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edited by Dávid Bartus, Zsolt Mráv and Melinda Szabó

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New research on the Cleveland Apollo

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Abstract: This paper presents new technical details on the original manufacture and modern reconstruction of the Cleveland Apollo, a nearly life-size ancient bronze sculpture of the youthful god acquired by the Cleveland Museum of Art in 2004. Although previous studies had shown the sculpture to be an indirect lost-wax casting, few joins had been discussed in detail. Recent, more comprehensive radiographs, combined with extensive external and internal visual analysis, now permit a more thorough explanation of the assembly, from work on wax models through casting (in at least six sections), patching, and finishing, as well as post-manufacture damage. Together with radiography, analysis of numerous and varied modern restoration materials provides a fuller picture of the way the object was more recently re-assembled. A new digital 3D model of the sculpture, now available, will be essential for future study, interpretation, and display.

Keywords: Cleveland Apollo (*Sauroktonos*), large-scale bronze assembly, reconstruction

Introduction

The nearly life-size bronze sculpture now known as the Cleveland Apollo received its initial scholarly presentation in Bucharest, Romania, in 2003, at the 16th International Congress of Antique Bronzes, when Lucia Marinescu recalled having seen it in pieces in 1992.[1] Nothing is known of the sculpture's modern discovery, but it is said to have been part of a family collection in Leutwitz, Germany (near Dresden) since the nineteenth century. Rediscovered when the estate was reclaimed following the reunification of Germany, the sculpture was sold to an antiques dealer and eventually reassembled. Marinescu described the sculpture as missing its left arm and right forearm and belonging to a German private collection. By 2003, it was with Phoenix Ancient Art in Geneva, Switzerland, from which it was acquired by the Cleveland Museum of Art in 2004, together with the non-joining left hand and creature.[2]

1 See publication: Marinescu 2004, 303, note 23; see also Bennett 2013, 61–62, 66–67, where Marinescu is said to have seen the sculpture in 1994. The sculpture is now in the Cleveland Museum of Art, Severance and Greta Millikin Purchase Fund 2004.30 (https://clevelandart.org/art/2004.30 [last access 23. 02. 2023]).

2 Bennett 2013, especially 10, 14, 54, 65–67, 71–72.

Since then, the sculpture has been extensively studied and published, including as the subject of a small Cleveland Museum of Art exhibition and monograph in 2013–2014.[3] It has not been exhibited outside Cleveland, however, and thus may remain less well known to scholars than other large-scale bronze sculptures of similar size and quality.[4] As preserved (Fig. 1), the sculpture consists of four parts: A) the head and body (including both legs and feet and the upper right arm) of an adolescent male figure, standing on his right leg but leaning to his left; B) the non-joining left hand and forearm; C) a four-footed serpentine creature; and D) a nearly rectangular baseplate.[5] Studies have shown the sculpture to be an indirect, lost-wax casting, with its figural components all from the same high-lead, low-tin bronze melt. The nearly rectangular baseplate, similar but not identical in composition, has been thought to be a later addition or reworking, though its corrosion suggests long exposure to elements.[6] Based on the pose and the distinctive *krobylos* hairstyle, the sculpture was initially labelled *Apollo Sauroktonos*, corresponding to a type long known by scholars and connected to a brief description by Pliny the Elder within his description of bronze sculptures by the Classical Greek artist Praxiteles (active in the 4th century BC; Plin. *HN* 34.19). More recently,

Fig. 1. The four extant parts of the bronze sculpture. A – head and body, B – left hand and forearm, C – serpentine creature, D – baseplate (Unless otherwise noted, all images are courtesy of The Cleveland Museum of Art. Photography by Howard Agriesti).

3 *Praxiteles: The Cleveland Apollo* (Focus exhibition, Cleveland 2013–2014: https://www.clevelandart.org/exhibitions/praxiteles-cleveland-apollo [last access 23. 02. 2023]; Bennett 2013).

4 Although not exhibited in *Praxitèle/ΠΡΑΞΙΤΕΛΗΣ* (Paris, Athens 2007) or *Serial/Portable Classic* (Milan, Venice 2015), the Cleveland Apollo does appear in chapters in the associated catalogues: Bennett 2007; Bennett – Snyder 2015.

5 Note that "right" refers to "proper right," and "left" to "proper left" throughout this report. More images are available online at https://www.clevelandart.org/art/2004.30# (last access 15. 02. 2023).

6 See Snyder et al. 2017, 333–338 for these and other technical details, which do not disagree with the received modern history of the piece (as described briefly above).

Michael Bennett and Antonio Corso have each suggested that the sculpture could be from the hand or workshop of Praxiteles himself, and Bennett has proposed that the name of the sculpture should be changed to *Apollo the Python-Slayer*.[7] Jenifer Neils, on the other hand, has suggested that the sculpture may not represent Apollo at all, but simply an "androgynous youth taunting a lizard."[8]

Fig. 2. The auto-aligned composites of x-ray films obtained in 2021 provide undistorted, 1:1 images of the entirety of the figure from both frontal and lateral views. (All radiographs digitized by David Brichford).

7 Bennett 2013, 80–85; Corso 2013, 26–28.

8 Neils 2017, 26.

While recognizing the importance of these and other questions of iconography and attribution, here we focus on this particular sculpture—the sole surviving large-scale bronze of this type—looking specifically at technical features of its ancient manufacture, post-manufacture damage, and modern reconstruction. Our findings are based on new and more comprehensive radiographs[9] (Fig. 2), combined with extensive visual and technical analysis. Additionally, the creation of a new digital 3D model allows a clearer delineation of these findings as well as the potential to consider multiple different virtual reconstructions of the non-joining and missing sections of the original sculpture.

Ancient Manufacture

Previous studies have recognized that the sculpture was cast in multiple sections but have focused primarily on two easily visible joins – one a fusion weld on the right foot of Apollo, the other with a pin on the small, separately cast serpent/lizard-like creature.[10] Our study, described further below, supports previous suggestions of at least six and as many as ten separate cast sections for the surviving portions of the main figure (Fig. 3): 1) head to mid-neck; 2) torso and right leg (including the heel and back of the foot); 3) front of the right foot; 4) right arm (upper); 5) left arm (lower, with hand), and 6) left leg—with the possibility that the penis may be separately cast and that the right leg may be separately cast from the upper thigh down (2a–c), the left hand may be separately cast and joined at the wrist (5a–b), and the left leg may be cast in two sections, possibly joined at mid-foot (6a–b).[11] Additional extant castings include the front and back of the creature plus the base, while non-extant sections likely included a tree or other support; it is possible that the right hand would also have been cast separately, giving a larger total of 15 or more original cast sections. In addition to details of casting, such as joins and chaplet holes, we also note below the location and form of multiple ancient patches and other finishing techniques and technical features.

Head and Neck

At least two square chaplet holes survive on the head, both on the right side: one just above the headband, the other toward the back (Fig. 4). The finely detailed strands of hair show some evidence of cold working, though most modelling appears to have been done in the working wax model. The head includes eyeholes for separately made eyes, one of which (the right) has been called ancient and said to be made of a white stone of unspecified type.[12] This eye includes a circular depression, now empty but presumably meant to hold a separately made iris and pupil. When viewed from the interior of the head with a borescope (Fig. 5), the eye has a roughly conical shape that fits neatly into its socket with two split bronze tabs helping to hold it in place. No sign of lashes appears, nor is there any indication of eyebrows, perhaps a reflection of the youth of the figure.

9 Radiographs taken in 2003, when the sculpture was being considered for acquisition, showed most of the sculpture (above the knees) in a nearly frontal view, plus two separate views of (1) the right lower leg and foot (from above), and (2) the non-joining creature and right forearm/hand. See Snyder et al. 2017, 332, Fig. 40.2b for head, neck, and shoulders. Though the museum installed a system for digital radiography in the interim, the high lead content of the bronze necessitated imaging with a higher energy system. The new radiographs were taken with a 2-million-volt linear accelerator with a source-to-film distance of 8.5 feet and a 2-mm focal spot. A custom easel setup was used to streamline the process and ensure individual plates would overlap, and each shot was taken at 80 rad for 18–20 seconds. Three different types of Agfa industrial x-ray film were included to obtain as much usable information as possible.

10 Bennett 2013, 2–4 (foot); Snyder et al. 2017.

11 For previous discussions of cast sections on this sculpture, see Bennett 2013, 60, 68 (citing unpublished reports).

12 Bennett 2013, 60. For further discussion of the material of the right eye, see below: *New Analytical Findings*.

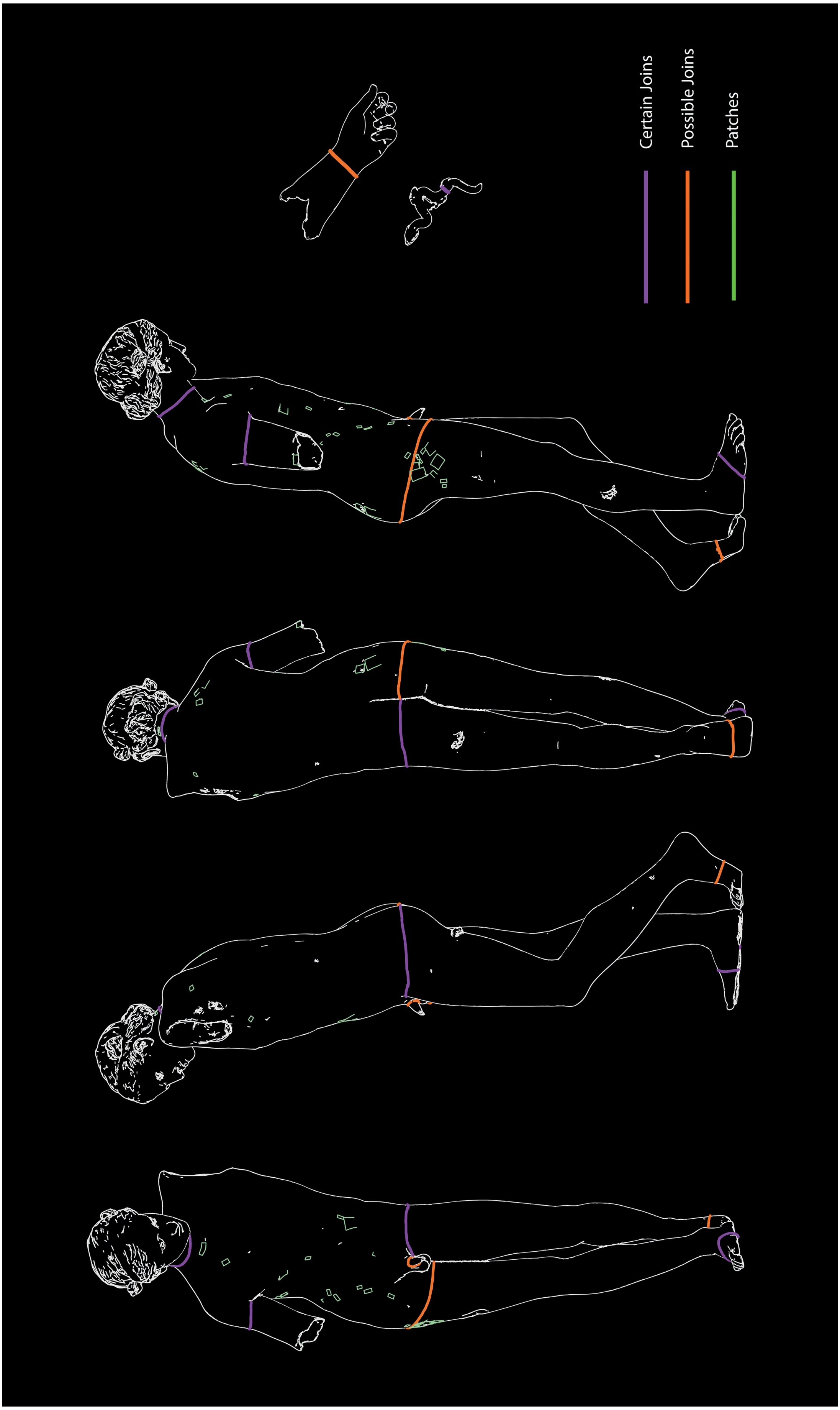


Fig. 3. The figure is comprised of six to ten surviving cast sections. These line drawings indicate both certain and possible joins, as well as the locations of patches visible on the surface. (Line drawings created from 3D model by Dale Utt III).

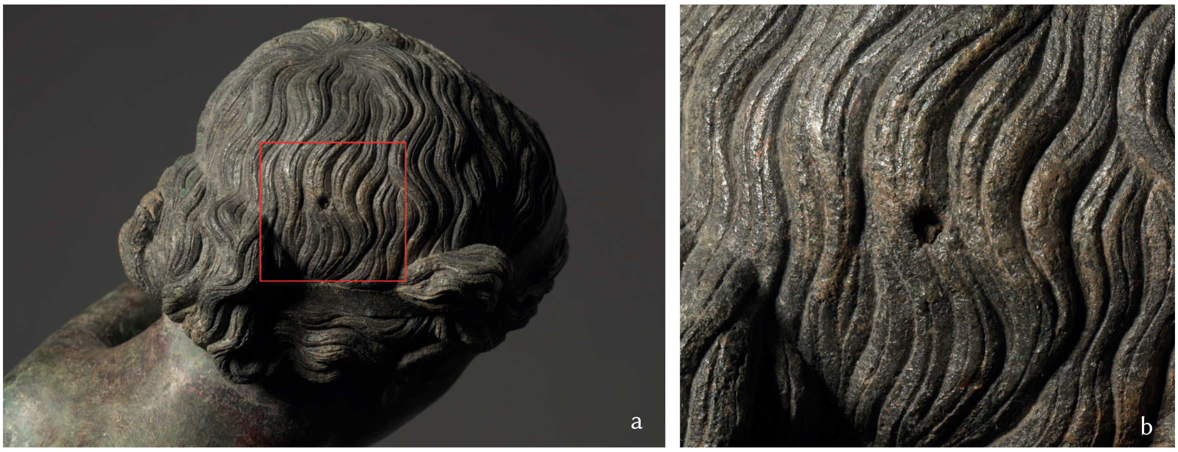


Fig. 4.a–b. Adjacent to the detail of one square chaplet hole on the head, there is evidence of cold working to delineate the strands of hair.

Another notable detail on the head is the use of copper inlay for the lips (Fig. 6). Deeply incised lines around the lips suggest that they had been hammered into very shallow channels, as on other ancient bronzes. This was confirmed by radiography and interior views with the borescope showing no internal attachments for the lips.[13]

Finally, the entire cast section of the head undoubtedly extends to mid-neck, revealed clearly for the first time in the new radiographs (Fig. 7). Although no evidence of the neck join appears on the surface of the sculpture, as much of this area is heavily damaged and restored, one missing ancient patch on the back of the neck seems to fall near the line of the join.

Torso and Right Leg

This represents the largest cast section of the sculpture, including the torso with right shoulder,[14] genitals, and at least part of the right (support) leg. Perhaps due to its large size, this section exhibits several areas of high porosity, particularly around the right mid-torso and upper right hip and thigh. This porosity, visible on radiographs and in occasional small holes on the surface, likely explains the high number of patches in this area (at least seven, delineated in Fig. 3), which also appears more susceptible to distortion, dents, and fractures, whether in antiquity or more recently. Extensive modern restoration may occlude additional ancient patching. Two unusual three-sided polygonal features also appear in this area, one just below the right nipple (Fig. 8) and the other some 3 cm left of the navel. Each of these may constitute three sides of a patch, still in place, with the fourth side hidden, though they could also relate to modern restoration.[15]

13 Note similar incised lines around the lips, often inlaid, of large bronzes across several centuries: e.g., Riace warriors (lower lips only); Apoxyomenoi in Vienna, Zagreb, and Fort Worth (Kunsthistorisches Museum, Antikensammlung, inv. VI 3168; Croatian Ministry of Culture; Kimbell Art Museum, inv. AP 2000.03a; Daehner – Lapatin 2015, 272–277, Cats 40–42); Head of a North African Man, from Cyrene (London, British Museum, inv. 1861,1127.13; Daehner – Lapatin 2015, 247, Cat. 28); Beneventum Head (Paris, Musée du Louvre, inv. Br 4; Daehner – Lapatin 2015, 302, Cat. 53). A Head of a Youthful Dionysus in Malibu features copper-tin alloy lips within a deeply incised line and set into a cast cavity with five holes (J. Paul Getty Museum, inv. 71.AB.447; Mattusch 1996, 195–198, Cat. 5).

14 The left shoulder has been lost but may also have been included in this section. An unrestored area near the left armpit reveals a seemingly finished edge of metal that may represent what is left of that original cast edge.

15 These less regular polygonal shapes are most often seen in locations where the sculpture's curvature requires something other than a standard rectangle. Near the lower patch on the abdomen, joined by

Fig. 5. The back of the right eye is seen with the help of a borescope placed through the empty left eye socket (a), revealing a conical shape held by two split bronze tabs (b). The shiny, saturated surface at the top is modern restoration adhesive.

Both nipples are copper inlays, and, like the lips, appear to have been hammered into shallow depressions in the bronze. Both are fully preserved, and a gouge on the right nipple reveals the bright pink color of the base metal. Handheld XRF analysis in this location reveals a high purity copper.

Fig. 6. Deeply incised lines around the inlaid lips indicate they were hammered into shallowly cut channels. This is further supported by the absence of detail seen in this area inside the head or on radiographs (see Fig. 7).

The penis may be separately cast, and the rest of the genitals join to the right leg (rather than the left), just above a clear stepped join on the medial thigh (Fig. 9). The horizontal line of this join appears to continue around towards the front (anterior) of the thigh before receding from view on the lateral side. The line may correspond to a dark horizontal line on the radiograph, as well as to a possible oval marking from a flow weld at the right hip. This falls just below the most extensive area of patching on the sculpture, with as many as twelve rectangular patches, the largest 2.0 × 3.5 cm (Fig. 10). One patch has been partially broken and lost, and the remainder lifted away to reveal the casting flaw it once covered (0.4 × 0.2 cm).[16] Another large patch (2.2 × 2.4 cm) has been lost on the upper right buttock, once covering a hole.

Two square chaplet holes appear on radiographs of the right leg, each with an associated ring of flashing (one just below the knee, the other about one-third of the way up the leg; Fig. 11). Neither

a crack, is another straight line and additional pitting. Again, modern epoxy and other restoration materials make it difficult to determine entirely what is ancient repair and modern intervention. The sides and back exhibit less patching—one just below the opening for the left arm (0.6 × 1.2 cm) and another near the left shoulder blade.

16 Some denting of the surface here has opened small cracks into the interior of the sculpture, while a much larger indentation appears farther down the leg; see below (Post-Manufacture Damage).

can be easily connected with anything visible on the surface. The core pins likely caused fractures in the core when inserted, allowing the metal to flow in during the pour.

Finally, a long straight, dark line runs down the shin on the frontal radiograph, perhaps corresponding to a dark and blotchy line running down the surface of the shin. While this less dense line in the radiograph may correspond to tinted epoxy added to the surface, its remarkably straight verticality and central position appear purposeful. Though it is uncertain what this represents, we continue to look for clues in better preserved bronze statues, perhaps related to ancient manufacture or internal supports.[17]

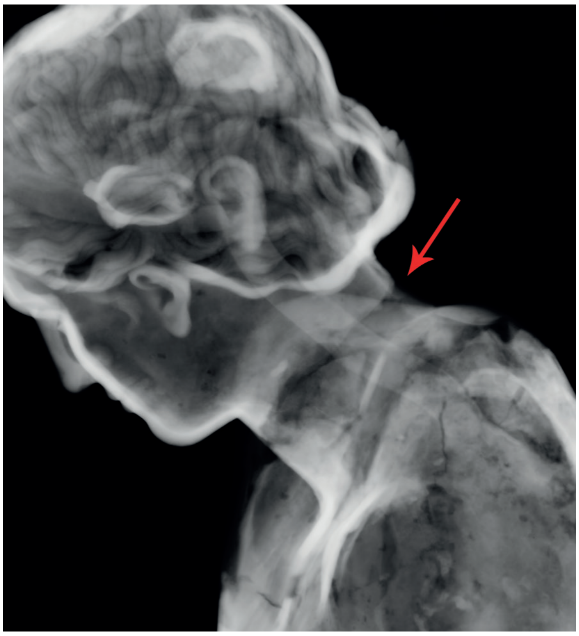


Fig. 7. The radiograph of the neck and shoulders clearly reveals the original cast edge of the head at mid-neck.

Right Foot (front section)

This is the most clearly visible join on the sculpture, with three roughly aligned ovals running across the upper surface, each measuring between 4–5 cm in length and approximately 2 cm in width (Fig. 12.a). A small hole is visible within the outermost oval, the result of a small loss due to corrosion, but there is no evidence of patching or cracking here or elsewhere along the join. The precise line of the join is even more readily visible on the hollow underside of the foot where not covered by modern epoxy (Fig. 12.b). The casting of the toes includes only those surfaces visible to the viewer, with much of the underside left open. Additionally, clear gaps appear between each of the toes, most notably between the second and third. These gaps are visible but not distracting to the viewer; it is uncertain whether they were always present or represent small losses. The separate casting of the front of the foot finds numerous parallels on other large-scale bronzes, presumably to facilitate mounting (see below [*Left Leg*] for additional discussion).[18]

Fig. 8. A three-sided polygonal feature, perhaps an ancient patch, can be seen beneath the right nipple, shown here. A gouge on the inlaid copper nipple itself reveals the pink-toned base metal.

17 During the conservation campaign of Riace B, for example, it was discovered that an iron bar was inserted in the right leg during manufacture for additional internal support. This was incorporated into the bronze casting and now appears as a vertical crack down the shin (Formigli 1984, 108–113; Giumlia-Mair 2015, 174–175). No trace of such an iron armature has been found within the Cleveland Apollo.

18 Examples include the Livadhostro Poseidon (Mattusch 1988, 82–83; Dafas 2019, 19), the Artemision god (Mattusch 1988, 137; Dafas 2019, 41), and the Riace warriors (with middle toes also separately cast: Mattusch 1988, 137, 204; Dafas 2019, 56). Additional examples may include the Antikythera youth (Dafas 2019, 73), the Marathon boy (though the front of the right foot is missing; Dafas 2019, 87–89), and the Piraeus Apollo (based on seams visible beneath the feet; Dafas 2019, 103). C. Mattusch (Mattusch

Fig. 9. The surface of the medial right thigh exhibits evidence of a stepped join, which may correspond to features seen on the radiograph (see Fig. 15).

Fig. 10. Numerous rectangular patches of varying sizes have been identified just below the right hip.

Fig. 11. Arrows indicate where two square chaplet holes are visible on the right leg in radiographs, with associated white rings of flashing.

Right Arm (Upper)

The upper right arm joins the torso section just below the shoulder, with a small gap of a few millimetres visible at the axilla, where the inner arm meets the chest. Inside the hollow upper arm, a significant flashing of bronze appears on the anterior wall, projecting over 1.5 cm into the hollow (Fig. 13.a). Lesser amounts of flashing are seen all around the circumference of this join. The flashing appears as a denser area on radiographs, where a concurrent fine line of less density indicates the join running all the way around the arm (Fig. 13.b). Although no flow-weld ovals are readily visible on the exterior surface, these can be seen in a panoramic radiograph image taken with a cut piece of film inserted into the arm (Fig. 13.c). The interior surface of the upper arm appears to show other evidence of manufacture in the form of a straight vertical line on the lateral wall, perhaps from a wax-to-wax join. Other possible signs of working techniques on the interior include a series of very small bronze globules, likely indicative of porosity within the core material. It is estimated that these were produced when the first layer of liquid core material was quickly brushed on, trapping small air bubbles that were then reproduced in the final bronze. On the exterior, three sides of an engraving for inserting a rectangular patch (1.2 × 2.7 cm) appear at the broken lower edge of the arm, on the lateral side, meant to cover a still-visible casting flaw. The thickness of the casting measures 5.55 mm.

Fig. 12. Three ovals seen on the top of the right foot (a), and a horizontal line across the underside (b) represent the most clearly visible join on the sculpture.

Left Arm (Lower, non-joining)

The upper left arm is entirely missing. The surviving portion of the left forearm and hand begins roughly 15 cm above the wrist at the greatest extent, though its broken surface is quite irregular (Fig. 1.b, Fig. 14). Within, just above the wrist, a significant flashing of bronze nearly fills the interior, though much of the upper hand is hollow.[19] The thumb and fingers are solid cast, with the nails and folds of the palm finely worked in the wax model. A square chaplet hole is visible on

1988, 137) also mentions several fragmentary front halves of feet from Olympia, and the Porticello foot and leg fragments show cast edges at mid-foot, the preserved front half with separately cast middle toe (Ridgway 1987, 75–80, 95, Cats S6–S8); see also Dafas 2019, 60–61. Two separately cast front sections of feet from the Roman period are now in Malibu (J. Paul Getty Museum, inv. 71.AB.229, 72.AB.103: Mattusch 1996, 212–215, Cats 18–19).

19 It is unclear whether this resulted from a (sloppy) join between separate cast sections, or from shifting or breakage of core material (as in Tampa Museum of Art, inv. 1986.142: Mattusch 1996, 215, Cat. 19, Fig. 1; 226, Cat. 23, Fig. 1). Separately cast hands are known in other sculptures, such as the Artemision god (Dafas 2019, 41) and the Riace warriors (Mattusch 1988, 204; Dafas 2019, 56), and also appear in the workshop scene on the Foundry Cup (Berlin Antikensammlung, inv. F 2294, BAPD 204340).

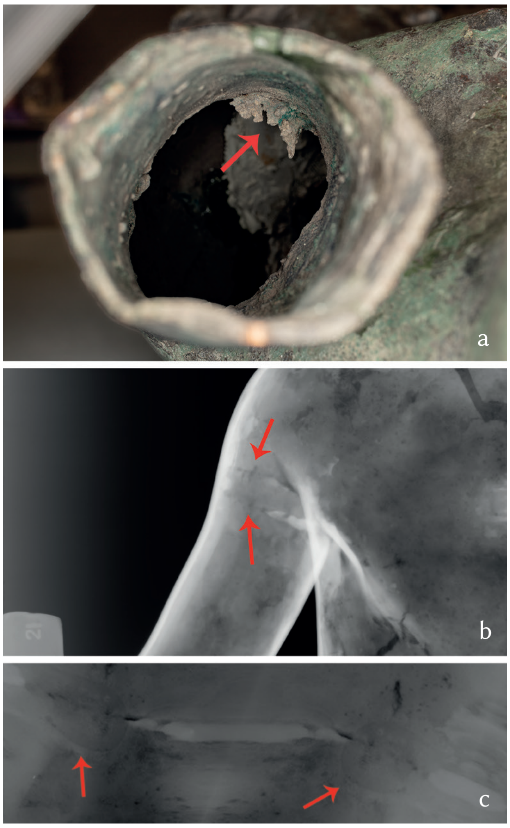


Fig. 13. Flashing within the upper right arm (a) is also seen on the radiograph as a spot of white density at the axilla (b). Arrows indicate a visible circle of less density in this region, which appears as a series of concentric circles on the panoramic radiograph (c).

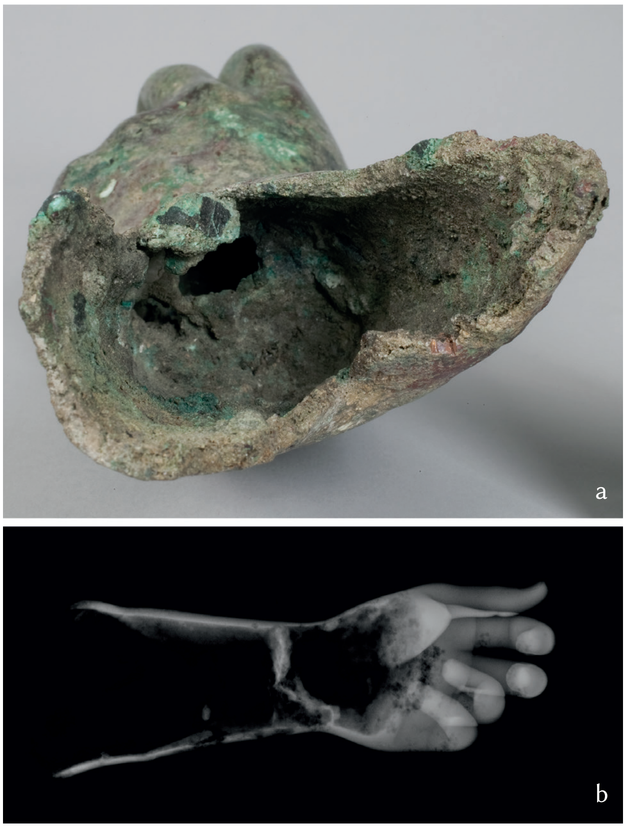


Fig. 14. Detail of the interior (a) and radiograph (b) of left forearm and hand, which show significant flashing that fills nearly the entirety of the interior in this location.

radiographs just above the wrist, possibly corresponding to a square mark on the lateral surface. The casting measures approximately 5.7–7.0 mm thick at the broken edge.

Left Leg

The left leg appears to join the torso at the groin and upper thigh, running below the iliac crest in the front, then to mid-buttock in the rear, where a small crack is visible, running into a hole visible on the surface and in radiographs (Fig. 15). A clear corner of the cast section is also visible in the profile radiograph, within the sculpture. The excess metal visible in the frontal radiograph near the outer edge of the left hip may be flashing from the join. Unfortunately, restoration material occludes much of this surface on the interior, preventing firm identification of the edge of the casting. Significant porosity appears in the radiographs of this leg and as pitting on the surface. At least two square chaplet holes are visible on the profile radiograph—one roughly one-quarter length up the thigh (above the knee), toward the outside, and the other on the ankle, likely related to a significant ring of flashing.[20] A slightly larger hole, nearly 1 cm square and not patched, appears roughly 13 cm above the heel.

20 As on the other leg, the rings of flashing could have resulted from slight weakening of the working model caused by piercing with chaplet. These chaplet holes cannot be easily located on the exterior surface, but the upper one is visible within the leg (with borescope).

Also of interest are three pairs of straight lines running vertically along much of the length of the left lower leg. These are visible in both radiograph views—one set towards the front of the leg, two towards the back. Because these are pairs of white lines, without increased density between them, they seem to represent a feature of the inner bronze surface, perhaps caused by long, slightly rounded strips of material pushed into the inner surface of the wax to ensure complete contact with the outer mold before additional core material was added. These very shallow furrows with slightly raised edges could also be seen on the interior with the borescope. We have not found similar examples of this in other large ancient bronzes.

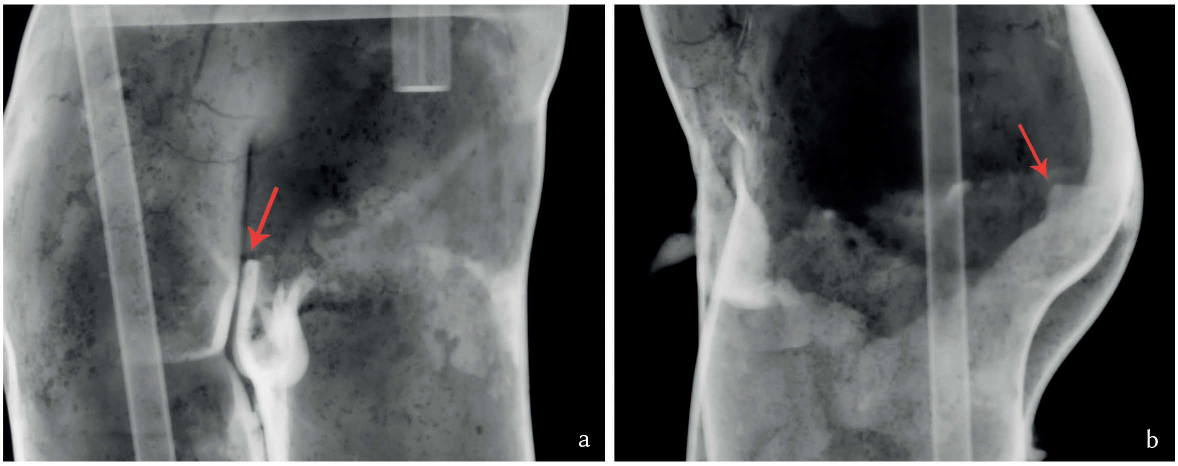


Fig. 15. The frontal view of the mid-buttock region shows a hole also visible on the surface (a), and the profile radiograph of this region (b) shows a corner of the cast section within the sculpture.

Finally, the underside of the resting surface of the left foot was left open (Fig. 12.b), permitting easy access to the interior, perhaps for divestment and/or anchoring. Within the opening, excess bronze at mid-sole may represent flashing from a flow weld, visible as a line of density on the profile radiograph (Fig. 16). Thus, although their positioning differs, both right and left feet may include separately cast front sections joined around the same point, as on other ancient sculptures.[21] A large white area appears in the heel on radiograph images, corresponding to a whitish mass clearly visible within. This material is relatively soft, scratching easily with a bamboo skewer, and was identified as lead carbonates with FTIR (Fourier-transform infrared), suggesting that it could be connected with an ancient tenon for anchoring.[22] The thickness of the casting in the foot measures 4.21 to 6.17 mm.

Creature

The four-footed serpentine creature (Fig. 1.c, Fig. 17.a–c) is clearly comprised of two solid-cast sections, with carefully delineated toes and shallowly incised scale patterns on the head, all made in the working wax model. The sections are now joined by modern green epoxy adhesive but also by means of a pin clearly visible in radiographs. This pin is magnetic and thus appears to be an iron alloy, though it has not been visually examined (which would require reversing the strong ad-

21 See above, with examples in note 18.

22 The best-preserved ancient lead anchoring tenons belong to the Riace bronzes, each with two flat feet; see: Formigli 1984, 135–137. But many other sculptures with one raised heel were cast with the resting surface of the partially raised foot left empty to allow for anchoring with lead tenons; on the Artemision god, for example, K. Dafas (Dafas 2019, 43) suggests that molten lead would have "reach[ed] probably to the level of the ankles."

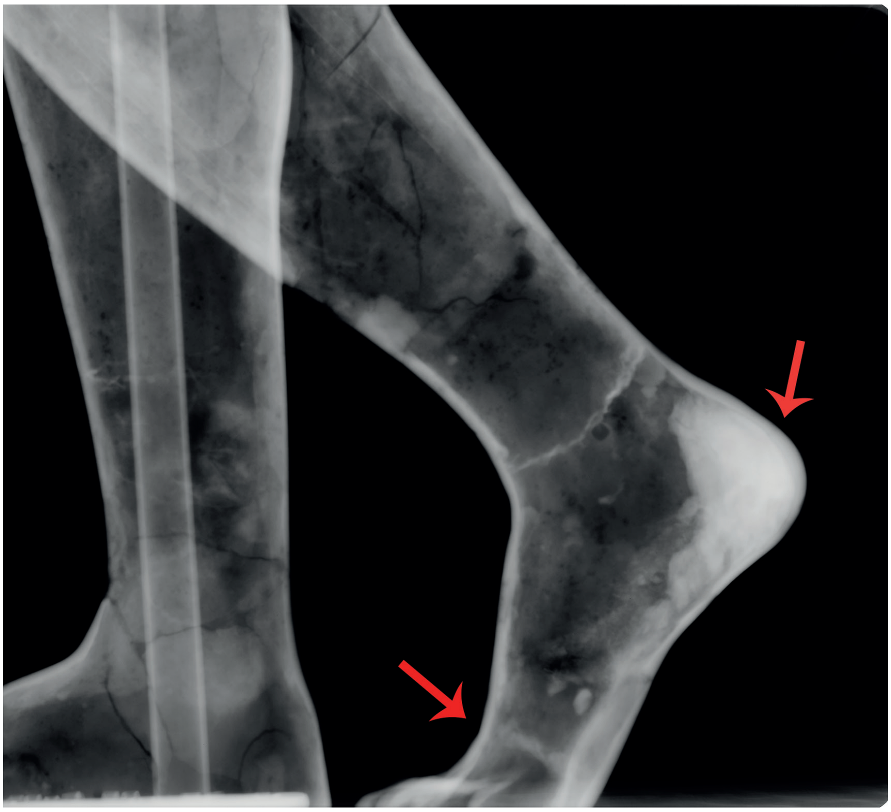
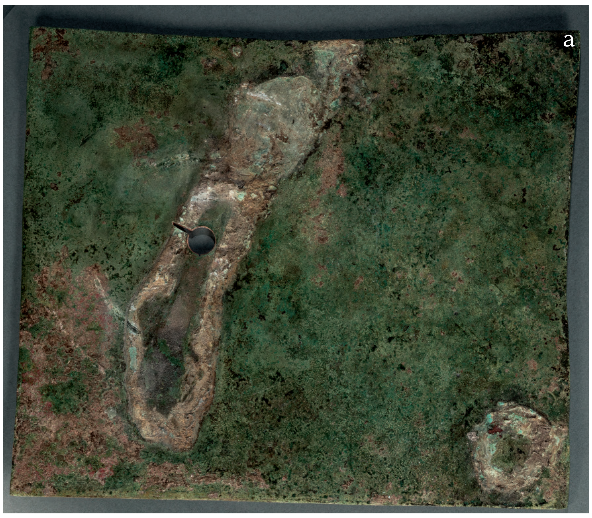


Fig. 16. Profile radiograph of the lower legs and feet. Arrows point to areas of density in the left foot, indicating a possible join at mid-sole and lead carbonates in the heel.

Fig. 17. A line of modern green epoxy bisects the creature at the point of the third leg (a) (Photography by Joan Neubecker). The radiograph (b) shows the metal pin repair and the more porous front half of the casting.

hesive join). Radiography shows much greater porosity in the front half than the back half of the creature, suggesting that perhaps the original back half was damaged during casting, necessitating a new or re-casting of that portion of the creature. The similar bronze composition of the two halves suggests that the failed back half was melted and re-cast, or that the new back was made from excess material at the same time. If true, this could help to explain why the fourth leg differs so much from the other three, and why it is located so far back on the body; originally, the fourth leg might have been significantly closer to the third leg, resulting in a slightly less unusual creature.[23]



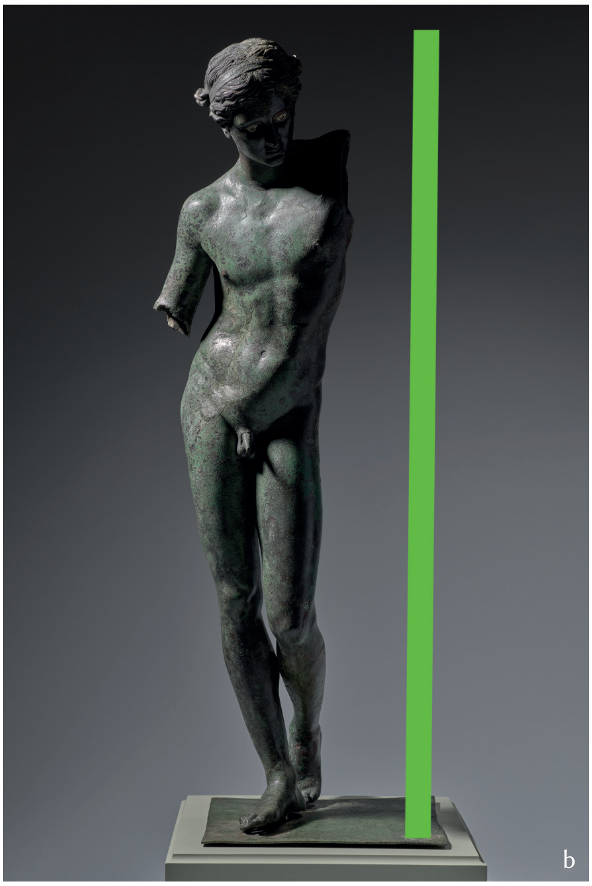


Fig. 18. The baseplate (a) has irregular edges. The solder circle seen in the corner seems to indicate a much thinner tree than seen in marble copies (b).

Baseplate

The baseplate is nearly square in shape, measuring 40.3 × 45.8 cm, but without any truly square corners (Fig. 18). The two front corners are closest to ninety degrees, and the front and right sides closest to straight lines, while the left and rear edges are noticeably concave. A modern hole (with additional large, pie-shaped metallo-graphic cross-section taken in 2013) facilitates placement of the modern rod in the right leg (see below [Modern Reconstruction]), and marks show the placement of both feet, once attached with lead solder. There is evidence of the sculpture being pivoted around the rod while on the plate, seen in the form of circular abrasions to the bronze. In addition, a nearly circular lead solder mark about 7 cm in diameter located at the front left corner likely corresponds to the placement of a tree, now lost. A tree of this size would be notably smaller than those in the Roman marble versions of the Apollo Sauroktonos, a detail perhaps only partly explained by the higher tensile strength of bronze (in comparison to marble). The placement so close to the corner and edge of the plate (and still quite close to the figure) further suggests the alteration or re-use of the baseplate, as previously suggested on the basis of material analyses. Those material analyses also suggested, however, that a small amount of ancient solder remains on the left foot of Apollo, suggesting "that the toe was once attached to

23 See Bennett 2013, 12–14, 80 for an alternative explanation of the unusual, asymmetrical creature: "rather than a lizard, this coiled reptile was Praxiteles's ingenious conception of the legendary Python, slain by Apollo before he took over the sanctuary" at Delphi (quotation from p. 80).

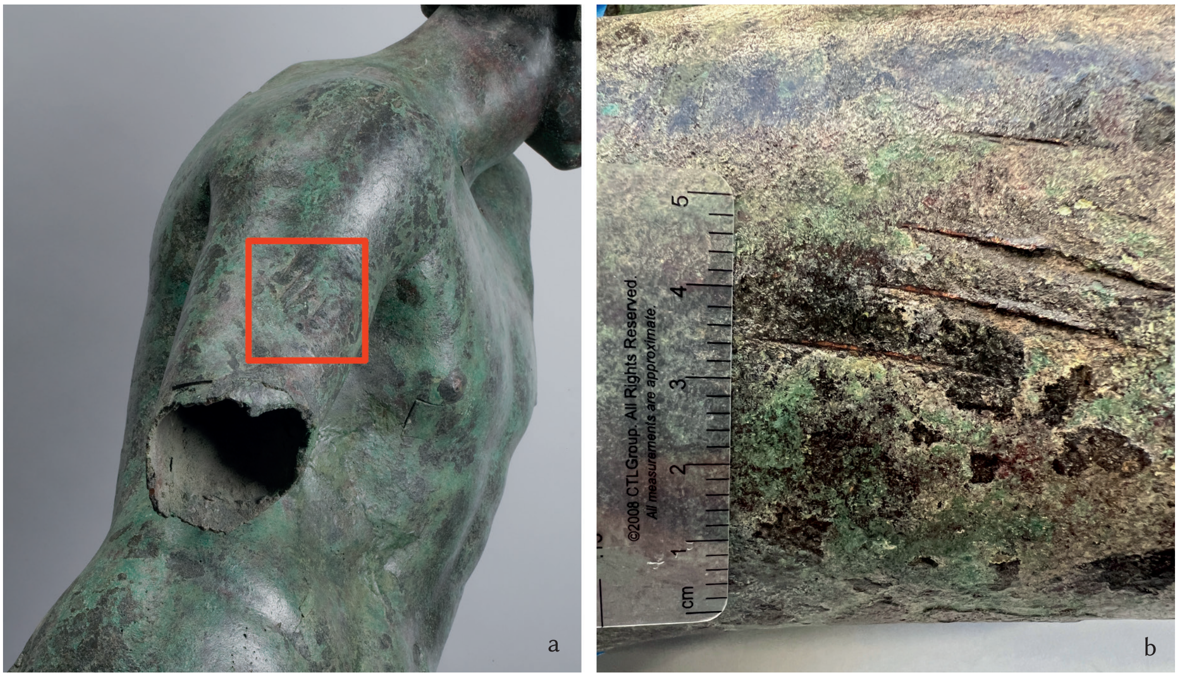


Fig. 19. The bronze has several parallel gouges on the right shoulder and upper arm (a). A detail shows these gouges from another angle, as Apollo lies on his back (b) (Overall photography by Joan Neubecker).

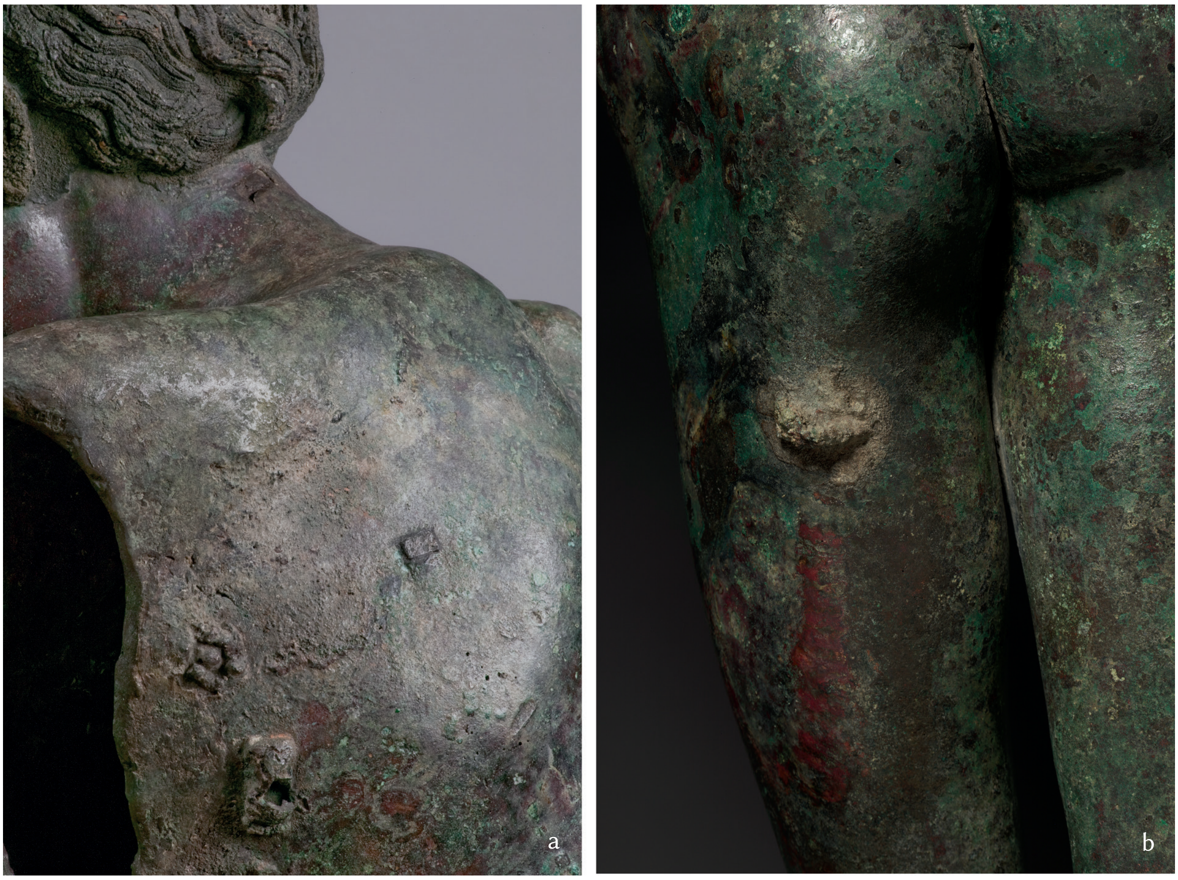


Fig. 20. The protruding lumps of metal on the left shoulder blade (a) and left upper thigh (b) appear in the same locations as tree branches on marble copies.

a piece of metal."[24] If the sculpture once stood on some form of this baseplate, one might expect more regular dimensions and the incorporation of holes or other features facilitating mounting both above (of the sculpture to the plinth) and below (of the plinth to a stone base). But perhaps such expectations are incorrect; given how few large ancient bronze sculptures survive with bronze baseplates, comparison remains difficult.[25]

Post-Manufacture Damage

Several aspects of the sculpture's condition seem related to post-manufacture damage rather than to original manufacture or modern restoration. First, the right side of the torso and right thigh exhibit numerous signs of deformation and breakage, now mostly repaired but with some small cracks opening into the interior of the leg. Second, a series of parallel gashes on the right shoulder and bicep must derive from some type of post-burial impact, as there is deformation of the corrosion layers, which are noted in the recesses of the marks (Fig. 19). The parallel alignment suggests contact with some type of tool that struck the bronze with enough force to displace a line of metal and push the edges upward and outward. Third, several curious lumps of metal are fused to the reverse at the left shoulder blade (2.8 × 1.4 cm) and left upper thigh (4.5 × 1.5 cm), protruding significantly from the surface (Fig. 20). Once thought possibly related to the now-lost tree, the lump on the thigh was shown by metallographic analysis "to have solidified from an oxygen-rich melt" during exposure to a high-temperature environment, such as a fire.[26]

Another protrusion of metal on the surface also appears to relate to high-temperature exposure but displays an entirely different phenomenon. On the lateral side of the right lower leg, approximately 32 cm up, an amorphous mass of metal sits atop a roughly 4 × 4 cm squarish area enclosing numerous small voids (Fig. 21). This seems to be a large casting flaw once covered by a patch, the bottom of which is still visible as a raised edge of bronze (approximately 3 cm long). If the sculpture was indeed subjected to high temperatures, the large patch, potentially composed of an alloy with a lower melting point than the surrounding bronze, could have begun to flow and then cooled into the resulting lumps now seen on the surface.[27]

24 Snyder et al. 2017, 336. For discussion of the baseplate and analysis of lead in the solder and in the bronze of the baseplate, suggesting "that perhaps the baseplate was reused or recast from the original sculptural assemblage," see Snyder et al. 2017, 336–337.

25 Other large bronze sculptures with bronze plinths include the under life-sized Livadhostro Poseidon (flat rectangular plinth with dedicatory inscription and four bronze feet beneath plinth to insert into stone base; see Mattusch 1988, 79, 82–83; Dafas 2019, 19); the Croatian Apoxyomenos (low rectangular plinth with flat top and four strips below, possibly modified in antiquity, feet of sculpture soldered to base without lead tenons; see: Saladino 2006, 47–48; Karniš Vidovič – Mille 2017); and the Washington Dionysos (flat hexagonal plinth with incised outline for foot and depression for big toe, traces of lead but no dowels or tenons for fastening; see Mattusch 1996, 230; now on loan to the Art Institute of Chicago, https://www.artic.edu/artworks/217295/statue-of-young-dionysos [last access 27. 07. 2024]).

26 Snyder et al. 2017, 331, 335–336, Fig. 40.5. The shoulder-blade lump requires further analysis, particularly given its possible proximity to a tree.

27 Jeffrey Maish discusses and illustrates the flawed casting and subsequently damaged patch in a 2022 internal report. Other possible evidence of exposure to a high-temperature environment came to light during exploratory handheld XRF of the bronze surface, undertaken in search of evidence for intentional patinas or protective coatings. Surprisingly, results indicated that the surface of the sculpture was 75–80% lead, far different from previous metallographic analysis (from cross-sections) that provided lead percentages of no more than about 15%. XRF of known bronze standards confirmed the machine was calibrated correctly during use. Though additional analysis is needed, the extremely high lead values seen on the surface may corroborate the earlier analysis that indicated exposure to fire; that is, the lead, with a lower melting point than copper, may have "sweated" to the surface during this event.

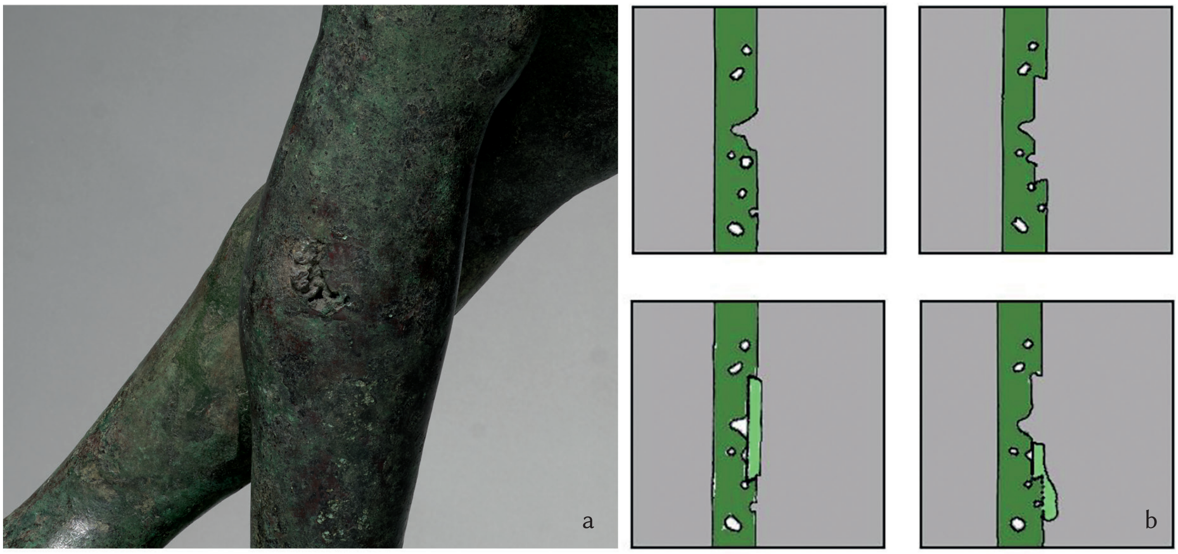


Fig. 21. The mass of metal seen on the right leg (a) appears to have a square outline visible. This illustration (b) suggests how a large patch could have partially melted in high temperatures (Illustration by Jeffrey Maish).

Modern Reconstruction

The modern reconstruction of the sculpture must have been done between 1992, when it was seen in pieces by Lucia Marinescu in eastern Germany, and early 2003, when it was with Phoenix Ancient Art in Geneva, Switzerland. The precise date of treatment, like the name and location of the restorer, remains unknown. Recent radiography and analysis of modern materials permits a better understanding of the extent of reconstruction, which has unavoidably influenced the interpretation of the sculpture since its initial publication.

Probably the most obvious aspect of the restoration is the long steel rod extending from the right hip through the entire right leg and continuing some 8.5 cm beyond the open bottom of the right foot, where modern materials completely seal off the opening into the leg (see Fig. 12.b). On the radiographs (see Fig. 2), the rod is seen running continuously from the opening in the foot, up the right leg, and ending at the top of the iliac crest on the outer right hip. This rod serves as a support for the sculpture when inserted into a hole in a modern structural base or platform (running through a hole in the accompanying bronze baseplate, presumably drilled at the same time the rod was inserted, based on evidence of machine cutting and lack of corrosion; see Fig. 18.a). When first acquired and photographed by the museum, the rod was positioned vertically, resulting in a very pronounced lean of the sculpture to its left side. In 2010, a new display platform was produced, with a slightly angled hole set at 10 degrees for the rod, reducing the lean of the sculpture to a more upright position, similar to those of several Roman marble versions of the Apollo Sauroktonos.[28] It is important to note that the feet of the sculpture do not sit entirely flush with the baseplate in either one of these configurations, perhaps due to differences in the relative positioning of the legs and torso between antiquity and the present. Additional internal modern interventions include a roughly horizontal plate composed of unknown material attaching the upper portion of the steel rod, at the right hip, to a squared acrylic rod running roughly vertically from within the midsection of the sculpture through the upper torso. There it is adhered to a horizontal squared rod spanning the

28 Despite this change in 2010, older photographs remain available online and appear in many subsequent publications; see, e.g., Bennett 2013, 82–83, with the Cleveland Apollo leaning farther than three marble versions.

interior from back to chest and supporting a second vertical rod that extends all the way into the top of the head. One rod terminates in the neck, while the other continues through the neck into the head of the sculpture, where it does not quite meet some foam adhered within the top of the head.

The ancient join at the neck had completely failed, and the area is extensively restored with a mix of plaster, wire mesh, fiberglass-bulked epoxy, and other materials supporting the acrylic rod and blocking the opening within the neck. On the exterior, tinted epoxy and toned plaster fills span the gaps, often covering the original bronze fragments to such an extent that ancient and modern materials are difficult to distinguish from one another. At the time of acquisition, the left eye was said to be a modern plaster replacement (which was itself replaced in 2014 for aesthetic and practical reasons).[29] Additional modern reconstructions include a large section of the left shoulder, the painted plaster fill clearly appearing as less opaque in radiographs. This was likely done for cosmetic reasons, to reduce the size of the opening into the torso and continue the line of the collarbones. Also notable is an area of fill running from one collarbone area to the other, across the upper chest (Fig. 22). Although the fill varies slightly in width, from 0.5–3.0 cm, the general contours of the areas above and below it roughly mirror one another, suggesting that the current positioning of the neck and head may be slightly higher than their original placement.[30] Alternatively, this fill may have been necessary to compensate for the considerable crushing and torsion of the abdomen and upper back, particularly on the right side. Here, too, several areas of fill are visible on the radiograph, as well as on the exterior, where the inpainting is slightly more visible than that up above. Finally, substantial portions of the crushed right abdomen and lower legs have been repaired and restored, with fewer losses and fills.

The extensive and varying modern restoration materials used in the 1990s or early 2000s have been generally noted in past reports, whether seen as a hard, green fill on the surface, or recognized in radiographs as areas of less density. However, they have not been identified until this point. In an effort to understand better the modern restoration materials used on the sculpture and thus aid in anticipating aging and preservation needs, small samples of three different restoration materials were analysed with FTIR spectroscopy. Analysis revealed that the rod in the foot is secured with a phenolic resin, a commonly found thermosetting epoxy. The green-coloured adhesive that secures and fills gaps between the broken fragments of bronze had a close match with Araldite, a phenolic resin.[31] The entire bronze was coated with a clear

Fig. 22. Detail of frontal radiograph, with arrow indicating dark, U-shaped line encircling the neck, where a large gap between pieces was filled.

29 The newly sculpted epoxy putty left eye more closely mimics the shape, colour, and gloss of the older right eye, and allows for easy removal when access to the interior is needed during study.

30 The one nearly straight edge and similarity to neck-bib joins seen on other ancient bronzes seems purely coincidental but should nevertheless be noted.

31 Epoxy and resin samples were removed with a scalpel and transferred to a diamond cell. The sample was compressed in a diamond anvil cell (Spectra Tech) and analysed between 4000 and 650 cm-1 with a Thermo Nicolet is50 with FTIR bench and Contiunμm Microscope. Spectra were collected as the sum of 32–64 scans at 4cm^{-} resolution. Data analysis was carried out with OMNIC and OMNIC Specta software. This seems to indicate the same adhesive was used for multiple types of repairs and supports throughout the object, with colorants added where they would be most visible.

Fig. 23. An R plot shows the relative probability of regions where the lead ore may have been obtained. (Graph by Patrick DeGryse and Sarah De Ceuster).

varnish, most likely to improve the saturation and colour of the significantly corroded metal, which appears to have suffered from bronze disease in the past. This varnish had a close match with Paraloid B-72, a colourless thermoplastic acrylic resin, which has been frequently used in conservation as a coating, consolidant, and adhesive from the 1970s through the present.[32]

New Analytical Findings

Recent study also provided the opportunity for several more detailed analyses, beginning with sampling material from the head. Previous analyses established that the separately cast parts of the sculpture, including the main figure, the detached forearm and hand, the creature, and the baseplate, were cast from the same melt.[33] Because initial sampling locations were chosen to be both accessible and inconspicuous, the head was not sampled at that time. Thus, to fill this gap in information, a small hole was drilled about 3 mm deep into an area beneath the hair at the nape of the neck. The powdered bronze sample was sent to Patrick Degryse at KU Leuven in Belgium, and lead isotope values were obtained (Tab. 1). These values for the head were characterized as nearly identical to the previous data for samples from other portions of the sculpture. Using the kernel density approach, Degryse and colleagues additionally analysed the new sample from the head together with the lead isotope data previously obtained by Ernst Pernicka and colleagues in 2014. They reconfirmed that the source of the lead ore is not the Aegean or Greece but possibly corresponds to French, Bulgarian, or Iranian ores, sources that are also hard to distinguish from each other as their isotopic signatures overlap (Fig. 23).[34] Of course, this does not mean the sculpture could not have been manufactured in the Aegean, rather that the raw materials do not seem to have come from that region.

Fig. 24. Detail of left eye, imaged at 3.9× magnification. The surface is relatively featureless apart from burial accretions.

Tab. 1. Lead isotope values for Apollo's head.

	206Pb/204Pb	207Pb/204Pb	208Pb/204Pb	207Pb/206Pb	208Pb/206Pb	208Pb/207Pb
Cl8	18.402	15.62	38.491	0.849	2.092	2.464

A second question left from previous studies was how precisely to characterize the ostensibly ancient right eye (Fig. 5.b, Fig. 24), said to be stone. Even under 40× magnification, the material exhibits no surface features characteristic of the most frequently encountered inlay materials; these would include grain structure (such as in marble), Schreger lines or striations (on ivory or bone), or bubbles

32 A sample of the coating from the same arm was dissolved with acetone on a cotton swab and transferred to a Low-e microscope IR slide from Kevley Technologies. This was analysed in transflectance mode.

33 Snyder et al. 2017.

34 See De Ceuster – Degryse 2020 for kernel density approach to interpreting lead isotope signatures of ancient artifacts.

(in glass).[35] Thus, FTIR spectroscopy was used to analyse a small scraping from the underside.[36] The resulting spectrum was compared to various material libraries and most closely matched calcium carbonate. The relative hardness of the material when sampled and the absence of sulphates immediately ruled out alabaster and gypsum. Petrographer David Saja examined the object under magnification and confirmed these observations, offering further thoughts that pink fluorescence that had been noted under ultraviolet light could indicate manganese content, something typical of some calcites. To further determine whether the eye was carved chalk or calcite, an additional small scraping was obtained for polarized light microscopy. The material is extremely fine grained, compositionally homogeneous, with minor slightly larger tabular grains that exhibit pleochroism. Thus, despite the presence of modern clear acrylic adhesive around the perimeter of the eye, which had called into question whether it was indeed ancient, it is highly likely that the original eye is carved from calcium carbonate in the form of chalk, and it was simply re-secured during the most recent restoration.[37] For comparison, the sclerae of the Riace bronzes, formerly thought to be ivory, have recently been described as white calcite.[38]

Fig. 25. A photo of the material collected from the interior of the sculpture includes several pieces of red-orange fired clay.

A third area for analysis came about when the plugged opening in the left foot was removed, releasing a significant amount of material that had loosened and fallen through the interior (presumably over many years, with the vibration of each movement of the sculpture). An entire petri dish was quickly filled with bits of epoxy and fiberglass as well as dirt, sand, and fired terracotta material (Fig. 25). Although none of the terracotta pieces seemed to preserve any clear contours of the sculpture, they may have derived from the original clay core, and the number and size of the pieces (some 3–4 cm long) provided opportunities for sampling and analysis. Unfortunately, thermoluminescence (TL) testing could not be used because of the high amounts of radiation the object received during radiography, first in 2003 and again in 2021.[39] With this in mind, neutron activa-

35 Many ancient inlaid eyes have been identified visually yet not properly analysed. On eyes of Greek bronzes, see Descamps-Lequime 2015, 156–159; Giumlia-Mair 2015, 176. For an image of marble eyes of similar shape to that of the Cleveland Apollo, see Dafas 2019, Pl. 177c (from Olympia, no inv. numbers listed).

36 The scraping was obtained with a clean tungsten needle. See footnote 32 for FTIR analysis settings. A spot test of materials scraped from the underside showed the presence of lead, and more research is necessary to determine if this is due to contamination from the adjacent leaded bronze or whether possible lead content within the stone can help narrow its origin.

37 The adhesive was identified based on visual appearance, UV-induced fluorescence, and analysis of other similar material on the sculpture. See footnote 32.

38 See Giumlia-Mair 2015, 176, with additional reference.

39 TL dating is commonly used for clay objects, including bronze cores, to provide an estimate of when the crystalline material was last fired, by measuring the amount of radioactive energy stored since that high-temperature event. The materials would have absorbed enough additional radiation through the two known radiography sessions to exclude the possibility of dating them in this way. (Also, the above-mentioned exposure to a high-temperature environment could have reset the signal at whatever point it occurred.)

Tab. 2. Neutron Activation Analysis of terracotta fragment from inside sculpture.

ANID	CMB006
Alt_ID	**2004.30**
Na (%)	0.19
Al (%)	8.68
K (%)	2,90
Ca (%)	3.66
Sc	15.1
Ti (%)	0.43
V	109
Cr	87
Mn	875
Fe (%)	4.06
Co	16.2
Ni	48.9
Zn	109
As	23.4
Rb	152
Sr	100
Zr	111
Sb	2.26
Cs	12.0
Ba	891
La	41.2
Ce	82.4
Nd	36.5
Sm	7.21
Eu	1.39
Tb	0.97
Dy	5.84
Yb	3.03
Lu	0.42
Hf	5.5
Ta	1.29
Th	13.5
U	2.90

tion analysis (NAA) was sought in order to determine where the raw material of the ceramic was obtained. One terracotta fragment was sent to Mike Glascock and colleagues at the University of Missouri Archaeometry Laboratory. The lab team undertook sampling, analysis, and interpretation of the submitted fragment, identified as CMB006.[40] The terracotta was compared to five different compositional databases of pottery from the Mediterranean region, including more than 10,000 specimens from Greece (Tabs 2–3).[41] The results included 10 matches characterized by Glascock as "good" but not "excellent." According to his report, "All of the ten closest specimens were from the western Mediterranean which strongly suggests that the fragments are not from the Attic region of Greece."[42] Of these matches, the closest was to a terracotta figurine fragment found at Naxos, Sicily, but thought to be an import from either Catania or Syracuse on the east coast of Sicily.[43] The report continues "The next nine nearest specimens came from the Catalonia and La Rioja regions of Spain and were identified as samples of majolica pottery," before concluding "With the exception of strongly suggesting that the terracotta fragments came from the western Mediterranean, we are unable to link the sample to a specific production site."[44] Although this leaves open a vast range of potential production sites for the Cleveland Apollo—assuming that the terracotta fragments were indeed from the clay core of the sculpture, rather than intrusive material

40 Two analytical samples were prepared from each specimen, taken with a tungsten carbide drill bit. Neutron activation analysis of ceramics at MURR (University of Missouri Research Reactor) which consists of two irradiations and a total of three gamma counts, constitutes a superset of the procedures used at most other NAA laboratories. The analyses at MURR described above, produce elemental concentration values for thirty-three elements in most analysed samples. Statistical analysis was carried out on base-10 logarithms of concentrations of these elements. For further details on NAA, see Glascock – Neff 2003.

41 These include the legacy databases created by the Lawrence Berkeley Laboratory (LBL), Brookhaven National Laboratory (BNL), and Manchester University (operating between the late 1960s and the early 1990s), the Bonn laboratory (closed around 2005), and the MURR database, which is still active. The first four databases contain approximately 25,000 specimens and the MURR database contains over 22,000 specimens. It is important to note that 25% of the data pertains to ceramics and clays from Greece.

42 Quotation from Section 5.3, "(CMB006) Terracotta fragments from inside the leg of an Apollo statue by Glascock," in unpublished report, "Neutron Activation Analysis of Objects from the Collections of the Cleveland Museum of Art (ANIDS: CMB001-006)" (revised January 2023, supported in part by NSF grant BCS-1912776 to the Archaeometry Laboratory at MURR). The report was revised slightly following a second analysis taken from the same specimen, with the same ten closest matches, all in the MURR database.

43 The fragment is Naxos 2179; see Uhlenbrock 2002, 329, Fig. 3. Jaimee Uhlenbrock (personal communication) suggests Syracuse or Catania as likely origins for the fragment.

44 Quotation from Section 5.3, "(CMB006) Terracotta fragments from inside the leg of an Apollo statue by Glascock," in unpublished report, "Neutron Activation Analysis of Objects from the Collections of the Cleveland Museum of Art (ANIDS: CMB001-006)" (revised January 2023, supported in part by NSF grant BCS-1912776 to the Archaeometry Laboratory at MURR).

not connected with its original manufacture—additional evidence may help to zero in on a smaller area, perhaps in or around eastern Sicily.[45]

Thin section petrography was also pursued in hopes of linking the clay with geographical regions from which it might have originated. Sonia Mugnaini and Marco Giamello, experts in diagnostics applied to cultural heritage conservation at the University of Siena, have undertaken the analysis of four pieces of terracotta material and three fragments of sandy material from the interior of the sculpture. This research is still in progress, so it remains unclear whether the terracotta relates to original manufacture, history of display, or restorations. We anticipate publishing the results of further analysis of this material when available.

Tab. 3. Terracotta specimens from MURR database matched to Cleveland fragment based on NAA.

ANID	Distance	Region	Country	Subregion	Site Name	Ware/Type	Period	Date Range
NAX035	0.0172	Western Mediterranean	Italy	Sicily	Sicilian Naxos	Figurine of Woman Holding Pig	Classical	Late 5th century BC
MAS081	0.0182	Western Mediterranean	Spain	Catalonia	L'Estartit	Majolica Tile	Spanish Renaissance	AD 16–17th century
MJ0210	0.0194	Western Mediterranean	Spain	Catalonia	Vilafranca Penedes	Majolica	Spanish Renaissance	AD 16–17th century
MJ0209	0.0195	Western Mediterranean	Spain	Catalonia	Vilafranca Penedes	Majolica	Spanish Renaissance	AD 16–17th century
NAJ053	0.0199	Western Mediterranean	Spain	La Rioja	Alcazar de Najera	Majolica	Spanish Renaissance	AD 16–17th century
MJ0201	0.0199	Western Mediterranean	Spain	Catalonia	Vilafranca Penedes	Majolica	Spanish Renaissance	AD 16–17th century
MJ0204	0.0200	Western Mediterranean	Spain	Catalonia	Vilafranca Penedes	Majolica	Spanish Renaissance	AD 16–17th century
MJ0234	0.0201	Western Mediterranean	Spain	Catalonia	Vilafranca Penedes	Majolica	Spanish Renaissance	AD 16–17th century
MJ0205	0.0202	Western Mediterranean	Spain	Catalonia	Vilafranca Penedes	Majolica	Spanish Renaissance	AD 16–17th century
MJ0230	0.0203	Western Mediterranean	Spain	Catalonia	Vilafranca Penedes	Majolica	Spanish Renaissance	AD 16–17th century

Digital 3D Model and Next Steps

A digital 3D model was created in 2022 using photogrammetry. The photogrammetric model was created with hundreds of photos taken in cross-polarized light to reduce surface gloss and glare and obtain the most accurate topographical information. The model is hosted on Sketchfab and available directly through the Cleveland Museum of Art website in Collection Online,[46] where users can view the sculpture in ways not possible in the galleries (from directly above or below, for example). For researchers, the model has proven useful with colour and surface texture removed to study the topography of the sculpture, especially in documenting patches. The location of patches and joins can also be clearly communicated through line drawings created from the 3D model (Fig. 3). In addition, the 3D model permits close comparison with digital models of similar but more complete Roman marble

45 It is worth noting that majolica pottery had a wide range of production sites, not only in Spain but also in eastern Sicily (at Caltagirone) and other parts of Italy. We have not yet identified the nine majolica specimens from Spain deemed close matches, but hope to do so as our research continues; perhaps, as Uhlenbrock has suggested (personal communication), these were imports to Spain from Sicily, which might explain their close matches to the Naxos fragment in the MURR database.

46 https://www.clevelandart.org/art/2004.30#3d (last access 23. 02. 2023). The model was produced by Howard Agriesti and Dale Utt III.

versions of the Apollo Sauroktonos, such as one now in Liverpool, from the Ince Blundell collection (Fig. 26). Thus, even when the actual sculptures cannot be physically displayed alongside one another (as the Liverpool and Louvre Apollos were in 2013 in Cleveland), viewers can take note of similarities and differences both obvious and subtle; some of these stem from differences in material, others from the piecing together of ancient and modern pieces.[47] Moreover, the digital model can communicate a range of possible spatial relationships between the figure, its detached hand, forearm, and creature, and numerous components that no longer survive, including the lower right arm and hand, the upper left arm, and the tree once used as a support. In the future, such visualizations might be incorporated into the gallery display as well as online. Finally, digital technology may allow additional interpretive technologies, such as incorporating radiographic images or images of the interior of the sculpture to help viewers understand certain details of ancient manufacture and modern reconstruction described above. Certainly, many questions remain about this important and enigmatic sculpture, and we hope that the digital model may encourage other scholars and students to engage with it in new and interesting ways.

Fig. 26. A 3D model overlay of the Cleveland Apollo with the Apollo Sauroktonos in Liverpool (NML, World Museum), allows for more direct comparisons (Overlay by Dale Utt III, Liverpool model by Ardern Hulme-Beaman).

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47 On the Ince Blundell Apollo (Ince 558, National Museums Liverpool, World Museum 59.148.12), see Bartman 2017, 78–81. Note that the head is ancient but perhaps from another sculpture, while significant portions of the arms, legs, and base with tree and lizard are modern. The Liverpool model was created by Ardern Hulme-Beaman.

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