gating system was used to create channels that would allow for the introduction of

4 Buddha (reverse of **2**).
Image © The Metropolitan Museum of Art

molten metal and for gases to disperse. The wax model was then encased in a refractory investment and heated in a furnace. After the wax melted and had been poured out, the temperature in the furnace was raised to fire the investment, and molten metal was poured into the cavity.

One of the challenges presented by the hollow lost-wax method is the necessity of supporting the core within the investment after the wax has been melted out. Often, core supports made from hammered metal rods are inserted through the wax layer into the core and secured in the investment. In some cases, the core is built around a metal armature, which may extend into the investment and support the core during casting. Sometimes the core extends through the wax layer in one or more areas, engaged and held in place by the investment.

Although there is insufficient evidence for precise dating—only the figure in Cleveland is inscribed—it is generally accepted that metal icons such as these were produced during the declining decades of the Gupta Empire and its aftermath in the 6th to 8th centuries (Brown, 2014; Guy, 2016).[3] There is little in the way of earlier material to examine and, therefore, no ready antecedents for some of the peculiarities of manufacture. To what extent the appearance of these metal icons, seemingly divorced from a gradual chain of technological development, is a circumstance of survival, or the result of a major change in religious practice (e.g. Brown, 2014), is not certain. What is apparent is that the ten standing Buddha images enumerated here, whether from North or South India, or Thailand, share a distinctive casting feature, rarely, if ever, encountered elsewhere, developed to meet the particular challenges of casting the form, drapery and posture of these images, and related to their intended devotional setting.

Visual Examination and Computed Radiography

The figures display varying degrees of corrosion. Whereas some clearly retain traces of archaeological corrosion products that attest to an extended period of burial, others have substantially metallic surfaces and may have been buried for a shorter period, or not at all.

As noted earlier, the backs of the figures are plain and undetailed, except for their heads.[4] Many have surviving metal tangs for mounting a mandorla (see **3**, **4**). Indeed, the surface feature most commonly observed on the backs of the figures is the poor quality of the casting, demonstrated by the presence of porosity. Pores result when gases in the melt or within the investment are trapped in the metal as it cools. This generally occurs in the last regions to solidify, so the localisation of porosity on the reverse of the figures indicates that they were cast face down. The orientation most likely would not have been strictly horizontal; rather, the investment was tilted downwards to ensure the flow of metal to the most important part of the image, the head. The consequences of the extensive porosity can be recognised on the backs of many of the figures (**4**, **13**), and in all of the radiographs: the poor quality of the casting necessitated large and/or multiple cast-in repairs (**14**, **15a**). With at least one exception, the image in the Cleveland Museum, there are no traces on the figures of the external gating system used to deliver metal to the investment and to allow gases to vent.

Numerous core supports of unalloyed copper, to judge

[1] Other examples of this type in museums outside of India are in the Norton Simon Museum, Pasadena (F.1972.01.S.), height 41.9 cm; and the Los Angeles County Museum (M.70.17), height 39.4 cm. Several metal Gupta-style standing Buddha images in the National Museum in New Delhi and other India museums are featured in *L'âge d'or*, 2007, pp. 252–257.

[2] The dimensions reported for these figures are intended to illustrate how broadly they range in size, but do not account for the presence or absence of tangs. The image in the Cleveland Museum is the only one to have an original base, which appears to have been integrally cast. The figure itself measures 35 cm, and with the base, a total of 46.5 cm. The image in the Rietberg Museum has lost its feet, but it can be judged to fall in the lower end of this range.

[3] The dates used here in the photo captions reflect their home institutions' catalogue information; several of these are likely to be on the early side. Material identifications, reflecting results of analyses carried out in conjunction with this study (e.g. for the two figures in the Asia Society Museum), or discovered in museum records or publications (e.g. figures in the Museum of Fine Arts, Boston, and in the Victoria and Albert Museum), are included in the captions.

[4] An exception is the South Indian image in the Museum of Fine Arts, Boston, on which the upper edge of the Buddha's cloak is visible (https://www.mfa.org/collections/object/standing-buddha-16227; accessed February 2019).

5 Buddha, India, 6th century, bronze, height 49.2 cm, width 17 cm, depth 12.7 cm. Asia Society, New York: Mr and Mrs John D. Rockefeller 3rd Collection (1979.9)

6 Buddha, India, probably Bihar, 6th century (?), copper alloy (confirmed as bronze on basis of XRF surface analysis), height 68.6 cm, width 27.3 cm, depth 17.8 cm. Asia Society, New York: Mr and Mrs John D. Rockefeller 3rd Collection (1979.8)

7 Standing Buddha, north-eastern India or Nepal, Gupta/Licchavi period, 591, bronze, height 46.5 cm, width 15.4 cm, depth 13.4 cm. Cleveland Museum of Art, Cleveland, Purchase from the J.H. Wade Fund (1968.40). © The Cleveland Museum of Art

8 Sultanganj Buddha, India, Bengal, Sultanganj, 6th–7th century, bronze, height 226 cm. Birmingham Museum and Art Gallery, Birmingham, Presented by Samuel Thornton, 1864 (1885A1116)

9 Buddha, India, probably Bihar, late 6th–early 7th century, copper alloy (reported as bronze in Northover n.d.), height 38 cm including tangs, width 14 cm. Victoria and Albert Museum, London, Purchased jointly by the Victoria and Albert Museum and the British Museum with the assistance of the Heritage Lottery Fund, The Art Fund, the British Museum Brooke Sewell Fund, the Friends of the V&A and private donors (IS.3-2004)

10 Standing Buddha, Thailand, Nakhon Pathom province, Mon-Dvaravati period, 8th–9th century, bronze, with later gilding, height 68.6 cm, width 26 cm, depth 13.7 cm. The Metropolitan Museum of Art, New York, Fletcher Fund, 1959 (59.149). Image © The Metropolitan Museum of Art

11 Standing Buddha, Thailand, Dvaravati period, 8th–9th century, bronze, height 34 cm. Rietberg Museum, Zurich, Legat Hans-Ulrich Jordi Rietberg (2006.70)

12 Standing Buddha, India, possibly Buddhapad, near Vijayawada, Andhra Pradesh, Post-Gupta period, circa 7th century, copper (reported as bronze in Gänsicke, 2016), height 50.3 cm, width 12.7 cm, depth 10.2 cm. Museum of Fine Art, Boston, 1921, Gift of the Government Museum, Madras (21.1504)

13 Buddha, reverse of Asia Society (1979.9) (**5**). Note possible location of square opening on the back of the head that accommodated a core extension or a tang from a mandorla, and the irregular surface marked by multiple cast-in repairs

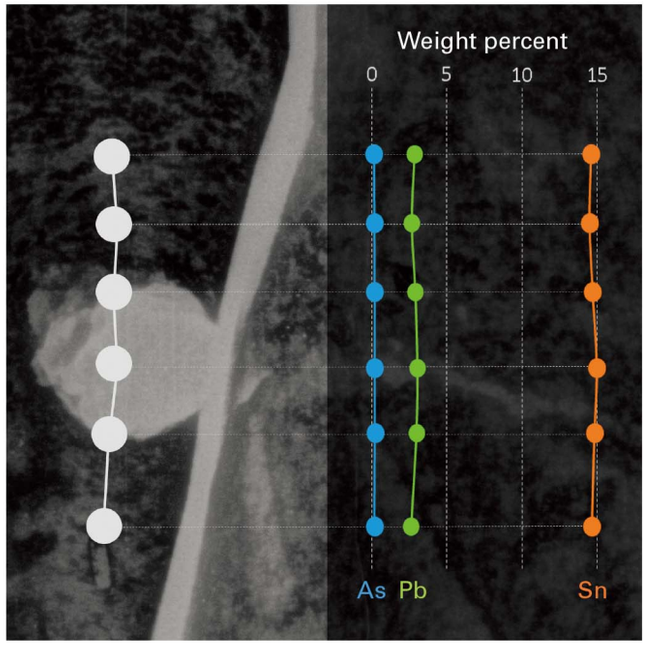
14 Computed radiograph, frontal view, digitally enhanced, Asia Society (1979.9) (**5**, **13**). Photograph by The Department of Objects Conservation. Image © The Metropolitan Museum of Art. Courtesy of Asia Society. This figure is characterised by an overall distribution of fine pores. Internal gates are visible in areas as radiopaque, i.e. white, circles and bands. The figure has an extensive cast-in repair in the chest and upper torso, extending to the right arm, and smaller repairs elsewhere. There is a small square opening on the back of the head that might have accommodated a core extension or a tang from a mandorla. Rivets connect the vertical and horizontal members of the armature

from their red colour, are prominent on the surface of the image on loan to The Metropolitan Museum, but for many of the other figures, it is unclear how the cores were supported during the casting process. A few iron core supports are discernable in the radiographs of some figures, i.e. Metropolitan Museum (69.222) (**16**), Asia Society (1979.9), and Victoria and Albert Museum (IS.3-2004). Core supports, one of which was analysed and found to be copper, were reported in the unpublished technical study of the Sultanganj Buddha.

Nearly all of the figures are known to have internal armatures that vary in shape and complexity,[5] but with the exception of the Sultanganj Buddha, none seems to have extended through the metal walls. Among the North Indian figures, only in the smaller Asia Society image (see **14**) and the Cleveland Museum image (**17**) are the armatures substantially well preserved.[6] The presence and configuration of iron armatures that are too corroded to be seen in the radiographs can often be demonstrated using magnets. An unusual feature, barely visible in the frontal radiographs of the Asia Society figure, are rivets used to join horizontal and vertical members of the armature. Both figures in the Asia Society may have had core extensions on the back of their heads, though these openings in the bronze walls conceivably accommodated a tang extending from a mandorla (see **13**, **14**) since, unlike many of the other Buddha images, neither has a tang for mounting a mandorla situated on the back of the figure.

An unusual casting feature common to all the figures, and not apparent on the surface, is clearly visible in frontal radiographs as roughly circular, radiopaque, i.e. white, forms (see **14**, **15a**), and in three-quarter and profile views as opaque horizontal bands (**17**, **18**). They are, therefore, cylindrical. The relative radiopacity of the bands indicates they are metal. Based on the radiographic evidence alone, they have been described as massive core supports running through the entire thickness of the core (Gänsicke, 2016; Czuma, April 1970; http://www.vam.ac.uk/content/articles/r/radiant-buddha/), but this seems not to be the case. Metal core supports generally have a different composition than the metal of the figure itself, chosen for its higher melting point, which ensured that the supports did not melt during the casting process. Conventional core supports, observed on many of the figures, are hammered rods made from iron or a cupreous metal; such supports are small, generally rectangular or square in section and they

15a Computed radiograph, frontal view, digitally enhanced, The Metropolitan Museum of Art (69.222) (**2**, **4**). Photograph by The Department of Objects Conservation. Image © The Metropolitan Museum of Art. Ten internal gates are visible in areas of the robe as radiopaque, i.e. white, circles, four cast-in repairs are visible and the figure's right foot is a modern restoration. Four cast-in lead repairs to front of the proper left side of the robe are seen as a string of radiopaque round and elongated patches



15b Line scans using XRF were carried out on the backs of several figures and except in areas of obvious repair no variations in composition were detected. Shown here are results of a scan carried across the surface of one of the internal gates, which can be seen as radiopaque "circles" in frontal view radiographs of The Metropolitan Museum Buddha image (see **2**, **15a** and inset). The minor degree of variation in composition (illustrated as calculated weight percentages of arsenic, lead and tin) at the six points scanned indicates that the metal associated with these gates is the same as the overall alloy composition, and that the gates were cast integrally with the figure

do not transect the core. They tend to be radiotransparent or at least have a radiotransparent boundary (see **16**).

Inspection of the surface in locations where this feature appears in the radiographs reveals no sign of core supports. Line scans using XRF were carried out on the backs of several figures, and except in areas of obvious repair no variations in composition were detected. This uniformity indicates that these transverse metal elements appearing as opaque bands in profile view radiographs were cast integrally with the sculptures, and suggests that they functioned as internal gates passing through the core to facilitate the flow of metal from the back to the front of the image (**15b**).

There is a consistency in the placement of the gates evident in the seven North Indian figures that have been radiographed; they are all found in the robe alongside the body, from the armpits to the calves and at the groin and between the legs. Strict adherence to these locations, although the actual number of gates varies from figure to figure, reflects their purpose, which was to channel the molten metal into the front of the robe, producing enough pressure for the melt to flow horizontally to fill the flaring draperies.[7] The angle of the X-ray beam, the distortion associated with condensing a three-dimensional form into a two-dimensional image and the curvature of the back of the figures, all cause some of the gates to appear in frontal views as if they overlap the body. Confirmation that the gates seen in the conventional radiographs of The Metropolitan Museum figure are exclusively associated with the robes came during an examination using volumetric (i.e. three-dimensional) X-ray imaging (**19**).[8]

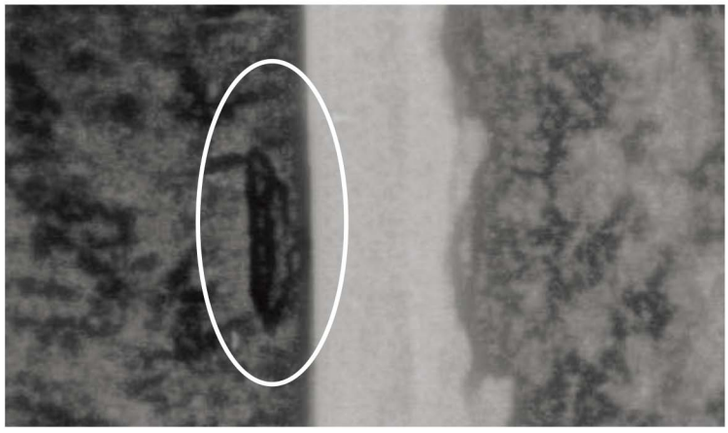
Figural statuary may be cast either vertically or horizontally. Various factors can affect the choice of orientation, including the figure's size and shape, attributes, the intended devotional context and local traditions. Larger images bring into play additional engineering considerations

[5] There is no mention of an armature in Peter Northover's unpublished study of the Victoria and Albert/British Museum figure, "Analysis and Metallography of a Standing Buddha #R1329", written sometime before it was acquired by its current owners. Highly corroded armatures can be difficult to locate, and further investigation using enhanced radiographic techniques and magnets would be useful in this instance.

[6] This is in spite of an assertion in Czuma (April 1970), that the figure has no internal armature spacing it off.

[7] In larger figures, e.g. the Sultanganj Buddha, which is discussed below, the gates were not confined to the draperies.

[8] A volumetric X-ray imaging process, developed by the Digitome Corporation, was used to produce a three-dimensional reconstruction of the Buddha figure from multiple conventional computed radiographs captured while it was placed in different orientations respective to the X-ray source.



16 Detail of a digitally enhanced computed radiograph, of The Metropolitan Museum of Art (69.222) (**2**, **4**) showing an iron core support. Photograph by The Department of Objects Conservation. Image © The Metropolitan Museum of Art

regarding the most feasible method of positioning and supporting the invested model during casting to ensure a continuous flow of molten metal that fills the entire cavity. To cast larger figures vertically, a deep pit, or a mound and scaffolding constructed high enough above the invested wax model figure, would be required.

Reconstructions of ancient bronze casting in South Asia, and in many regions around the world as well, generally propose that standing figures were cast in a vertical orientation, head facing down, so that the metal was poured from above into the tangs, if present, and the feet. The downward flow of metal takes maximum advantage of gravity, since in this position gases present in the investment rise to the feet and tangs, and there tends to be less porosity and other casting flaws in the all-important head, torso and attributes. This process allows an image to be elaborated in the round. A Thai 8th century Bodhisattva Avalokiteshvara in The Metropolitan Museum (**20**), for example, has sturdy legs that can be viewed as long, unobstructed conduits facilitating, with the aid of gravity, a direct flow of metal to the upper body and head, front and back.

The Indian Gupta-style Buddha images were, however, cast horizontally face down with metal poured in at the back.[9] Figures cast by this method are relatively unflawed on the front, while the external gates and vents, as well as the previously noted porosity and cast-in repairs would be concentrated on the reverse. The method does make it impractical to cast a figure with significant modelling or details on the reverse, and its use seems limited to figures that were not meant to be seen in the round. This drawback was of limited concern here, since devotional images in India typically were placed in temple niches where the back of the figure was not visible. This was standard practice in India for stone carvings as well, and these were also rarely finished in the round. Furthermore, the tradition of attaching large mandorlas made it less important to finish Buddha images on the reverse.

Although a horizontal casting would ensure minimal flaws on the all-important front of an image, the founder is not able to take full advantage of gravity. In the case of a typical Gupta-style standing figure, the challenge was to assure the lateral flow of metal into the sinuous robes. In fact, the physical properties of metal—specifically the ability to carry its own weight—allowed for even more expansive drapery than could be carved in stone. To overcome this difficulty, Indian metalworkers used internal gates transecting the core that allowed metal poured into the back of the figure to flow directly into recessed areas of the draperies on the front.

On most of the figures there is nothing on their surfaces, obverse or reverse, that indicates the presence of the gates. The Metropolitan Museum Buddha image, however, has particularly thin walls, and it appears that shrinkage, associated with cooling and final solidification of the metal constituting the internal gates, pulled the bronze wall on the reverse inward towards the core, causing it to crack. The very thin gaps caused by cracking were filled with lead as were larger casting flaws present on the back and, exceptionally, on the front of the figure (see **15a**).[10]

Measuring 2.26 metres in height and weighing approximately 500 kilograms, the image at the Birmingham Museum and Gallery, commonly referred to as the Sultanganj Buddha, is by far the largest surviving figure (see **8**). Although it was not possible to re-investigate it during this phase of the current study, the results of an extensive visual examination carried out in 1974 provided useful insights. Unfortunately, the whereabouts of the numerous photographs and photomicrographs cited in the unpublished report are unknown.[11]

The examiner(s) documented a number of core supports, measuring approximately 5 mm square, one of which they specifically identified as copper. They also described a complex iron armature. The armature appears to extend through the metal walls on the bottom of the feet and perhaps elsewhere, which would have helped keep the core in alignment during casting, as well as facilitate handling of the massive investment during the casting process. Furthermore, the examiners identified a series of iron strips "as binders to hold the core together".

Although its size precluded radiography at the time of the initial study, damages to the figure permitted direct observation of certain internal features, including what the examiners described as "a number of copper rods projecting from the casting into or through the core", with a consistent diameter of 14 mm (+/– 1mm). These may well be internal gates, as was indeed suggested at the time by W.T. (Tom) Chase, who is cited in the report. The examiners observed, however, that some of the gates do not fully penetrate the core, which led them to reject Chase's theory. After considering other possible explanations, this question is left unresolved in the final report. The magnitude of the

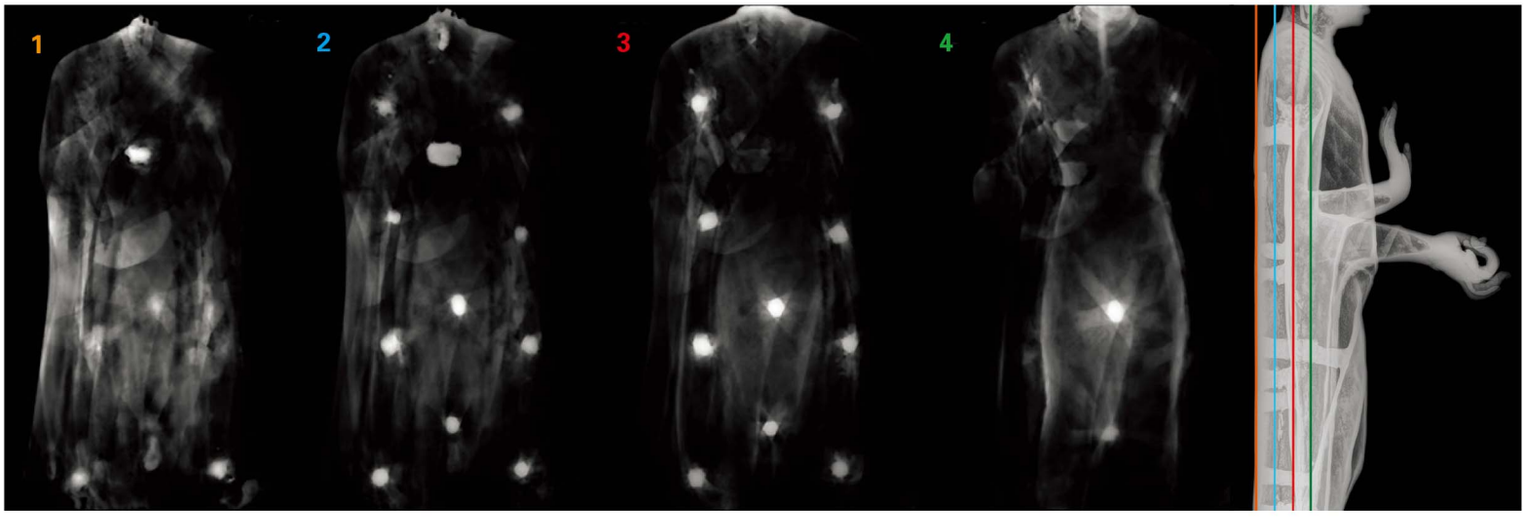
[9] This orientation has been previously demonstrated for small, solid Sri Lankan bronze castings (Kasthuri, 2016, figs 9, 10) and a South Indian solid-cast figure of Vishnu (Johnson, 1972).

[10] As a rule, the cast-in repairs are only seen on the backs of the figures and these were made using a cupreous alloy. In this case, owing perhaps to the particular thinness of the metal walls, the strategy of using internal gates to bring metal to the draperies proved not entirely successful. In fact, sometimes, once the positions of the gates known from the radiographs are translated onto the front and back surfaces of the figures, minute variations in relief can be observed. In the future, reflective transformation imaging (RTI) will be used to document this subtle topography.

[11] G.S. Learmonth, "Science and Technology of the Sultanganj Buddha", unpublished report, Birmingham Museum and Art Gallery. The original report is undated, but in its current form it includes several more recent appendices.

17 Computed radiograph, three-quarter view, digitally enhanced, Cleveland Museum of Art (1968.40) (**7**). © Cleveland Museum of Art. The internal gates are visible as radiopaque, i.e. white bands. Extant lengths of the armature are visible in the head, chest and legs, with less easily discernable, more corroded, sections in the torso

18 Computed radiograph, profile view, digitally enhanced, The Metropolitan Museum of Art (69.222) (**3**). Photograph by The Department of Objects Conservation. Image © The Metropolitan Museum of Art. The internal gates are visible as radiopaque, i.e. white, bands. An extant section of the iron armature is visible in the head and chest



19 These four computed radiographs represent a sequence of parallel planes (viewing levels) moving forward within a volumetric (3-D) X-ray image of The Metropolitan Museum figure. The approximate locations of the individual planes are indicated (1–4) in the profile radiograph. The feature visible in the centre of the chest in viewing levels 1 and 2 is a cast-in repair in the rear wall of the figure. Taken together, the images demonstrate that the eight gates are seemingly aligned with the walls of the body in the conventional, i.e. two-dimensional, frontal radiographs (**15a**) are actually located entirely in the robe. This can be concluded from the absence of these eight gates in the viewing level just in front of the robe. The gates at the groin and between the legs are still visible because they extend further towards the front of the figure. Image © The Metropolitan Museum of Art. A video of the volumetric X-ray imaging can be viewed at www.metmuseum.org/3DXRayGuptaBronze

20 Bodhisattva Avalokiteshvara, north-eastern Thailand, second quarter of the 8th century, copper alloy inlaid with silver and glass or obsidian, height 142.2 cm, width 57.2 cm, depth 38.7 cm. The Metropolitan Museum of Art, New York, Rogers Fund, 1967 (67.234). Image © The Metropolitan Museum of Art

21 Standing Buddha, North India, Uttar Pradesh, Banda district, Dhanesar Khera, circa 400, Gupta dynasty (300–699), bronze, height 37.2 cm, width 13.3 cm, depth 10.8 cm. The Nelson-Atkins Museum of Art, Kansas City, Missouri. Purchase: William Rockhill Nelson Trust (44-13). Photo courtesy of the Nelson-Atkins Museum of Art. © Nelson-Atkins Museum of Art

Sultanganj Buddha certainly would have required adaptations and modifications in casting technique not required for smaller images.

A figure, associated with the Gupta corpus that predates the earliest figures discussed thus far, was reportedly found at Dhanesar Khera in Uttar Pradesh (Smith and Hoey, 1885). It is now in the Nelson-Atkins Museum of Art, Kansas City (**21**) (Masteller, 2016, pp. 9–10, 34–37). In terms of manufacture, this figure offers no evidence of having been cast with internal gates and is so far exceptional within the corpus of cast Gupta-style standing Buddha figures (**22**). It has a sufficient number of core supports necessary to support its core, and appears to have had no armature. Another significant difference is the presence of modelled details on the back of the figure, i.e. two lengths of pleated drapery, one terminating just below the figure's left hand and the other at the hemline (**23**).

An opening is visible in frontal radiographs at the height of the figure's left hand. On the back of the figure itself, a patch covering this opening is just discernable. Its relatively regular shape, and the placement of the opening at the longitudinal centre of the figure, suggest that the image was used to house devotional material, a practice not typically associated with North India. By way of contrast, the large casting flaw near the bottom of the radiograph that appears prominently on the reverse view—like casting flaws on other figures studied here—is irregular in shape and has roughly executed cast-in repairs. This large, singular casting flaw at the bottom of the robe suggests that the figure was cast vertically with the head down. Porosity here is the result of gases that were trapped on the underside of the robe and unable to travel upwards and escape through the legs.

Discussion

For the ten figures cast with internal gates, there are still a number of open questions regarding their manufacture. First, how were the cores supported once the wax was melted out of their respective investments? For the majority of the figures studied, it does not appear that the few core supports, visible on their surfaces or observed in the radiographs, would be adequate to support the core during the final stages of the casting process. An exception is the Sultanganj Buddha, which has multiple core supports in addition to an iron armature that extended through the soles of the feet. It is difficult to say definitively for the other figures that the armatures did, or did not, extend through the bottom of their tangs. Visual and radiographic examination are hampered due to losses, possible alterations made during their time as active devotional images, or restoration and remounting in modern times. At what stage, and how, were the channels for the internal gates created? There is no conclusive evidence of this from the visual and radiographic examinations, but one possibility is that the core was modelled around wooden dowels, mea-

22 X-ray radiograph, frontal view, Nelson-Atkins Museum of Art (44-13) (**21**). © Nelson-Atkins Museum of Art. An opening in the back wall is visible, in addition to a large cast-in repair at the bottom of the robe. There are no internal gates and there appears to be no armature inside this figure

23 Standing Buddha, reverse of Nelson-Atkins Museum of Art (44-13) (**21**). © Nelson-Atkins Museum of Art. The bottom edge of the patch on the back (indicated by arow) and the roughly finished cast-in repair at the bottom of the robe are visible

suring between approximately 9 to 11 mm in diameter in the case of The Metropolitan Museum image, based on the volumetric X-ray imaging, that were removed before the core had completely dried.

Another issue is the external gating system that supplied metal to the internal gates and for the cast as a whole. The Buddha image in the Cleveland Museum has a short cylindrical rod of metal extending up from the back surface. Its location corresponds to an area on the figure's left leg at about knee height, where there are no internal gates. Therefore, if the rod is part of the external gating system, as is most likely, it proves that the metal would have flowed into the back wall of the figure and not directly into an internal gate. The same can be suggested for a roughly finished area on the back of the figure's neck that indicates the former location of a gate or vent. The slight depressions and tears in the metal wall, associated with the internal gates on the back of The Metropolitan Museum figure, are further evidence that these gates were not directly connected to external gates or to vents. Further consideration of modern foundry practices, as well as examinations of the backs of the several figures for which technological information has come from reports rather than direct inspection by the authors, may provide insight into this question.

Bulk alloy composition and trace-element data might offer a broader understanding of this technologically distinctive corpus. To date, quantitative elemental analysis, which requires removing a subsurface sample from the object, has only been carried out on one of the North Indian Gupta-style figures, Victoria and Albert Museum IS.3-2004, and there are few published analyses of South Asian cupreous metals dating to the first half of the first millennium. The last mentioned figure been characterised by Northover as a medium–high tin bronze with a small amount of lead. Semi-quantitative surface analysis of four of the five other North Indian figures has produced data suggesting that they are similar, but no conclusions can be entertained until more accurate analyses have been undertaken.[12]

Bronzes tend to be harder and more brittle when more tin is present in the alloy. This places a premium on a casting method that minimises the need for mechanical cold working to improve heavily pitted surfaces and remove gating apparatus from the front, which is the visual and devotional focus of the believer. Furthermore, in view of the relatively large amount of tin in their alloys, the surfaces of some of the figures appear surprisingly golden. Whether the choice of alloy, perhaps in combination with thermal treatment, was used to affect surface colouration, remains an open question.

The casting method seen in the North India images was not confined to this region, but spread to South India (see **12**) and to Thailand (see **10**, **11**). Whereas these three fig-

[12] The Metropolitan Museum (69.222); Asia Society (1979.8 and 1979.9); Cleveland Museum (1968.40) (Czuma, February 1970, p. 66).

24 Computed radiograph, frontal view, digitally enhanced, The Metropolitan Museum of Art (59.149) (**10**). Photograph by The Department of Objects Conservation. Image © The Metropolitan Museum of Art. Ten internal gates are visible in areas of the robe as radiopaque, i.e. white circles. Also observed is a very complex iron armature held together with rivets. Only one cast-in repair is visible, but there is abundant porosity, likely concentrated at or just below the back surface

ures show regional stylistic and typological features, the use and placement of internal gates is identical to the North Indian examples. In fact, the correlation, noted earlier, between the gates and Buddha's garment in the North Indian images is obvious in the radiographs of the South Indian figure in the Museum of Fine Arts, Boston, and the Dvaravati figure in The Metropolitan Museum. On the former, the Buddha wears his monastic robes exposing the right shoulder in the southern Indian manner (see **12**) and the gates are present only on the left, draped side of the image (Gänsicke, 2016, fig. 6).

On the Dvaravati image, the internal gates were placed in the robe a significant distance from the body (**24**). The complex metal armature present inside this image is in keeping with prevailing tradition in Thailand, where armatures are common, even on smaller figures. Here, the armature is unusually elaborate, even by Thai standards; moreover, it was constructed using rivets, a practice not otherwise previously observed by the authors (see also Becker, Strahan and O'Connor, 2014; Strahan, 1997, pp. 27–30), but which are also present on the armature inside the smaller Asia Society figure. Losses to the reverse of the Dvaravati image in the Rietberg Museum provide access to the casting cavity in which three internal gates and a heavily corroded iron armature are visible within the surviving core material (**25**).

The authors cannot recall any parallels for this approach to casting, either in their own research or in published studies. It may well be that this system of internal gates represents a novel technique designed to meet the needs of casting Buddha images in a particular style that emphasises the incorporeal. Since classical Gupta stone statuary serves as the model for these standing Buddha images, it is likely that the casting method originates in North Indian foundries and, indeed, the majority of images surviving are associated with this region.

This process, based on the use of internal gates, was certainly not used for the Nelson-Atkins Museum figure, and this basic difference in method, along with the vertical orientation during casting, distinguishes it from its North Indian relatives. In addition to these technological differences, and the probability that it predates the other Gupta-style Indian figures examined here, the Nelson-Atkins Museum figure shares some significant stylistic features with Gandharan sculpture (Pal, 1978, cat. 7, p. 61; Masteller, 2016, pp. 34–37). In view of the most recent observations relating to its manufacture and new developments in art historical thought, further scrutiny of its stylistic and devotional attributes and a more in-depth technical examination of the Nelson-Atkins figure would be useful for understanding its position within the North Indian corpus of Gupta-style Buddha images.

The presence of a smelting and metalworking site at Nalanda indicates that at least some workshops were located in monasteries (Nazim, 1940, p. 44, pl. VIIIe). This is hardly surprising, given the religious strictures governing the casting of devotional images and the wealth of metal statuary commissioned by, and for, monasteries. It is unlikely that the North Indian figures were produced in any single workshop, in spite of their highly idiosyncratic use of internal gates and their seemingly consistent alloy composition. More probably, the variety of armatures, the varying degrees of reliance on both iron and cupreous core supports, differences in wall thicknesses, the possible use of core extensions, and other features relating to manufacture, indicate that these works were produced in multiple centres.

In summary, an innovative casting method tailored to the style of Gupta and post-Gupta standing Buddha figures was developed in North India, at the latest by the middle of the 6th century, and from there spread to South India and Thailand. Unlike changes in style or iconography that are readily visible, an interior gating system, such as one identified here, would not be apparent from surface examination, even by a master metalworker. Thus, the importation of metal icons alone cannot account for the dissemination of this technological development, which could only have been transmitted by direct observation of the casting process. North Indian craftsmen may have travelled to other regions. Moreover, if bronze metallurgy was part of the curriculum at Nalanda, as suggested by Ghosh (1939, p. 23), and perhaps at other monastic centres of learning, drawing pilgrims and students throughout Asia, they might have provided a venue for propagating new technologies. Although the bronze figures found at Nalanda mostly postdate the late Gupta and early post-Gupta figures, evidence of metal processing and/or casting reported there invites

closer enquiry.

Further investigation of comparable Indian and Thai images in other collections may well uncover additional examples demonstrating this distinctive technological style. The early Buddhist images of Sri Lanka, the Himalayas and elsewhere in Southeast Asia, would be a logical place to look for evidence of other paths and chronologies of transmission. Given the timespan between the generally accepted dates of circa 550 for the smaller image in the Asia Society Museum (see **5**), and 591 for the image in the Cleveland Museum of Art (see **7**) (Pal, 1978, cat. 71, p. 118), and the 8th to 9th century date assigned to the Dvaravati figures in The Metropolitan Museum and the Rietberg Museum (see **10**, **11**), it can be established that this method of manufacture was practised for at least 150 years, and likely longer, and over a broad geographical area.

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References

Becker, Lawrence, Donna Strahan, and Ariel O'Connor, "Technical Observations on Casting Technology in First-Millennium Cambodia, Thailand, and Vietnam", in John Guy, *Lost Kingdoms, Hindu-Buddhist Sculpture of Early Southeast Asia*, exh. cat., pp. 267–270, New York, 2014.

Brown, Robert, "Carrying Buddhism: The Role of Metal Icons in the Spread and Development of Buddhism", J. Gonda Lecture 2012, Amsterdam, 2014.

Czuma, Stanislaw J., "A Gupta-style Bronze Buddha", *The Bulletin of the Cleveland Museum of Art* 57, no. 2 (February 1970), pp. 55–67.

Czuma, Stanislaw J., "Addenda: A Gupta Style Bronze Buddha", *The Bulletin of the Cleveland Museum of Art* 57, no. 4 (April 1980), p. 127.

Gänsicke, Susanne, "Bodies in Bronze: Four South Indian Temple Bronzes in the Museum of Fine Arts, Boston", in Raghu Menon, Claudia Chemello and Achal Pandya, eds, *Metal 2016, Proceedings of the Interim Meeting of the ICOM-CC Metals Working Group, September 26–30, 2016, New Delhi*, London and New Delhi, 2016, pp. 14–21.

Ghosh, Amalananda, *A Guide to Nalanda*, Delhi, 1939.

Guy, John, "Parading the Buddha in the Post-Gupta Age: A Newly Discovered Masterpiece of Indian Bronze Sculpture", *Orientations* (March 2016), pp. 102–112.

25 Standing Buddha, reverse of Rietberg Museum (2006.70) (**11**). Three internal gates (A) and traces of an iron armature (B) are indicated with arrows

Harris, E.B., *Description of Buddhist Remains Discovered at Sooltangunge*, London, 1864.

Johnson, Ben, "Krishna Rājamannār Bronzes: An Examination and Treatment Report", in Pratapaditya Pal, *Krishna: The Cowherd King*, Los Angeles County Museum of Art Monograph Series I. Los Angeles, 1972, pp. 45–58.

Kasthuri, K.A. Anusha, "Preliminary Investigation of Sri Lankan Copper-alloy Statues", *STAR: Science & Technology of Archaeological Research*, 2, no. 2 (2016), https://doi.org/10.1080/20548923.2016.1209055.

L'âge d'or de l'Inde classique: l'empire des Gupta, exh. cat., Paris: Éditions de la Réunion des musées nationaux, 2007.

Li, Rongxi, *A Biography of the Tripitaka Master of the Great Ci'en Monastery of the Great Tang Dynasty*, Berkeley, 1995.

Masteller, Kimberly, *Masterworks from India and Southeast Asia: The Nelson-Atkins Museum of Art*, Kansas City, Mo., 2016.

Nazim, M., "Excavations at Nalanda", in Rao Bahadur K.N. Dikshit, ed., *Annual Report of the Archaeological Survey of India, 1936–37*, Delhi, 1940, pp. 42–45, pl. VIIIe.

Pal, Pratapaditya, *The Ideal Image: The Gupta Sculptural Tradition and Its Influences*, exh. cat., New York, 1978.

Strahan, Donna K., "Bronze Casting in Thailand", in Hiram W. Woodward, Jr., *The Sacred Sculpture of Thailand: The Alexander B. Griswold Collection, The Walters Art Gallery*, Baltimore, 1997, pp. 27–42.

Smith, Vincent A., and William Hoey, "Ancient Buddhist Statuettes and a Candella Copper-Plate from the Banda District", *Journal of the Asiatic Society of Bengal*, 64, no. 1 (1895), pp. 159–162.