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An Achaemenid God in Color

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Abstract: A limestone relief fragment with a figure in a winged disk from the fifth-century BCE Hall of 100 Columns at Persepolis in southwestern Iran that entered the Harvard Art Museums' collections in 1943 preserves significant traces of its original coloration and has played a key role in the rediscovery of polychromy at the Achaemenid Persian capital. After tracing the fragment's journey to Cambridge, MA, this article presents the results of recent technical studies of its pigment remains, including visible light-induced infrared luminescence (VIL) imaging, X-ray fluorescence (XRF) spectroscopy, and the analysis of micro samples by Raman spectroscopy, Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), and polarizing light microscopy (PLM). The new scientific data is compared to the findings of ongoing investigations of polychromies at Persepolis and other Achaemenid Persian sites and evaluated for the information it can and cannot provide on the original appearance of the figure in the winged disk, likely the Zoroastrian god Ahuramazda. The article reviews past attempts at reconstructing the relief's coloration and the assumptions that guided them, recounts the experience of creating a tangible three-dimensional color reconstruction for an exhibition, and concludes with some general thoughts on the valuation of colorfulness.

Keywords: Persepolis; Iran; Achaemenid; relief sculpture; polychromy; pigments; Egyptian blue; analysis; raking light; reconstruction

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1. Introduction

Museums around the world, including most larger and several smaller institutions in the United States of America, hold in their collections fragments of sculptural reliefs from the ancient Persian capital city Persepolis [1–3] (pp. 238–251). The Harvard Art Museums in Cambridge, MA, are the keeper of six such limestone fragments, including one from the Hall of 100 Columns with the partial representation of a figure in a winged disk, most commonly interpreted as the god Ahuramazda. These museum objects are fragmentary in more than one sense. Separated from their original architectural setting and adjacent carvings, they preserve only slivers of a comprehensive sculptural program created on the site of Persepolis during the Achaemenid Persian empire (c. 550 to 330 BCE) to render visible and perpetuate the power of Achaemenid kingship [4]. Viewed by themselves, the fragments do not speak of majesty; Ahuramazda literally had his wings clipped when his depiction was removed from the site. Yet, the three-dimensional context—the stone and mud brick architecture and other sculptures in relief and in the round—constituted only a part of the overall picture. The appearance of the reliefs was determined by their surface, once brightly painted and sometimes also otherwise adorned. Ancient visitors to the palaces at Persepolis saw color as well as form.

For the greater part of the 20th century, color played a marginal role in scholarship on and public awareness of the ancient world. Recent decades have brought intensified efforts to reintroduce color into modern views of the past, and polychromy studies have made great strides. There are new scientific methods of investigation, and a rapidly growing number of exhibitions, publications, and conferences have opened up fresh approaches to ancient polychromies [5–15]. These studies leave little doubt that painting architecture and sculpture was standard practice in ancient societies, and they provide ample illustration that a monument's surface treatment could convey its essence. Since ancient Egypt and the Middle East have always tended to be colorful in Western minds (witness the admiration for the painted bust of Nefertiti), what has jolted scholars and the public alike has been, primarily, the realization that much of the white marble sculpture of ancient Greece and Rome was painted. However, there have also been detailed studies of the original coloration of monuments in Mesopotamia, the Levant, and Iran and popular digital attempts to recreate their former appearance [16–20]. Glaring gaps in our knowledge persist, but Classical antiquity has been pulled out of what one might be tempted to term its splendid isolation and reintegrated into the more colorful universe of which it once was a part.

On this basis, we may begin to study the colored architecture and sculpture of the ancient Middle East and Mediterranean region as closely connected and on a continuum of sorts, moving beyond establishing the mere presence of color to asking more nuanced questions. Which pigments, binding media, and ground layers were used on what kinds of supports? Was there a difference between indoor and outdoor surfaces? Was every surface painted? How did coloration relate to styles of carving? How did approaches to polychromy change over time, and to what extent were they regionally specific? Was paint application determined by the function of a monument, and could it have a ritual role? How far was polychromy dependent on what was represented? For example, were images of deities colored differently from those depicting humans? Finally, and fundamentally, how would an ancient viewer at a given place and time have looked at a colored monument? How would they have perceived individual colors and the interplay of sculptural form, surface treatment, space, and light? As careful analyses considering both textual sources and the material record can demonstrate, the way color was understood and valued in different areas of the ancient Mediterranean and Middle East differs significantly from modern European and North American conventions [21,22]. Consequently, preconceived notions may be inherent in the very vocabulary we use to describe remnants of ancient polychromy, a bias that is particularly difficult to overcome in cultural environments such as Achaemenid-period Iran, which has left us with few written texts.

Keeping these questions and caveats in mind, the present paper focuses on the Persepolis relief fragment with the figure in a winged disk now at Harvard. We seek to recontextualize the relief by reconstructing its original appearance to the extent this is possible and by exploring how it might have been received by those who saw it. Since we do not have any reports of ancient visitors experiencing the Hall of 100 Columns, we need to fall back on more general considerations of the intended effect of the building's sculptural decoration. The fragment preserves patches of red, blue, and green pigment that, in its current condition, are easily visible to the naked eye. First studied over 50 years ago by Judith Lerner [23–25], then a doctoral student at Harvard University, the fragment's polychromy inspired investigations of the traces of coloration remaining on the architectural facades at Persepolis itself as well as the scientific examination of pigment samples from the site, the latter involving conservation scientists at Harvard [26,27]. The Harvard Art Museums have been at the forefront of research into the materials and making of art since the early twentieth century, as is illustrated by the extensive collection of pigments initiated by the museums' second director, Edward Waldo Forbes (1873–1969), which continues to grow [28,29].

When the Harvard Art Museums hosted the exhibition "Gods in Color: Painted Sculpture of Classical Antiquity" in fall 2007 [30–32], it seemed a good moment to revisit the fragment's coloration. The incised patterns on the figure's robe were examined under

raking light, and the preserved traces of paint were analyzed in the museums' Straus Center for Conservation and Technical Studies. The results of these investigations informed a three-dimensional color reconstruction that was created for inclusion in the exhibition. In 2012 and again in 2021, the initial research was followed by further technical imaging, notably visible light-induced infrared luminescence (VIL) imaging, whose capability of revealing Egyptian blue had meanwhile been discovered [33–35]. Attempts at elemental mapping of the relief's surface by scanning macro-X-ray fluorescence (MA-XRF) had to be postponed because of repeated instrument failure.

Because of its comparatively extensive pigment traces, first described exactly one hundred years ago in 1923, the relief fragment has played—and has the potential to continue to play—a key role in understanding the polychromies of Persepolis. The long history of research focused on this particular object makes for an instructive case study, as it exposes continuities in interpretation even in the face of new technologies. This article traces the history of the fragment, outlines its original placement at Persepolis, and describes the results of the scientific examinations undertaken between 2007 and 2021. After taking stock of both the data gathered so far on the fragment's remaining polychromy and the limitations imposed by the loss of much of its painted surface, the paper goes on to review other evidence that might hold clues to the original coloration and intended effect of the relief, such as remnants of surface treatments preserved on other architectural sculptures at Persepolis and nearby Naqsh-e Rustam; the appearance of the god Ahuramazda in written sources; and comparisons with monuments and artifacts in other media, such as glazed brick decoration, inlaid gold jewelry, and textiles. It considers the heuristic value of creating a three-dimensional color reconstruction and ends with brief remarks on colorfulness and its appreciation (and deprecation) through the ages.

It should be noted that this article is intended not as the definite publication of the fragment's polychromy (a new color reconstruction is not provided) but rather as a foundation on which further research may build. We hope that our in-depth exploration will contribute to the study of the Achaemenid Persian empire not just by helping reconstruct its material culture but also by offering a glimpse of the ideas that lay behind it.

2. Description and History of the Fragment

2.1. The Fragment and Its Original Location

The relief fragment (1943.1062) at the center of this article is of brownish limestone and shaped like an upright rectangle, missing an elongated section in the upper left corner (Figure 1). The height of the fragment is 73 cm (28 3/4 in.); the greatest preserved width is 44.3 cm (17 7/16 in.); and the maximum thickness is c. 10 cm (3 15/16 in.). Carved in low relief, it depicts a bearded figure facing right, the lower body emerging from what is most often termed a disk but is rendered as a ring. The ring is fully preserved, but the outstretched wings, tail feathers, and two curled appendages that grow from it are cut off, indicating that substantial parts of the relief are missing, especially on the sides but also below.

The fragment's history can be read on its sides and back (Figure 2). The top and bottom are flat and relatively even. Although the top surface is weathered, the parallel marks of a claw chisel—also called a toothed chisel and well attested at Persepolis [36]—can still be made out. Most of the bottom is covered in whitish-brown accretions. Clearly, these two surfaces are ancient. They constitute the original top and bottom of the relief block, which joined other architectural elements above and below. In contrast, the left and right edges of the fragment are jagged. The shattered surfaces and occasional pick marks and grooves suggest the use of a pick, hammer, and/or pointed chisel to separate the fragment from the larger block and straighten the resulting (and perhaps also pre-existing) breaks. The back of the fragment, too, is roughly worked. Presumably, its thickness was further reduced after extraction to make it less unwieldy and lighten the load for transport. The back also reveals a horizontal break meeting a shorter, vertical one. The latter continues down from the vertical edge of the fragment's stepped corner. The smallest of the three

resulting pieces is filed down at the back. These breaks likely occurred when the relief was trimmed to create an object of suitable dimensions and format, i.e., relatively flat and roughly rectangular, for display on the wall in a collector's home or a museum. Modern fills and overpaint render the damage less visible in front, while dripped glue at the back attests to an earlier, sloppy repair.

Figure 1. Relief fragment from the Hall of 100 Columns, Persepolis (Iran): Ahuramazda in the winged disk, mid-5th century BCE. Harvard Art Museums/Arthur M. Sackler Museum, Bequest of Grenville L. Winthrop, 1943.1062. ©President and Fellows of Harvard College.

The original location of the fragment at Persepolis is not difficult to pinpoint, as other parts of the block and other components of the relief—preserving the wings and tail feathers of the ring—have remained on site; in fact, the block and its polychromy were noted before it was broken up. A large horizontal rectangle, the block formed part of the uppermost section of the doorjamb of a monumental entrance to the southern part of the Hall of 100 Columns, so named after the ten rows of ten columns in its interior that were once topped with capitals in the shape of addorsed bull foreparts (Figure 3a). An inscription excavated in the building attests that its construction was begun by king Xerxes (r. 486–465 BCE) and completed by his son Artaxerxes I (r. 465–424 BCE) [37] (pp. 124–137). Situated east of the Apadana, the audience hall erected by Darius I (r. 522–486 BCE), the Hall of 100 Columns was the second space at Persepolis where the king could have hosted large social gatherings, and its excavators referred to it as Throne Hall. For a period, the building also served as an extension of the Treasury, located to the south. The main approach to the Hall of 100 Columns was through a columned portico in the north. The square hall itself had two entrances on each side; those in the south, east, and west led to long, comparatively

narrow vestibules and storerooms. Apart from the stone columns with capitals in the shape of addorsed bull foreparts, stone-clad doorways, and stone-framed windows and niches, the building was constructed of mudbrick and wood. These latter materials are largely lost, lending the ruins a somewhat skeletal appearance.

(**a**) (**b**)

Figure 2. Side (**a**) and back (**b**) views of the fragment with figure in a winged disk (photographs: Mary Kocol, Peter Schilling) ©President and Fellows of Harvard College.

(**a**) (**b**)

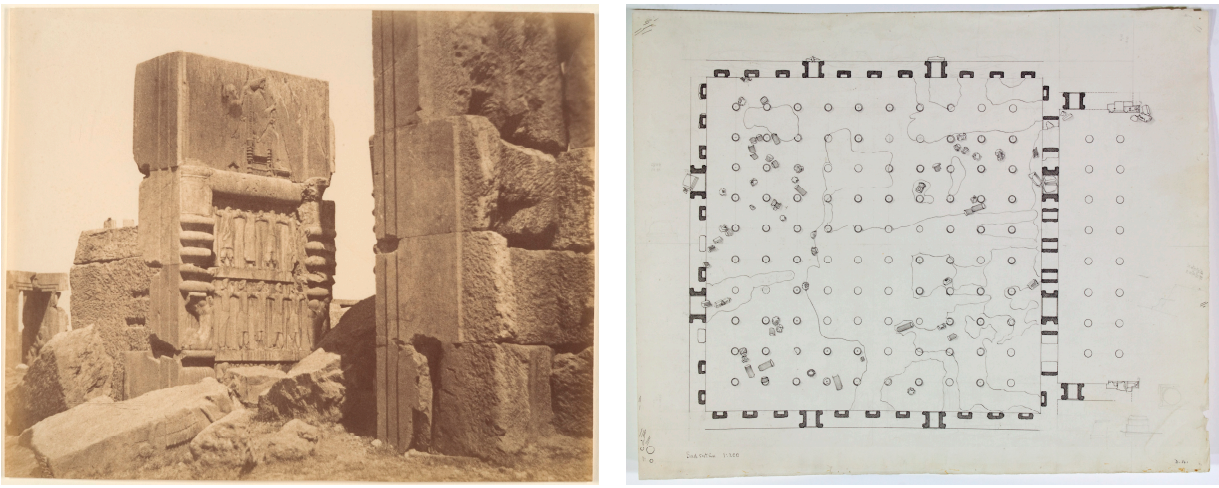
Figure 3. The Hall of 100 Columns from the southeast (**a**) and a view of the western jamb of the southeast doorway (**b**), seen in 2008 (photographs: Susanne Ebbinghaus).

The south doorways were 11 m (36 ft.) tall, 2.5 m (8.2 ft.) wide, and 3 m (9.8 ft.) deep [38]; those in the north were even taller. The carved doorjambs depicted, in the north,

the king at audience above five registers of armed guards, and, in the south, the king seated on a throne atop a gigantic stool supported by three files of representatives of the empire's subject peoples (Figure 3b) [37] (pp. 134–36, pls. 102–113). The smaller east and west doorways featured the king in the guise of a royal hero defeating mythical beasts. In all these representations, the figure of the king faces into the hall. In the reliefs of the south doorways, he is alone but for an attendant with flywhisk and towel shown at a smaller scale behind the throne. Above the king and his attendant extends a canopy richly adorned with two winged disks, multiple bulls and lions, and bands of rosettes; at the very top of the jamb, just below the lintel, hovers the figure in the winged disk, referred to here as Ahuramazda. The god extends one hand in a greeting and holds a flower in the other. He is oriented in the same direction as the king and the subject peoples below. The fragment now at Harvard comes from the western jamb of the eastern doorway in the south façade [25]. The god would have looked north into the hall, the same direction in which the king would have walked if he entered the building through this doorway.

2.2. From Persepolis to Cambridge, MA

Today, a blank piece of stone fills the void left by the absent Harvard fragment in the reconstructed doorway at the site. As a photograph taken by Italian photographer Luigi Pesce (1818–1891) in 1857 illustrates [1] (pp. 137–139), [39] (p. 159), the blocks that formed the three topmost courses of the western jamb and depicted the royal baldachin and the figure in the winged disk had toppled by the mid-19th century (Figure 4a). The corresponding eastern jamb remained largely intact, which means that the relief fragments visible on the ground in Pesce's photograph must have fallen from the doorway's western side. In the left foreground is the block carved with the winged disk's tail feathers and curled appendages. Pesce's photograph conveys a sense of the substantial thickness of these blocks. The block comprising the figure in the winged disk is not visible in this photograph but can be spotted lying immediately to the north of the southeast doorway in an undated plan of the Hall of 100 Columns drawn by German scholar Ernst Herzfeld (1879–1948) (Figure 4b) [40]. From 1931 to 1934, Herzfeld led the first large-scale excavations at Persepolis under the auspices of the Oriental Institute of Chicago (now the Institute for the Study of Ancient Cultures, West Asia & North Africa), but he had already carried out explorations on the site in November and December 1923 and March 1924 [41].



(**a**) (**b**)

Figure 4. (**a**) Southeast doorway of the Hall of 100 Columns, photographed by Luigi Pesce, 1857. Albumen silver print. Metropolitan Museum of Art, Gift of Charles K. and Irma B. Wilkinson, 1977: 1977.683.71. (**b**) Plan of the Hall of 100 Columns, drawn by Ernst Herzfeld. Ernst Herzfeld/National Museum of Asian Art Archives, Smithsonian Institution, Ernst Herzfeld Papers, FSA_A.06_05.0861.

It appears that once it had fallen, the block with the figure in the winged disk lay right-side up, with soil accumulating around it until only the upper part of the god's figure projected from the ground. This, at least, is suggested by the fact that substantial traces of coloration have survived only on the lower part. An annotated sketch from 1923 of the proper left wing of an Ahuramazda figure from the southeastern doorway of the Hall of 100 Columns—according to the notes, showing "fresh" colors when it was excavated—must refer to the block from the western jamb (see below, Fig. 6) [42] (p. 2). It seems that Herzfeld located and cleared this block, a state captured both on a later page of the same sketchbook [42] (p. 4) and in a photograph that shows the block in a diagonal position near the doorway, its carved front in the shade except for Ahuramazda's spotlighted back [43] (digital image), [44] (pl. 11/12, fig. 21). The block is in one piece, but its right end is missing. The diagonal position would explain why Herzfeld drew only the wing on the right, lower side: this was the part that he freed from the earth and where the colors were the brightest (he gave no detail for the outermost feathers because this end of the block had broken off). When he returned to Persepolis in 1931, he added a pencil note to his sketch, stating that he found the relief "completely destroyed/shattered, by dealers, the small Ahuramazda figure chiseled out" (*vollkommen zerstört/trümmert gefunden, von Händlern, die kleine Ahuramazda-Figur heraus gemeisselt*).

Italian architect Giuseppe Tilia (1931–2001) and his wife, Swedish scholar Ann Britt Pettersson Tilia (1926–1988), who carried out studies and conservation work for the Italian Institute for the Middle and Far East (IsMEO) at Persepolis in the 1960s and 1970s, encountered the block broken in three pieces, with its central part missing [26] (p. 33, pl. 24, fig. 19). A drawing published by Ann Britt Tilia [26] (p. 34, fig. 1a) demonstrates that the Harvard fragment does not directly join the parts of the block that are preserved on site; there is extensive loss of relief surface to the left and right of the figure, where only smaller chunks carved with wing feathers remain. These smaller pieces were not integrated into the re-erected doorway. Taken together, the available evidence suggests that the fragment with the figure in the winged disk—like other Persepolis fragments at Harvard and elsewhere—was removed not long before Iran passed the *National Heritage Protection Act* on 3 November 1930 [2,45]; the removal caused significant damage. The information published in 1943, based on dealer correspondence [46], that the fragment was in England in 1914 [47] (p. 44 n. 1) is contradicted by Herzfeld's documentation.

The story of the fragment's second life as a collector's item and eventual museum object can be resumed on 9 February 1931, when it was acquired by the Brummer Gallery in New York through the youngest Brummer brother, Ernest (1891–1964), who was then still based in Paris. Here, the fragment—identified as "Assyrian relief"—received the inventory number P7339. The inventory card [48] lists "Sasoun" as the seller, a reference to the Sassoon brothers of Isfahan, Iran, who also maintained an address in Paris and had amassed a great number of fragments of architectural sculptures from Persepolis during these years [2] (pp. 142–158). The fragment arrived in the New York gallery on 25 February 1931, where it was sold the very next day and at significant profit to Harvard alumnus Grenville L. Winthrop (1864–1943). The object was provided with an expert certificate and published with an illustration in an encyclopedia of world art by the Spanish scholar José Pijoán (1881–1963), a teacher at Pomona College in California and the University of Chicago with an apartment in New York City [48–50]. The sale was finalized in June 1932.

A large-scale collector, Winthrop was focused on European paintings, drawings, and prints, as well as early Chinese bronzes and jades. He did not collect Greek and Roman antiquities but purchased a small number of Egyptian works [51,52]. In addition to the fragment discussed here, he would acquire five further pieces from Persepolis, all through the Brummer Gallery: two heads of royal guards and three figures of attendants carrying provisions (1943.1063–1066; 1943.1311) [53]. Photographs of Winthrop's house at 15 East 81st Street in New York show the relief fragments encased in dark wooden frames atop matching pedestals, interspersed with European works of art (Figure 5). In a faint echo of its original location, the fragment with the winged disk was placed against a closed door (as

were two others). Its missing upper left corner had been filled in to create a proper rectangle, a restoration only removed in the early 1980s. Coincidentally, while in Winthrop's house, the fragment was located just across Fifth Avenue from a cast of the east doorjamb of the southeastern doorway of the Hall of 100 Columns on display at the Metropolitan Museum of Art [54]. After Winthrop's death in 1943, his extensive collection came to the Fogg Museum of Art, which is now one of the three Harvard Art Museums. Other institutions in the United States that hold relief fragments from the Hall of 100 Columns include the University of Pennsylvania Museum of Archaeology and Anthropology in Philadelphia, the Institute for the Study of Ancient Cultures in Chicago, and the Seattle Art Museum [3].

Figure 5. The relief fragment on view in the third-floor hallway of Grenville Winthrop's New York City home, 1943. Grenville Winthrop Papers (SC 21), folder 302. Harvard Art Museums Archives, Harvard University, Cambridge, MA. ©President and Fellows of Harvard College.

Winthrop's six Persepolis relief fragments entered the Harvard Art Museums' collection incrusted with a layer of calcium carbonate. In 1965, in preparation for display, the reliefs were brought to the conservation lab, where the calcium carbonate deposits were softened by soaking and then removed with knives. The treatment record states: "When the stone was cleaned and wet, the colored areas became more obvious" [55]. So far, no pigment remains have been discovered on the other five fragments. This is not entirely surprising, considering that they formed part of outdoor facades long exposed to the elements.

3. Tracing Color

3.1. With the Naked Eye and Magnification

Once one knows to look for them, the areas of pigment on the surface of the fragment with Ahuramazda are easily visible. As mentioned above (Section 2.2), traces of paint that can be seen with the naked eye are confined to the fragment's lower half. The surviving colors were first observed by Ernst Herzfeld immediately after the relief block of which the fragment formed part was unearthed in the fall of 1923 [42] (p. 2). Herzfeld drew a pencil sketch of the proper left wing, which he annotated—in German—with color terms (Figure 6). According to his notes, there was red paint on the topmost row of small feathers, blue on the middle one, and red again on the lowest. The uppermost row of longer feathers appeared light blue; in the middle row, he recognized red toward the wing tip and "perhaps" red and blue closer to the ring. The lowest row of feathers he described as blue with red ends. He noted that the red tended toward carmine rather than pure cinnabar and that the blue was more like cobalt than cerulean. The colors outlined in the sketch are nearly identical to those of a watercolor of the figure in the winged disk that he would

later publish (in black and white) in his *Iran in the Ancient East*, where he used red and purple for Ahuramazda's robe, dark blue for his hair and beard, yellow for the ring with its appendages, and green for the flower (see below, Section 4.3.1) [56,57] (pl. 64).

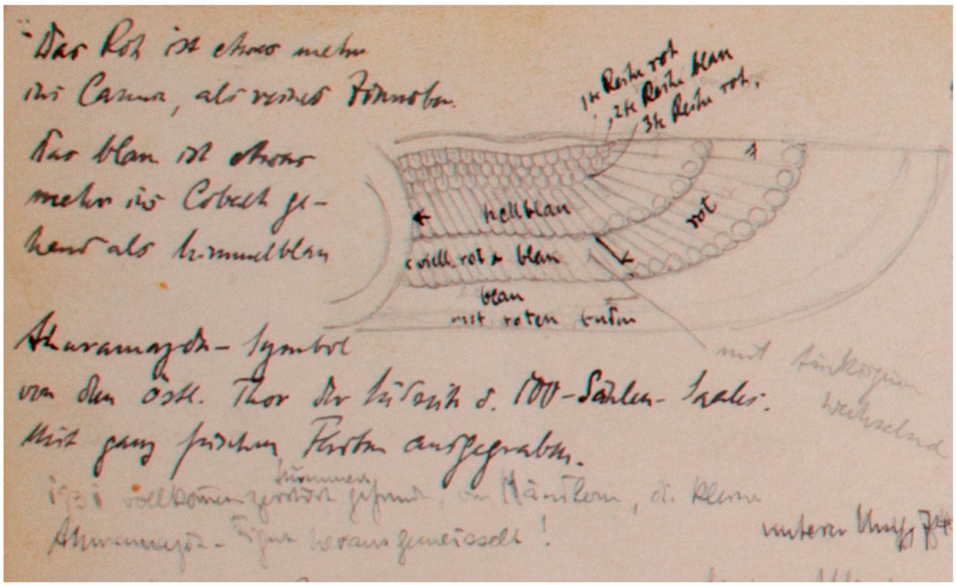


Figure 6. Detail of a sketchbook page from 1923. Ernst Herzfeld/National Museum of Asian Art Archives, Smithsonian Institution, Ernst Herzfeld Papers, FSA_A.6_02.01.06.003 (Detail).

After the fragment at Harvard had been treated in the conservation lab, Judith Lerner was the first to map the newly revealed traces of color for her publications, which appeared in the early 1970s [23–25]. Most obvious as one gazes at the relief surface are the patches of bright red color on the lower part of the god's finely pleated robe (Figure 7a). Spots of bright red also occur higher up on the garment, on the wide sleeve (which is really a pseudo-sleeve since the robe is a belted rectangle; see Section 4.3.2 below). Upon closer inspection, the color on the lower part of the sleeve, below the elbow level, is a darker red or purple (Figure 7b). The traces of this dark red extend to two broad decorative bands—one running horizontally across the sleeve and one along its edge—indicated by incision (see Figure 8b below). No other color seems to have survived inside these bands. The bands are lined on both sides with narrow borders that preserve bright red; under magnification, blue can be seen, as well. Traces of bright red, dark red, and blue can be detected on the overlapping edges of the sleeves in front of the figure. The robe is incised with multi-spoked pinwheels that take a clearer shape under raking light, discussed below (Section 3.2). The only color readily visible within the confines of the pinwheels on both the upper and lower part of the sleeve is bright red. No pigment can be discerned on the uppermost part of the garment, nor on the god's hands, face, beard, hair, and crown. There is green on the stem of the flower held in the god's left hand, and specks of bright red and green survive on the petals of its blossom.

The feathers of the wings continue inside the ring, where they are incised rather than sculpted. As Herzfeld saw, the first and third rows of small, scale-like feathers at the top of the wing are red, while the second, intermediary row shows traces of blue. Enough of the bright red paint survives to indicate that the small feathers were outlined in a different color, which appears lost. Similarly, no red survives on their shafts, suggesting that these, too, were painted in another color. The rendering inside the ring skips the uppermost red row of small feathers and comprises only the blue and lower red rows.

(**a**) (**b**)

Figure 7. Pigment remains on the lower left part of the relief (**a**) and the sleeve of the robe (**b**) (photographs: Susanne Ebbinghaus) ©President and Fellows of Harvard College.

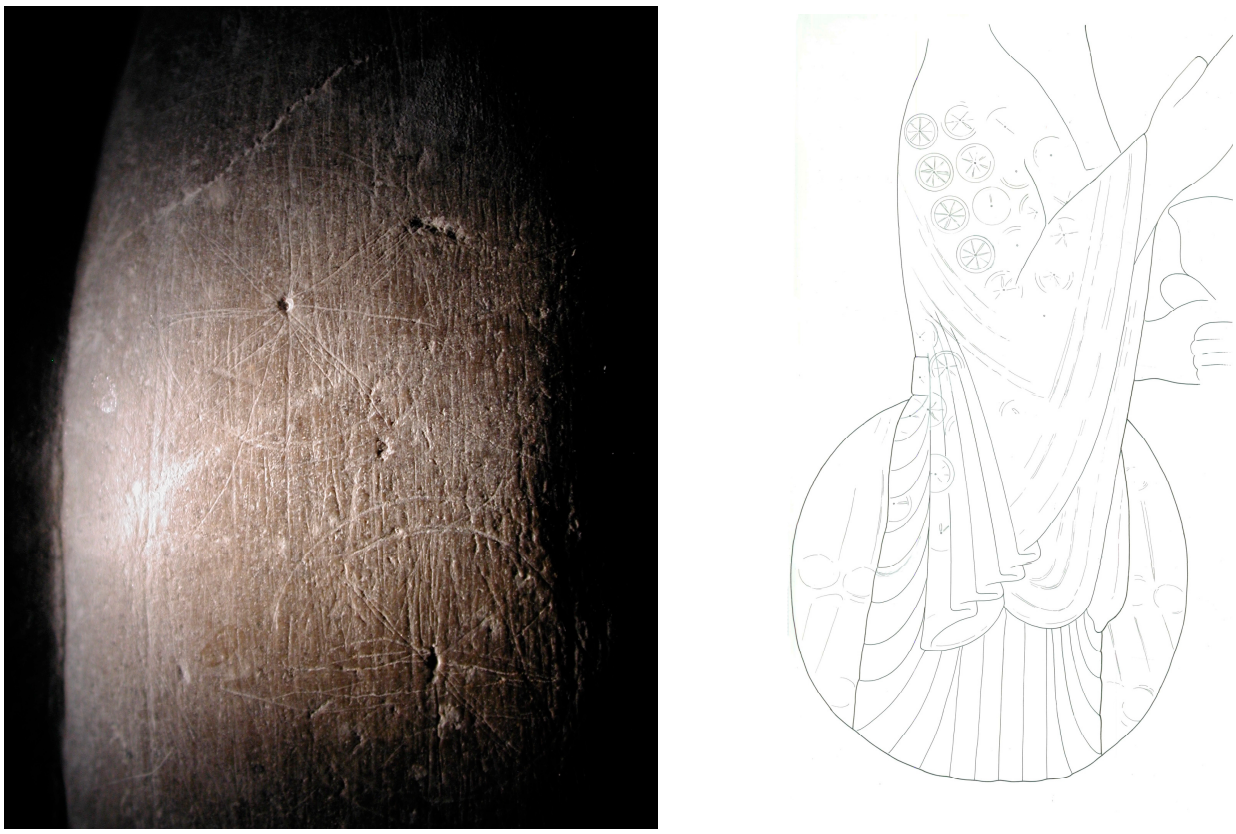
In terms of avian anatomy, the small feathers closest to the arm bone would be described as the lesser coverts. The first row of longer feathers below, the so-called median coverts, preserve traces of green pigment both inside and outside of the ring. Inside the ring (see Figure 7a), the remains of four rounded areas of blue paint can be seen in the lower parts of the median coverts, suggesting that these feathers had blue eyespots, or ocelli. The greater coverts, forming the second row of long feathers, were red with blue eyespots, as is most clearly visible on the left edge of the relief. On these feathers, as on the three rows of small, scale-like feathers above, there is evidence for outlines now devoid of color for both the feathers themselves and their eyespots; since the longer feathers are layered, a border appears only on one side. Moving over to the lower righthand corner of the relief, patches of green reveal the original color of the third and lowest row of long feathers—the flight feathers, or remiges—as well as of the tail feathers growing out of the lower part of the ring. This means that both the "light blue" and the "blue" that Herzfeld noted for the first and the third row of long feathers, respectively, are, in fact, green. Mixed in with whitish accretions, the green is very pale and can easily be mistaken for light blue. We need to remember that Herzfeld saw the relief in a newly excavated but uncleaned state; the surviving pigments had not faded but were obscured by layers of calcite.

The distribution of pigments that can be observed on the wing feathers of the fragment at Harvard is corroborated by what the Tilias found when—prompted by Lerner—they took a closer look at the wing fragments from the same block that remain at Persepolis. Inspecting the wetted relief surfaces with a magnifying glass, they saw "the colors standing out brightly" [26] (p. 33). They noted the same overall color scheme and could add that the lower ends of the green flight feathers, cut off on the Harvard fragment, bore "scarlet red" eyespots [26] (pp. 33–34, 36, fig. 1a). Apart from a tiny yellowish speck, possibly simply dirt, that was discovered under magnification on the lower left section of the ring of the winged disk, no pigment traces are visible on the ring itself or on what is preserved of the upper wing edges and the ring's appendages on the Harvard fragment. The Tilias did not report any remnants of pigments on these features, either. Neither the fragment at Harvard nor those at Persepolis show any paint on the background of the relief.

3.2. Under Raking Light

In preparation for the application of paint, a rough drawing was incised into the relief surface. It is most visible on—but was not confined to—the central part of the fragment comprising the god's garment and the interior of the winged disk. Here, the details were not carved in relief but left to be rendered in paint, requiring extra guidance. The incised lines can be observed with greater clarity when the relief surface is scrutinized with the help of raking light. Created by a strong light source held low, raking light "rakes" or "grazes" the surface it illuminates, resulting in the long, deep shadows typical of sunrise or sunset.

The resulting findings were documented in two ways. Individual areas of the relief surface were photographed by objects conservator Henry Lie, then the head of the Straus Center for Conservation and Technical Studies (Figure 8a). In addition, archaeological draftsperson Catherine Swift Alexander made a drawing mapping the incised lines on the figure and inside the ring (Figure 8b). She started the drawing under regular lighting conditions and amended it after scrutinizing the relief surface with a flashlight held at different angles—a low-tech version of reflectance transformation imaging (RTI). However, it is not just different kinds of lighting and different lenses or imaging technologies that yield more information. Throughout our study, we noticed the value of repeated looking and of engaging a second pair (or multiple pairs) of eyes and exchanging notes. During a close examination of the fragment when it was installed in the "Gods in Color" exhibition and hit by daylight from above, one of the authors of this paper discovered further faint lines in the neck and shoulder zone of the figure that informed the 2007 color reconstruction.



(**a**) (**b**)

Figure 8. (**a**) Detail of the god's garment in raking light (photograph: Henry Lie); (**b**) drawing of incised lines in the center of the fragment (Catherine Swift Alexander). ©President and Fellows of Harvard College.

Most immediately, raking light reveals that the god's robe was decorated with a pinwheel pattern. Inscribed with a compass (there is a centering hole), the wheels are between 2.2 cm and 2.4 cm (slightly less than 1 inch) in diameter and consist of two concentric circles and eight spokes. The spokes are somewhat carelessly drawn but appear to be shaped like a lancet leaf rather than straight or tapering. The person who sketched these patterns disregarded the carved drapery. On the lower part of both the robe and its sleeve, the preserved pinwheels continue undisturbed across the garment's pleats. This approach differs from the more careful treatment of such ornaments on the robe of the king elsewhere at Persepolis [26] (pp. 53–55, fig. 6), [37] (pl. 143), but considering Ahuramazda's comparatively small scale and elevated location, it was a sensible time-saving measure with little visual impact. Paradoxically, a pinwheel even appears to have been incised on the short section of the god's belt visible behind the sleeve.

The other evident embellishment of the robe is comprised of the broad borders of its sleeves. Meeting at right angles, they run along both the sleeve's edge and its outer side and consist of a wide central band set between two narrower ones. Despite intensive scrutiny by multiple people, no pattern could be detected on the central band. It should be noted that this part of the surface is particularly clean and smooth. The preserved outlines of the decorative borders are mostly doubled up. When creating the 2007 color reconstruction, we paid no further attention to this feature in the assumption that it was due to careless sketching, but we should consider the possibility that the framing bands themselves were framed by even narrower bands. At first glance, the border lining the edge of the sleeve seems to stop above the pleated part, but barely visible incisions might indicate its continuation. Similarly faint and not captured in the drawing illustrated here are incised lines that must constitute the robe's upper border. Triangular shapes spotted here and elsewhere in the medium-width bands are difficult to distinguish from the background noise of other lines, long and short, that crisscross the relief surface, caused by polishing, cleaning, or accidental scratching. The fact that triangle borders are incised more faintly than other elements of the clothing on other Persepolis reliefs [26] (pl. 33, figs. 39–40), [37] (pl. 142), however, suggests that the triangle shapes on the fragment are more than just a figment of our imagination. Presumably, they are less prominent because the painter needed less guidance executing such simple, repetitive patterning.

Painting the feathers onto the plain surface of the winged disk's interior would have been more challenging, and extensive incisions survive in this area. They delineate the median and greater coverts with their eyespots and confirm that the eyespots—like the feathers themselves—were surrounded by a border that must have been rendered in a different color. The borders of neighboring feathers and eyespots are circumscribed with a continuous outline. It appears that the sketched lines did not demarcate individual feathers but distinct areas of color in a paint-by-number approach (see Figure 7a). On some of the sculpted feathers, too, faint incisions indicate their borders. Centering marks demonstrate that the eyespots, both inside and outside of the ring, were drawn with a compass.

Raking light also throws into stark relief what is already noticeable to the naked eye, namely that the stone surface of the fragment is not uniform. The fragment's lower half is mostly smooth and polished, although there are areas with striations, likely from a scraper or rasp employed before the surface was treated with finer abrasives. In the upper part of the fragment, the finish varies even more. Ahuramazda's robe, neck, face, beard, and hands are smooth, but there is a small rough patch immediately below the tip of his beard. The greater part of the god's hair is unfinished, as are the left side of his crown and the right side of the flower he holds. The tool marks are those of a claw chisel like the one used on the fragment's top and bottom edges. The background, too, displays prominent claw chisel marks. The sculptor used a flat chisel to smoothen a strip of the background around part of the god's figure as well as on the lower edge of his hair and his crown but did not continue this step across the rest of these surfaces. Different parts of the fragment represent different phases of the working process [58] (pp. 4–7, pl. 1). As already argued by Lerner [23,24], the relief surface is unfinished rather than intentionally roughened. This

may have been due to time constraints or, perhaps more likely, to the god's position just below the top edge of the doorjamb. It is highly probable that the lintel was in place by the time the doorjamb relief was in the finishing stages, which would have made it difficult to wield tools in its upper reaches. At the same time, the god's high perch would have made it hard to see details of the carving from below, especially once the surface was painted. The workers may well have assumed that the rough parts would go unnoticed. May we take this as a hint that the background was painted, too?

One last remark: raking light does not show clear evidence of differential weathering or "paint ghosts" caused by differences in the composition or application of the paints used on the fragment. As Egyptian blue, azurite, and malachite pigments lose their intensity when they are too finely ground, blue and green paints tended to be applied more thickly, protecting the surface below from eroding, sometimes to the point of it standing out in low relief [59,60]. On the fragment at Harvard, there is no obvious difference in surface preservation between the green feathers, the blue eyespots, and their frames. Tilia observed such a contrast for the wings of the depictions of Ahuramazda from other doorways of the Hall of 100 Columns, but she assumed that whatever substance was applied to the outlines of the feathers and eyespots corroded those surfaces [26] (p. 36, pl. A:2–3).

3.3. Technical Imaging

A variety of imaging techniques were employed to obtain information about the decoration of the relief, as detailed below. Technical imaging equipment specifications are given in Appendix A.

3.3.1. Ultraviolet-Induced Visible Fluorescence (UVF) Photography

Ultraviolet-induced visible fluorescence photography is a common technique used to observe and document some materials or conditions that fluoresce in the visible light range (400–600 nm) when illuminated by UV light (typically in the long-wave range of the electromagnetic spectrum, 315–400 nm). For objects such as a painted stone relief, this technique may discern some pigments, binding media, coatings, or restoration materials such as adhesives or fills. Examination of the relief fragment under UV light did not reveal any such details.

3.3.2. Reflected Infrared Photography (IRP)

Reflected infrared photography captures the characteristic response of materials to IR radiation (750–1050 nm): some remain transparent, while others absorb and appear more opaque. While used more commonly to examine carbon-based underdrawings in paintings, this technique may be useful to differentiate pigments or other materials based on their relative absorbance or reflectance. IR photography of the relief fragment enhanced the appearance of repairs to the breaks described in Section 2.1 but did not show any contrasting areas of polychromy (Figure 9).

(**a**) (**b**)

Figure 9. (**a**) Reflected infrared photograph showing the branching repair lines across breaks in the stone; (**b**) the relief fragment in visible light; ©President and Fellows of Harvard College.

3.3.3. Visible-Induced Infrared Luminescence (VIL) Photography

Visible-induced infrared luminescence photography (VIL) is used to detect and map materials that fluoresce in the near-infrared (IR) range (750–1050 nm) when excited in the visible light range (380–700 nm). Luminescence is the emission of light from energy changes that do not involve heat. Fluorescence is a type of luminescence. Both terms correctly describe the effect observed here. VIL imaging records the luminescence emitted by specific pigments, including Egyptian blue—a calcium copper silicate with the ideal formula $CuCaSi_4O_{10}$. Giovanni Verri first published the use of VIL imaging in 2008 and 2009 as it was applied to determine polychromed patterns on objects in the collections of the British Museum, such as a neo-Assyrian stone relief [33–35].

When the fragment at Harvard was first re-examined in 2007, VIL imaging was not yet established as an imaging technique in art conservation. Jens Stenger and Katherine Eremin tested VIL photography in 2012 with promising results. In 2021, using refined protocols such as higher light levels and longer exposure times, VIL photography produced much-improved detection and resolution (Figure 10). The results complemented the earlier instrumental analysis of samples that had confirmed the use of Egyptian blue and, importantly, revealed the distribution of remnants of the pigment on the surface. The technique can be sensitive enough to visualize single pigment particles, otherwise invisible to the naked eye, and this was apparent when comparing the VIL images with the live object. The VIL image shows the highest concentration of remaining Egyptian blue on and around the lower half of the figure. It is important to note that the observed pigment particles are what is left after—and in some ways also the product of—two and a half millennia of weathering and multiple rounds of cleaning, restoration, and de-restoration; particles may have become dislodged and reattached elsewhere, and their current distribution may not be identical to the original application.

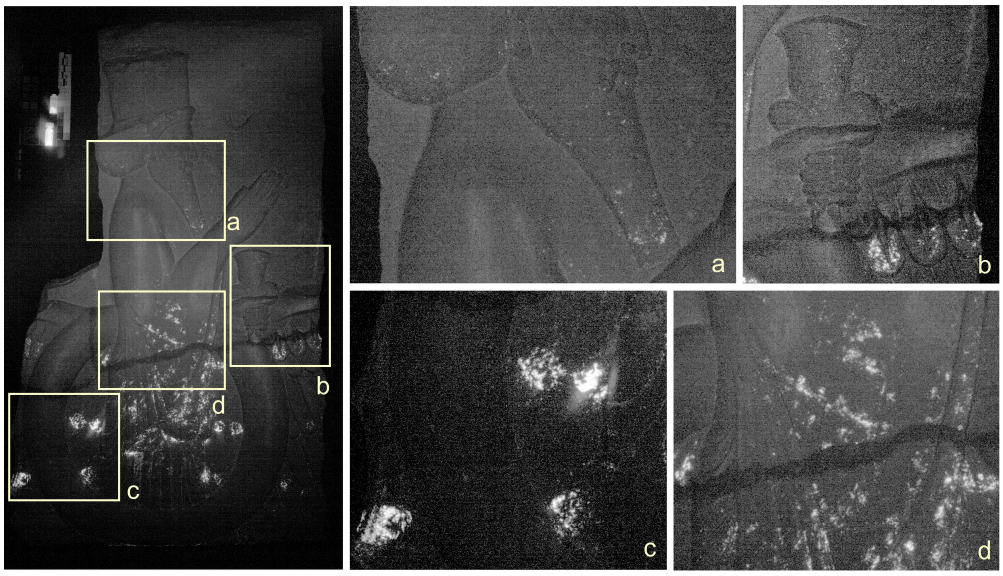


Figure 10. VIL photography carried out in 2021 revealed the fluorescing remnants of Egyptian blue pigment, which appear as glowing specks on (**a**) the beard and hair, (**b**,**c**) flower and feathers, and (**d**) sleeve. The Egyptian blue standard in a vial is at the top left of the overall image. ©President and Fellows of Harvard College.

Significant occurrences of the pigment correspond with the following:

- The beard and hair (Figure 10a; the particles at the back curve of the hair and concentrated at the bottom tip of the beard were not detected in the 2012 VIL imaging attempt);
- The small feathers in the second row on both sides of the figure (Figure 10b);
- The right half of the flower petals (Figure 10b);
- Most of the eyespots at the ends of the feathers, especially those encircled by the ring of the winged disk (Figure 10c);
- Broad areas of the robe, especially the sleeve, which might indicate a mixture of Egyptian blue with a red pigment or pigments to create a purple color (Figure 10d);
- The sleeve above and below the wide decorative band under the elbow, where stronger concentrations appear to partly coincide with the location of pinwheels (Figure 10d);
- Patterned borders along the sides of the wide bands that decorate the edges of the sleeves and run in a curve under the right arm (Figure 10d). Although they do not define a sharp pattern, the remnants suggest an alternating application of Egyptian blue along the borders. The wide bands themselves show a notably reduced presence of Egyptian blue particles inside the borders.

VIL imaging gives us a much better sense of the polychromy of the figure of Ahuramazda than could be detected in regular lighting conditions. It provides the only direct indication that the god had a blue beard and blue hair, confirming the coloring of the beard and contradicting the black hair proposed in the 2007 reconstruction. Other propositions made in 2007 are called into question by the new VIL photography-derived evidence. There was significant luminescence in many parts of the god's robe, suggesting the use of blue and/or purple where we had assumed neither, including within the pinwheels. On the other hand, there is little evidence to support the notion that the broad decorative bands were painted a purple color created by mixing blue and red. Generally, it seems safe to conclude that the areas showing minimal luminescence in the VIL photographs—the crown and flesh of the figure, the ring of the winged disk, and the unfinished background of the relief—were not originally painted with Egyptian blue.

3.4. Materials Analysis

Materials analysis was undertaken to determine the composition of the stone and the remaining pigments. The analytical techniques were non-destructive in situ X-ray fluorescence spectroscopy (XRF), Raman spectroscopy (Raman), FTIR spectroscopy (FTIR), scanning electron microscopy with energy dispersive microanalysis (SEM-EDS), polarized light microscopy (PLM), and thin section petrography. The analytical techniques are described in more detail in Appendix A.

3.4.1. Stone Composition

XRF analysis of the stone in undecorated areas showed high levels of calcium, with trace levels of iron and strontium, consistent with limestone, as shown in Figure 11. No sulfur was detected in any area without colored pigment, indicating that calcium sulfate was not present at a significant level. However, the presence of trace amounts of calcium sulfate cannot be ruled out, as high levels of sulfur are required for detection with the in-situ XRF system used. Analysis of samples by FTIR and Raman spectroscopy indicated the presence of calcite (Raman peaks at 1086 cm^{-1}, 712 cm^{-1}, 281 cm^{-1}) but did not detect any other phases. Petrographic analysis of a thin section from a sample of the stone showed that this is a bioclastic packstone with a diverse fossil assemblage of pellets, crinoids, bivalves, echinoderms, and foraminifera, visible in Figure 12. This limestone is likely Mesozoic in age and is consistent with the description by Alireza Askari Chaverdi and his coauthors [61] for stone from monuments at Persepolis.

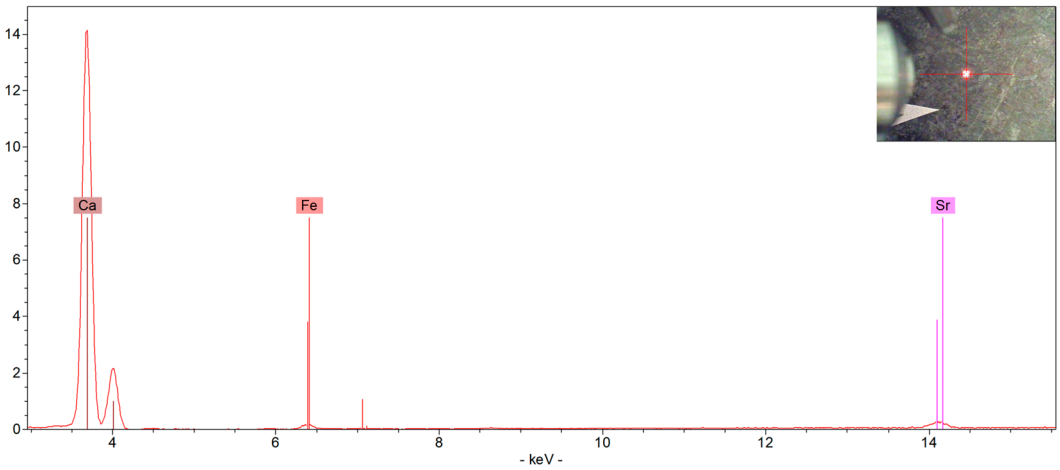


Figure 11. XRF spectrum from undecorated limestone showing high levels of calcium (Ca) with some iron (Fe) and strontium (Sr); ©President and Fellows of Harvard College.

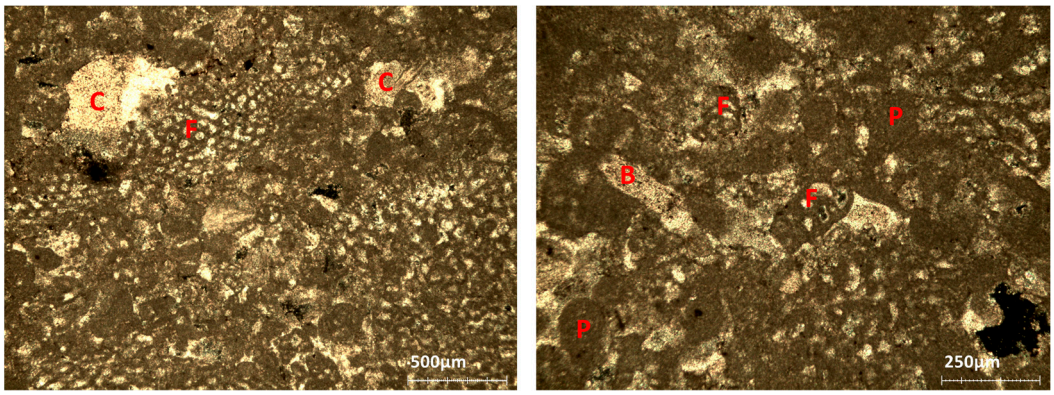


Figure 12. Details of the petrographic thin section of the undecorated limestone under cross-polarized light; assemblage shown includes bivalves (B), crinoids (C), foraminifera (F), and pellets (P). ©President and Fellows of Harvard College.

3.4.2. Pigment Composition

Analysis was undertaken of the pigment traces present on the relief in order to inform the reconstruction of the original polychromy scheme. The first stage involved XRF of points where distinct grains of blue, green, or bright or dark red pigment were visible with the naked eye or under magnification, or areas where pigment was suggested by bright areas in the VIL image (Figure 13). Spectra from these areas were compared with those from the undecorated stone to determine which elements were present at higher levels in the colored areas.

Based on the XRF results and careful examination, microsamples of pigment were removed from several areas for in-depth analysis. The areas sampled are shown in Figure 14.

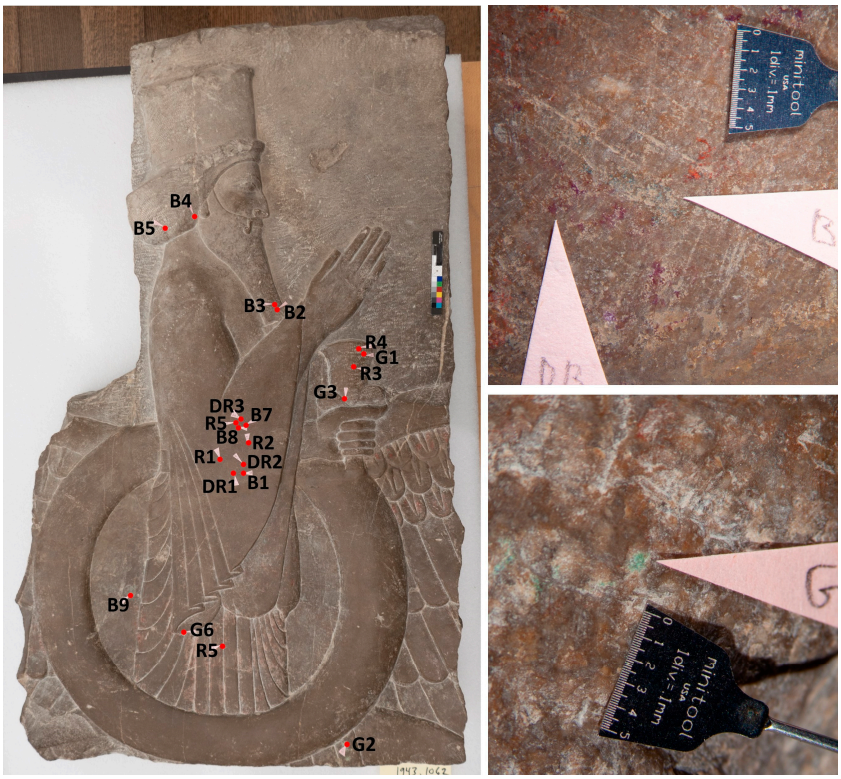


Figure 13. Location of XRF analyses of key areas of visible pigment; spots analyzed are numbered by color: DR dark red, R bright red, B blue, G green. Detail (**right upper**) shows areas analyzed as DR1 and B1, and detail (**right lower**) shows area G1. ©President and Fellows of Harvard College.

Due to the sparsity of pigment remaining on the relief, the samples consisted of only a few grains of pigment, which did not allow for examination of stratigraphy. SEM-EDS analysis of the powders did not provide clear information on particle morphology as the powders were extremely mixed, with calcium carbonate dominating. The best SEM-EDS results were obtained on pressed samples after the FTIR analysis, which destroyed the original morphology.

FTIR analysis did not detect any evidence of an organic binder in any of the samples, likely due in part to the small sample size. Other studies of Achaemenid pigments showed a similar lack of detectable binder, although lipid was identified in one of several red (hematite-rich) lumps studied by Maria Letizia Amadori and others [62].

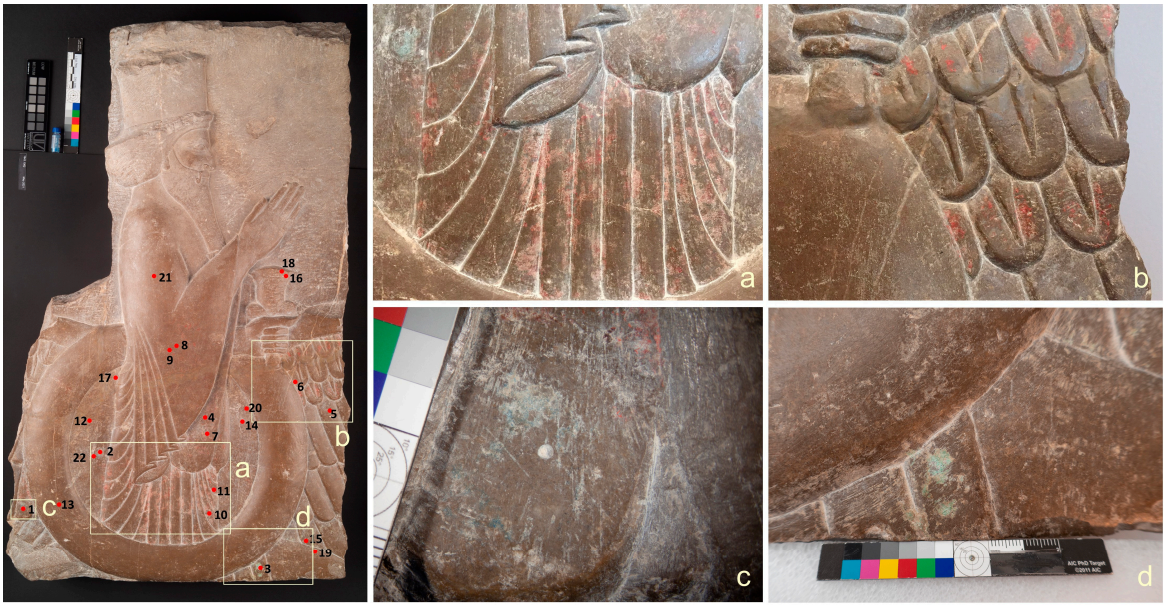


Figure 14. Sample map and details of areas with visible pigment sampled for analysis, including (**a**) the lower part of the robe and (**b**–**d**) feathers of the winged disk; ©President and Fellows of Harvard College.

Blue Pigments

XRF analysis of multiple areas of visible blue pigment from a short feather, the eyespots of longer feathers, and the god's robe showed high levels of copper. Representative XRF spectra from blue pigment and undecorated limestone are illustrated in Figure 15. These copper-rich areas also produced a high VIL response. The results are consistent with the presence of Egyptian blue inferred from the VIL imaging, but the presence of additional blue pigments cannot be ruled out from XRF alone. No tin was detected in any spectrum, showing that the Egyptian blue present was produced from copper rather than scrap bronze [63]. Some spectra from blue areas also showed an increase in iron and mercury compared to those from the undecorated limestone. Although this may be an indication of intentional mixing of red ocher and/or cinnabar with the Egyptian blue, it could have been caused by the transfer of small amounts of neighboring pigment due to weathering and cleaning.

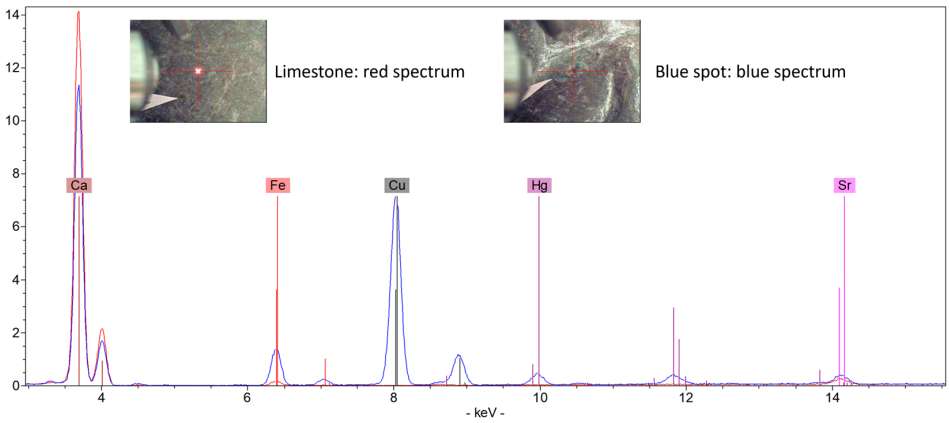


Figure 15. Comparison of XRF spectrum from remnants of blue pigment with high VIL response (blue line) to XRF spectrum from undecorated limestone (red line), showing higher copper (Cu) and iron (Fe) in the blue pigment and higher calcium (Ca) in the limestone. Some mercury (Hg) and strontium (Sr) are also present. ©President and Fellows of Harvard College.

Raman analysis of blue samples from the eyespots (samples 1 and 2), robe (sample 4), and feathers (samples 6 and 17) failed to produce any peaks other than those for calcite (1086 cm^{-1}, 712 cm^{-1}, 281 cm^{-1}). However, FTIR analysis of the five blue samples identified Egyptian blue and calcite in all samples. A representative spectrum for a sample of blue pigment and an Egyptian blue reference spectrum are illustrated in Figure 16. Spectroscopic analysis showed no evidence of other blue pigments, such as the copper carbonate azurite $Cu_3(CO_3)_2(OH)_2$ or natural ultramarine, the mineral lazurite $Na_{6\text{-}10}Al_6$ Si_6 $O_{24}S_{2\text{-}4}$. Although, so far, no ultramarine has been identified in Achaemenid stone sculpture itself, a recent study demonstrates that both ultramarine and Egyptian blue were present on architectural facades at Persepolis [20] (p. 154, fig. 4.4), [64]. The high levels of copper in all areas with blue pigment could indicate either azurite or Egyptian blue. However, the correlation of these areas with those showing a strong VIL response and the lack of any azurite in the FTIR and Raman spectra suggests only Egyptian blue is present. Hence, it is unlikely that azurite was used on this relief.

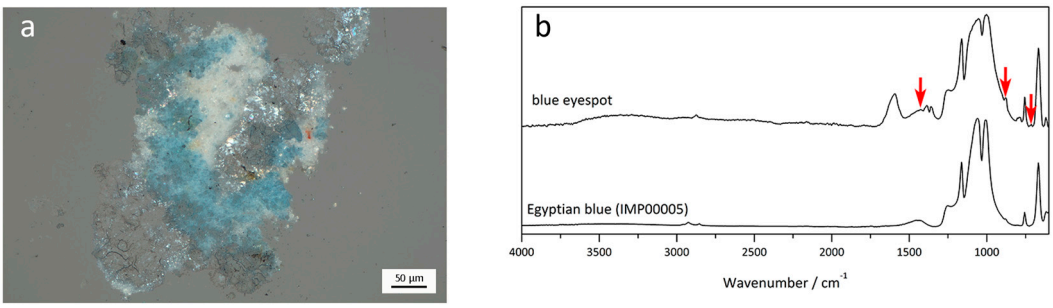


Figure 16. (**a**) Photomicrograph of blue sample 17 from feathers pressed on diamond cell for FTIR; (**b**) comparison of FTIR spectrum from blue areas of sample with reference spectrum for Egyptian blue, showing the close match. Arrows mark additional peaks from calcite (reference spectrum not included). ©President and Fellows of Harvard College.

SEM-EDS analysis of the samples indicated the presence of mixtures of calcium carbonate (likely calcite), copper calcium silicate, and rare iron oxides. A representative spectrum from the copper calcium silicate is shown in Figure 17. Analysis of multiple particles of copper calcium silicate gave consistent spectra, and the calculated composition corresponds closely to that of pure Egyptian blue, $CuCaSi_4O_{10}$, with a slight excess of calcium due to the presence of abundant calcium carbonate intermixed with the Egyptian blue particles. There were no particles of copper carbonate, confirming that azurite is unlikely to be present.

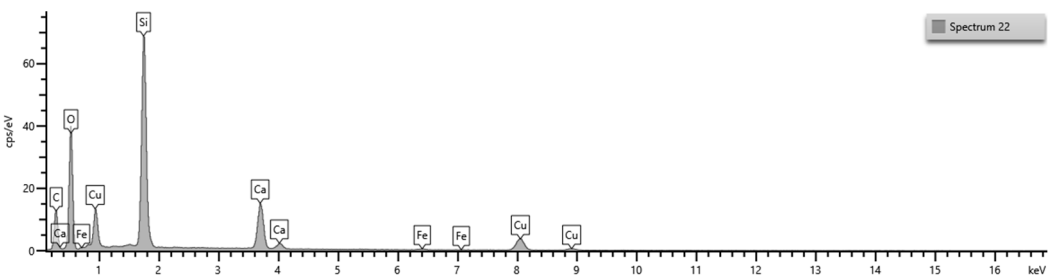


Figure 17. SEM-EDS spectrum of particles in blue sample 17, showing high levels of silicon, copper, and calcium with an elemental ratio close to ideal of 4:1:1, indicating Egyptian blue; ©President and Fellows of Harvard College.

Green Pigments

XRF analysis of several areas with remnants of green pigment—all located on the wing or tail feathers—indicated high levels of copper with slight increases in iron. A comparison

of representative XRF spectra from an area of green pigment and from undecorated limestone is shown in Figure 18. This suggests the use of a green copper pigment, most likely the copper carbonate malachite $Cu_2CO_3(OH)_2$, in green areas.

Raman and FTIR analysis of green samples from the feathers (samples 3, 5, 14, and 15) and flower (sample 16) confirmed the presence of malachite with associated calcite. Representative FTIR and Raman spectra from a green sample and reference spectra of malachite are illustrated in Figure 19. No other green pigment, for example, green earth, was detected in the spectra. Although the high levels of copper found in green areas could be due to the presence of azurite, azurite was not detected in any of the samples analyzed by FTIR or Raman. This indicates it is unlikely that azurite was present in green areas, and it is unlikely that malachite is present as an alteration product of original azurite.

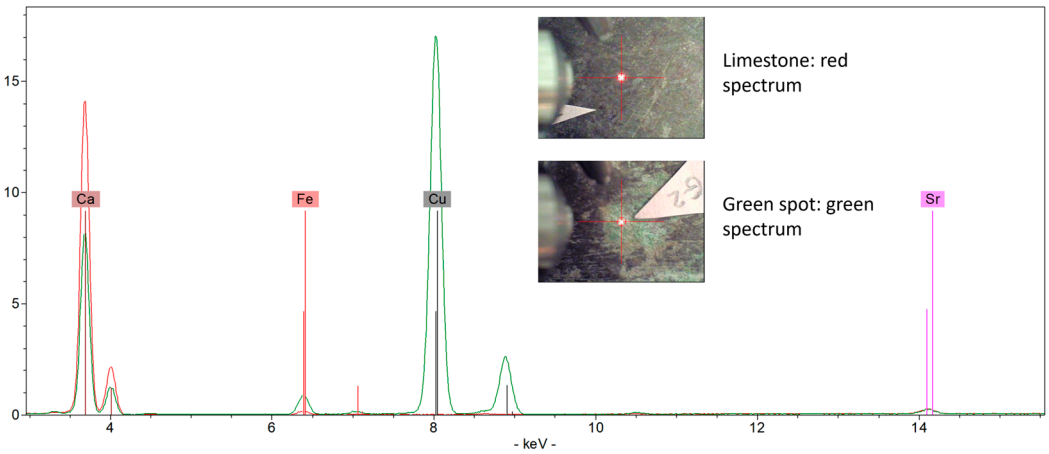


Figure 18. Comparison of the XRF spectrum from remnants of green pigment (green line) with the XRF spectrum from undecorated limestone (red line), showing higher copper (Cu) and iron (Fe) in the green pigment and higher calcium (Ca) in the limestone; some strontium (Sr) is also present. ©President and Fellows of Harvard College.

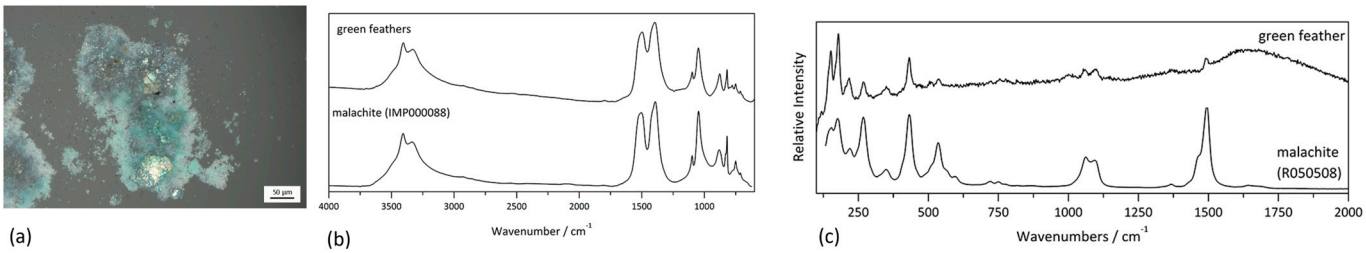


Figure 19. (**a**) Photomicrograph of green sample 3 from feathers pressed on diamond cell for FTIR; (**b**) comparison of FTIR spectrum from green areas of sample with reference spectrum for malachite, showing the close match; (**c**) comparison of Raman spectrum from green areas of sample with reference spectrum for malachite, showing the close match. ©President and Fellows of Harvard College.

SEM-EDS analysis of the samples indicated the presence of mixtures of calcium carbonate (likely calcite), copper carbonate (presumed to be malachite), silica (likely quartz), and rare iron oxides. A representative SEM-EDS spectrum from an area of copper carbonate is shown in Figure 20.

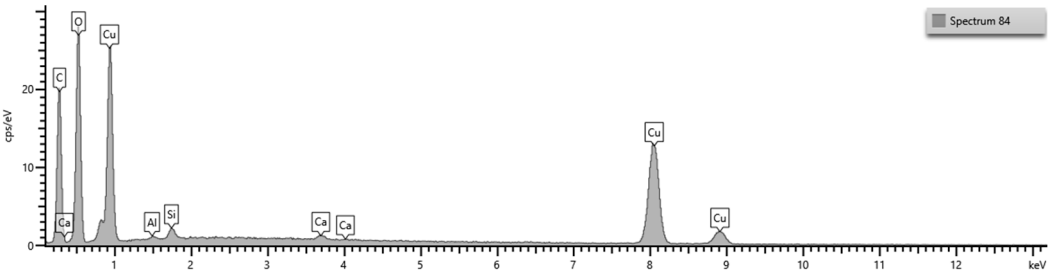


Figure 20. SEM-EDS spectrum of particles in green sample 3 showing the high level of copper suggesting copper carbonate, likely malachite; ©President and Fellows of Harvard College.

Red Pigments

Remnants of red pigment occur as both bright and dark red, the latter sometimes described as purple. XRF analysis of the darker red indicated higher levels of iron than in the stone, with traces of mercury in some areas. XRF analysis of the brighter red showed the highest levels of mercury and variable levels of iron that were normally above those measured in the undecorated limestone. A comparison of representative XRF spectra from dark and bright red areas and undecorated limestone is illustrated in Figure 21. The XRF results suggest the use of red ocher—a naturally occurring mixture of iron oxides (chiefly hematite, Fe_2O_3), clays, and other minerals—in darker red areas. Analysis of the brighter red areas reveals these mainly contain cinnabar—mercuric sulfide (HgS)—mixed with some red ocher. Trace levels of arsenic were present in XRF spectra from some areas with remnants of red pigment. This could be due to the presence of arsenic as a trace element in the red ocher or the use of an arsenic sulfide pigment, such as realgar (red), pararealgar (orange/yellow), or orpiment (yellow).

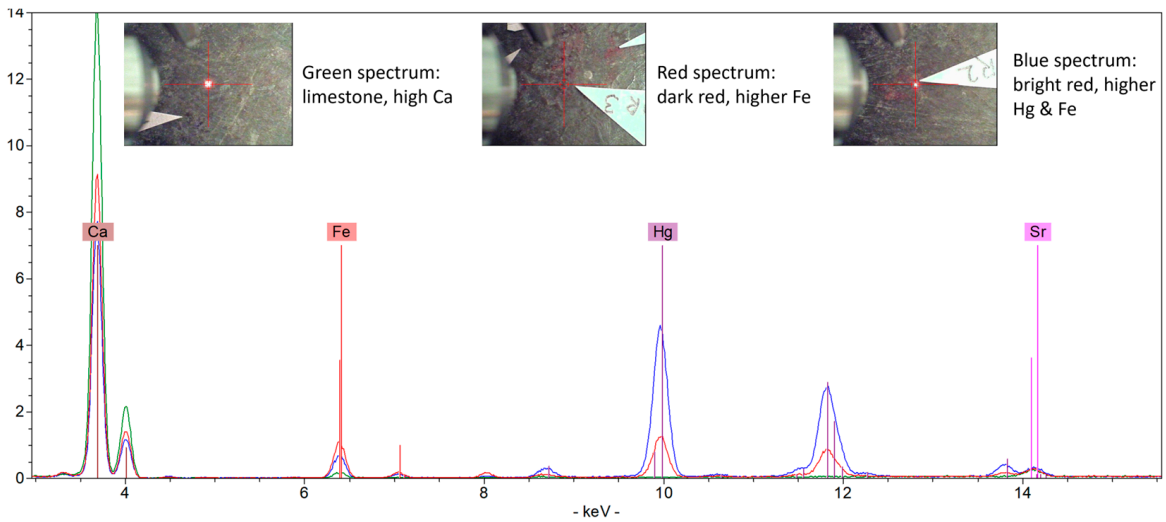


Figure 21. Comparison of XRF spectra from remnants of dark red pigment (red line) and bright red pigment (blue line) with XRF spectrum from undecorated limestone (green line), showing higher iron (Fe) in both red pigments, higher mercury (Hg) in the bright red pigment, and higher calcium (Ca) in the limestone; some strontium (Sr) is also present. ©President and Fellows of Harvard College.

Raman analysis showed the presence of cinnabar in bright red samples from the sleeve (sample 9), "skirt" (samples 10 and 11), and flower (sample 18), and a mixture of cinnabar and hematite in dark red samples from the wide bands on the sleeves (samples 7 and 8) and from the robe (sample 23). Both Raman and FTIR analysis identified calcite in some red samples. Representative Raman spectra from dark and bright red areas compared with reference spectra for hematite and cinnabar are shown in Figure 22. No other red colorants, such as an arsenic sulfide, were detected by Raman analysis.

SEM-EDS analysis of dark red samples revealed a mixture of particles with high levels of calcium (likely calcite), particles with high levels of iron (which appear brighter in the backscattered electron image), and occasional particles with aluminum and silicon (varied silicates). Analysis of these iron-rich particles indicated these are iron oxides with no detectable arsenic by EDS analysis. Further sampling and more extensive analysis would be required to assess the presence of arsenic in the iron-oxide particles. A representative SEM-EDS spectrum from the iron-rich particles is illustrated in Figure 23a. SEM-EDS analysis of bright red samples showed a mixture of high levels of calcium (likely calcite), some iron-rich particles, and particles with high levels of mercury and sulfur (which appear very bright in the BSE image). A representative SEM-EDS spectrum from the mercury sulfide particles in the bright red sample is given in Figure 23b.

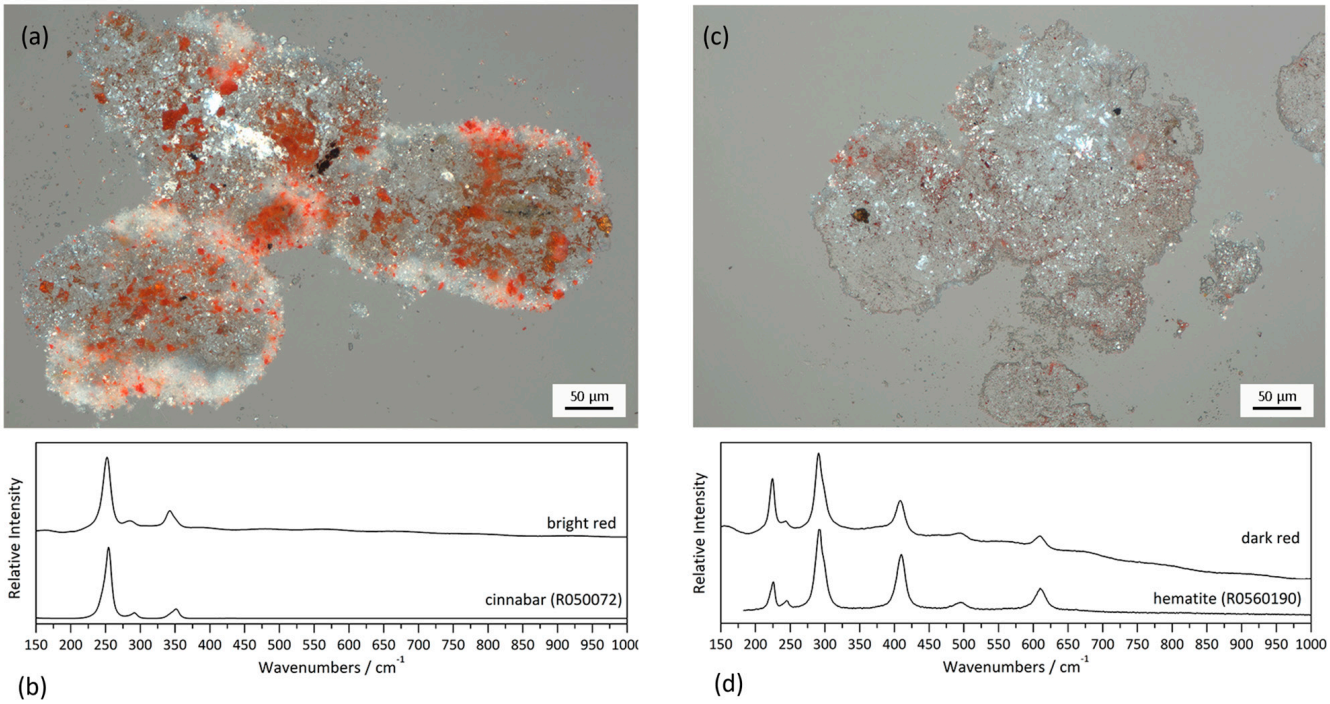


Figure 22. (**a**) Photomicrograph of bright red sample 10 pressed on diamond cell; (**b**) comparison of Raman spectrum from bright red areas of sample with reference spectrum for cinnabar, showing the close match; (**c**) photomicrograph of dark red sample 8 pressed on diamond cell; (**d**) comparison of Raman spectrum from dark red areas of sample with reference spectrum for hematite, showing the close match. ©President and Fellows of Harvard College.

The analyses show that arsenic sulfides—such as orpiment, pararealgar, or realgar—were not employed to paint the relief or, if they were used, are not preserved. This suggests that the presence of arsenic with iron in some red areas analyzed by XRF may be a property of the specific red iron oxide pigment(s) used at Persepolis. Looking to ancient Greece, trace arsenic was detected in hematite particles on Attic sculpture [65] and in red pigment from the agora of Kos [66]. In contrast, Stefano Ridolfi and others [67] suggested realgar was used in areas of Darius's Palace and the Hall of Columns based on the detection by XRF of arsenic with iron. The presence of realgar at Persepolis is attested by the identification of realgar in a lump of pigment from the site [27].

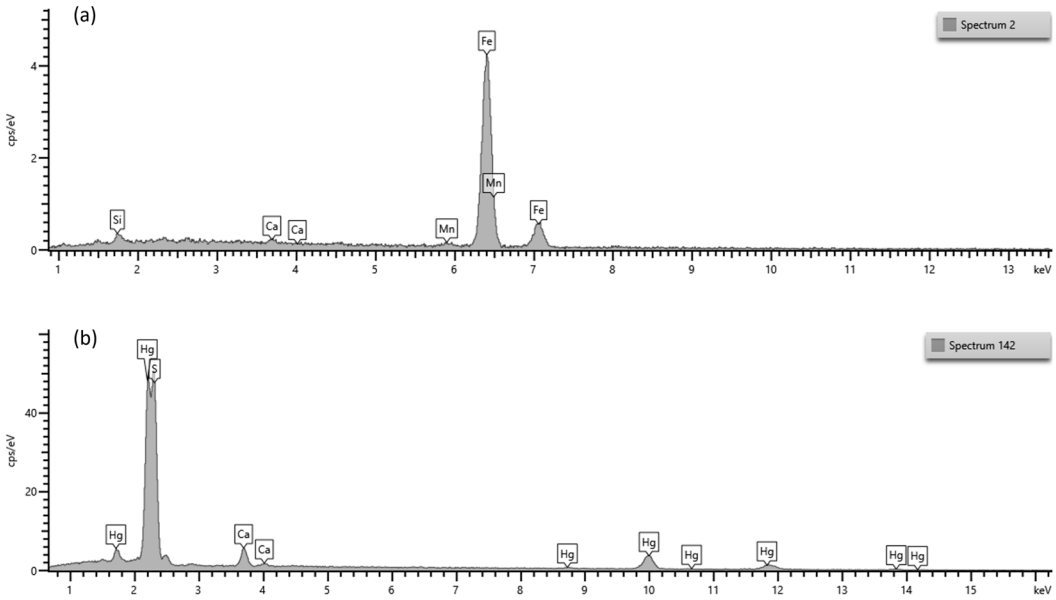


Figure 23. SEM-EDS spectra of (**a**) particles in dark red sample 8 showing the high iron content, indicating iron oxide (traces of aluminum, silicon, and calcium are also present from associated minerals); (**b**) particles in bright red sample 10 showing the high mercury and sulfur content indicating cinnabar (trace levels of calcium are also present from associated calcium carbonate). ©President and Fellows of Harvard College.

Examination of dark red (purple) sample 23 from the robe by optical microscopy revealed a variable mixture of white, red, black, and purplish particles. Analysis by Raman, FTIR, and SEM-EDS indicated the presence of calcite, iron oxides (including hematite), and likely carbon black. The purple-red particles, shown in Figure 24, did not give identifiable Raman or FTIR spectra and could not be specifically identified in the SEM. They may be an organic red (the lack of fluorescence under UV indicates madder is unlikely) or another iron oxide, possibly in a poorly crystalline form. The analysis of ocher-based pigment lumps excavated at Persepolis revealed they had a varied mineralogy [62], and Emily Aloiz and others found that at Pasargadae, purer hematite was used for darker red, whilst red ocher was used for a pinkish decoration on painted plaster [68]. These findings suggest that different ochers were selected to create specific shades.

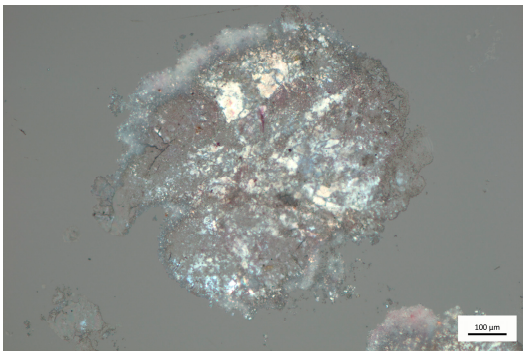


Figure 24. Photomicrograph of pressed-out dark red pigment sample 23 showing purple particles. ©President and Fellows of Harvard College.

Other Pigments

Samples were taken from the ring and its appendages and from the outlines of feathers and eyespots to try to identify their original color(s). Although these areas must have been painted originally, there are no visible traces of red, blue, or green pigment. The

samples removed consisted of one white sample (sample 22 from an eyespot outline) and five somewhat yellowish samples from the ring and the right appendage (samples 13 and 19), feathers or their outlines (samples 12 and 20), and the sleeve (sample 21). Raman and FTIR analysis indicate calcite in all samples. A comparison of the FTIR spectrum from the white sample and a reference spectrum for calcite is shown in Figure 25. Weak peaks in Raman spectra from two yellowish samples may suggest the presence of goethite (hydrated iron oxide), as shown in Figure 26. In addition, one sample contained a weak peak at 1008 cm^{-1}, which may indicate the presence of gypsum (hydrated calcium sulfate).

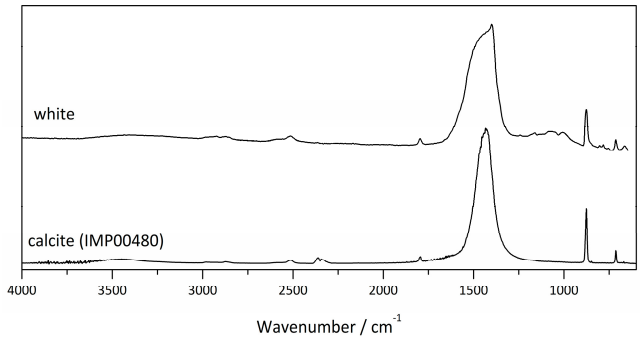


Figure 25. Comparison of the FTIR spectrum from white sample 22 with the reference spectrum for calcite, showing the close match.

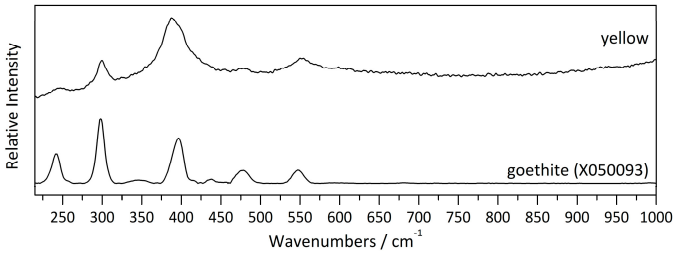


Figure 26. Comparison of the Raman spectrum from "yellow" sample 12 with the reference spectrum for goethite (hydrated iron oxide), showing a close match.

SEM analysis indicated some iron-rich areas in these yellowish samples, which would be consistent with the presence of iron oxide. These yellowish areas may, hence, indicate the use of yellow ocher, a natural yellow mixture of iron oxides, such as goethite, clays, and other minerals. Overall, these results are somewhat inconclusive and offer few clues as to the original coloration of the ring or its appendages. The two samples with significant iron come from within the ring, from spots that could have coincided with feather outlines. The white sample is certainly from the outline of an eyespot. If nothing else, its analysis provides no evidence for the "corrosive material" that Tilia postulated for the feather frames (see Section 3.2 above).

The presence of calcite in the white sample and in many colored samples might indicate the use of calcite as a white pigment and/or as a white ground layer. However, calcite could simply be derived from the calcite-based limestone of the relief, which was covered with accretions before the fragment was cleaned in the 1960s. Since only microsamples could be taken, it was not possible to investigate layering or stratigraphy to determine if a ground layer was present. It has been noted that a white ground layer would have provided a better surface for polychrome decoration than the gray stone. Recent studies have identified a white ground layer on sculptures at Persepolis, with gypsum used up to the time of Xerxes [67] and the phosphate mineral fluorapatite (produced by burning animal bones) used on later sculpture [61,67]. No phosphorous was detected by XRF or by SEM-EDS in any of the samples from the Harvard relief. Fluorapatite has distinctive Raman and FTIR spectra (main Raman peak at 964 cm^{-1}) and was not detected in any of

the samples. Although there was some evidence of gypsum in one yellowish sample from inside the disk, no other samples contained any gypsum. It is, hence, unlikely that either a phosphate or gypsum ground layer was used on this relief.

Comparison with Other Studies

A comparison of the results from this study with previous studies of the Harvard relief specifically [27,69] and of pigments on stone sculpture and plaster floors at Persepolis and Pasargadae more generally is shown in Table 1. Although the 1984 study by Leon Stodulski and others [27] did not find yellow ocher on the relief, the current analyses and comparison with the 2016 study by Aloiz and others [68] suggest that the use of yellow ocher is likely. No evidence for a ground layer or definite white pigment has been found on the Harvard relief in either study. This contrasts with the identification of a white ground layer of gypsum or fluorapatite (depending on the date) discovered on the surface of several sculptural elements on-site at Persepolis [61,67]. The 1984 study also analyzed samples taken from buildings at Persepolis, including reliefs of the Hall of 100 Columns, the Tripylon/Central Building, and the Apadana, and did not detect either gypsum or fluorapatite in any sample. However, a white ground layer of lime (calcite) was found under red hematite and cinnabar on samples from painted floors at the site [27,68]. The presence of a calcite ground layer would be hard to detect on the limestone relief without larger samples suitable for cross-section.

Table 1. Comparison of pigments identified on stone sculptures and plaster floors from Persepolis and Pasargadae. Note that not all colors are included in all studies.

Color	This Study	1966–1967 Internal Report [69]	Stodulski et al. 1984 [27]	Ambers & Simpson 2005 [70]	Aloiz et al. 2016 [68]	Askari Chaverdi et al. 2016 [61], Ridolfi et al. 2019 [67]
Blue	Egyptian blue (eyespot, robe, small feathers)	Egyptian blue	Egyptian Blue	N/A	Egyptian Blue	Egyptian blue
Green	Malachite (feathers)	Malachite	Malachite	N/A	Malachite	N/A
Yellow	Yellow ocher (feather/feather outline)	N/A	N/A	N/A	Earth pigment?	N/A
Red	Cinnabar, hematite (sleeve, skirt, top of flower)	Hematite	Cinnabar, hematite	Hematite	Cinnabar, hematite, red ocher	Hematite, cinnabar, realgar (from arsenic in XRF)
Dark red (purple)	Cinnabar, iron oxides (including hematite), carbon, unknown (robe, bands on sleeves)	N/A	N/A	N/A	N/A	N/A
White	Calcite (eyespot outline)	Calcite	Calcite	N/A	Lime	Fluorapatite, gypsum

As shown in Table 1, the pigments detected on the stone sculpture and painted plaster are very similar—Egyptian blue, malachite, cinnabar, red and yellow ochers, carbon black, and calcite [27,68,70]. This palette is somewhat limited when compared to the overall variety of pigments found at Persepolis [27,62]. Analysis of pigment lumps from the original east portico of the so-called Tripylon and pigment lumps or coatings in pottery bowls included Egyptian blue, azurite, tyrolite (a green copper arsenic mineral), sulfur (yellow), calcite, and red realgar (probably partially altered to yellow pararealgar) [27]. Analysis of lumps of pigment more recently excavated in the West Craft zone at Persepolis identified azurite, malachite, green earth, and yellow and red ocher, the latter two containing mixtures of goethite, magnetite, hematite, carbonates, clays, and quartz [62]. Blue pellets from the same context were identified as Egyptian blue, and a piece of scrap bronze with a crust of Egyptian blue provides evidence for the local production of Egyptian blue [62]. The use of scrap bronze is surprising given the lack of tin present in the Egyptian blue analyzed in this and other studies, and it may reflect variations in the copper source used.

Comparison with Glaze Colorants

In addition to painted sculpture, glazed bricks were used to great effect throughout the first millennium BCE for polychrome decoration at sites including the Achaemenid Persian capital city Susa [68,71–76]. As the comparatively well-preserved polychromy of the glazed bricks offers clues to the original coloration of contemporary limestone reliefs, it is worth considering the particular palettes of these two techniques. The color palette of pre-Achaemenid glazes consists mainly of white, orange-yellow, blue-green, and black; dark blue, green, pink, and brown glazes appeared in the Achaemenid period. Red glaze is notably absent at all sites, in marked contrast to the color scheme employed for painted decoration, where red is a key component. This difference is likely owed to the difficulty of producing a consistent red glaze, which requires close control in a reducing environment, whilst red earths and ochers are widespread and, hence, easily sourced for use as inexpensive pigments. Red cinnabar, although less common, was also readily available and widely used in the ancient world. Although red glaze posed a problem, glazes in a range of yellows and browns could be easily produced under normal oxidizing conditions and were used extensively. The abundant use of yellow-orange glaze contrasts with the limited yellow pigment traces on the reliefs, perhaps because red was preferred or perhaps due to poor preservation of yellow ocher.

As with the pigments, a variety of glaze colors were derived from a limited suite of elements: copper was combined with lead and antimony for green glaze; mixtures of cobalt and copper were used for blue glaze; mixing lead and antimony produced yellow-orange glazes (incorporation of some iron resulted in a more orange shade); combinations of manganese, iron, and sometimes copper resulted in black and brown glazes; and antimony was combined with sodium or calcium for white glaze. A comparison of the pigments and glaze colorants used in the Achaemenid period is given in Table 2. Despite similarities at the elemental level, the raw materials and technology differed significantly, apart from Egyptian blue and blue glaze, which both required the addition of a copper source to silica and alkalis and heating to fuse the raw materials.

Table 2. Comparison of Achaemenid pigments and glaze colorants.

	Pigments	**Glaze Colorants**
Blue	Cu in Egyptian blue or azurite	Co, Cu
Green	Cu in malachite; Cu and As in tyrolite; Fe in green earth	Cu, Pb-Sb, (Fe)
Yellow	Fe in yellow ocher	Pb-Sb, (Fe)
Red	Fe in red ocher; Hg and S in cinnabar; As and S in realgar	N/A
White	Ca in calcite; Ca and S in gypsum; Ca, P, and F in fluorapatite	Ca-Sb, Na-Sb
Brown	Ochers and carbon black	Mn, Fe, Cu
Black	Carbon black	Mn, Fe, Cu

4. Imagining Divine Splendor

Taking stock of the evidence gathered from the visual examination, technical imaging, and chemical analysis, we may state with certainty that the representation of Ahuramazda in the winged disk was intricately painted, including with bright colors such as Egyptian blue, malachite green, and cinnabar red. A darker iron oxide red was also used and might have been mixed with other pigments to create a purple color. Generally, though, the scarcity of paint remains and the small size of the samples would have impeded the recognition of pigment mixtures and of the layering of different colors or shades even if these existed. The god's robe was painted both bright and dark red and decorated with pinwheels picked out in multiple colors. The ornamental borders consisted of a wide band that was at least partly painted in dark red and framed by narrower bands of triangles painted in bright red and blue. The god's hair and beard were blue, and the flower he held was green, blue, and red. The colors of the feathers of the winged disk alternated by row. The three rows of small feathers at the top were red, blue, and red, respectively, and the three rows of longer feathers below were green, red, and green. All feathers were outlined

in a different color, and the longer feathers preserved on the fragment had blue eyespots. So far, there is no indication of the treatment of the god's skin, lips, eyes, eyebrows, and crown, or of the background of the relief, nor is there certainty about the color or colors of the ring, the ring's appendages, and the outlines of the individual feathers and their eyespots. We do not know which binding medium was employed nor whether the surface was polished or received a coat of wax or gum after it was painted. These variables, too, would have impacted the relief's appearance.

The following sections augment the information gleaned from the close-up study of the fragment with evidence of a more circumstantial nature, including clues derived from examining the surfaces of other Persepolis reliefs and from considering textual and visual sources for the iconography of Ahuramazda. We then review the sequence of color reconstructions that have been supposed for the god's image as it appeared in the southern doorways of the Hall of 100 Columns—from a watercolor by Herzfeld to the painted plaster replica created at the Harvard Art Museums in 2007—and propose how the latter may be improved in the light of new findings and the much-enlarged bibliography on the topic of sculptural polychromy.

4.1. Polychromy at Persepolis

How do the results of the recent, in-depth examinations of the fragment at the Harvard Art Museums fit within the larger context of ongoing research on the sculptural polychromies at the site of Persepolis and other royal residences? What else do we know about the coloration of the doorjambs of the Hall of 100 Columns, and how can evidence from other buildings at Persepolis help us reconstruct the original appearance of the fragment with Ahuramazda? How do we bring together the findings of investigations of individual fragments to better understand the appearance of Achaemenid Persepolis as a whole?

In recent years, much work has been conducted on the pigments and color schemes employed at Persepolis through the examination of the carved surfaces of both the buildings at the site and the dispersed fragments in museums worldwide [3,20]. On site, the "skin" of one of the monumental bulls framing the northern portico of the Hall of 100 Columns still preserves extensive traces of blue paint, suggesting that the original colors of the sculptural decoration would have yielded some surprises for modern western viewers [17] (pp. 115–23) [20]. A wide range of pigments has been identified on the façade of the tomb of Darius the Great (r. 522–486) at Naqsh-e Rustam, providing an important chronological fixed point [20] (pp. 129–133), [77], although it is not entirely clear whether the painted decoration of the royal tombs continued to be refreshed, perhaps even long after a ruler's death. This aspect of caretaking has not received much attention in modern scholarship [20]. As the Hall of 100 Columns was built under Xerxes and his successor, Artaxerxes I, an ongoing study of the polychromy of the facade of the tomb traditionally attributed to Xerxes at Naqsh-e Rustam offers points for comparison [78]. Early on, extensive traces of Egyptian blue were identified on the tombs of later Achaemenid kings above the terrace complex (Figure 27).

Figure 27. Traces of pigment, today appearing blue and green, on the facade of the tomb attributed to Artaxerxes II (r. 405–359) (photograph: Alexander Nagel).

As mentioned above (Section 3.4.2: "Other Pigments"), layers of white pigment made from burnt animal bones survive on some stone sculptures and are thought to have served as a ground for other surface treatments. The different blues preserved on the king's beard and identified in paint residues on paper squeezes taken of the Old Persian inscription on Darius's tomb help us gain insights into Achaemenid color symbolism and the "mineral universe" [79] that Achaemenid rulers and their workers were actively engaging in. The squeezes present an interesting case. Throughout his work in exploring and documenting the many pasts of ancient Persia, Herzfeld used wet paper squeezes to copy stone inscriptions and carvings. The process involved beating a sheet of soaked paper into the marks and depressions of the surface. Once the paper had dried, it was peeled off. The result was a mirror image of the inscription or relief in actual size. The examination of such paper squeezes is relatively new in the field of modern polychromy studies [20] (pp. 152–154), [80]. Recent analysis of pigment remains on the paper squeezes made by Herzfeld's team in 1932 and 1933 has identified traces of Egyptian blue and ultramarine, which attest that both the architectural facades and sculptural decoration indoors were painted in brilliant colors [64]. No ultramarine was found in any sample from the relief fragment at Harvard (see Section 3.4.2: "Blue Pigments").

The background of the sculptures carved on the parapet and staircase facades of the Tachara, or Palace of Darius, and the Apadana, the great audience hall, was painted with Egyptian blue [20] (pp. 109, 206, fig. 6.3). Paint bowls were excavated in front of these facades, indicating their use by the painters active at Persepolis [81]. Remains of wall plaster and the glazed brick facades at Persepolis and Tol-e Ajori (the latter dated to before 520 BCE) have been examined in recent years [68,72,82,83]. Egypt has been identified as the source of the cobalt acting as a colorant in the blue glazes from the monumental building at Tol-e Ajori, near the terrace complex of Persepolis, further strengthening the idea of multicultural engineering and engagement on the site [84]. Floor plaster, too, has been analyzed [85]. It is important to note that much of this analysis is carried out by Iranian scholars based in Iran.

Combining all these efforts by different international teams should be a major goal as a critical prerequisite to achieving a more wholistic understanding of the polychromies of the Achaemenid capital. Attempting to draw some preliminary conclusions, we can say that colors covered both outdoor and indoor architectural sculptures, creating magnificent brilliance and producing radiance and excitement. The colors on the reliefs were not meant to be realistic. We are only beginning to grasp the true meaning behind concepts such as blue bulls, blue hair, and blue beards. Where the background of the reliefs was painted blue on the Apadana and the Tachara, the brown limestone was not visible at all. Could this also have been the case for the sculpted doorjambs of the somewhat later Hall of 100 Columns?

The surface of the fragment at Harvard is well preserved for a reason: the block that contained it fell from its original position relatively early on, and soil soon covered much of its surface. The lower part of the doorjamb and large parts of the other three jambs of the south facade of the Hall of 100 Columns remained standing. Exposed to the elements and temperature changes, it is not surprising that they show fewer traces of paint. Moreover, their surfaces were covered with lime dissolved in water as molds were taken from them on several occasions in the late 19th and early 20th centuries for the creation of plaster casts bound for European museums [16,20] (pp. 147–156). However, remnants of color are abundant and even visible to the naked eye on the lower sections of the southwestern doorway (Figure 28a,b). As noted by Herzfeld in 1923, "the throne legs laid bare were of a bright blue color. Also, remains of red paint were found higher above on the throne…" (translated by Nagel [16], p. 604). A closer look at the other three Ahuramazda figures helps us understand that details such as the hair, feathers inside the ring, the lotus flower, and other features were carved in relief in some cases, while they were left to be added in paint in others (Figure 29a,b).

(**a**) (**b**)

Figure 28. Blue (**a**) and red ocher (**b**) pigment remains on the dais carrying the enthroned king. Hall of 100 Columns, southwestern doorway (photographs: Alexander Nagel).

(**a**) (**b**)

Figure 29. Figure in the winged disk from the eastern doorjamb of the southeastern (**a**) and southwestern (**b**) doorway of the Hall of 100 Columns, photographed in situ in 2007 (photographs: Alexander Nagel).

There is no evidence to confirm the proposition made in the 2007 color reconstruction of the fragment at Harvard that parts of Ahuramazda's robe and his crown were originally gilded. However, there is actual evidence of gilding from architectural sculptures in the immediate vicinity. In 1932, Herzfeld observed traces of gold leaf on the edge of the king's cloak in the Tripylon, sometimes also referred to as Council Hall or Central Building. Moreover, it has long been known that reliefs at Persepolis, as well as at Pasargadae to the north, were fitted with precious metal components (Figure 30) for applied dress ornaments, the king's crown, and perhaps also jewelry on the ruler's arm [20,26].

Figure 30. Relief of the enthroned king in the Tripylon, with holes for the attachment of precious metal components (photograph: Alexander Nagel).

As we seek to reconstruct the original appearance of the palaces at Persepolis, we should also think about the human labor—conceptual as well as physical—that built them. Epigraphic evidence can help us better understand the social frameworks of the building process. For example, we know that women were involved in painting reliefs, even though their exact contributions remain to be investigated [20] (pp. 29–30).

4.2. Iconographic Considerations

"A great god is Ahuramazda, who created this earth, who created yonder heaven, who created man, who created blissful happiness for man, who made Xerxes king, the one king of many, the one master of many".

Old Persian inscriptions such as this one by king Xerxes that was carved onto the Gate of All Nations, the monumental entrance to the Persepolis citadel (XPa), declare the close relationship between the Achaemenid ruler and the god Ahuramazda. Xerxes, like Darius and later Achaemenid kings, derived his power—and his character and skills (XPl)—from the deity; he conquered and built an empire by the god's grace (XPh). It is by the god's favor that he erects buildings, and he asks the god to protect them (XPa, XPf) [86–88]. A similar sentiment informs the Babylonian inscription by Xerxes's son that was found in the Hall of 100 Columns: "King Artaxerxes says: My father, king Xerxes, laid the foundations of this palace. With the protection of Ahuramazda, I, king Artaxerxes, have finished it" (A1Pb) [87].

The close relationship between the king and the god repeatedly emphasized in the Achaemenid royal inscriptions is one of the reasons that the figure in the winged disk hovering above images of the king has been taken to represent Ahuramazda. In Darius's rock relief at Bisotun (the earliest occurrence of this imagery) and on the facades of the royal tombs at Naqsh-e Rustam and Persepolis, the figure in the winged disk is placed in front of the king, both men raising a hand as if exchanging a greeting. In the southern doorjamb reliefs of the Hall of 100 Columns (Figure 2), the disk's wings are spread out over the canopy that is shading the enthroned king below and is itself decorated with figureless winged disks. There is no direct interaction between the two figures, but if the bearded man in the winged disk is taken to be Ahuramazda, the protagonists of each doorjamb relief—king, god, and the representatives of the empire's subject peoples elevating the king—enact a concise visualization of Achaemenid kingship as expressed in the royal inscriptions [4] (pp. 131–181).

In the northern doorways of the Hall of 100 Columns, the winged disk appears without a figure, pointing to one of its origins, the Egyptian winged sun. Inhabited winged disks go back to Assyrian art, where the male figure represented the sun god Shamash or the god Ashur ([58] pp. 133–138 gives an overview of disk shapes). The figure in the winged disk became a popular iconographic feature throughout Achaemenid art of all scales and can be found on several buildings at Persepolis, tombs beyond Fars such as Ashkawt-i Qizqapan in Iraqi Kurdistan, and on seals and jewelry [89–93]. As the Faravahar, it continues to be an important symbol of Zoroastrianism to this day. For a number of reasons, among them the similarities between the figure in the winged disk and the figure of the king, some scholars have argued that the motif should not be understood as the image of a deity but more abstractly as the old Iranian concept of *xwarnah*, god-given fortune or royal glory [94–96]. A recent proposal suggests that the assimilation of god to king is owed to Ahuramazda's role as the ancestral god of the Achaemenid dynasty [97].

There are no Old Persian writings mentioning the god's appearance. The Avesta (the main collection of Zoroastrian texts) and Middle Persian texts describe him as "radiant" and "all light," giving him the star-adorned heaven as a garment (Yasna 1.30.5; Yasht 13.3) [23,98] (pp. 179–180). Since these texts and the Achaemenid inscriptions share basic concepts [99], it is tempting to connect Ahuramazda's star-adorned robe with the pinwheel pattern on the garment of the figure in the winged disk and to interpret the pinwheels as eight-pointed stars, even if the overall color of the garment was red rather than (sky) blue. Circular ornaments on the robe of the king in reliefs at Persepolis are of a floral nature [26] (pp. 53–57, fig. 6, pls. 33–34, figs. 39–42), [37] (pls. 142–143, 198), but the textile covering the king's throne in the northern doorways of the Hall of 100 Columns also features starburst-like designs inserted into circular shapes [26] (pp. 45–48, figs. 3–4). The throne cover is lined by a wide band with striding lions framed by triangle borders. The same decoration appears on the royal robe and has, by analogy, been suggested for Ahuramazda's garment in the south doorways.

An actual woven textile band with striding lions in Achaemenid style, framed above and below by narrower bands with triangles, has survived in the form of a horse's chest strap (Figure 31) from a burial mound at Pazyryk in the Altai Mountains of southern Siberia (Russia). To achieve the red, blue, and purple colors, the wool had been dyed with red madder and cochineal as well as blue indigo. It is thought that this band of fabric was originally part of a highly prestigious Achaemenid garment or tapestry that reached Scythian lands by gift and/or trade; the saddlecloth associated with the strap was decorated with Achaemenid-style tower motifs on purple ground. Attached to a felt base, the band with lions was lined with strips of foal fur dotted with gold-covered leather pieces [100,101] (pp. 281–282, fig. 162; pp. 306–307, cat. 223). The golden ornaments are coarse versions of the gold appliqués of floral or figural shape that embellished sumptuous clothing in the Scythian area as well as in the Achaemenid empire, with predecessors in pre-Achaemenid Iran and Mesopotamia [102–107]. Considering that the garment of the royal figure carved into a doorway to the hall of Palace P at Pasargadae appears to have been enhanced with metal attachments [108] (p. 93, pls. 80–81), it is conceivable that the star patterns on Ahuramazda's robe at Persepolis were meant to represent openwork gold appliqués. Gold-adorned garments for deities had a long tradition in the ancient Middle East [109]. Perhaps actual gold was applied to the relief, although this would have been gold leaf rather than sheets since, unlike at Pasargadae, there are no rivet holes.

Gilding seems likely for Ahuramazda's crown, judging by the evidence of the king's crown on some of the reliefs at Persepolis (see Figure 30) [37]. In the Hall of 100 Columns, the unfinished royal crown on a doorway of the northern facade is framed by two slots probably intended to attach a metal sheet [26] (pp. 61–62, fig. 9, pl. 37, fig. 48). A fragment of such a gold crown from a sculptural relief was excavated in the Apadana and is kept today in the National Museum of Iran in Tehran [26] (pl. C:3). If actual gold was applied to the king's crown, it would have been fitting that Ahuramazda's crown was similarly

treated. Again, though, there is no provision for attachment, necessitating the assumption of gold leaf.

Figure 31. Breast strap of a saddlecloth from a burial mound at Pazyryk (Altai), 5th–4th century BCE (detail). The State Hermitage Museum, St. Petersburg, Russia. Photograph ©The State Hermitage Museum/photo by Vladimir Terebenin.

Other points where the stone reliefs at Persepolis were enhanced with a different material were the king's beard and hair. Royal images at Persepolis had inlaid beards and curls of hair made of Egyptian blue, likely in imitation of lapis lazuli, and such blue curl inlays were found in different areas of the Persepolis terrace [16,26] (p. 39, pl. C: 2). Recent examination of the figure of Darius on the façade of his tomb at Naqsh-e Rustam has revealed distinctive traces of blue paint in his beard [20] (129, 131, fig. 3.25), [77]. The blue beard of the Achaemenid king was part of a longstanding convention in Western Asia. The color of the beards of heroes was compared to lapis lazuli, and actual lapis or an imitation was used on images of heroes and mythological creatures [23,79] (but see [18] pp. 203–204). Similar associations existed in Greece [13] (pp. 54, 61–89).

4.3. History of Reconstruction Attempts

The human brain has many marvelous capabilities that most of us rarely consider. Many of us might have experienced that it is easier to detect patterns—and things in general—that we know and are looking for rather than the unfamiliar and unexpected. This unconscious bias in perception is directly linked to the brain working efficiently. Imagine you had to take in every detail in your field of view at every moment: you would never get to see the forest for the trees. To avoid this, the brain fills in from memory, making it difficult to see familiar things afresh [110]. This affects the study of ancient polychromy in multiple ways. As alluded to above, it presents an obstacle to recognizing details, especially if they deviate from an overall scheme or formula. Looking at an object from multiple angles, in different lighting conditions, with different lenses, and with extra pairs of eyes can help discover new features.

A reconstruction created by somebody else will also provide a different perspective, but it can never be unseen. Once it has entered the stock of images in our brain, it will color, as it were, what we see from there on out. It is essential, therefore, to take a close and conscious look at previous reconstructions and to question their approach before attempting a reconstruction of one's own. In the case of the fragment with Ahuramazda, the earlier reconstructions are connected by the assumption that the image of the god was jewelry-like in appearance. This seems appropriate for a "radiant" deity (see Section 4.2), but is this proposition sustained by the results of the fragment's recent re-examination?

4.3.1. Two-Dimensional Renderings, 1930s–1970s

"On a deep black background the colors stand out, luminous and almost transparent, like *cloisonné* enamel."

This is how Herzfeld described the original appearance of the figure in the winged disk hovering high up on both sides of the two south doorways of the Hall of 100 Columns in his *Iran in the Ancient East* [57] (p. 255), the 1941 publication of the Lowell Lectures he delivered in Boston in fall of 1936, some seven years before the arrival of Winthrop's Persepolis fragments on the Harvard campus. He goes on to describe the colors: "Turquoise blue changes with a light scarlet red; the yellow has an orange or gold shade; deep purple and lapis blue, and, scantily used, an emerald green complete the color scheme." The accompanying illustration in *Iran in the Ancient East* is black and white [57] (pl. 64), but the original watercolor can be found among Herzfeld's papers in the National Museum of Asian Art Archives in Washington, D.C. (Figure 32) [56]. In the watercolor, Ahuramazda faces left, not right as in the fragment at Harvard. Accordingly, the watercolor must show the god in the winged symbol on one of the eastern doorjambs that remained largely intact through the ages. In his text, however, Herzfeld references a watercolor sketch he made before the relevant relief was destroyed, as if he was referring to the block that once contained Harvard's fragment. This has caused significant confusion (discussed in [3], pp. 113–115). Possibly, Herzfeld made the watercolor at a later point, drawing on earlier sketches and notes (such as Figure 6) but using as a model for the overall representation one of the reliefs preserved on site (a similar scenario was suggested by Tilia [26] p. 42, n. 3).

Figure 32. Watercolor of a figure in the winged disk. Ernst Herzfeld/National Museum of Asian Art Archives, Smithsonian Institution, Ernst Herzfeld Papers, FSA_A.06_05.0904 (Detail).

The color scheme of the wings in the watercolor corresponds to what Herzfeld noted in his sketchbook; as explained above (Section 3.1), he mistook the remains of malachite green on the longer feathers for turquoise. He recognized green on the flower, where he would have expected it. Green, yellow (ring and appendages), purple (part of the robe), and lapis blue (hair and beard) are not mentioned in the sketchbook. This means that even though the specificity with which Herzfeld describes the colors ("an orange or gold shade") makes it very likely that he did indeed see them, we cannot be entirely certain that he saw them on this particular block rather than on one of the other Ahuramazda reliefs in the Hall of 100 Columns or the nearby Tripylon. His watercolor might also have been informed by the knowledge that the relief decoration at Persepolis could be enhanced by gold appliqués and Egyptian blue beard inlays (see above, Section 4.2). But it is the wording "*cloisonné* enamel" that points to what likely was the most important source of influence, more than any earlier—more fanciful—reconstructions [3,20,111], namely the glazed brick decoration excavated by French archaeologists in the Palace of Darius at Susa in western Iran [112]. Herzfeld himself had found a piece of similar glazed decoration at Persepolis [111]. The shallow carving of the limestone reliefs with their plain, clearly circumscribed surfaces facilitates the association with their glazed brick counterparts. And

while the presence of brighter colors, notably red, is implicit in the term "enamel," one wonders whether Herzfeld's seeing turquoise on the stone relief was not inspired by the glazed bricks' characteristic color scheme.

In addition to distinct color fields and bright colors, Herzfeld's proposal comprises a third key component, namely a dark background creating a strong contrast to the brilliantly painted figure. The saturated, shiny surfaces resulting from the polishing of the limestone used at Persepolis are remarkable (they can be seen at the site on spots of the reliefs visitors love to touch). Herzfeld was clearly struck by the aesthetic effect, writing about the masonry that it "goes to the extreme of highly polished stones, looking, when well preserved, like mirrors of black marble" (p. 236, [57]).

Lerner's 1971 reconstruction built on the observations she made on the newly cleaned fragment at Harvard, on comparisons with the glazed brick decoration in Susa, and on Herzfeld's notes, drawings, and watercolor of the figure decoration of the Hall of 100 Columns and the Tripylon [23,24]. She corrected the color sequence of the long feathers to green–red–green and (mistakenly) replaced the blue of the middle row of short feathers with green. She added detail inside the winged ring but did not quite understand what it represented. For the ring and its appendages, she adopted the yellow from Herzfeld's watercolor. She also followed Herzfeld in giving Ahuramazda whitish skin and a dark blue beard and hair (accidentally printed as black in the 1973 publication [24]). For the god's robe, she drew on another Herzfeld color sketch, this one of the king, with a hemline featuring red walking lions on a blue ground, and on the patterns incised on the royal robe in other Persepolis reliefs. She assumed that these decorations represented embroidery or gold appliqués and that the latter might have been rendered in yellow paint. She chose gold for the crown. Since she could not detect any traces of color on the background, she did not include it in her reconstruction. She wondered about color symbolism but cautioned that too little was preserved for drawing firm conclusions.

The color reconstruction Tilia published in 1978 was drawn by her husband Giuseppe and based on that of Lerner as well as conversations between Lerner and Ann Britt Tilia in Persepolis (1969) and Princeton (1974/1975). The Tilias introduced a number of modifications that were informed by their close inspection of the fragments from the same block that had remained on site and of the other reliefs depicting the figure in the winged disk [26] (pp. 32–42, pl. A:1). They proposed, correctly, that the patterns visible inside the disk represented a continuation of the wing feathers, and they recognized that the individual feathers and their eyespots were outlined in a different color. As mentioned above (Section 3.2), they observed the remains of a whitish substance and noticed that the stone surface was less smooth in these framing areas, which led them to assume "that a special colour had been used or a special foundation, which had a corroding effect on the stone, and possibly one that was meant to imitate a metal, perhaps gold" [26] (p. 36). They found the same white material on the shafts of some small feathers. In the reconstruction, they gave these features a golden color and also used gold for the ring and its appendages. The resulting effect led Tilia to elaborate on Herzfeld's comparison: "Since the way of framing the feathers of the winged symbols with another colour, possibly gold, reminds us of the Egyptian *cloisonné* technique, the semi-precious stones and the glass paste being encircled by gold, . . . we are inclined to believe that pieces of Egyptian jewellery . . . had inspired the way of colouring the winged symbols at Persepolis" [26] (pp. 38–39). This had also been Lerner's thought.

The Tilias also proposed that the crown was gilded and that the beard and hair were blue. They were uncertain about the skin color since they had found no pigment traces on the flesh of any figures at Persepolis, and they ended up choosing a slightly pinkish hue. They had, however, detected red paint on the eyes of several figures and hence gave the god red eyes. For the robe, they turned to a representation of the figure in the winged disk in the Tripylon, where areas of red paint remained on the garment. There, they observed concentric circles as well as broad bands with walking lions. Returning to the reliefs of the Hall of 100 Columns, they could make out similar incisions, including

compass holes for the circular ornaments. They could not contribute any further pigment discoveries [26] (pp. 56–57), so their reconstruction, too, has red lions on blue ground. The circular ornaments are rendered schematically, in gold with a green center, the latter probably inspired by the floral decoration of the royal garment [26] (p. 54, fig. 6).

4.3.2. The Three-Dimensional Proposal from 2007: A Critique

The 2007 "Gods in Color" exhibition at the Harvard Art Museums was not the first time a painted plaster reconstruction offered a glimpse of the sculptural decoration of the Hall of 100 Columns to the United States public. From 1899 to 1905, for example, visitors to the Hall of the Ancients in Washington, DC, could admire a painted cast of the lower part of one of the southern doorjambs. The section depicting the dais-bearing subject peoples was topped by a three-dimensional throne with a dummy king [20] (pp. 47–48, fig. 1.8), [111] (p. 63, fig. 7). The 2007 presentation was informed by detailed observation and research, but like its Washington predecessor, it also sought to bring an ancient monument to life for modern exhibition visitors. This goal drove decisions such as the application of gilding to the god's crown and the patterns of his robe. Even if there was nothing to prove the use of gilding on this particular relief fragment, we determined that it would be instructive to show this option since such evidence existed elsewhere at Persepolis. The 2007 reconstruction should be considered a proposal, not a one-on-one documentation of the actual findings. In any case, it is now partly outdated by the results of more recent examinations. The discussion that follows below gives an update.

But first, a quick word on three-dimensional color reconstructions. Physical color reconstructions of ancient sculptures have been criticized for conveying too great a degree of certainty when there is so much that remains unknown [113,114]. This was also the main concern raised by other curators when Susanne Ebbinghaus proposed hosting the painted casts constituting the core of the "Gods in Color" exhibition. Moreover, the most common material used for reconstructions, plaster, has different properties from marble or, in this case, gray limestone, and this will affect both the paint application and the final appearance of the painted sculpture. Digital or paper reconstructions are certainly easier to adjust when new discoveries are made, as are images projected onto the original sculpture. Tangible three-dimensional reconstructions offer a further benefit, however, besides being visually powerful. Creating them can be an effective heuristic tool [115]. Ebbinghaus experienced this when she tried, brush in hand, to transfer to the plaster cast of the relief fragment a new color reconstruction that Lerner had sketched on paper. At several points, it proved difficult to align the sketched design with the cast's actual surface. This prompted Ebbinghaus to take another look at the original and ultimately led to the reconstruction being amended by features such as the triangle borders framing the wide bands on the god's robe. Even as virtual reality and artificial intelligence are opening up new frontiers in visualizing ancient polychromies [116], painted plaster casts retain a basic advantage: they involve the same physical act of painting as the creation of the original, even if materials and tools are not exactly identical.

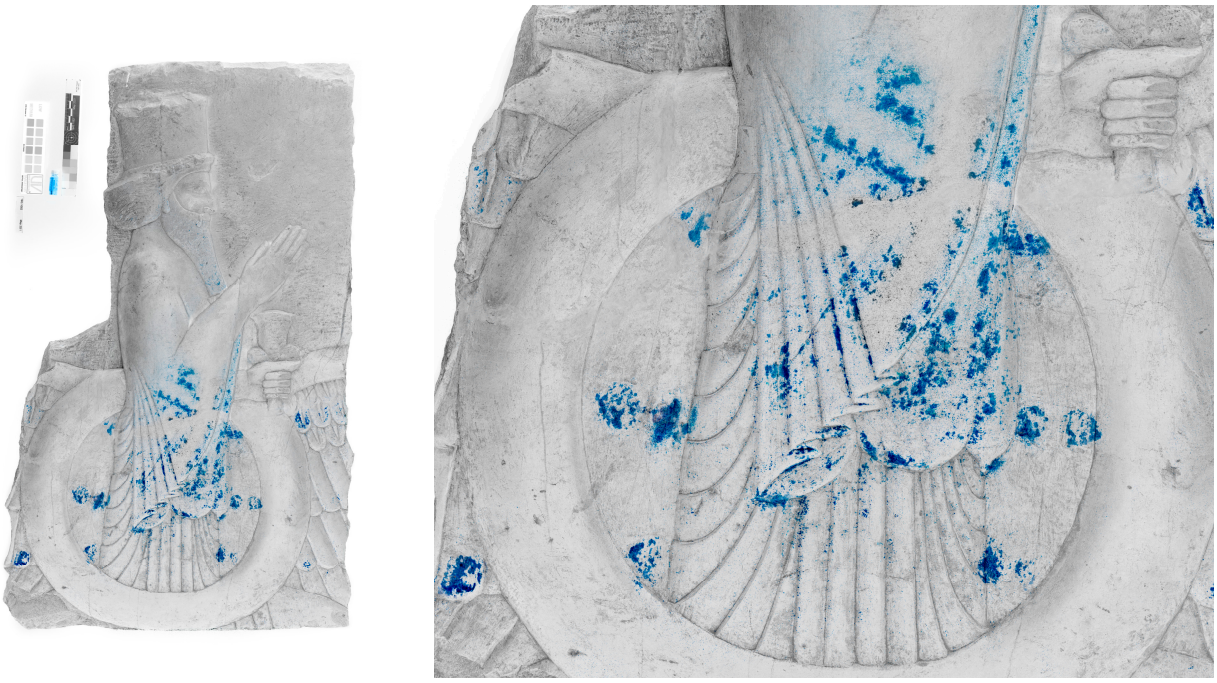
The 2007 reconstruction, shown in Figure 33, consists of a painted plaster cast based on a replica derived from a 3D scan of the relief. It was spraypainted in a medium gray color to imitate the appearance of the Persepolis limestone. The decoration was applied by brush, using acrylic paints whose colors had been matched to those of color reconstructions made with authentic pigments by Ulrike Koch-Brinkmann and Vinzenz Brinkmann [31]. Gold leaf was employed for gilding.

Figure 33. The color reconstruction attempt from 2007, which is now partly outdated. Harvard Art Museums/Arthur M. Sackler Museum, 1943.1062.X. ©President and Fellows of Harvard College.

The 2007 version of Ahuramazda's robe was informed by the incisions traced under raking light, the visible remains of color, and the results of the pigment analysis. As mentioned above (Section 4.2), notions of the god's star-adorned robe, together with the actual practice of enhancing prestigious clothing with gold appliqués in the Achaemenid empire and beyond, prompted us to propose that the pinwheel patterns were, in fact, starbursts and were originally gilded. Since there are no holes for the attachment of gold sheets, we used gold leaf. The Brinkmanns' reconstruction of the sixth-century BCE Greek statue of Phrasikleia with gold and tin foil rosette patterns dotted over her red dress offers a parallel from the Greek world, in this case, based on the physical remains of these materials on the statue [117].

Additional inspiration came from the archers represented in the glazed brick decoration of Darius' palace at Susa [102,112]. Their long garments are of the same kind as those of Ahuramazda and the king. This so-called court robe consists of a rectangular piece of cloth with a slit for the head. It was belted at the waist, creating sleeves of sorts as well as the folds in the lower part of the robe [118]. At Susa, the robes are comprised of different horizontal segments separated by broad bands with triangle borders; further decorative bands run along the outer edges of the garment. Based on the incisions surviving on the reliefs, the Tilias reconstructed this same type of robe for the king and the figure in the winged disk (see above, Section 4.3.1). However, the patterned zones are distributed differently at the two sites: at Persepolis, the topmost zones are ornamented, and the lower one appears to have been plain, while it is the top and bottom zones that bear decoration on the archers' robes at Susa. The fragment at Harvard confirms the Tilias' findings. But the different coloration of the textile panes at Susa (yellow and brown, or white and yellow) provides an explanation for the surviving traces of bright and dark red pigment on Ahuramazda's robe and prompted us to assume a darker red or purple middle section. The colorful triangle borders at Susa also helped us recognize the presence of such borders from spots of pigment preserved in relevant areas on the fragment at Harvard.

As it turns out, we should have looked to Susa, too, for the coloration of the starbursts. One version of the archers' robe shows closely related patterns with the following color scheme: an orange center surrounded by white spikes, with blue and orange alternating in the interstices. Alternating red and blue is what the VIL image combined with preserved specks of bright red paint suggests for the background of the starbursts on Ahuramazda's robe (see Figures 7b, 10 and 34). The blue inside the starbursts is most obvious in the first row of patterns below the wide decorative band running in a curve along the god's arm. In the 2007 color reconstruction, we had painted the starburst backgrounds all red.



(**a**) (**b**)

Figure 34. (**a**) Color-adjusted VIL image overlay on a grayscale image of the fragment, showing remaining Egyptian blue particles and distribution; (**b**) detail; ©President and Fellows of Harvard College.

Comparison between the 2021 VIL image and the 2007 color reconstruction reveals further differences. These become easier to see when a color-adjusted VIL image is laid over a grayscale image of the relief (Figure 34). It should be noted, however, that the distribution of the surviving pigment is patchy, and it is not always clear whether a pattern is original or the result of pigment loss or displacement from weathering and cleaning of the relief.

The borders to both sides of the wide horizontal band on the god's robe are a case in point. A basic triangle pattern seems to be present, albeit not neatly delineated. The apparent pattern differs from the version reconstructed in 2007. The latter was based on the triangle borders of the garments of the Susa archers, where blue and yellow-orange triangles alternate with each other and with white triangles on the opposite side, a scheme paralleled on the breast strap from Pazyryk (see Figure 31). As explained above (Section 3.4.2: "Comparison with Glaze Colorants"), a red glaze does not occur on the glazed bricks at Susa; the orange glaze would have come closest to the bright red paint found in the triangle borders on the fragment at Harvard. The roughly triangular shapes in the VIL image are larger in size and have the opposite orientation from what we had assumed in 2007. The larger size leaves no room for red triangles alternating with the blue ones. This suggests that the border consisted of opposing blue and red triangles, without any white ones. Different versions of the triangle pattern are attested in Achaemenid jewelry and on other small-scale objects, including blue triangles opposed with alternating red and lapis ones [102] (p. 95, fig. 77), [119] (p. 103, cat. 15; p. 129, cat. 66). At the western edge of the

empire, the rosette borders of the Achaemenid robe of the reclining banqueter in the early fifth-century BCE tomb at Karaburun in northern Lycia are lined with red triangles [120] (pp. 111–113, figs. 1–2).

VIL imaging has confirmed that wide bands with patterned borders were also painted onto the overlapping sleeve edges in front of the figure, arranged in a similar way as at Susa (and a little differently from the 2007 color reconstruction). A triangular pattern is highly likely for these borders, too, but while there are significant remnants of Egyptian blue, they do not form clear triangular shapes. Neither incisions nor pigment traces indicate that the wide band separating the robe's upper from its middle zone was depicted on the chest, where it is present on the archers at Susa and in the Tilias' reconstruction. Since no pattern could be determined for any of the wide bands, they were left plain in the 2007 reconstruction. According to the VIL image, these bands did not include substantial amounts of Egyptian blue. The use of another blue pigment, such as ultramarine, cannot be excluded, but so far, no other blue pigment has been identified on the fragment (Section 3.4.2: "Blue Pigments"). The bands almost certainly bore decoration, perhaps indeed walking lions or, considering the relatively small scale of the figure, a simpler motif. Spots of luminescence throughout the robe could mean that some Egyptian blue was mixed in with the overall red, or they could be the result of blue particles from the starbursts and triangles having been displaced as the relief was exposed to the elements and later, during the cleaning process. The latter scenario is quite likely since Egyptian blue pigment was not very finely ground, and the paint tended to be applied relatively thickly.

The VIL image shows notable traces of Egyptian blue in the lower left part of the pleated sleeve, on the robe below the belt at the back, and at the top of the skirt, all areas that would be in the shade if this were a three-dimensional sculpture or an actual person. On the sleeve, the blue survives in and next to the grooves separating the individual pleats. This makes one wonder: could Egyptian blue—and potentially other pigments, such as carbon black—have been applied to indicate shading and thereby enhance the three-dimensional effect of the relief? And might the choice of a darker red for the lower portion of the sleeve represent a more schematic attempt at rendering shade? Shadows are painted onto the carved drapery of Greek sculptures of this time [121] (pp. 94–95, fig. 17), [122] (p. 40, fig. 2.31), but the use of this painterly device is not normally looked for on the Persepolis sculptures (though Herzfeld employed it in his watercolor, see Figure 32). The sculptures' shallow relief with clearly delineated forms and unbroken surfaces does not itself model with light and shade and, hence, does not seem to call for this kind of treatment in paint. Or perhaps we do not expect it because of the traditional assumption that Achaemenid art, including monumental sculpture, is largely decorative in nature? The evidence of the Harvard fragment is not conclusive, but it should encourage us to look for shading on other Achaemenid sculptures, especially those of a mid-fifth century BCE or later date when shading had become common in Greece. Even though sculptures from the period of Xerxes and Artaxerxes I are carved in similar ways as sculptures from the reign of Darius, they need not have been painted in the same style.

It remains an open question whether or not gold leaf was applied to the starburst patterns and the crown. This special treatment would have helped draw attention to the figure of Ahuramazda in the relatively dark spot just under the lintel, and one can imagine the sparkle that would have been caused by the reflected light of torches illuminating the great hall. The blue beard proposed in all color reconstructions since Herzfeld's watercolor has been confirmed by the latest round of VIL imaging, which has also demonstrated that the god's hair was blue. In 2007, the hair was painted black as an alternative proposition. No specks of pigment can be seen with the naked eye on either the hair or the beard, and it is very well possible that other pigments were originally present. Egyptian blue is relatively bright, and one could imagine that it was mixed with carbon black to create a darker color [21] (pp. 408–409, 412–414). It is also possible that ultramarine was used, as Herzfeld assumed; in fact, it is quite likely that different colors or at least shades were

employed to lend structure to the hair, which has carved curls in the representation of the god on the opposite doorjamb (see Figure 29a).

The god's skin and facial features were left unpainted in the color reconstruction, both because there was no evidence and because Lerner and Ebbinghaus had different ideas about its color. In the art of some Mediterranean regions, notably Egypt and Greece, male skin was at times given a darker tone than female skin, a distinction often attributed to traditional notions about the different lifestyles (outdoor versus indoor) of men and women and more generally connected to ideas about proper conduct and beauty [123]. In Mesopotamia, this distinction did not exist and remains of skin color preserved on sculpture range from yellowish orange to red and brown [18] (pp. 181–186, 204–208). Light and dark skin tones occur among the Susa archers [112]. What color, then, was the skin of an Achaemenid god? Anything from white to yellowish white to some shade of pink to a (darker) reddish brown or brown is conceivable. The pigment traces observed on the tomb facades at Naqsh-e Rustam [3,16,20,77,78] indicate that the eye was outlined in black, and black would have been used for the eyebrow, as was quite standard in Assyrian reliefs and paintings. The lips were likely red, possibly also the visible nostril and the corners of the eye; the sclera would have been white, and the iris and pupil a darker color. Paint may also have been used to add an earring.

VIL photography suggests that there was blue paint on the unfinished lotus flower in addition to the visible red and green. A likely template for the arrangement of the calyx and petals is provided by the representation of Ahuramazda from the southwest doorway of the Hall of 100 Columns, where the details of the flower are carved (see Figure 29b). An improved reconstruction should follow this scheme, which requires at least three different colors.

Turning to the winged disk, sufficient pigment traces are preserved on the feathers inside and outside of the ring to securely establish the color of each row. VIL imaging has confirmed the use of blue on the second row of the short, scale-like feathers and for the eyespots of the first and second rows of the long feathers. Tilia could observe that the third row of long feathers, whose lower ends are not preserved on the Harvard fragment, had red eyespots [26] (pp. 33–34, fig. 1). In contrast, the coloration of the ring and its appendages remains unknown. It should be noted that the ring need not have been painted in one color alone. The disk of the glazed brick winged symbol at Susa is composed of three concentric rings (white, greenish blue, and white) and a yellow-orange center [112] (fig. 343). Yellow was chosen for our reconstruction because yellow ocher tends to be more fugitive than other colors [124] (p. 52) and with a nod to the idea that the winged disk was intended to resemble inlaid gold jewelry. As discussed above (Section 4.3.1), this notion was inspired by the fact that the individual feathers and their eyespots were outlined in a different, now-lost color. Again, ocher seemed plausible for these outlines, and it was also applied to the shafts of the short feathers.

A large inlaid gold pectoral in the form of a winged disk (part of the finds from looted tombs in Lydia that became known as the "Lydian Treasure") provides a stunning illustration of the presumed precious metal prototypes [125] (pp. 174–175, no. 128). Like Ahuramazda's vehicle at Persepolis, it resembles the Egyptian winged sun in the shape of the wings, which may not be entirely coincidental, considering the long history of inlaid gold jewelry in Egypt [126,127]. The Hall of 100 Columns also features other Egyptianizing elements. The disk of the pectoral from Lydia consists of a layered agate cut so that its carnelian center is encircled by narrow white and brown rings. The feathers are inlaid with turquoise, carnelian, and a brownish stone, and the stone forming each feather is enclosed by a slim band of gold. Such outlines are not proprietary to inlaid jewelry, however. Notably, they exist on the Susa glazed bricks, heightening the decorative, almost scintillating appearance of the wings of the sun disk and of various mythological creatures alike [112] (figs. 343, 345–346). On the bricks, most of these outlines are white; light blue occurs around the outermost feathers. White is also what a single sample certainly deriving from such an outline indicates for the Harvard relief, although two samples from nearby

spots have been tentatively defined as ocher (see Section 3.4.2: "Other Pigments"). Of course, the white might have been a ground layer.

On the whole, it seems quite likely that both the painted stone and the glazed brick reliefs were borrowing effects from jewelry, but among the comparisons between media, the comparative ease with which a painter could have added detail should not be forgotten. The carving of the long feathers indicates that they are layered, reminding us not to discount the possibility that there was shading. We also need to keep in mind that what is preserved of a painted surface tends to be the lowest layer. Even if the small size and high perch of the figure in the winged disk make this doubtful, it is possible that the individual feathers were further refined by lines rendering their barbs (compare [121] p. 107, fig. 29).

The claw chisel marks of the unfinished background lend it a speckled appearance and an overall grayish color quite different from the unified, deeply saturated taupe of the polished stone. One would think that it was meant to be covered with paint, but neither have the recent examinations produced certain evidence for coloration nor does Herzfeld appear to have observed any when he saw the newly excavated block. Fine specks of luminescence that may be observed in the high-resolution VIL images in the lower three-quarters of the fragment, including on the background (see Figure 34), may be stray particles loosened by weathering or displaced by modern cleaning rather than indicating the remnants of original paint in these areas [128].

Blue has been found on relief backgrounds elsewhere at Persepolis (see Section 4.1), was used as a background in glazed brick decoration, and was a common background color in Greek relief sculpture of the time [129] (pp. 38, 43), [130] (pp. 103–142). It would have been a suitable background, at least for this section of the doorjamb relief, as it would contrast with most of the figure in the winged disk, except for the beard and hair. But if it was Egyptian blue, one would expect stronger luminescence in the VIL image. This leaves three possibilities: the background was painted a different kind of blue, both the carving and the painting of the relief were left unfinished, or the background was left blank intentionally. As Herzfeld's enthusiasm illustrates, the latter idea holds some appeal for a modern viewer. There is an ancient parallel, as well, albeit quite far away, namely the frieze of the late fifth-century BCE Erechtheum on the Athenian Acropolis. Here, flat-backed figures carved from white Parian marble were attached to frieze slabs of dark blue-gray Eleusinian limestone [129] (p. 127, fig. 115), [130] (pp. 118, 128). As the marble figures were probably at least partially painted, the overall effect of this elaborate ensemble would have been quite similar to a Persepolis relief with unpainted background. One could speculate that artists in both Athens and Persepolis picked up on a design trend of the time, but Athens looking to Achaemenid Persia for inspiration would not be unprecedented [131].

Overall, Herzfeld's vision quoted above (Section 4.3.1) has held up well to scrutiny, perhaps unsurprisingly so, since he saw the relief when it was at least in part freshly excavated. Most likely, the colors of the god in the winged disk were more saturated than he assumed and than his choice of the words "almost transparent" implies. The coloration of the patterns on Ahuramazda's robe and of the feathers with their eyespots may well have resembled cloisonné, but we cannot exclude that this was tempered by other, more painterly effects. The latter need not have counteracted the intention to give the image a precious, jewelry-like quality. Unfortunately, the absence of any sizeable remains of mid-fifth-century BCE wall paintings from the heartland of the Achaemenid empire means that we are reduced to speculation regarding the artistic toolkit of the workers who painted the reliefs in the Hall of 100 Columns.

4.4. The Bigger Picture

Questions linger about the coloration of the figure in the winged disk, but the occurrence of pigments such as cinnabar, Egyptian blue, and malachite in combination with the elaborate design leaves no doubt that it was both bright and intricate. Even though the figure would have received little direct and ambient light in its original context high up on the jamb of a tall doorway, directly under the lintel, this choice of pigments would have

both secured its visibility and enhanced its legibility. The latter became apparent when the ancient fragment was moved from its usual spot in the galleries of the Harvard Art Museums to be the focus of a temporary installation that addressed its dislocation, and was replaced with the 2007 color reconstruction. Inserted among the other Persepolis relief fragments—now devoid of paint—in the museums' collection, the reconstruction stood out not just for its colors but also because they made the details much easier to read, even at a distance (Figure 35). As an experiment has demonstrated, the architectural sculpture of ancient Greek temples benefitted from the same effect [132]. The juxtaposition of the painted with the plain relief fragments also served to show that colorfulness does not necessarily detract from the sense of sculptural volume.

Figure 35. The 2007 color reconstruction on view at the Harvard Art Museums in 2021 (photograph: Katya Kallsen) ©President and Fellows of Harvard College.

The reconstruction has had its detractors, however, mostly on the grounds of its "garish" colors. As mentioned above (Section 4.3.2), the selection of the hues used in this particular reconstruction attempt was not very scientific, but the problem is first and foremost in the eyes of the beholder, as it is a matter of taste and expectations [133].

There are no texts from Achaemenid-period Iran that could help us see Ahuramazda's image with the eyes of a member of the Persian elite at the time of Artaxerxes I, but we may safely assume that the effort expended on the surface treatment of the relief served a purpose. The figure in the winged disk was resplendent and vibrant, as would befit a god. In addition to bright colors, the heavily adorned robe and jewelry-like winged disk enhanced the divine image. The remainder of the doorjamb relief was no less ornate [20,26], reminding us that it was created in the service of the great king whose image was at its center, showing him enthroned and empowered by the god hovering above as well as supported by the representatives of the empire's subject peoples depicted below (see Figure 3b). In metaphorical form, the doorjambs of the southern doorways of the Hall of 100 Columns presented an enduring rendering of the king's audience that would have been ceremonially enacted in the hall itself, with dazzling garments, golden paraphernalia, the air infused with incense, and Ahuramazda invoked by spoken word and perhaps also by representations on tapestries and the royal baldachin. Zooming even farther out (see Figure 3a), the combination of enormous scale and intricate surface decoration in the

architecture of the Hall of 100 Columns must have inspired awe, as should be expected for a building under the god's protection (Section 4.2).

Greek artists of the sixth and early fifth centuries BCE, too, employed rich polychromy to characterize their deities: the Athena with scaly cape aegis from the west pediment of the temple of Aphaia on Aegina makes for a particularly good comparison with the somewhat later Achaemenid god [9,31]. As Adeline Grand-Clément has shown, *poikilia*—variegation, colorfulness, intricacy, brilliance—was highly appreciated by Greeks of earlier periods [134]. It acquired a negative connotation in the wake of the Persian wars, at least for mortals. Recent examination has revealed that the garment of at least one pedimental sculpture of the most classical of monuments, the Parthenon, was, in fact, painted with figure decoration that would have lent it a dazzling appearance [135]. In contrast, sumptuous, vividly patterned clothing worn by humans, more particularly men, was, for the Greeks, an emasculating trope associated with the east and Achaemenid Persia in particular [136,137]. Xenophon recounts (*Hellenica* 3.4.19) that while campaigning in Asia Minor, the Spartan king and commander Agesilaus undressed captives to encourage his men: they would be able to see that their enemies were white-skinned because they never went without clothing, and in battle, it would be as if they were fighting women.

It is, of course, simplistic to say that Greeks were put off colorfulness by exuberant clothing, such as the robe worn by Ahuramazda and the Susa archers, and found reworked into horse trappings at Pazyryk. But it is not at all improbable that modern western chromophobias [138] have a root in notions like the one expressed by Aristotle in his *Poetics* (1450b), where he remarks with regard to painting that a simple outline of an image will give more pleasure than "the most beautiful colors smeared on at random" (for context, see [13] (p. 97)). As we have seen, Ahuramazda's image was colorful—but not without order.

5. Conclusions

The wish to create a physical, painted plaster color reconstruction to be included in the Harvard Art Museums' 2007–2008 edition of the "Gods in Color" exhibition series prompted more than a decade and a half of intermittent research on the original polychromy of the fragment of a figure in the winged disk from the Hall of 100 Columns at Persepolis—the western doorjamb of its southeast entrance, to be precise. The first observations on the polychromy of this relief go back to the fall of 1923, almost exactly one hundred years before the publication of the present article, when Ernst Herzfeld carried out explorations at Persepolis and cleared the soil around the block that then still comprised the Harvard fragment. The authors hope that the examination of dispersed museum fragments like this will proceed in concert with investigations carried out at the site itself, connecting scientific efforts over different continents and contributing to an ever-sharper image of the original appearance of the royal palaces at Persepolis.

What has been gained from the recent re-examination? Scrutiny of the fragment's surface has confirmed the unfinished nature of the relief in its upper parts. Raking light has helped establish the general parameters of the decoration on the robe worn by the figure in the winged disk, here identified as the god Ahuramazda, as well as the design of the feathers within the ring of the disk. By charting traces of Egyptian blue, VIL imaging has given further definition to the intricacies of the relief's original polychromy. In material terms, the combined analytical techniques identified the colorants on the relief as Egyptian blue, malachite, cinnabar, red ocher, and possibly yellow ocher, with calcite and carbon black also present. The current study has allowed for the examination of many more points and samples than previous studies and has confirmed the palette that was previously proposed. There is no clear indication for the application of either a gypsum or a fluorapatite ground layer, nor for the employment of other pigments found at Persepolis such as realgar, azurite, or ultramarine blue. While the absence of holes or grooves makes it unlikely that any parts of the relief were clad in gold sheet, the god's crown and patterns on his robe might have been gilded with gold leaf. In the case of the relief's background, the continued absence of

decisive evidence for paint inspires some confidence that it may be taken as evidence of absence.

The critical review of earlier color renderings in light of the new findings has shown that while details need to be amended, the overall appearance of the relief as brilliantly colored and jewel-like, first envisioned by Ernst Herzfeld and elaborated by Judith Lerner and Ann Britt and Giuseppe Tilia, still holds. Building on the earlier proposals, the three-dimensional reconstruction created in 2007 was intended to fulfill a didactic role in the "Gods in Color" exhibition, but, in the process of its making, also proved to be an effective heuristic tool. It, too, is now outdated, and features like the black hair of the god require revision based on new information gleaned from VIL imaging. This relatively recent technique indicated the presence of Egyptian blue in unexpected places, illustrating the potential of new scientific technologies to serve as a corrective to well-established art historical notions. In the case of Ahuramazda's image at Persepolis, the emphasis on its precious, enamel-like character and conceptual colors (such as the blue hair and beard) and long-held ideas about the decorative nature of Achaemenid Persian art more generally have impeded consideration of the potential use of mixed pigments and shading. This study has not provided conclusive evidence for a more painterly approach, but this may be a productive angle to pursue in future investigations.

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Appendix A. Imaging and Analytical Instrumentation and Parameters

For all technical imaging, a Canon Mark III 5D DSLR camera (Canon Inc., Tokyo, Japan) and Zeiss 50 mm Makro-Planar ZE lens (Carl Zeiss AG, Oberkochen, Germany) were used. The internal camera filtration was removed to allow for full bandwidth response at the detector. External filters and light sources per technique:

- Visible light photography: PECA 918 (Peca Products, Inc., Beloit, WI, USA) and Kodak WRATTEN 2E filters (Eastman Kodak Co., Rochester, NY, USA), Elinchrom Style RX 1200 strobe (Elinchrom LTD, Renens, Switzerland);
- UVF photography: PECA 918 and Wratten 2E filters, Triple Bright 3 lights (UV Systems, Inc., Renton, WA, USA);
- IRP: Tiffen 87A filter (Tiffen Co., Hauppauge, NY, USA), Lowell Pro-light Tungsten Focusing Flood lights (Lowel-Light Manufacturing, Inc./Tiffen Co., Burbank, CA, USA);
- VIL photography (2021): Tiffen 87A filter, Sylvania LED 13 PAR 30LN bulbs (Osram Sylvania, Inc., Wilmington, MA, USA).

XRF spectroscopy was undertaken using a Bruker Artax XRF spectrometer (Bruker, Billerica, MA, USA) with a Silicon Drift Detector (SDD) and a rhodium anode X-ray tube. The primary X-ray beam is collimated to give a spot size of 0.65 mm. Using the Bruker Artax (version 7.6) software, spectra were acquired for 100 s live time at 50 kV and 600 μA at selected points. A helium flux was used to increase the detection efficiency for light elements (atomic number of potassium and lower).

The Raman spectrometer used was a Bruker Optics 'Senterra' dispersive Raman microscope with an Olympus BX51M microscope. The Raman spectrometer has 532 nm, 633 nm, and 785 nm lasers available. There are three gratings for the 785 nm laser, covering the 70–3200 wavenumber range, four gratings for the 633 nm laser covering 28–3500 wavenumbers, and three gratings for the 532 nm laser covering 70–3710 wavenumbers. The spectrometer resolution is ~3–5 wavenumbers (dependent on the wavenumber). The system uses an Andor 'iDus' CCD detector, operated at −55 C. There are five software-controlled settings for the power of each laser: 100%, 50%, 25%, 10%, and 1%. The estimated actual power on the sample at the 100% setting is 8.5 milliwatts for the 532 nm laser, 10.9 mW for the 633 nm laser, and 37.5 mW for the 785 nm laser. The microscope has 20×, 50×, and 100× objectives, with laser spot sizes approximately 5, 2, and 1 microns, respectively. The microscope contains a joystick-controlled motorized stage, and the setting of the analysis area is accomplished with the aid of an attached video camera. The instrument is controlled via OPUS software version 5.5.

FTIR spectrometric analyses were carried out using a Nicolet 510M spectrophotometer with auxiliary MCT detector (Nicolet Instrument Corporation, Madison, WI, USA) coupled to a Spectra-tech IR-plan infrared microscope with a 32× objective. The sample was compressed onto a diamond cell (2 mm × 2 mm) with a stainless-steel roller, and the sample area was defined by double apertures contained in the microscope. An absorbance spectrum (4000–500 cm^{-1}) was measured (resolution setting 8 cm^{-1}) and subtracted against a blank background. The spectrum was compared with a database of artists' materials at the Straus Center for Conservation.

SEM was undertaken on samples that gave poor signals on Raman and FTIR analysis. A JEOL JSM-6460LV scanning electron microscope (JEOL USA, Inc., Peabody, MA, USA) with an Oxford X-MaxN energy-dispersive X-ray spectrometer with 80 mm^2 detector, operated by Oxford INCA software (Oxford Instruments NanoAnalysis, USA, Concord, MA, USA), was used to determine the elemental composition and help with identification. The samples were analyzed in a low vacuum (35 Pa) without carbon coating at a voltage of 20 kV.

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