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# First Steps in Vermeer's Creative Process: New Findings from the National Gallery of Art

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*Recent scientific analysis of two genre paintings by Johannes Vermeer at the National Gallery of Art in Washington (Woman Holding a Balance and A Lady Writing) has uncovered a level of freedom and spontaneity in Vermeer's preparatory painting stages that was not previously known. Researchers built on decades of research and used a suite of new, noninvasive analytical techniques to image Vermeer's painted sketch and underpaint—layers hidden below the paintings' surfaces—more clearly and precisely than was previously possible. Here we analyze and interpret our findings in the context of Vermeer's career and in relation to works by his peers, high-life Dutch genre painters of the seventeenth century. For further exploration, see "[Methodology & Resources](#)," "[Experimentation and Innovation in Vermeer's Girl with the Red Hat](#)," and "[Vermeer's Studio and Girl with a Flute](#)" in this issue.*

## Introduction

- 1 Johannes Vermeer (1632–1675) is celebrated for his uncanny ability to distill daily life into moments of almost preternatural calm—a talent derived as much from his compositional sensitivity as from his tranquil paint surfaces. And yet below the surface, a remarkably different vision exists. As a recent comprehensive technical study of all four works by and attributed to Vermeer at the National Gallery of Art in Washington, DC, has revealed, Vermeer worked with extraordinary freedom in the early stages of his creative process. Now hidden below the surface, this process fundamentally shapes the tranquil images we see today.
- 2 Vermeer depicted commonplace activities with a sensibility unmatched by his contemporaries. While Gerrit Dou (1613–1675), Gerard ter Borch (1617–1681), Gabriel Metsu (1629–1667), and Frans van Mieris (1635–1681)—who, like Vermeer, specialized in so-called “high-life” genre scenes—typically relied on rhetorical gestures, ancillary figures, emblematic references, and other pictorial devices for emotional effect, Vermeer depended less on such elements. Instead, he examined the world around him with a different intent, scrupulously attentive to light, color, and compositional harmony. His distinctively personal manner of painting infused even the simplest actions and environments with transcendent beauty.
- 3 In *A Lady Writing*, a young woman interrupts her task to meet the viewer's gaze (fig. 1). Her quill has fallen back in her hand and her calm eyes examine us, intruders who have happened

upon this utterly quiet tableau. An unseen light source illuminates the scene with a diffuse glow, animating a hushed color harmony of muted yellows with warm gray and taupe. Smooth, nearly imperceptible brushstrokes graze the curves of the woman's face to describe subtle gradations of light, and the sleeve of her butter-colored housecoat shimmers with barely seen touches of a lighter yellow.

- 4 *Woman Holding a Balance* centers on a figure seemingly lost in thought (fig. 2). The viewer is held at a distance by the crumpled tablecloth that forms a gentle *repoussoir*. Vermeer's subtle rendering of light defines the privacy of the space beyond that barrier: daylight filtering through the window at upper left caresses the woman with soft highlights and picks out glistening reflections on the empty pans of the balance, but the illumination is tightly focused. In the shadowy foreground, just a few blurred highlights shape the tablecloth that spills over into the viewer's space.
- 5 In this article, we focus on these two high-life genre paintings by Vermeer to show how the discovery of Vermeer's bold handling in his paintings' initial phases contravenes simplistic assumptions about his process as suggested by his refined surfaces. This new research also sheds light on how his painting process was fundamental to those aspects of his personal style that distinguish him from his closest contemporaries. Elsewhere in this issue of *JHNA*, we argue that the freedom of his underpaint eventually shaped his approach to painting *tronies* (bust-length paintings of imaginary figures) and, through them, found repercussions in his later, more strongly abstracted works.<sup>1</sup> Comparing and integrating results from various technical examinations, our interdisciplinary team of researchers has built a more refined understanding of how the artist worked, the choices he made regarding the process and materials used to construct a given painting, and their implications for the final aspect of his exquisitely crafted paintings. The findings of our in-depth analysis are presented in detail in the scientific literature.<sup>2</sup> In this special issue, we interpret the findings in an art-historical context.

## A History of Study at the National Gallery

- 6 For almost fifty years, the National Gallery has supported a tradition of scholarly inquiry into Vermeer's artistry, process, and relationship to other high-life genre painters.<sup>3</sup> The exhibition *Johannes Vermeer (1995–1996)*, co-organized by the National Gallery and the Mauritshuis, The Hague, was an important moment in Vermeer studies. Bringing together the largest number of the artist's works ever shown in a public institution until that time, it offered an unprecedented opportunity to study his work collectively and in depth, from a range of perspectives that included studies of his materials and techniques.<sup>4</sup> A more recent contribution was the exhibition *Vermeer and the Masters of Dutch Genre Painting: Inspiration and Rivalry* (2017–2018), co-organized with the National Gallery of Ireland, Dublin, and the Musée du Louvre, Paris. That show placed Vermeer within larger social, economic, aesthetic, and technical trends of seventeenth-century Dutch painting, offering a more nuanced approach to his "uniqueness." It explored the idea that Vermeer, while standing apart from his contemporaries in many respects, was not an isolated genius but part of a network of elite artists working at the highest level of the Dutch art market in the third quarter of the seventeenth century.<sup>5</sup> Detailed analysis of archival data by Adriaan Waiboer, Piet Bakker, Teuntje van de Wouw, and Marit Slob

mapped the personal and professional relationships between all of these artists.<sup>6</sup> Technical research has tended to focus on individual artists, or even on individual works, but Melanie Gifford and Lisha Glinsman's comparative technical research for the exhibition took a broader view, using material evidence to further explore artistic relationships where no archival evidence is available.<sup>7</sup>

- 7 Building on this enriched contextual understanding, the National Gallery's history of art-historical and material research into Vermeer, and the work of colleagues at other institutions where similar explorations are underway,<sup>8</sup> we recently undertook a comprehensive technical study of all four works at the National Gallery by or attributed to Vermeer—*A Lady Writing*, *Woman Holding a Balance*, *Girl with the Red Hat*, and the controversial *Girl with a Flute*—to understand better how his painting practices contributed to the formation of his personal style.
- 8 We now have a clearer sense of how Vermeer created the distinctive visual qualities of his paintings. Chemical imaging techniques have yielded new insight into Vermeer's use of pigments throughout his paintings and allowed us to visualize his preparatory paint layers (hidden below the surface) more comprehensively than previously possible. Although his painting surfaces (like those of other high-life genre specialists) are far more finished than paintings by contemporaries like Rembrandt van Rijn (1606–1669), for example—whose loose brushwork allowed the underlayers to play an important role in the final image—our technical study of the National Gallery's works by Vermeer revealed that his initial laying out of a composition was surprisingly free and robust.

## Vermeer and the High-Life Network

- 9 For most of his mature career, Vermeer and his peers in high-life genre painting—such as Dou, Ter Borch, Metsu, and Van Mieris—were among the mostly highly paid painters working in the Dutch Republic. They created idealized images of daily life that presented elite art collectors with a vision of well-appointed interiors furnished with imported carpets, porcelains, and tooled leather wall hangings, inhabited by women (and sometimes men) clad in pristine, shimmering garments who write letters, play musical instruments, or engage in other genteel activities.<sup>9</sup>
- 10 After this new type of genre painting emerged around 1650, artists and patrons seem to have come to a collective understanding of its defining characteristics. Not only did these artists depict a set of elegant subjects that defined the high-life genre style, but, as Gifford and Glinsman's technical research determined, certain essential materials and painting practices evidently served as a threshold for entry into this elite art market. This research also found that, within the parameters of their collective style, virtually all these artists adopted a few unique and recognizable practices that served to trademark their works in a highly competitive market.<sup>10</sup> Distinguishing between the material traits that Vermeer shared with most other high-life genre specialists and those he used to set his work apart allows us to focus here on those painting practices that formed the basis of his personal style.

- 11 One of the material traits shared by almost all these artists is the use of costly pigments, including high-quality red lake, such as cochineal, and ultramarine, the rich blue made from lapis lazuli.<sup>11</sup> Although scholars often have cited Vermeer's use of ultramarine as an identifying feature of his paintings, in reality nearly all these artists used this precious blue pigment. Those who achieved the highest prices for their works often used ultramarine profusely, while those who realized somewhat lower prices used it sparingly but strategically, reserving it for small details that would catch the eye of a discerning collector.<sup>12</sup> Another widely shared trait was the fine-scaled brushwork key to creating the paintings' heightened naturalism. Patrons and collectors celebrated these high-life genre artists for the precision of their handling and the apparent verisimilitude of their works. Quintessential *fijnschilders* ("fine painters") like Dou or Van Mieris, operating at the highest end of the market, even boasted of their labor-intensive technique, presumably as a marketing strategy.<sup>13</sup>
- 12 These precious paintings were not, however, interchangeable, and the ability to discern fine distinctions of both personal and collective style was considered the mark of an elite connoisseur. Connoisseurs visited celebrated collections and painters' studios, training themselves in the nuances of artistic style, and some buyers even specialized in collecting the work of a favorite artist.<sup>14</sup> In 1665 the Leiden collector Johan de Bye held a public exhibition of his twenty-seven paintings by Dou, while in Delft, the wealthy collector Pieter van Ruijven (often described as Vermeer's principal patron) came to own twenty-one of Vermeer's works, a substantial part of the thirty-five known paintings.<sup>15</sup> Like his fellow artists, Vermeer adopted certain painting practices to create a distinctive personal style, but an essential characteristic of his trademark style deliberately flouted one important shared standard of high-life genre paintings: the emphasis on precise, refined brushwork.
- 13 Vermeer's subjects were elegant and his materials costly, but his brushwork, however refined, is notably different from that of his competitors. Modern viewers often see a photographic accuracy in Vermeer's compositions, but to seventeenth-century collectors of high-life genre his studied imprecision must have appeared strikingly free, suggestive rather than descriptive. A comparison to works by Van Mieris (fig. 3) and Metsu (fig. 4) highlights Vermeer's distinctive approach. Among his contemporaries, Van Mieris set the standard for meticulously recorded high-life genre paintings, describing every luxurious detail of his elegant interiors using a minute, sharply defined application of paint.
- 14 He worked over many days, waiting for each brushstroke to dry as he built a composition of crisp, distinct details (fig. 5). Metsu painted more efficiently but still adhered to the standard of precise brushwork. After quickly painting an entire tabletop with still life details, working wet into wet, he adroitly created sharply focused details without resorting to Van Mieris's slow painting process, simply adding fine black contour lines to throw his forms into sharp relief (fig. 6).<sup>16</sup> Vermeer took a different approach. He too worked wet into wet, but apparently not as a time-saving strategy; he applied his final paint with slow discipline. His use of this technique blurred details with strokes of fluid paint that, relative to those of his peers, seem quite broadly handled. Rather than emphasizing material details, as Van Mieris did, he used this blurred handling to depict light itself as it enveloped and inflected the figures and furnishings in those same domestic spaces (fig. 7). Paradoxically, perhaps, it is precisely this subtle blurring of forms

that makes Vermeer's paintings look so convincingly real. While the crisp illumination of works by Dou, Van Mieris, and others emphasizes the staged perfection of their painted worlds, Vermeer breaks down that barrier by recreating in his paintings the same light that suffuses the world we inhabit.

- 15 Vermeer's rendering of light was a key element of his personal style, although the ways in which he achieved this varied over the course of his career. Early in his career, in paintings such as *The Milkmaid* (figs. 8, 9), this quality was expressed in large-scale dots of highlight. He continued throughout his career to abstract the depiction of light by using circular highlights, but in late works such as *A Woman Writing a Letter, with her Maid*, that abstraction of light expanded to include fabrics sculpted by broad planes of light and shade (figs. 10, 11).
- 16 Since the 1960s, it has been suggested that Vermeer's characteristic circular highlights could have derived from images seen in a camera obscura.<sup>17</sup> He was almost certainly familiar with this optical device, which uses a pinhole or lens to project a scene onto a viewing surface. In *A Lady Writing*, the introduction of these distinctive highlights on polished surfaces—such as pearls and the metal studs of the jewelry box—indeed evokes how a camera obscura would show the optical effect known as “circles of confusion” or halation (fig. 12). But Vermeer brought this visual vocabulary to unreflective surfaces as well (fig. 13),<sup>18</sup> a strong indication that he was not simply replicating a projected image. From the start of his career, he depicted abstract, rounded highlights even on matte fabric, evidence that this way of expressing light was integral to his mode of expression.<sup>19</sup> The images from a camera obscura may have resonated with Vermeer, causing him to adapt their visual qualities selectively to his own artistic ends.<sup>20</sup> When he touched rounded highlights into wet paint to depict the tucked sleeve of a yellow jacket, these fluid circles do not describe the texture of the fabric; they are an abstraction of light itself.
- 17 Painters seem to have catered to collectors' focus on the individual by deliberate quotations of aesthetic and technical qualities that distinguished each other's work. They evoked fellow artists' compositions and also adopted distinctive features of their personal styles.<sup>21</sup> Although Vermeer's output was comparatively small, quotations of his work by fellow artists suggest that the visual qualities of his paintings were well known in these circles.<sup>22</sup> When Vermeer's contemporaries referenced his works, they borrowed characteristic details, such as specific costumes or furniture that appeared in his compositions, and, on occasion, his distinctive way of handling paint.
- 18 The visual quality imparted by Vermeer's painting technique also served as a style signifier. In *Woman Reading a Letter* (fig. 14), Gabriel Metsu deliberately and adroitly adduced elements characteristic of Vermeer's work.<sup>23</sup> After he first painted the woman wearing a reddish jacket typical of his own oeuvre, Metsu reworked this feature to replicate the iconic yellow jacket that appears in several of Vermeer's paintings (fig. 15). However, Metsu did not set aside his own, efficient painting practices in favor of the slow, fluid paint application, finished with soft, circular highlights, that Vermeer used to create the yellow jacket in *A Lady Writing*. Always efficient, he quickly repainted the jacket with blocks of yellow light and shade, and he quoted Vermeer's trademark circular highlights elsewhere. As a final touch, he simply sprinkled dotted highlights onto the prominent, cast-off shoe in the foreground (fig. 16).



## Vermeer Below the Surface

- 19 The smooth final surfaces of Vermeer's paintings embody a characteristic calmness that seems to match the mood of the scenes he depicted and gives no indication of the working processes that preceded them. However, new chemical imaging techniques, combined with microscopic examination, have given us an unprecedented opportunity to visualize earlier stages of Vermeer's creative process. Moving below the distinctive surfaces of *Woman Holding a Balance* and *A Lady Writing* allows us to explore new evidence of how Vermeer created his remarkable evocation of light and how the fundamental design stages of his paintings, now hidden from view, presaged his final, luminous touches. The research methods discussed in this study offer two avenues of approach: analysis both at specific points on the paintings (including sampling and non-sampling methods) and across the entire paintings. This is a brief overview of our methods; full details are found in "Methodology and Resources" elsewhere in this issue. Further information can be found by clicking on the figures, which illustrate the main techniques used in this article.
- 20 We gathered detailed information at specific points through microscopic analysis of a few paint samples: polarizing light microscopy (PLM) identified individual pigment particles in a few grains of paint collected from the paint surface (fig. 17); light microscopy of paint cross sections showed the layer structure (fig. 18); and analyzing those samples using scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS) gave information on the pigments in each layer. It was also possible to infer pigment mixtures at specific points without taking samples using X-ray fluorescence analysis (XRF)—which, like EDS, identifies chemical elements present—and fiber-optic reflectance spectroscopy (FORS), which gives information on electronic transitions and molecular structure from which color values can be determined.
- 21 Chemical imaging performed across entire paintings offers a powerful way to visualize the distribution of painting materials, which can reveal aspects of Vermeer's paint handling for specific parts of the composition. We inferred where pigments were used throughout each painting based on chemical elements with X-ray fluorescence imaging spectroscopy (XRF element mapping) (fig. 19), or identified pigments based on electronic transitions and molecular structure information obtained with reflectance imaging spectroscopy (RIS). In multispectral infrared reflectography (MS-IRR), three infrared images are combined in a false-color infrared reflectogram (IRR) (fig. 20) that separates pigments more clearly than is possible with traditional infrared reflectography.
- 22 Finally, the information collected through these varied analytical methods was interpreted in the context of the paintings themselves, studied at high magnification. Because it is essential to compare paint handling at the same scale, when this evidence is presented in close details and photomicrographs scale bars indicate the magnification (fig. 21).

## Canvas and Ground

- 23 In choosing his painting support and ground, the foundations of his refined surfaces, Vermeer followed practices that were standard among Dutch artists and used supplies that were widely available from specialist art suppliers. Nearly all of Vermeer's extant paintings are on finely

woven canvases.<sup>24</sup> Canvas weave analysis shows that in several cases, two or more of his paintings used canvas from the same bolt. These findings include pairs of paintings painted within a short time, some being probable pendants, but also some canvas matches that apparently span several years, suggesting that he bought supplies in batches that he used over time.<sup>25</sup> He probably bought his canvases already prepared with a ground layer from a specialist primer.<sup>26</sup> In choosing a surface on which to build his composition, he favored light-colored grounds of lead white and chalk lightly tinted with earth colors and black: a warm gray for *A Lady Writing*, for example, and buff for *Woman Holding a Balance*.<sup>27</sup>

- 24 We are not certain why Vermeer, unlike many of his peers in high-life genre painting, nearly always chose canvas as his support.<sup>28</sup> By the middle of the seventeenth century, most Dutch artists worked on canvas, a painting support that was lightweight and less expensive than the wood panels common earlier in the century. Some genre painters, like Pieter de Hooch (1629–1684) and Metsu, frequently used canvas supports, especially for larger works; but others, notably Dou and Van Mieris, chose wood and sometimes copper supports, whether because their works’ smaller dimensions made this preferable or because they sought a smoother surface for their fine-scaled brushwork. Perhaps this is another sign that Vermeer aspired to a more suggestive visual effect than the performatively minute handling of artists like Dou and Van Mieris.

## Painted Sketch

- 25 Typically, seventeenth-century Dutch artists planned out their compositions directly on the prepared ground. Some began, as earlier generations of Netherlandish artists had, with a careful underdrawing in chalk, charcoal, or ink, but by the mid-seventeenth century the fundamental design stage for many painters was a monochromatic brown painted sketch (This is sometimes called the *doodwerf* [“dead color”], but we avoid that term here, since both modern and historical writers have used it in more than one context, some referring to the monochromatic painted sketch but others to the colored underpaint stage that often followed it.).<sup>29</sup> The character of this sketched design stage varied from one artist to another. Although some artists, such as Rembrandt, worked with a loose handling of paint that allowed the painted sketch to play a visible role in the final image, high-life genre painters tended to conceal this preparatory stage beneath the precise final surfaces of their paintings. For example, to achieve his signature level of fine detail, Van Mieris prepared his compositions with a brushed design in two or more stages. Infrared reflectography of his paintings shows that he first laid out the design with brisk strokes and then elaborated many details with fine lines, including delicately hatched shadows—all of which was deliberately hidden by the surface paint.<sup>30</sup>
- 26 In Vermeer’s *The Art of Painting* (1666–68; Kunsthistorisches Museum, Vienna), summary notations in white chalk can be seen in the unfinished work on the easel, suggesting that Vermeer himself may have initially planned the placement of key compositional forms with such a drawing.<sup>31</sup> However, technical examination of the National Gallery’s paintings reveals that he primarily laid out his compositions with the standard monochromatic brown painted sketch.<sup>32</sup> Although he brought his paintings to a high level of finish, he occasionally left minute openings through which we see evidence of the brown sketch with a stereomicroscope. Microscopic analysis of a sample from one of these openings in *Woman Holding a Balance* found



a dark brown earth pigment (figs. 22, 23),<sup>33</sup> but Vermeer's sketch paint is difficult to visualize using the available methods of technical imaging. Infrared reflectography revealed evidence of Van Mieris's preparatory design because it includes carbon-containing black pigments, but in our study, MS-IRR did not show evidence of Vermeer's sketch because he did not consistently add black to his brown paint. An XRF iron map can plot the location across the painting of earth pigments, which are primarily composed of iron oxides, but the sketch itself cannot be isolated, because iron-containing earth pigments are also present in the ground layer beneath the sketch and in many areas of final paint that lie over it. Likewise, an XRF map for manganese, which could show the manganese oxide that is present in certain brown earths such as sienna and umber, also records these pigments when they appear in the ground layer, making it difficult to distinguish between sketch and ground.<sup>34</sup> However, using high magnification to study Vermeer's paintings, the rare openings that he left in his painted surfaces do afford glimpses of the painted sketch, which give evidence of his brushwork in this preliminary design stage.

- 27 By comparison with a *fijnschilder* such as Frans van Mieris, the handling of Vermeer's painted sketch seems bold. He seems to have used the sketch to lay out the details of his composition, as Van Mieris did, but he worked more broadly. In *Woman Holding a Balance*, a minute opening below the woman's hand that rests on the table reveals two parallel lines of brown sketch paint, probably where the hairs of Vermeer's brush separated as he swept it along the contour of the hand (figs. 24, 25). Just as important, Vermeer used his painted sketch to define and emphasize the play of light. Where Van Mieris hatched shadows in a graphic fashion, Vermeer brushed out broad zones of shadow and left the light-colored ground exposed to serve as highlights. In a lion's-head finial, one of the most freely painted passages of *A Lady Writing*, Vermeer left evidence of his loose brushwork in the painted sketch where he blocked out an area of shadow. Between the solidly handled strokes of final paint, small openings reveal streaky brown paint. Here, too, the lines of paint are evidence of a paintbrush fanned out by the pressure of quick paint strokes (figs. 26, 27).

## Underpaint

- 28 Like most of his contemporaries, Vermeer next laid out an underpaint that he painted directly on the brown painted sketch. For those who have spent hours contemplating the refined surfaces of Vermeer's paintings, the forceful character of the underpaint below the surface, as revealed by technical research, may come as a surprise. In fact, freely brushed underlayers have been cited as evidence against Vermeer's authorship of an unfinished painting below the *Girl with the Red Hat* (ca. 1669), as we discuss elsewhere in this issue.<sup>35</sup> In the underpaint, Vermeer further developed the play of light and shadow he first laid out in the painted sketch, but in this stage, he also planned the colors of his composition. Although published research sometimes describes colored paint glimpsed below the surface as "local underpaints," Vermeer does not seem to have worked on isolated areas of his compositions, completing all paint layers of a tablecloth, for example, before beginning to paint the figure. Where paint layers overlap, it is clear that he completed the underpaint for the entire composition as an independent stage that our research shows is strikingly different in character from his final paint.<sup>36</sup> Perhaps most important, the brushwork of his underpaint established the physical structure of his composition, with passages of thicker paint modeling the forms in low relief.<sup>37</sup>

- 29 The tonal transitions visible today in the woman's face in *A Lady Writing* exemplify Vermeer's remarkable finesse (fig. 28). On the forehead, he blended his paint imperceptibly from light into shadow, and he modeled the curve of the shadowed cheekbone with delicately interwoven, threadlike strokes (fig. 29). However, below the chin, a tiny gap in the final paint—scarcely visible to the naked eye—reveals underlying paint of a very different character. Under high magnification, it is clear that the paint below incorporates coarsely ground pigments brushed out with vigorous strokes that left a furrowed path far more textured than the surface (fig. 30). We know that Vermeer occasionally left narrow gaps like this between compositional forms as a deliberate strategy.<sup>38</sup> Here he exploited the underlayer: just as his wet-into-wet brushwork was a repudiation of hard-edged detail, this elusive glimpse of texture below the surface deliberately blurs the contour between the woman's face and the fur collar of her jacket. Gifford's previous research used episodic evidence like this to highlight the rough character of Vermeer's underpaint, which is remarkably textured in comparison to the subtle final surface we see today.<sup>39</sup>

## Vermeer's Handling in the Underpaint

- 30 The imaging techniques employed in the present study have revealed much more of the underpaint of Vermeer's paintings, giving new insights into the character of this hidden stage in his creative process. XRF element mapping creates images that plot the distribution of individual chemical elements across a painting, from which we can infer the artist's use of specific pigments. In conjunction with magnified examination of the surface and analysis of cross-section samples, mapping can provide information about the paint layering structure, sometimes offering a vivid image of the paint handling in the preparatory stages.
- 31 At the underpaint stage of *A Lady Writing*, Vermeer laid out the tucked sleeve of the yellow jacket by noting the pattern of light and shade in broad, schematic form. He brushed out the shadowed back of the sleeve with ochre, an iron oxide pigment recorded in the XRF iron map (figs. 31, 32). In that map we also see where Vermeer dragged a wide brush through the still-wet ochre, wiping away paint to leave a few wide troughs. With these quick gestures, his brush left broad lines that created just a summary indication of folds, utterly unlike the subtle depiction of folds in the final paint.
- 32 In the underpaint, Vermeer also provisionally indicated a lighter-colored fold of the sleeve, possibly a highlight, with just a few broad strokes of coarsely ground lead-tin yellow (fig. 33). His choice of material also diverged from his finely ground final paint, where he may also have used a different grade of lead-tin yellow (fig. 34).<sup>40</sup> With magnification, the texture of these hasty strokes is visible through the final surface paint (fig. 35).
- 33 In the underpaint, a false-color IRR also reveals the quick brushwork and the surprisingly abrupt tonal transitions with which Vermeer depicted the fall of light in the figure of *A Lady Writing*. Unlike traditional infrared reflectography, MS-IRR creates a false-color IRR using three narrow infrared spectral band reflectance images chosen to visually emphasize features of interest. Infrared light penetrates upper paint layers to show underlayers, and while the colors rendered in the false-color IRR do not correlate with what may be observed in normal light, they do help to

distinguish between various materials that might look confusingly similar in a traditional reflectogram.

- 34 In comparison to the final surface of *A Lady Writing*, the false-color IRR of the forearm shows exaggerated contrasts of light and shadow in the underpaint, from dabbed white highlights to dark brown shadow (figs. 36, 37). A detail of the face shows that Vermeer used a quick and summary touch in his underpaint, daubing thick white highlights onto the forehead and cheekbones (figs. 38, 39).
- 35 Magnified examination confirms the importance of strong colors at this stage of the painting process. In *Woman Holding a Balance*, Vermeer also modeled the flesh tones in the face with a high-contrast underpaint in varied colors. In the chin and neck, glimpses of the underpaint are visible through intentional gaps: shades of a warm brown at the throat shift to a lighter red-brown color and warm tan closer to the chin.<sup>41</sup> Although Vermeer's cool final paint muted these strong colors, they still contribute to the final appearance, gently warming the pale face (figs. 40, 41).
- 36 In places, Vermeer's underpaint combines forcefully textured brushwork with strong contrasts in both light and color, creating passages whose character shapes the play of light in the delicate final image.<sup>42</sup> In *A Lady Writing*, Vermeer depicts a wide tonal range in the play of light on the crumpled tablecloth. While bright light throws folds of fabric on the tabletop into sharp relief, half-light brings the shadowed side of the table to life, drawing out subtle folds and swags in what would otherwise have been a solid, dark mass. He prepared these delicately differentiated light effects with a bold underpaint, laying out lighted areas with thick, vigorously brushed highlights rich in lead-tin yellow while leaving the brown painted sketch to represent the shadows. A cross section taken from the edge of the painting shows the application of the yellowish underpaint—ranging from thick to almost imperceptibly thin—which Vermeer muted with a smooth layer of dark final paint to create a half-shadow on the lighted tabletop (figs. 42, 43).
- 37 The XRF tin maps record Vermeer's varied handling, with brushwork that is far more energetic than the calm surface would suggest, in the deep swag of the hanging cloth accented with a sweep of stippled dabs of the brush (fig. 44).
- 38 In his final paint, Vermeer softened the sharp contrasts—the XRF lead map that records lead white pigment mainly in surface paint (the M-line energy) shows the smoothly modeled, whitish highlights of the final image (fig. 45)—but the high-contrast, brightly colored underpaint glimmers through the final paint.<sup>43</sup> It enlivens the folds of the cloth atop the table and contributes color and texture to the subtle modeling in the shadowed repoussoir.

## Copper Drier

- 39 Our analysis also has uncovered new evidence that the paint Vermeer prepared for the underpaint stage was materially different from his final paint, evidently specifically formulated to enable him to complete this phase of work more quickly. In the tablecloth of *Woman Holding a Balance*, the XRF copper map shows folds that differ from the final image, evidence that the

copper-containing paint corresponds to an underlying paint layer (figs. 46, 47).<sup>44</sup> The standard presentation of XRF maps is a grayscale image in which whiter or brighter areas signify a stronger signal; here, white areas map the presence of copper, while darker or black areas correspond to little or no signal for copper. In figure 48, we have inverted this map so that the darkest areas correspond to the greatest amount of copper, where the underpaint must have been most heavily applied. In this format, the XRF copper map shows a textured quality that calls to mind broad brushstrokes rapidly applied—paint handling that has no counterpart on the final surface. A minute detail may offer further evidence of the haste with which Vermeer brushed out this underpaint. His horizontal brushstrokes—shown in the inverted copper map—must have stopped abruptly at the left edge, splattering blue-black paint onto the buff-colored ground on the tacking margin (fig. 49).<sup>45</sup>

- 40 Paint samples from the tablecloth, along with FORS and MS-IRR, as well as magnified examination of the painting's surface paint, show that Vermeer used similar paints for both the underpaint and final paint of the tablecloth: primarily ultramarine, black, and probably yellow lake. None of these pigments, however, would be a source of the copper seen in the XRF map.<sup>46</sup> Instead, it seems that Vermeer added another copper-containing material as a drier to accelerate the curing of his oil paint. The seventeenth-century art lover Sir Theodore Turquet de Mayerne reported that some artists added small amounts of the copper-based pigment verdigris to pigments that otherwise dry slowly in an oil medium.<sup>47</sup>
- 41 Evidence for such a copper-based drier has been found previously in black areas of Vermeer's paintings (black pigments being notoriously slow to dry);<sup>48</sup> however, the most recent analysis has clarified at which stage of his painting process Vermeer used it and hints at why. The false-color IRR confirms that the area of the tablecloth is rich in black pigment (fig. 50), and in microscopic samples and magnified examination of the painting, there is no evidence of a green-colored underpaint, as has been observed in some other works by Vermeer.<sup>49</sup> Microscopic analysis of new paint samples confirms what we inferred from the copper map: that Vermeer used a copper drier more liberally in his underpaint. SEM-EDS analysis of a minute paint sample taken from the tablecloth, a cross section that includes both the surface and underpaint layers, found low levels of copper dispersed throughout the paint (typical of verdigris used as a drier, rather than discrete particles of verdigris pigment). But a line scan for copper across these two layers shows more copper in the underpaint than in the surface paint, evidence that Vermeer deliberately manipulated the properties of his paint at these two different stages (figs. 51, 52 ).<sup>50</sup>
- 42 By adding more drier in the underpaint than in other layers, Vermeer presumably hastened the curing of specific slow-drying pigments so that he could resume work on the painting's subsequent stages with little delay. This hints at time pressure as a practical motivation, but there also were aesthetic consequences. Vermeer seems to have appreciated—or at least accepted—the brush-furrowed texture in his underpaint. The underpaints based on fast-drying pigments, such as the white lead that dominates the flesh tones, show this rough texture (see figs 30, 37, 39). Adding a drier to the underpaint may have helped to preserve the brush-furrowed texture in paints with slow-drying pigments as well. Conversely, his strategy of adding comparatively little drier to his final paints must have helped him to finish his image slowly, working wet into wet.

As he completed each passage, his slow-drying brushstrokes would continue to level, filling in the underpaint's rough texture.<sup>51</sup>

## Plotting out the Play of Light

- 43 In *A Lady Writing*, a comparison of the final painted image and the preparatory stages (here also revealed by the XRF copper map) shows the essential role of Vermeer's underpaint in constructing his subtle play of light. In the finished image, light from an unseen window picks out the focal points of the composition—the objects on the table, the woman's face and her jacket's yellow sleeve, her Spanish leather chair silhouetted against a lighted wall—while leaving the rest of the space in half-light. Because her form casts a shadow on the chair, the window's light picks out a single diamond shape on the gold-tooled black leather back and just one of the finials. In time, the viewer might notice a second chair at the left, its diamond pattern barely perceptible in the dim shadows. The only difference between these two chairs appears to be the varied play of light on the wall behind them. Intuitively, we might expect that, in planning this play of light, Vermeer would have prepared the shadowed chair with darker underpaint than its brightly lit counterpart. However, the XRF copper map and magnified examination of the surface show that although Vermeer prepared the chair on the right in the underpaint stage with black, copper-rich underpaint, he seems not to have underpainted the shadowed chair at all, leaving just the brown painted sketch to serve as shadows in the underpaint stage (figs. 53, 54). Magnified examination confirms that in the lighted chair on the right, the painted sketch was followed by both black underpaint and the dark final paint (fig. 55), while in the shadowed chair on the left dark final paint lies directly on the painted sketch (fig. 56).
- 44 Vermeer's mastery in using contrast to direct the viewer's perception is revealed in the counterintuitive lighting structure—i.e., the darkest underpaint preparing the brightest chair. Although both chairs appear dark in the final image, the shadowed chair at the left was depicted in low contrast against an equally dark, shadowed wall and the chair on the right in high contrast, silhouetted against the lighted wall. The heavily applied black underpaint of the lighted chair creates a densely colored form whose contrast with the white wall amplifies the light.

## An Improvisational Approach

- 45 The XRF copper maps also document Vermeer's improvisatory development of his compositions. After he completed his underpaint, and before continuing to the final paint stage, he "resketched" possible changes, a practice he shared with Ter Borch.<sup>52</sup> Both painters tested out these newly sketched ideas using a different, blackish paint, darker than the initial brown sketch. Ter Borch refined a few forms in this stage and allowed the resketched strokes to play a role in his final image. For Vermeer, resketching seems to have been a more practical tool that he used only as needed to test alternative ideas for his composition. In *A Lady Writing*, both the false-color IRR and the XRF copper map show quick strokes of dark paint, which presumably include a copper drier, where Vermeer tested an alternate pattern of curls and hair ribbons, including a form that falls against the woman's cheek. In the final paint, he adjusted the curls and ribbons yet again (figs. 57, 58, 59).<sup>53</sup>



- 46 Vermeer's improvisations seem to have continued as he revised the composition during the final stage of painting *A Lady Writing*. Where Vermeer's peers depicted figures engaged in activities of daily life, Vermeer, with a revision as small as the angle of a quill, engaged the viewer in a moment of absolute stillness. The woman's pen lies loosely in her hand, forgotten as she turns to meet the viewer's gaze. But in the underpaint he depicted her actively engaged in writing, a more anecdotal approach that recalls Ter Borch's earlier composition of a letter writer (fig. 60). The XRF lead map shows that in Vermeer's first version the woman held her pen almost vertically; the XRF copper map confirms this, showing that in the underpaint the background was brushed up to the margins of the vertical quill, leaving a narrow reserve for the original form. After evaluating the schematic plan for the composition he had laid out in his underpaint, Vermeer shifted the painting's meaning with his final-stage change of the pen's position (figs. 61, 62, 63).

## Conclusion

- 47 The character of Vermeer's final paint, and indeed the overall tenor of his working practice, is remarkably different from that of his preparatory stages. When he returned to the painting to achieve the final image, he ground his pigments more finely than in his underpaint and was more sparing with the copper drier. In contrast to his vigorous, quickly worked underpaint, the final surface of Vermeer's paintings reveals a patient, disciplined touch.
- 48 In the yellow jacket of *A Lady Writing*, the texture of the underpaint—broad yellow highlights and deep lines depicting folds in the ochre shadow (see figs. 31, 32) —established a skeletal structure. Over the textured underpaint, Vermeer's fluid final paint dried slowly, settling to a still surface that scarcely retains the texture of the small, soft brushes he must have used. Vermeer worked with three different pigments—ochre, lead-tin yellow, and transparent yellow lake<sup>54</sup>—to create a subtle range of yellow colors: warm brownish shadows, mid-tones modulated from grayish yellow to taupe, and pale, icy highlights. He worked wet into wet without blending, setting discrete touches of one color into another (figs. 64, 65). The remarkable finesse of his final brushwork, a meditation on the play of light, is given structure by the underpaint below.
- 49 In *Woman Holding a Balance*, Vermeer worked slowly as he applied the final paint of the table over the broad brushwork of the underpaint. Painting wet into wet with much smaller brushes, he adjusted his handling to evoke light playing over the surfaces of varied materials (fig. 66). He captured gleaming highlights on pearls and gold chains with unblended dabs of pure white lead or lead-tin yellow. To depict the blurred variations in light dimpling the soft surface of the crumpled tablecloth, he used slower drying paints to his advantage. Here, microscopic examination shows that he set rounded, fluid touches of highlight into the deep-toned shadows while the paint was still wet. As they dried, the two paints leveled to an almost perfectly smooth surface, leaving no trace of the vigorous brushwork below.
- 50 The combined evidence of microscopic analysis and chemical imaging builds a new and more detailed picture of the artist at work. Rather than embodying the meticulous *fijnschilder* approach, Vermeer worked decisively and confidently in the preparatory painting stages of *Woman Holding a Balance* and *A Lady Writing*, two works from the middle of his career. Although the underlayers are scarcely apparent today, their contributions to the finished



works were essential. In the painted sketch and underpaint, Vermeer's strong contrasts of light and shade laid out bold, schematic patterns of illumination that he modulated in his final images: preserving the value contrast of a chair silhouetted against a bright wall; using the delicate tonal transitions of interwoven flesh tones to mute a stark patch of highlight on a cheekbone. Similarly, Vermeer laid out his underpaint with bold color contrasts that glimmer through the subtle colors of his final paint: in an underpainted tablecloth, bright yellow highlights against brown shadows pick out the folds of fabric in the half-shadow of the final image, and underlying flesh tones that range from brick red to ivory infuse life into the pale skin of the finished painting.

- 51 It was not unusual for painters to handle their underpaint a little more freely than the final paint. Nevertheless, some sources specifically urged painters to smooth the texture of their preparatory layers by sanding or scraping the surface before proceeding to the final painting.<sup>55</sup> Examinations of other high-life genre paintings by Vermeer's contemporaries suggest that a delicate surface called for an underpaint executed with restraint. Van Mieris, the most refined of painters, usually applied his underpaint in thin layers with small strokes that left only a mild impression of the brush.<sup>56</sup> Jacob Ochtervelt (1634–1682), in his most meticulous works, filled in the colors of his compositions with a thin, streaky underpaint that had no impact on the smooth final surface of his paintings; by contrast, he painted later works much more broadly, and there he made no effort to control the texture of his hastily brushed out underpaint.<sup>57</sup> The texture of Vermeer's underpaint—coarsely ground pigments, applied in fast-drying, brush-furrowed strokes—was essential to his carefully structured compositions; its forceful texture fills an essential role. His final paint—based on finely ground pigments and applied with soft brushes in fluid strokes that evaded hard contours—might have offered a bland, unvarying surface if he had brushed it onto a smooth underlayer. Instead, the texture of Vermeer's underpaint offered a “tooth” that secured subsequent paint layers, and the decisive brushstrokes modeled his forms in relief, providing a skeleton that supported the delicate flesh of his final paint surface. Although Vermeer later obscured his freely brushed underpaint almost completely with his final paint, he deliberately left a few gaps in the final paint, allowing the brushmarked underpaint to shimmer along the contours of forms.
- 52 The implications of these findings change not only how we think of Vermeer's working methods but also how we approach the evolution of his style. Elsewhere in this issue, we discuss how, in the final phase of his career, in paintings such as *The Lacemaker* (ca. 1669–70; Musée du Louvre) or *Woman Writing a Letter, with her Maid* (ca. 1670; National Gallery of Ireland), Vermeer's work became increasingly schematic as he abstracted his distinctive emphasis on the play of light into a high-contrast pattern in blocks of light and shadow. A clearer understanding of the underlying structure of these earlier genre paintings not only answers questions about his process but also helps us to pose new ones about his artistic trajectory.

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## Illustrations



Fig. 1 Johannes Vermeer, *A Lady Writing*, ca. 1665, oil on canvas, 45 x 39.9 cm. National Gallery of Art, Washington, DC, Gift of Harry Waldron Havemeyer and Horace Havemeyer, Jr., in memory of their father, Horace Havemeyer, inv. 1962.10.1 (not shown to scale with fig. 2). (artwork in the public domain)



Fig. 2 Johannes Vermeer, *Woman Holding a Balance*, ca. 1664, oil on canvas, 39.7 x 35.5 cm. National Gallery of Art, Washington, DC, Widener Collection, inv. 1942.9.97 (not shown to scale with fig. 1), (artwork in the public domain)



Fig. 3 Frans van Mieris, *Brothel Scene*, ca. 1658–1659, oil on panel, 42.5 x 33.3 cm. Mauritshuis, The Hague, inv. 860 (not shown to scale with fig. 4) (artwork in the public domain)



Fig. 4 Gabriel Metsu, *The Intruder*, ca. 1660, oil on panel, 66.6 x 59.4 cm. National Gallery of Art, Washington, DC, Andrew W. Mellon Collection, inv. 1937.1.57 (not shown to scale with fig. 3) (artwork in the public domain)



Fig. 5 Van Mieris, *Brothel Scene* (fig. 3), detail showing precise handling and sharp details

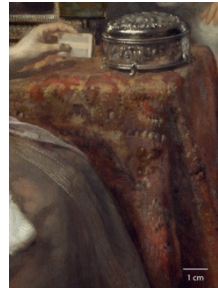


Fig. 6 Metsu, *The Intruder* (fig. 4), detail showing rapid handling of paint, with a fine black contour below the silver box that nonetheless suggests precise handling



Fig. 7 Vermeer, *A Lady Writing* (fig. 1), detail of the tabletop and hands showing wet-in-wet blurred paint handling





Fig. 8 Johannes Vermeer, *The Milkmaid*, ca. 1660, oil on canvas, 45.5 x 41 cm. Rijksmuseum, Amsterdam, inv. SK-A-2344 (artwork in the public domain)



Fig. 9 Vermeer, *The Milkmaid* (fig. 8), detail of tabletop with dotted highlights



Fig. 10 Johannes Vermeer, *Woman Writing a Letter, with her Maid*, ca. 1670, oil on canvas, 71.1 x 60.5 cm. National Gallery of Ireland, Dublin, Presented, Sir Alfred and Lady Beit, 1987 (Beit Collection), inv. NGI.4535. Photo © National Gallery of Ireland (artwork in the public domain)



Fig. 11 Vermeer, *Woman Writing a Letter, with her Maid* (fig. 10), detail of woman writing

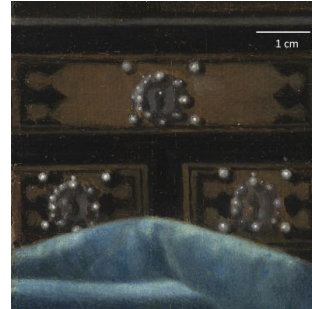


Fig. 12 Vermeer, *A Lady Writing* (fig. 1), detail of the highlights on the reflective surfaces of the decorated casket



Fig. 13 Vermeer, *A Lady Writing* (fig. 1), detail of the highlights on the matte fabric sleeve



Fig. 14 Gabriel Metsu, *Woman Reading a Letter*, 1664–1666, oil on panel, 52.5 x 40.2 cm. National Gallery of Ireland, Dublin, Presented, Sir Alfred and Lady Beit, 1987 (Beit Collection), inv. NGI.4537. Photo © National Gallery of Ireland (artwork in the public domain)



Fig. 15 Metsu, *Woman Reading a Letter* (fig. 14), detail of the yellow jacket, repainted over Metsu's typical red jacket



Fig. 16 Metsu, *Woman Reading a Letter* (fig. 14), detail of dotted highlights on shoe in the foreground

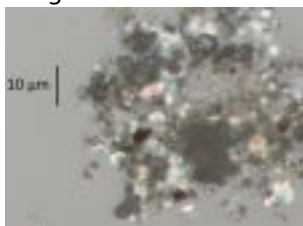


Fig. 17 Vermeer, *A Lady Writing*, dispersed pigment sample (photographed with slightly uncrossed polars) (see fig. 34)

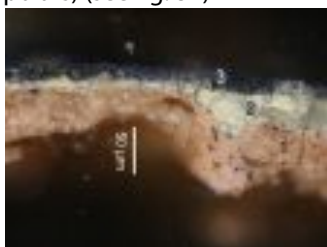


Fig. 18 Vermeer, *A Lady Writing*, paint cross section (see fig. 43) (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>)

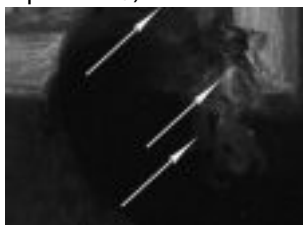


Fig. 19 Vermeer, *A Lady Writing*, detail of the XRF copper map (Cu K) (see fig. 59) (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>)



Fig. 20 Vermeer, *A Lady Writing*, false-color false-color IRR (red channel=2100–2400 nm, green

channel=1500–1800 nm, blue channel=1100–1400 nm) (see fig. 58)



Fig. 21 Vermeer, *A Lady Writing*, photomicrograph (see fig. 64)

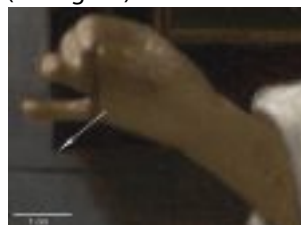


Fig. 22 Vermeer, *Woman Holding a Balance* (fig. 2), detail showing location of the sample in Fig. 23 (exposed painted sketch was sampled during treatment, before inpainting)



Fig. 23 Vermeer, *Woman Holding a Balance*, dispersed pigment sample of the brown painted sketch (photographed with slightly uncrossed polars). The sample includes fragments of the ground, which appear as brightly lit (birefringent) particles.



Fig. 24 Vermeer, *Woman Holding a Balance* (fig. 2), detail of hand. The white rectangle indicates the location of fig. 25.



Fig. 25 Vermeer, *Woman Holding a Balance*, photomicrograph of the edge of the hand. White arrows indicate traces of the painted sketch, where Vermeer planned the edge of the hand, visible in the gap between compositional elements.





Fig. 26 Vermeer, *A Lady Writing* (fig. 1), detail of the lion's-head finials. The white rectangle indicates the location of fig. 27.

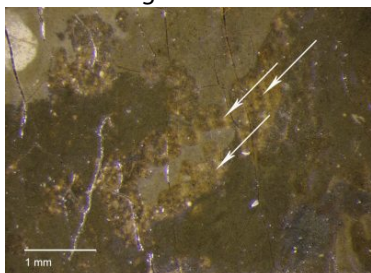


Fig. 27 Vermeer, *A Lady Writing*, photomicrograph of the finial with white arrows that indicate the painted sketch, visible through openings in the final paint



Fig. 28 Vermeer, *A Lady Writing* (fig. 1), detail of the face with locations of Figs. 29 and 30



Fig. 29 Vermeer, *A Lady Writing* (fig. 1), detail of the upper face showing minute brushstrokes



Fig. 30 Vermeer, *A Lady Writing* (fig. 1), detail of the chin with a gap in the final paint showing a diagonal stroke of brushmarked underpaint



Fig. 31 Vermeer, *A Lady Writing* (fig. 1), detail of the sleeve



Fig. 32 Vermeer, *A Lady Writing*, detail of the XRF iron map (Fe K). The white arrows indicate troughs in brushmarked underpaint, created by the removal of wet paint (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>).



Fig. 33 Vermeer, *A Lady Writing*, dispersed pigment sample showing coarsely ground lead-tin yellow pigment in the underpaint of the lighted tablecloth (photographed with slightly uncrossed polars)



Fig. 34 Vermeer, *A Lady Writing*, dispersed pigment sample showing more finely ground lead-tin yellow pigment in the final paint of a highlight on the yellow jacket (photographed with slightly uncrossed polars)

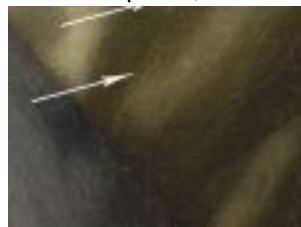


Fig. 35 Vermeer, *A Lady Writing* (fig.1) detail of the sleeve. The white arrows indicate the texture of a lead-tin yellow-rich underpaint, partially visible below the darker colored surface paint.



Fig. 36 Vermeer, *A Lady Writing* (fig. 1), detail of the forearm



Fig. 37 Vermeer, *A Lady Writing*, detail of the false-color IRR (as in fig. 20). The white arrows correspond to areas of thickly applied lead white-rich underpaint in the forearm (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>).



Fig. 38 Vermeer, *A Lady Writing* (fig. 1), detail of the face

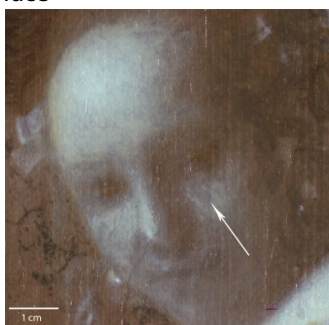


Fig. 39 Vermeer, *A Lady Writing*, detail of the false-color IRR (as in fig. 20). The white arrow corresponds to a thickly daubed white highlight in the cheek (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>).

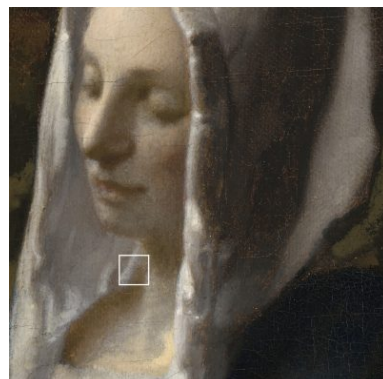


Fig. 40 Vermeer, *Woman Holding a Balance* (fig. 2), detail of the neck and face. A white rectangle marks the area shown in fig. 41.

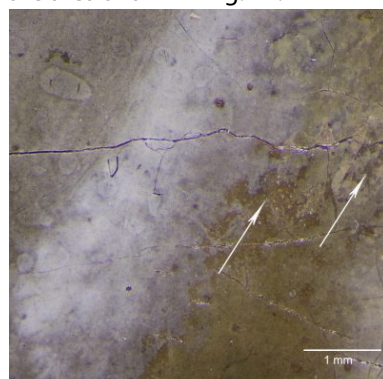


Fig. 41 Vermeer, *Woman Holding a Balance*, photomicrograph. The white arrows indicate a darker colored underpaint, visible at the intersection of the head covering and flesh.

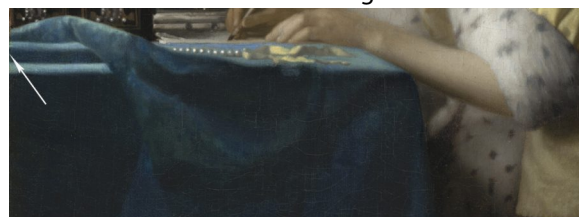


Fig. 42 Vermeer, *A Lady Writing* (fig. 1), detail of the tablecloth. The white arrow indicates the location of the cross-section in fig. 43.

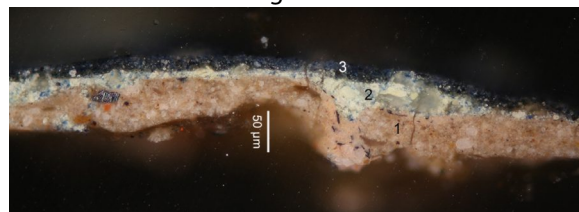


Fig. 43 Vermeer, *A Lady Writing*, paint cross section taken from tablecloth, with smoothly brushed, dark final paint (3) over a textured lead-tin yellow-rich paint mixture corresponding to a half-light in the underpaint (2) and the ground (1)

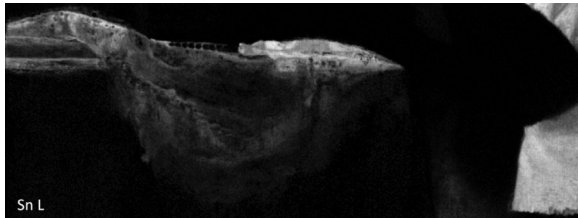


Fig. 44 Vermeer, *A Lady Writing*, detail of the XRF tin map (Sn L), showing the texture of stippled brushmarks where the underpaint of the tablecloth includes highlights based on lead-tin yellow (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>)

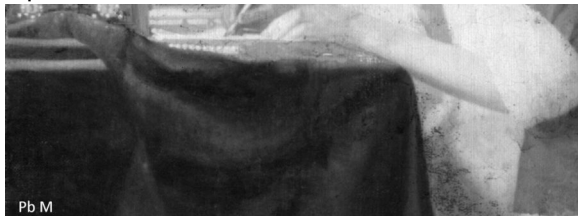


Fig. 45 Vermeer, *A Lady Writing*, detail of the XRF lead map (Pb-M), showing the texture of blended final (surface) paint of the tablecloth (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>)



Fig. 46 Vermeer, *Woman Holding a Balance* (fig. 2), detail of the tablecloth

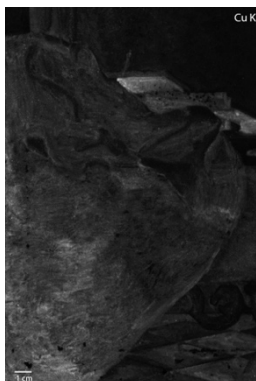


Fig. 47 Vermeer, *Woman Holding a Balance*, detail of the XRF copper map (Cu K), showing the texture of broad brushstrokes in the copper-rich underpaint layer of the tablecloth (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>)

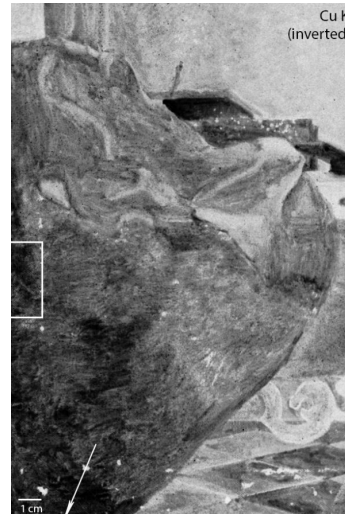


Fig. 48 Vermeer, *Woman Holding a Balance*, detail of the XRF copper map (Cu K), inverted and the histogram adjusted; the darkest areas emphasize thickly applied areas of underpaint. The rectangle marks the location of the detail in fig. 49. The arrow indicates the location of the cross section in fig. 51 (outside the area imaged here) (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>).

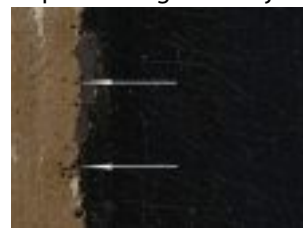


Fig. 49 Vermeer, *Woman Holding a Balance*, detail of the tacking margin along the left edge beside the tablecloth, with arrows indicating flicked splatters of quickly applied blue-black underpaint. These paint splatters are not visible in fig. 44, as they are located outside the area mapped (see n. 44).





Fig. 50 Vermeer, *Woman Holding a Balance*, false-color IRR (as in fig. 37). The white rectangle marks the location of the XRF copper map in figs. 47 and 48 (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>).



Fig. 51 Vermeer, *Woman Holding a Balance*, paint cross section from the tablecloth shown in autofluorescence (excitation: bandpass filter 355-425 nm; transmission: long pass filter 470 nm). The sample is marked with the diagonal path of a SEM-EDS line scan for copper (shown in fig. 52) through three layers: repaint, final paint, and underpaint (the ground is not included in this sample). The location of the sample is marked with a white arrow in fig. 48.

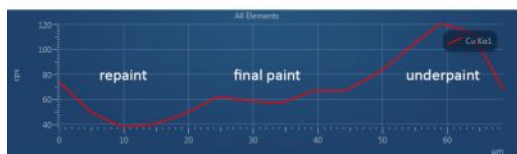


Fig. 52 Vermeer, *Woman Holding a Balance*, SEM-EDS line scan of the sample in fig. 51 showing the relative amounts of copper in three paint layers: repaint, final paint, and underpaint.

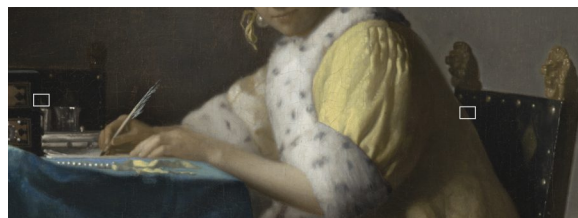


Fig. 53 Vermeer, *A Lady Writing* (fig. 1), detail of the two chairs, with the locations of photomicrographs shown in fig. 55 (shadowed chair, left) and fig. 56 (lighted chair, right)



Fig. 54 Vermeer, *A Lady Writing*, detail of the XRF copper map (Cu K, gamma adjusted), with the locations of photomicrographs shown in fig. 55 (shadowed chair, left) and fig. 56 (lighted chair, right) (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>)

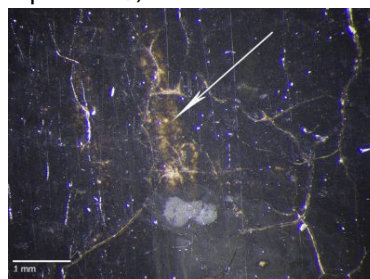


Fig. 55 Vermeer, *A Lady Writing*, photomicrograph of a gap in the paint in the shadowed chair on the left, showing that no underpaint is present on top of the brown sketch, indicated by the white arrow

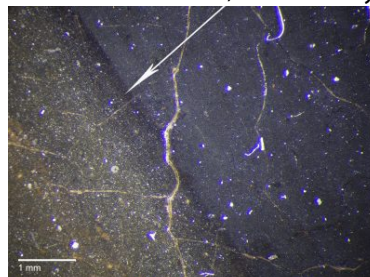


Fig. 56 Vermeer, *A Lady Writing*, photomicrograph of a gap between final paint of the lighted chair on the right and the jacket, showing the dark underpaint of the chair, indicated by the white arrow



Fig. 57 Vermeer, *A Lady Writing* (fig. 1), detail of the face

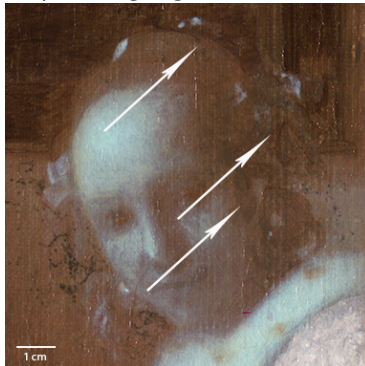


Fig. 58 Vermeer, *A Lady Writing*, detail of the false-color IRR (as in fig. 20). The white arrows indicate areas of resketching in the hair and ribbons (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>).

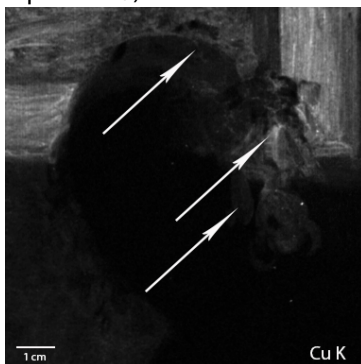


Fig. 59 Vermeer, *A Lady Writing*, detail of the XRF copper map (Cu K). The white arrows indicate strokes of resketching paint that contain copper (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>).



Fig. 60 Gerard ter Borch, *Woman Writing a Letter*, 1655, oil on panel, 38.3 x 27.9 cm. Mauritshuis, The Hague, inv. 797 (artwork in the public domain)

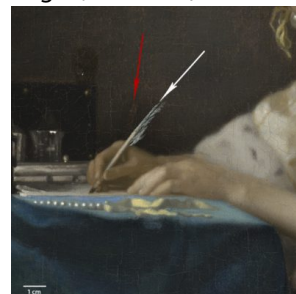


Fig. 61 Vermeer, *A Lady Writing* (fig. 1), detail of the hands and the final position of the quill (white arrow)



Fig. 62 Vermeer, *A Lady Writing*, detail of the XRF lead map (Pb L), showing an earlier, alternate position of the quill (red arrow) as well as the final position (white arrow) (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>)

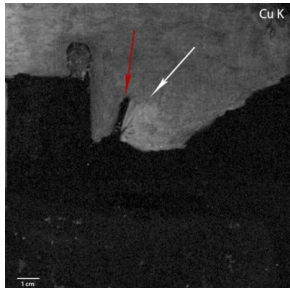


Fig. 63 Vermeer, *A Lady Writing*, detail of the XRF copper map (Cu K, gamma adjusted), revealing the reserve in the background for the original position of the quill (red arrow) (photo: Dooley et al., "Comparing Vermeer's Painting Techniques," <https://heritagesciencejournal.springeropen.com/>)

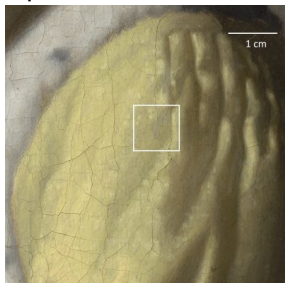


Fig. 64 Vermeer, *A Lady Writing* (fig. 1), detail of the sleeve. The white rectangle indicates the location for fig. 65.

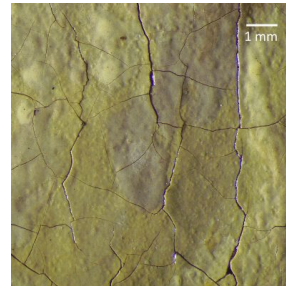


Fig. 65 Vermeer, *A Lady Writing*, raking-light photomicrograph of the sleeve

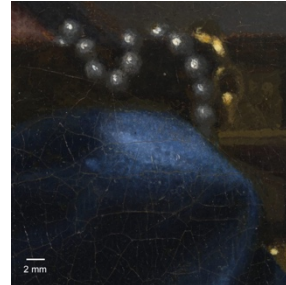


Fig. 66 Vermeer, *Woman Holding a Balance* (fig. 2), detail of highlights on the jewelry and tablecloth

## Bibliography

Aillaud, Gilles, Albert Blankert, and John Michael Montias. *Vermeer*. Paris: Hazan, 1986.

Albrecht, Maya, Sabrina Meloni, Annelies van Loon, Ralph Haswell, and Onno de Noord. "Discovering Trends in Jan Steen's Grounds Using Principal Component Analysis." In *Ground Layers in European Painting 1550–1750*. Proceedings of Centre for Art Technological Studies and Conservation conference 5 ("Mobility Creates Masters"), Copenhagen, June 2019, edited by Anne Haack Christensen, Angela Jager, and Joyce H. Townsend, 118–31. London: Archetype, 2020.

Atkins, Christopher D. M. *The Signature Style of Frans Hals: Painting, Subjectivity, and the Market in Early Modernity*. Amsterdam: Amsterdam University Press, 2012.

Bailey, Anthony. *A View of Delft: Vermeer Then and Now*. London: Chatto & Windus, 2001.

Bailey, Martin. *Vermeer*. London: Phaidon, 1995.



Bakker, Piet. "Gerrit Dou and His Collectors in the Golden Age" (2017). In *The Leiden Collection Catalogue*, 3rd ed., edited by Arthur K. Wheelock Jr. and Lara Yeager-Crasselt (New York, 2020–). Accessed April 5, 2022. [HTTPS://THELEIDENCOLLECTION.COM/ESSAYS/GERRIT-DOU-AND-HIS-COLLECTORS-IN-THE-GOLDEN-AGE](https://theleidencollection.com/essays/gerrit-dou-and-his-collectors-in-the-golden-age).

———. "Painters of and for the Elite: Relationships, Prices and Familiarity with Each Other's Work." In Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*, 85–99.

Baxandall, Michael. *Patterns of Intention: On the Historical Explanation of Pictures*. New Haven and London: Yale University Press, 1985.

Bièvre, Elizabeth de. *Dutch Art and Urban Culture 1200–1700*. New Haven and London: Yale University Press, 2015.

Binstock, Benjamin. "The Apprenticeship of Maria Vermeer." *Artibus et Historiae* 29, no. 57 (2008): 9–47.

———. *Vermeer's Family Secrets: Genius, Discovery, and the Unknown Apprentice*. New York: Routledge, 2009.

Blankert, Albert. *Museum Bredius: Catalogus van de schilderijen en tekeningen*. The Hague: Dienst voor Schone Kunsten der Gemeente 's-Gravenhage, 1978.

Blankert, Albert, Rob Ruurs, and Willem L. van de Watering. *Vermeer van Delft 1632–1675*. Utrecht: Spectrum, 1975; published in English as *Vermeer of Delft: Complete Edition of the Paintings*. Oxford: Phaidon, 1978.

Borenus, Tancred. "The New Vermeer." *Apollo* 2, no. 3 (September 1925): 125–26.

Bredius, Abraham. *Künstler Inventare; Urkunden zur Geschichte der holländischen Kunst des XVIten, XVIIten und XVIIIten Jahrhunderts*. 7 vols. The Hague: Martinus Nijhoff, 1915–22.

———. "Het Schildersregister van Jan Sysmus, stads-doctor te Amsterdam, II." *Oud Holland* 8 (1890): 217–34.

Brentjens, Yvonne. "Twee meisjes van Vermeer in Washington." *Tableau* 7, no. 4 (February 1985): 54–58.

Brown, Christopher. *Carel Fabritius: Complete Edition with a Catalogue Raisonné*. Oxford: Phaidon, 1981.

———. Review of Johannes Vermeer van Delft 1632–1675, by Albert Blankert, Rob Ruurs, and Willem L. van de Watering. *Simiolus* 9, no. 1 (1977): 56–58.

Brusati, Celeste. *Artifice and Illusion: The Art and Writing of Samuel van Hoogstraten*. Chicago: University of Chicago Press, 1995.

Bürger, Willem [Étienne Joseph Théophile Thoré]. "Van der Meer de Delft." *Gazette des Beaux-Arts* 21 (July–December 1866): 297–330; 458–75; 542–75.

Costaras, Nicola. "A Study of the Materials and Techniques of Johannes Vermeer." In Gaskell and Jonker, *Vermeer Studies*, 144–167.

Cropper, Elizabeth. *The Domenichino Affair: Novelty, Imitation, and Theft in Seventeenth-Century Rome*. New Haven: Yale University Press, 2005.

Delaney, John K., Kathryn A. Dooley, Annelies van Loon, and Abbie Vandivere. "Mapping the Pigment Distribution of Vermeer's Girl with a Pearl Earring." *Heritage Science* 8, no. 4 (January 7, 2020). Accessed May 2, 2022. [HTTPS://DOI.ORG/10.1186/S40494-019-0348-9](https://doi.org/10.1186/s40494-019-0348-9).

Dooley, Kathryn A., E. Melanie Gifford, Dina Anchin, Lisha Demming Glinsman, Marjorie E. Wieseman, Alexandra Libby, and John K. Delaney. "Comparing Vermeer's Painting Techniques in *Woman Holding a Balance* and *A Lady Writing* Using Chemical Imaging Spectroscopy." *Heritage Science* (forthcoming-[HTTPS://HERITAGESCIENCEJOURNAL.SPRINGEROPEN.COM/](https://heritagesciencejournal.springeropen.com/)).

Eastaugh, Nicholas, Valentine Walsh, Tracey Chaplin and Ruth Siddall. *The Pigment Compendium* 2017. Rev. ed. (e-version). London: The Pigmentum Project, 2016.

Ekkart, Rudolf E. O. "Het portret van de familie Meerman door Pieter van Slingelandt." In *De Arte et Libris: Festschrift Erasmus, 1934–1984*, edited by Abraham Horodisch, 69–75. Amsterdam: Erasmus Antiquariaat en Boekhandel, 1984.

Filipczak, Zirka Z. "Vermeer, Elusiveness, and Visual Theory." *Simiolus* 32, no. 4 (2006): 259–72.

Gaskell, Ivan and Michiel Jonker, eds., *Vermeer Studies* 55. New Haven: Yale University Press in association with the National Gallery of Art, 1998.

Giebe, Marlies. "Johannes Vermeers 'Kupplerin': Restaurierung Und Maltechnische Befunde." In Uta Neidhardt and Marlies Giebe, eds., *Johannes Vermeer: Bei der Kupplerin*, 39–64. Exh. cat. Dresden: Michel Sandstein in association with Gemäldegalerie Alte Meister, Staatliche Kunstsammlungen, 2004.

Gifford, E. Melanie. "Evocation and Representation: Rembrandt's Landscape Painting Technique." In Christiaan Vogelaar and Gregor J. M. Weber, eds., *Rembrandt's Landscapes*, 120–43. Exh. cat. Zwolle: Waanders in association with Gemäldegalerie Alte Meister, Staatliche Museen Kassel/Stedelijk Museum De Lakenhal, Leiden, 2006.

———. “Fine Painting and Eloquent Imprecision: Gabriel Metsu’s Painting Technique.” In Adriaan E. Waiboer, *Gabriel Metsu*, 154–79. New Haven: Yale University Press in association with the National Gallery of Art, 2010.

———. “Lievens’ Technique: ‘Wonders in Smeared Paint, Varnishes and Oils.’” In *Jan Lievens: A Dutch Master Rediscovered*, edited by Arthur K. Wheelock Jr., 41–53. Exh. cat. New Haven: Yale University Press in association with the National Gallery of Art, 2008.

———. “Material as Metaphor: Non-Conscious Thinking in Seventeenth Century Painting Practice.” In *Studying Old Master Paintings: Technology and Practice*, edited by Marika Spring, 165–72. London: Archetype in association with The National Gallery, 2011.

———. “Painting Light: Recent Observations on Vermeer’s Technique.” In Gaskell and Jonker, *Vermeer Studies*, 185–99.

———. “Rubens’s Invention and Evolution: Material Evidence in The Fall of Phaeton,” *Journal of Historians of Netherlandish Art* 11, no. 2 (Summer 2019). Accessed May 2, 2022. [HTTPS://DOI.ORG/10.5092/JHNA.2019.11.2.1](https://doi.org/10.5092/JHNA.2019.11.2.1).

Gifford, E. Melanie, Anikó Bezur, Andrea Guidi di Bagno, and Lisha Deming Glinsman, “The Making of a Luxury Image: Van Aelst’s Painting Materials and Artistic Techniques.” In Tanya Paul, James Clifton, Arthur K. Wheelock Jr., and Julie Hochstrasser, *Elegance and Refinement: The Still-Life Paintings of Willem van Aelst*, 80–84. Exh. cat. New York: Skira Rizzoli, 2012.

Gifford, E. Melanie, and Lisha Deming Glinsman, “Collective Style and Personal Manner: Materials and Techniques of High-Life Genre Painting.” In Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*, 65–84, 270–74.

Gifford, E. Melanie, Dina Anchin, Alexandra Libby, Marjorie E. Wieseman, Kathryn A. Dooley, Lisha Deming Glinsman, John K. Delaney. “First Steps in Vermeer’s Creative Process: New Findings from the National Gallery of Art,” *Journal of Historians of Netherlandish Art* 14:2 (Summer 2022). DOI: [10.5092/JHNA.2022.14.2.1](https://doi.org/10.5092/JHNA.2022.14.2.1).

Gifford, E. Melanie, Kathryn A. Dooley, John K. Delaney. “Methodology & Resources: New Findings from the National Gallery of Art.” *Journal of Historians of Netherlandish Art* 14:2 (Summer 2022). DOI: [10.5092/JHNA.2022.14.2.4](https://doi.org/10.5092/JHNA.2022.14.2.4).

Gimpel, René. *Diary of an Art Dealer, 1918–1939*. Translated by John Rosenberg. New York: Universe Books, 1987.

Gottwald, Franziska. *Das Tronie: Muster, Studie und Meisterwerk: die Genese einer Gattung der Malerei vom 15. Jahrhundert bis zu Rembrandt*. München: Deutscher Kunstverlag, 2011.

Gowing, Lawrence. *Vermeer*. London: Faber and Faber, 1952.

Graaf, Johannes Alexander van de. "Het De Mayerne manuscript als bron voor de schildertechniek van de barok. Brit. Mus., Sloane 2052." PhD. thesis, Rijksuniversiteit te Utrecht, 1958.

Groen, Karin. "Painting Technique in the Seventeenth Century in Holland and the Possible Use of the Camera Obscura by Vermeer." In Wolfgang Lefèvre, ed., *Inside the Camera Obscura: Optics and Art under the Spell of the Projected Image*, 195–210. Berlin: Max-Planck Institute for the History of Science, 2007.

Groen, Karin, Inez D. van der Werf, Klaas Jan van den Berg and Jaap J. Boon. "Scientific Examination of Vermeer's *Girl with a Pearl Earring*." In Gaskell and Jonker, *Vermeer Studies*, 169–183.

Hand, John Oliver. *National Gallery of Art: Master Paintings from the Collection*. New York: Abrams in association with the National Gallery of Art, 2004.

Hirschfelder, Dagmar. "Training Piece and Sales Product: On the Functions of the Tronie in Rembrandt's Workshop." In *Rembrandt 2006*. Vol. 1: Essays, edited by Michiel Roscam Abbing, 112–33. Leiden: Folio, 2006.

———. *Tronie und Porträt in der niederländischen Malerei des 17. Jahrhunderts*. Berlin: Gebr. Mann, 2008.

Hirschfelder, Dagmar, and León Krempel, eds. *Tronies: Das Gesicht in der Frühen Neuzeit*. Berlin: Gebr. Mann, 2014.

Houbraken, Arnold. *De groote schouburgh der Nederlantsche konstschilders en schilderessen*. 3 vols. Amsterdam, 1718–21; rev. ed., The Hague: J. Swart, C. Bouquet, and M. Gaillard, 1753; reprint, Amsterdam: B. M. Israël, 1976.

Van Hout, Nico. "Functies van Doodverf: De onderschildering en andere onderliggende stadia in het werk van P. P. Rubens." PhD thesis, Katholieke Universiteit Leuven, 2005. Accessed April 23, 2022. [HTTPS://LIRIAS.KULEUVEN.BE/RETRIEVE/66039](https://lirias.kuleuven.be/retrieve/66039).

Howard, Helen. "Vermeer and Technique: Paint Application." In "Research: The Meaning of Making," The National Gallery (London) website. Accessed March 10, 2022. [HTTPS://WWW.NATIONALGALLERY.ORG.UK/RESEARCH/ABOUT-RESEARCH/THE-MEANING-OF-MAKING/VERMEER-AND-TECHNIQUE/PAINT-APPLICATION](https://www.nationalgallery.org.uk/research/about-research/the-meaning-of-making/vermeer-and-technique/paint-application).

———. "Vermeer and Technique: Secrets of the Studio." In "Research: The Meaning of Making," The National Gallery (London) website. Accessed May 4, 2022. [HTTPS://WWW.NATIONALGALLERY.ORG.UK/RESEARCH/ABOUT-RESEARCH/THE-MEANING-OF-MAKING/VERMEER-AND-TECHNIQUE/SECRETS-OF-THE-STUDIO](https://www.nationalgallery.org.uk/research/about-research/the-meaning-of-making/vermeer-and-technique/secrets-of-the-studio).

———. “Vermeer and Technique: Vermeer’s Palette.” In “Research: The Meaning of Making,” The National Gallery (London) website. Accessed March 10, 2022. [HTTPS://WWW.NATIONALGALLERY.ORG.UK/RESEARCH/ABOUT-RESEARCH/THE-MEANING-OF-MAKING/VERMEER-AND-TECHNIQUE/VERMEERS-PALETTE](https://www.nationalgallery.org.uk/research/about-research/the-meaning-of-making/vermeer-and-technique/vermeers-palette).

Libby, Alexandra, E. Melanie Gifford, Dina Anchin, Marjorie E. Wieseman, Kathryn A. Dooley, Lisha Deming Glinsman, John K. Delaney. “Experimentation and Innovation in Vermeer’s *Girl with the Red Hat*: New Findings from the National Gallery of Art.” *Journal of Historians of Netherlandish Art* 14:2 (Summer 2022) DOI: [10.5092/JHNA.2022.14.2.2](https://doi.org/10.5092/JHNA.2022.14.2.2).

Jager, Ronald de. “Meester, leerjongen, leertijd: Een analyse van zeventiende-eeuwse Noord-Nederlandse leerlingscontracten van kunstschilders, goud- en zilversmeden.” *Oud Holland* 104, no. 2 (1990): 69–111.

Jansen, Guido, and Peter C. Sutton, eds. *Michiel Sweerts (1618–1664)*. Exh. cat. Zwolle: Waanders in association with the Rijksmuseum, Amsterdam; Fine Arts Museums of San Francisco; Wadsworth Athenaeum Museum of Art, Hartford, 2002.

Johnson, C. Richard, Jr., and William A. Sethares. “Canvas Weave Match Supports Designation of Vermeer’s Geographer and Astronomer as a Pendant Pair.” *Journal of Historians of Netherlandish Art* 9, no. 1 (Winter 2017). Accessed April 18, 2022. [HTTPS://DOI.ORG/10.5092/JHNA.2017.9.1.17](https://doi.org/10.5092/JHNA.2017.9.1.17).

Johnson, C. Richard, Jr., and William A. Sethares, eds. *Counting Vermeer: Using Weave Maps to Study Vermeer’s Canvases*, RKD Studies. The Hague: RKD (Netherlands Institute for Art History), 2017; reissued September 23, 2020. Accessed April 18, 2022. [HTTPS://COUNTINGVERMEER.RKDSTUDIES.NL/CONTENTS](https://countingvermeer.rkd.nl/content).

Kolfin, Elmer, Carol Pottasch, and Ruth Hoppe. “The Metamorphosis of Diana.” *ArtMatters: Netherlands Technical Studies in Art* 1 (2002): 90–103.

Krempel, Leon. “Allegorische Tronie-Paare bei Johannes Vermeer.” In Hirschfelder and Krempel, *Tronie*, 97–112.

Kühn, Herman. “A Study of the Pigments and the Grounds Used by Jan Vermeer.” *Reports and Studies in the History of Art* 2 (1968): 154–202.

Laurenze-Landsberg, Claudia. “Neutron-Autoradiography of Two Paintings by Jan Vermeer in the Gemäldegalerie Berlin.” In Wolfgang Lefèvre, ed., *Inside the Camera Obscura: Optics and Art under the Spell of the Projected Image*, 213–25. Berlin: Max-Planck Institute for the History of Science, 2007.

Levy-Halm, Koos. “Where Did Vermeer Buy His Painting Materials? Theory and Practice.” In Gaskell and Jonker, *Vermeer Studies*, 137–43.

Libby, Alexandra, and Arthur K. Wheelock Jr. "Johannes Vermeer/*A Lady Writing*/c. 1665," Dutch Paintings of the Seventeenth Century, NGA Online Editions, April 24, 2014; revised December 9, 2019. Accessed July 16, 2021. [HTTPS://PURL.ORG/NGA/COLLECTION/ARTOBJECT/46437](https://purl.org/nga/collection/artobject/46437).

Liedtke, Walter A. "Dutch Paintings in America." In B. P. J. Broos, Edwin Buijsen, Rieke van Leeuwen, and Hans Hoetink, eds., *Great Dutch Paintings from America*, 14–59. Exh. cat. Zwolle: Waanders in association with the Royal Cabinet of Paintings Mauritshuis, 1990.

———. *Vermeer: The Complete Paintings*. Ghent: Ludion, 2008.

Liedtke, Walter A., Richard C. Johnson, and Don H. Johnson. "Canvas Matches in Vermeer: A Case Study in the Computer Analysis of Fabric Supports." *Metropolitan Museum Journal* 47 (2012): 101–8.

Liedtke, Walter A., and Arthur K. Wheelock Jr. "Young Woman Seated at a Virginal." In *The Leiden Collection Catalogue*, 3rd ed., edited by Arthur K. Wheelock Jr. and Lara Yeager-Crasselt, 2020–. Accessed January 11, 2022. [HTTPS://THELEIDENCOLLECTION.COM/ARTWORK/YOUNG-WOMAN-SEATED-AT-A-VIRGINAL](https://theleidencollection.com/artwork/young-woman-seated-at-a-virginal).

Liedtke, Walter A., Michiel Plomp, Axel Rüger, and Renier Baarsen. *Vermeer and the Delft School*. Exh. cat. New York: Metropolitan Museum of Art, 2001.

Loon, Annelies van, Alessa A. Gambardella, Victor Gonzalez, Marine Cotte, Wout De Nolf, Katrien Keune, Emilien Leonhardt, Suzan de Groot, Art Ness Proaño Gaibor, and Abbie Vandivere. "Out of the Blue: Vermeer's Use of Ultramarine in *Girl with a Pearl Earring*." *Heritage Science* 8, no. 25 (February 28, 2020). Accessed May 2, 2022. [HTTPS://DOI.ORG/10.1186/S40494-020-00364-5](https://doi.org/10.1186/S40494-020-00364-5).

Loon, Annelies van, Abbie Vandivere, John K. Delaney, Kathryn A. Dooley, Steven De Meyer, Frederik Vanmeert, Victor Gonzalez, Koen Janssens, Emilien Leonhardt, Ralph Haswell, Suzan de Groot, Paolo D'Imporzano and Gareth R. Davies. "Beauty is Skin Deep: The Skin Tones of Vermeer's *Girl with a Pearl Earring*." *Heritage Science* 7, no. 102 (December 11, 2019). Accessed May 2, 2022. [HTTPS://DOI.ORG/10.1186/S40494-019-0344-0](https://doi.org/10.1186/S40494-019-0344-0).

Loughman, John. "Een stad en haar kunstconsumptie: Openbare en privé-verzamelingen in Dordrecht, 1620–1719." In *De Zichtbaare Werelt: Schilderkunst uit de gouden eeuw in Hollands oudste stad*, edited by Pieter Marijnissen, 34–64. Exh. cat. Zwolle: Waanders in association with the Dordrechts Museum, 1992.

Lunsingh Scheurleer, Th. H., Cornelia Willemijn Fock, and A. J. van Dissel, eds. *Het Rapenburg: Geschiedenis van een Leidse gracht*. 6 vols. Leiden: Afdeling Geschiedenis van de Kunsthierarchie Rijksuniversiteit, 1988–92.



Mahon, Dorothy, Silvia A. Centeno, Margaret Iacono, Federico Caró, Heike Stege and Andrea Obermeier. "Johannes Vermeer's *Mistress and Maid*: New Discoveries Cast Light on Changes to the Composition and the Discoloration of Some Paint Passages." *Heritage Science* 8, no. 30 (March 27, 2020). Accessed May 2, 2022, [HTTPS://DOI.ORG/10.1186/S40494-020-00375-2](https://doi.org/10.1186/S40494-020-00375-2).

Martin, Wilhelm. *Gerard Dou*. Translated by Clara Bell. London: G. Bell and Sons, 1902.

Malraux, André. *Vermeer de Delft*. Paris: Gallimard, 1952.

Meloni, Sabrina. "A Recycled Panel." *Mauritshuis in Focus* 24, no. 2 (2011): 32.

Montias, John Michael. *Art at Auction in 17th Century Amsterdam*. Amsterdam: Amsterdam University Press, 2002.

———. *Artists and Artisans in Delft: A Socio-Economic Study of the Seventeenth Century*. Princeton: Princeton University Press, 1982.

———. "Recent Archival Research on Vermeer." In Gaskell and Jonker, *Vermeer Studies*, 93–109.

———. *Vermeer and His Milieu: A Web of Social History*. Princeton: Princeton University Press, 1989.

———. "Works of Art in Seventeenth-Century Amsterdam." In *Art in History/History in Art: Studies in Seventeenth-Century Dutch Culture*, edited by David Freedberg and Jan de Vries, 331–72. Santa Monica: Getty Center for the History of Art and the Humanities, 1991.

Naumann, Otto. *Frans van Mieris (1635–1681) the Elder*. 2 vols. Doornspijk: Davaco, 1981.

Noble, Petria, and Epcó Runia. *Preserving Our Heritage: Conservation, Restoration and Technical Research in the Mauritshuis*. Zwolle: Waanders, 2009.

Peer, A. J. J. M. van, "Drie collecties schilderijen van Jan Vermeer," *Oud Holland* 72, no. 2 (1957): 92–103.

Peeters, Natasja. "The Painter's Apprentice in Fifteenth and Sixteenth Century Antwerp: An Analysis of the Archival Sources." *Mélanges de l'École française de Rome: Italie et Méditerranée modernes et contemporaines*, nos. 131–2 (2019), 221–27, <https://doi.org/10.4000/mefrim.6461>.

Peggie, David. "Vermeer and Technique: Drying and Paint Defects." In "Research: The Meaning of Making," The National Gallery (London) website. Accessed May 4, 2022. [HTTPS://WWW.NATIONALGALLERY.ORG.UK/RESEARCH/ABOUT-RESEARCH/THE-MEANING-OF-MAKING/VERMEER-AND-TECHNIQUE/DRYING-AND-PAINT-DEFECTS](https://www.nationalgallery.org.uk/research/about-research/the-meaning-of-making/vermeer-and-technique/drying-and-paint-defects).

Pottasch, Carol. "Underdrawings in the Paintings of Frans van Mieris." In Quentin Buvelot, *Frans van Mieris 1635–1681*, 62–68. Exh. cat. Zwolle: Waanders 2005.

Prak, Maarten. "Guilds and the Development of the Art Market during the Dutch Golden Age." *Simiolus* 30, nos. 3/4 (2003): 236–51.

———. "Paintings, Journeyman Painters and Painters' Guilds during the Dutch Golden Age." In *Invisible Hands? The Rise and Status of the Painter's Journeyman in the Low Countries c. 1450–c. 1650*, edited by Natasja Peeters, 133–49. Groningen Studies in Cultural Change 23. Leuven: Peeters, 2007.

Richardson, Clare, and Kate Stonor. "The Conversion of Saint Paul Series at the Courtauld: Rubens's Artistic Process Revealed by New Technical Discoveries." *Journal of Historians of Netherlandish Art* 13, no. 1 (Winter 2021). Accessed May 2, 2022. [HTTPS://DOI.ORG/10.5092/JHNA.2021.13.1.1](https://doi.org/10.5092/jhna.2021.13.1.1).

Roscam Abbing, Michiel. *De schilder en schrijver Samuel van Hoogstraten 1627–1678: Eigentijdse bronnen en oeuvre van gesigeneerde schilderijen*. Leiden: Primavera Pers, 1993.

Sandrart, Joachim von. *Teutsche Academie der Bau-, Bild- und Mahlerey-Künste. Nuremberg, 1675–1680*. Scholarly annotated online edition, edited by Thomas Kirchner, Alessandro Nova, Carsten Blüm, Anna Schreurs and Thorsten Wübbena, 2008–2012. Accessed April 18, 2022. [HTTP://WWW.SANDRART.NET](http://www.sandrart.net).

Schölzel, Christoph. "On the Restoration and Painterly Technique of *Girl Reading a Letter at Open Window* by Johannes Vermeer." In Stephan Koja, Uta Neidhardt, and Arthur K. Wheelock Jr., eds., *Vermeer: On Reflection*, 195–219. Exh. cat. Dresden: Sandstein in association with Staatliche Kunstsammlungen, Gemäldegalerie Alte Meister, 2021.

Scholten, Frits. "The Larson Family of Statuary Founders: Seventeenth-Century Reproductive Sculpture for Gardens and Painters' Studios." *Simiolus* 31, nos. 1/2 (2004–5): 54–89.

Seymour, Charles, Jr. "Dark Chamber and Light-Filled Room: Vermeer and the Camera Obscura." *The Art Bulletin* 46, no. 3 (September 1964): 323–31.

Sheldon, Libby, and Nicola Costaras. "Johannes Vermeer's 'Young Woman Seated at a Virginal.'" *The Burlington Magazine* 148, no. 1235 (2006): 89–97.

Sivel, Valerie, Joris Dik, Paul Alkemade, Libby Sheldon, and Henny Zandbergen. "The Cloak of *Young Woman Seated at a Virginal*: Vermeer, or a Later Hand?" *ArtMatters: Netherlands Technical Studies in Art* 4 (2007): 90–96.

Slatkes, Leonard J. *Vermeer and His Contemporaries*. New York: Abbeville Press, 1981.

- Sluijter, Eric Jan. "Emulative Imitation among High-Life Genre Painters." In Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*, 36–49.
- . *Rembrandt and the Nude*. Amsterdam: Amsterdam University Press, 2006.
- Snyder, Laura J. *Eye of the Beholder: Johannes Vermeer, Antoni van Leeuwenhoek, and the Reinvention of Seeing*. New York: W. W. Norton & Company, 2015.
- Steadman, Philip. *Vermeer's Camera: Uncovering the Truth behind the Masterpieces*. Oxford: Oxford University Press, 2001.
- Stols-Witlox, Maartje. *A Perfect Ground: Preparatory Layers for Oil Paintings, 1550–1900*. London: Archetype Publications, 2017.
- Swillens, Pieter T. A. *Johannes Vermeer: Painter of Delft, 1632–1675*. Utrecht: Spectrum, 1950.
- Thienen, Frithjof van. *Jan Vermeer of Delft*. New York: Harper, 1949.
- Valentiner, Wilhelm R. "Zum 300. Geburtstag Jan Vermeers, Oktober 1932: Vermeer und die Meister der Holländischen Genremalerei." *Pantheon* 5, no. 10 (October 1932): 305–324.
- Vandivere, Abbie, ed., "The Girl in the Spotlight: A Technical Re-Examination of Vermeer's *Girl with a Pearl Earring*." Special Collection, *Heritage Science* 7–8 (2019–20). Accessed May 2, 2022. [HTTPS://WWW.SPRINGEROPEN.COM/COLLECTIONS/GITS](https://www.springeropen.com/collections/gits).
- Vandivere, Abbie. "The Technical (Re-)Examination of Vermeer's *Girl with a Pearl Earring*." *Heritage Science* 8, no. 26 (March 11, 2020). Accessed May 2, 2022. [HTTPS://DOI.ORG/10.1186/S40494-020-00370-7](https://doi.org/10.1186/S40494-020-00370-7).
- Vandivere, Abbie, Annelies van Loon, Tom Callewaert, Ralph Haswell, Art Ness Proaño Gaibor, Henk van Keulen, Emilien Leonhardt, and Joris Dik. "Fading into the Background: The Dark Space surrounding Vermeer's *Girl with a Pearl Earring*." *Heritage Science* 7, no. 69 (September 16, 2019). Accessed May 2, 2022. [HTTPS://DOI.ORG/10.1186/S40494-019-0311-9](https://doi.org/10.1186/S40494-019-0311-9).
- Vandivere, Abbie, Annelies van Loon, Kathryn A. Dooley, Ralph Haswell, Robert G. Erdmann, Emilien Leonhardt, and John K. Delaney. "Revealing the Painterly Technique beneath the Surface of Vermeer's *Girl with a Pearl Earring* Using Macro- and Microscale Imaging." *Heritage Science* 7, no. 64 (September 2, 2019). Accessed May 2, 2022. [HTTPS://DOI.ORG/10.1186/S40494-019-0308-4](https://doi.org/10.1186/S40494-019-0308-4).
- Vandivere, Abbie, Jørgen Wadum, Klaas Jan van den Berg, and Annelies van Loon. "From 'Vermeer Illuminated' to 'The Girl in the Spotlight': Approaches and Methodologies for the Scientific (Re-)Examination of Vermeer's *Girl with a Pearl Earring*." *Heritage Science* 7, no. 66 (August 29, 2019). Accessed May 2, 2022. [HTTPS://DOI.ORG/10.1186/S40494-019-0307-5](https://doi.org/10.1186/S40494-019-0307-5).

Vandivere, Abbie, Jørgen Wadum, and Emiliene Leonhardt. "The Girl in the Spotlight: Vermeer at Work, His Materials and Techniques in *Girl with a Pearl Earring*." *Heritage Science* 8, no. 20 (March 2, 2020). Accessed May 2, 2022. [HTTPS://DOI.ORG/10.1186/S40494-020-0359-6](https://doi.org/10.1186/s40494-020-0359-6).

Van de Velde, Carl. *Frans Floris (1519/20–1570): Leven en werken* (monograph). *Verhandelingen van de Koninklijke Academie voor Wetenschappen, Letteren en Schone Kunsten van België, Klasse der Schone Kunsten* 37, no. 30. Brussels: Palais der Academiën, 1975.

Verslype, Ige. "The Restoration of 'Woman in Blue Reading a Letter' by Johannes Vermeer." *The Rijksmuseum Bulletin* 60, no. 1 (2012): 2–19.

Vries, Lyckle de. "Tronies and other Single Figured Netherlandish Paintings." *Leids Kunsthistorisch Jaarboek* 8 (1990): 185–202.

Wadum, Jørgen. "Contours of Vermeer." In Gaskell and Jonker, *Vermeer Studies*, 210–23.

———. "Historical Overview of Panel-Making Techniques in the Northern Countries." In *The Structural Conservation of Panel Paintings*, proceedings of a symposium at the J. Paul Getty Museum, Los Angeles, 1995, edited by Kathleen Dardes and Andrea Rothe, 149–77. Los Angeles: Getty Conservation Institute, 1998.

Wadum, Jørgen, René Hoppenbrouwers, and Luuk Struick van der Loeff. *Vermeer Illuminated: Conservation, Restoration and Research: A Report on the Restoration of the View of Delft and the Girl with a Pearl Earring by Johannes Vermeer*. Wormer: V+K in association with the Royal Cabinet of Paintings Mauritshuis, The Hague, 1994.

Wagner, Jens, and Heike Stege. "The Examination of Selected Panels by Jacobus Vrel using Imaging Methods." In Berndt Ebert, Cécile Tainturier, and Quentin Buvelot, *Jacobus Vrel: Searching for Clues to an Enigmatic Artist*, 136–48. Exh. cat. Munich: Hirmer, 2021.

Waiboer, Adriaan E. "Vermeer and the Masters of Genre Painting." In Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*, 65–84.

———. "Vermeer's Impact on His Contemporaries." *Oud Holland* 123, no. 1 (2010): 51–64.

Waiboer, Adriaan E., and Marit Slob. "Tables 1–6." In Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*, 258–69.

Waiboer, Adriaan E., Arthur K. Wheelock Jr., and Blaise Ducos. *Vermeer and the Masters of Genre Painting: Inspiration and Rivalry*. Exh. cat. New Haven: Yale University Press in association with the National Gallery of Ireland, 2017.

Wald, Robert. "The Art of Painting: Observations on Approach and Technique." In Sabine Haag, Elke Oberthaler, and Sabine Pénot, *Vermeer, Die Malkunst: Spurensicherung an einem*

*Meisterwerk*, 312–27. Exh. cat. St. Pölten: Residenz in association with Kunsthistorisches Museum, Vienna, 2010.

Wallert, Arie. “The Materials and Methods of Michiel Sweerts’s Paintings.” In Jansen and Sutton, Michiel Sweerts, 37–47.

Wetering, Ernst van de. “Painting Materials and Working Methods.” In Josua Bruyn, Bob Haak, Simon H. Levie, Pieter J. J. van Thiel, and Ernst van de Wetering, *A Corpus of Rembrandt Paintings*. Vol. 1, 1625–1631, 11–33. The Hague: Martinus Nijhoff, 1982.

———. “Principaelen’ and Satellites.” In Lene Bøgh Rønberg and Eva de la Fuente Pedersen, *Rembrandt?: The Master and His Workshop*, 106–22. Exh. cat. Copenhagen: Statens Museum for Kunst, 2006.

———. “Rembrandt’s Self-Portraits: Problems of Authenticity and Function.” In Ernst van de Wetering, with contributions by Karin Groen, Peter Klein, Jaap van der Veen, and Marieke de Winkel, and with the collaboration of Paul Broekhoff, Michiel Franken, and Liedeke Peese Binkhorst, *A Corpus of Rembrandt Paintings*. Vol. 4, The Self-Portraits, 87–317. Dordrecht: Springer, 2005.

Wheelock, Arthur K., Jr. *Dutch Paintings of the Seventeenth Century*. The Collections of the National Gallery of Art Systematic Catalogue. Washington: National Gallery of Art, 1995.

———. *Jan Vermeer*. New York: Abrams, 1981.

———. “Johannes Vermeer/ *Girl with a Flute*/probably 1665/1675.” In *Dutch Paintings of the Seventeenth Century*, NGA Online Editions, April 24, 2014. Accessed November 22, 2021. [HTTPS://PURL.ORG/NGA/COLLECTION/ARTOBJECT/1237](https://purl.org/nga/collection/artobject/1237).

———. “Johannes Vermeer/ *Girl with the Red Hat*/c. 1665/1666.” In *Dutch Paintings of the Seventeenth Century*, NGA Online Editions, April 24, 2014. Accessed July 16, 2021. [HTTPS://PURL.ORG/NGA/COLLECTION/ARTOBJECT/60](https://purl.org/nga/collection/artobject/60).

———. “Johannes Vermeer/ *Woman Holding a Balance*/c. 1664,” *Dutch Paintings of the Seventeenth Century*, NGA Online Editions, August 30, 2017. Accessed July 16, 2021. [HTTPS://PURL.ORG/NGA/COLLECTION/ARTOBJECT/1236](https://purl.org/nga/collection/artobject/1236).

———. Review of *Johannes Vermeer van Delft 1632–1675*, by Albert Blankert, Rob Ruurs, and Willem L. van de Wetering. *Art Bulletin* 59 (September 1977): 439–41.

———. “*Saint Praxedis*: New Light on the Early Career of Vermeer.” *Artibus et Historiae* 7, no. 14 (1986): 71–89.

———. “The Story of Two Vermeer Forgeries.” In *Shop Talk: Studies in Honor of Seymour Slive*, edited by Cynthia P. Schneider, William W. Robinson and Alice I. Davies, 271–75. Cambridge, MA: Harvard University Art Museums, 1995.

———. *Vermeer & the Art of Painting*. New Haven: Yale University Press, 1995.

———. “Zur Technik zweier Bilder, die Vermeer zugeschrieben sind.” *Maltechnik–Restauro* 84, no. 4 (October 1978): 242–57.

Wheelock, Arthur K., Jr., Albert Blankert, Ben Broos, and Jørgen Wadum. *Johannes Vermeer*. Exh. cat. Washington, DC: National Gallery of Art in association with the Royal Cabinet of Paintings Mauritshuis, 1995.

Wieseman, Marjorie E. “Acquisition or Inheritance? Material Goods in Paintings by Vermeer and His Contemporaries.” In Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*, 50–63.

Wieseman, Marjorie E., Alexandra Libby, E. Melanie Gifford, Dina Anchin. “Vermeer’s Studio and the *Girl with a Flute*: New Findings from the National Gallery of Art,” *Journal of Historians of Netherlandish Art* 14:2 (Summer 2022). DOI: [10.5092/JHNA.2022.14.2.3](https://doi.org/10.5092/JHNA.2022.14.2.3).

Wouw, Teuntje van de, and Adriaan E. Waiboer. “Timelines.” In Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*, 254–57.

Zijl, M. I. E. van. “De Delftse Wandtapijten.” In *De Stad Delft: Cultuur en maatschappij van 1572 tot 1667*, edited by Ineke V. T. Spaander and Rein-Arend Leeuw, 202–9. Exh. cat. Delft: Stedelijk Museum Het Prinsenhof, 1981.

## Endnotes

- 1 The findings of our research specific to the National Gallery’s tronies, *Girl with the Red Hat* (ca. 1669) and *Girl with a Flute* (ca. 1669/1675), are published elsewhere in this issue: Alexandra Libby, E. Melanie Gifford, Dina Anchin, Marjorie E. Wieseman, Kathryn A. Dooley, Lisha Deming Glinsman, John K. Delaney, “Experimentation and Innovation in Vermeer’s *Girl with the Red Hat*: New Findings from the National Gallery of Art,” *Journal of Historians of Netherlandish Art* 14, no. 2 (Summer 2022), DOI: [10.5092/JHNA.2022.14.2.2](https://doi.org/10.5092/JHNA.2022.14.2.2); Marjorie E. Wieseman, Alexandra Libby, E. Melanie Gifford, Dina Anchin, “Vermeer’s Studio and *Girl with a Flute*: New Findings from the National Gallery of Art,” *Journal of Historians of Netherlandish Art* 14, no. 2 (Summer 2022), DOI: [10.5092/JHNA.2022.14.2.3](https://doi.org/10.5092/JHNA.2022.14.2.3).



- 2 The findings of this in-depth analysis are presented in further scientific detail in *Heritage Science*. See Kathryn A. Dooley, E. Melanie Gifford, Dina Anchin, Lisha Deming Glinsman, Marjorie E. Wieseman, Alexandra Libby, and John K. Delaney, “Comparing Vermeer’s Painting Techniques in *Woman Holding a Balance* and *A Lady Writing* Using Chemical Imaging Spectroscopy,” *Heritage Science* (forthcoming-[HTTPS://HERITAGESCIENCEJOURNAL.SPRINGEROPEN.COM/](https://heritagesciencejournal.springeropen.com/)).
- 3 The history of art-historical research into the National Gallery’s paintings by and attributed to Vermeer, spearheaded by former curator Arthur K. Wheelock Jr., is summarized in Arthur K. Wheelock Jr., “Johannes Vermeer/ *Girl with a Flute*/probably 1665/1675,” *Dutch Paintings of the Seventeenth Century*, NGA Online Editions (April 24, 2014), accessed May 2, 2022, [HTTPS://PURL.ORG/NGA/COLLECTION/ARTOBJECT/1237](https://purl.org/nga/collection/artobject/1237); Arthur K. Wheelock Jr., “Johannes Vermeer/ *Girl with the Red Hat*/c. 1665/1666,” *Dutch Paintings of the Seventeenth Century*, accessed July 16, 2021, [HTTPS://PURL.ORG/NGA/COLLECTION/ARTOBJECT/60](https://purl.org/nga/collection/artobject/60); Arthur K. Wheelock Jr., “Johannes Vermeer/ *Woman Holding a Balance*/c. 1664,” *Dutch Paintings of the Seventeenth Century*, NGA Online Editions (August 30, 2017), accessed May 2, 2022, [HTTPS://PURL.ORG/NGA/COLLECTION/ARTOBJECT/1236](https://purl.org/nga/collection/artobject/1236); and Alexandra Libby and Arthur K. Wheelock Jr., “Johannes Vermeer/ *A Lady Writing*/c. 1665,” *Dutch Paintings of the Seventeenth Century*, NGA Online Editions (April 24, 2014, revised December 9, 2019), accessed May 2, 2022, [HTTPS://PURL.ORG/NGA/COLLECTION/ARTOBJECT/46437](https://purl.org/nga/collection/artobject/46437).

For over six decades, the material aspects of Vermeer’s work also have been a focus of research at the National Gallery. In the 1960s, the National Gallery commissioned one of the first technical studies devoted exclusively to Vermeer’s paintings; see Herman Kühn, “A Study of the Pigments and the Grounds used by Jan Vermeer,” *Reports and Studies in the History of Art* 2 (1968): 154–202. This was followed, in 1973–1974, by an intensive study conducted by a research team comprised of Wheelock (then Finley Fellow at the National Gallery), visiting Kress Professor and former Mauritshuis director Ary Bob de Vries, National Gallery paintings conservator Kay Silberfeld, and National Gallery technical advisor Robert Feller. The results of this and subsequent technical investigations informed numerous publications, including Arthur K. Wheelock Jr., “Zur Technik zweier Bilder, die Vermeer zugeschrieben sind,” *Maltechnik–Restauro* 84 (1978): 242–57; Arthur K. Wheelock Jr., *Vermeer & the Art of Painting* (New Haven: Yale University Press, 1995).

- 4 Arthur K. Wheelock Jr. et al., *Johannes Vermeer*, exh. cat. (Washington, DC: National Gallery of Art in association with the Royal Cabinet of Paintings Mauritshuis, 1995). Technical research on Vermeer’s works at the National Gallery of Art and the Mauritshuis informed the catalogue, and focused studies were published in a volume of papers presented at two symposia organized in conjunction with that exhibition: Ivan Gaskell and Michiel Jonker, eds., *Vermeer Studies*, *Studies in the History of Art* 55 (New Haven: Yale University Press in association with the National Gallery of Art, 1998).

- 5     Adriaan E. Waiboer, Arthur K. Wheelock Jr., and Blaise Ducos, *Vermeer and the Masters of Genre Painting: Inspiration and Rivalry*, exh. cat. (New Haven: Yale University Press in association with the National Gallery of Ireland, 2017).
- 6     Adriaan E. Waiboer, “Vermeer and the Masters of Genre Painting,” 3–19, in Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*; Piet Bakker, “Painters of and for the Elite: Relationships, Prices and Familiarity with Each Other’s Work,” 85–95, in Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*; Teuntje van de Wouw and Adriaan E. Waiboer, “Timelines,” 254–57, in Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*; Adriaan E. Waiboer and Marit Slob, “Tables 1–6,” 258–69, in Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*.
- 7     E. Melanie Gifford and Lisha Deming Glinsman, “Collective Style and Personal Manner: Materials and Techniques of High-Life Genre Painting,” 65–84, 270–74, in Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*.
- 8     Dorothy Mahon et al., “Johannes Vermeer’s *Mistress and Maid*: New Discoveries Cast Light on Changes to the Composition and the Discoloration of Some Paint Passages,” *Heritage Science* 8, no. 30 (2020), accessed May 2, 2022, [HTTPS://DOI.ORG/10.1186/S40494-020-00375-2](https://doi.org/10.1186/S40494-020-00375-2); see also the several articles cited in Abbie Vandivere, ed., “The Girl in the Spotlight: A Technical Re-Examination of Vermeer’s *Girl with a Pearl Earring*,” Special Collection, *Heritage Science* 7 and 8 (2019–20), accessed May 2, 2022, [HTTPS://WWW.SPRINGEROPEN.COM/COLLECTIONS/GITS](https://www.springeropen.com/collections/gits).
- 9     Marjorie E. Wieseman, “Acquisition or Inheritance? Material Goods in Paintings by Vermeer and His Contemporaries,” in Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*, 50–63.
- 10    Gifford and Glinsman, “Collective Style and Personal Manner,” 72–75.
- 11    In XRF analysis, deep-colored red lakes in paintings by Vermeer (as well as other elite Dutch artists) are frequently associated with distinctively high levels of potassium (probably due to a recipe using high levels of potash) as well as aluminum (the colorless carrier of the dyestuff for this lake pigment), and where FORS analysis has been available, it shows the presence of an insect-based dyestuff such as cochineal. Willem van Aelst (1627–1683), a contemporary specialist in elite still life, also paired this particular red lake with costly ultramarine in his most luxurious works but in his late works replaced each with a less expensive substitute; see E. Melanie Gifford et al., “The Making of a Luxury Image: Van Aelst’s Painting Materials and Artistic Techniques,” in Tanya Paul et al., *Elegance and Refinement: The Still-Life Paintings of Willem van Aelst*, exh. cat. (New York: Skira Rizzoli, 2012), 76–77, 83. The inventory of the property of Cornelis Dusart (1660–1704) valued a red lake at sixty guilders per ounce, as costly as the best ultramarine (the inventory lists several grades of ultramarine, valued from ten to sixty guilders per ounce); see Koos Levy-Halm, “Where Did Vermeer Buy His Painting Materials? Theory and Practice,” in Gaskell and Jonker, *Vermeer Studies*, 140.
- 12    Jan Steen, for example, used ultramarine in his high-life subjects while using predominantly less expensive blue pigments in “low-life” genre scenes, and Pieter de

- Hooch limited his use of ultramarine to localized details (Gifford and Glinsman, “Collective Style and Personal Manner,” 68, 70–71).
- 13 Dou asserted that it took him more than three days to paint a tiny broom scarcely larger than a fingernail, and on one occasion, at least, van Mieris charged by the hour. On Dou, see Joachim von Sandrart, *Teutsche Academie der Bau-, Bild- und Mahlerey-Künste* (Nuremberg 1675–1680), 321, scholarly annotated online edition, ed. T. Kirchner, A. Nova, C. Blüm, A. Schreurs and T. Wübbena (2008–2012), accessed April 21, 2022, <http://ta.sandrart.net/-text-547>; on van Mieris, see Bakker, “Painters of and for the Elite,” 88. Dou’s pupil Pieter van Slingelandt worked so slowly on a modestly sized family portrait—allegedly spending “a month or six weeks painting a jabot with lace”—that it took three years to complete, causing the patrons to bring a court case against him; see Rudolf E. O. Ekkart, “Het portret van de familie Meerman door Pieter van Slingelandt,” in *De Arte et Libris: Festschrift Erasmus, 1934–1984*, ed. Abraham Horodisch (Amsterdam: Erasmus Antiquariaat en Boekhandel, 1984), 69–75.
- 14 Eric Jan Sluijter, “Emulative Imitation among High-Life Genre Painters,” 36–49, in Waiboer, Wheelock, and Ducos, *Vermeer and the Masters of Genre Painting*.
- 15 On De Bye’s collection of paintings by Dou, see Piet Bakker, “Gerrit Dou and His Collectors in the Golden Age” (2017), in *The Leiden Collection Catalogue*, 3rd ed., ed. Arthur K. Wheelock Jr. and Lara Yeager-Crasselt (New York, 2020– ), accessed April 5, 2022, [HTTPS://THELEIDENCOLLECTION.COM/ESSAYS/GERRIT-DOU-AND-HIS-COLLECTORS-IN-THE-GOLDEN-AGE](https://theleidencollection.com/essays/gerrit-dou-and-his-collectors-in-the-golden-age). Johan de Bye’s exhibition list was first published in Wilhelm Martin, *Gerard Dou*, trans. Clara Bell (London: G. Bell and Sons, 1902), 145–46; see also Th. H. Lunsingh Scheurleer, Cornelia Willemijn Fock, and A. J. van Dissel, eds., *Het Rapenburg: Geschiedenis van een Leidse gracht*, vol. 3b (Leiden, 1988), 486, appendix 1. On van Ruijven, see John Michael Montias, *Vermeer and His Milieu: A Web of Social History* (Princeton: Princeton University Press, 1989), 246–62.
- 16 Gifford and Glinsman, “Collective Style and Personal Manner,” 73.
- 17 Charles Seymour Jr., “Dark Chamber and Light-Filled Room: Vermeer and the Camera Obscura,” *The Art Bulletin* 46, no. 3 (September 1964): 323–31; more recently, see Philip Steadman, *Vermeer’s Camera: Uncovering the Truth behind the Masterpieces* (Oxford: Oxford University Press, 2001). For a rebuttal of the theory that Vermeer employed a camera obscura as an artistic aid, see Walter A. Liedtke, *Vermeer: The Complete Paintings* (Ghent: Ludion, 2008), 179–89.
- 18 Wheelock et al., *Johannes Vermeer*, 162.
- 19 In *Diana and her Nymphs* (ca. 1653–54; Mauritshuis, The Hague), large, round touches of paint highlight the folds of Diana’s yellow skirt; see E. Melanie Gifford, “Material as Metaphor: Non-Conscious Thinking in Seventeenth Century Painting Practice,” in *Studying Old Master Paintings: Technology and Practice*, ed. Marika Spring (London: Archetype in association with The National Gallery, 2011), 166–68; and E. Melanie Gifford, “Painting Light: Recent Observations on Vermeer’s Technique,” in Gaskell and Jonker, *Vermeer Studies*, 194–96.
- 20 On Vermeer’s selective use of the visual qualities of a camera obscura for creative purposes, see also Zirka Z. Filipczak, “Vermeer, Elusiveness, and Visual Theory,” *Simiolus: Netherlands Quarterly for the History of Art* 32, no. 4 (2006): 259–72;

- and Laura J. Snyder, *Eye of the Beholder: Johannes Vermeer, Antoni van Leeuwenhoek, and the Reinvention of Seeing* (New York: W. W. Norton & Company, 2015).
- 21 Waiboer, “Vermeer and the Masters of Genre Painting.”
- 22 Adriaan E. Waiboer, “Vermeer’s Impact on His Contemporaries,” *Oud Holland* 123, no. 1 (2010): 51–64.
- 23 E. Melanie Gifford, “Fine Painting and Eloquent Imprecision: Gabriel Metsu’s Painting Technique,” in Adriaan E. Waiboer et al., *Gabriel Metsu*, exh. cat. (New Haven and London: Yale University Press in association with the National Gallery of Art, 2010), 171–73.
- 24 C. Richard Johnson Jr and William A. Sethares, eds., *Counting Vermeer: Using Weave Maps to Study Vermeer’s Canvases*, RKD Studies (The Hague: RKD Netherlands Institute for Art History, 2017; reissued September 23, 2020), accessed April 18, 2022, [HTTPS://COUNTINGVERMEER.RKDSTUDIES.NL/CONTENTS](https://countingvermeer.rkd.nl/content). The only surviving panel paintings associated with Vermeer, *Girl with the Red Hat* and *Girl with a Flute*, both in the National Gallery of Art, Washington, are discussed elsewhere in this issue: Libby et al., “Experimentation and Innovation in Vermeer’s *Girl with the Red Hat*” (via [THIS LINK](#)); Wieseman et al., “Vermeer’s Studio and *Girl with a Flute*” (via [THIS LINK](#)).
- 25 Canvas weave analysis has identified a direct match between *Woman Holding a Balance* and *Woman with a Pearl Necklace* (ca. 1662–63; Gemäldegalerie, Staatliche Museen zu Berlin), which in turn matches both *Woman with a Lute* (ca. 1663–64; Metropolitan Museum of Art, New York) and *A Lady Writing a Letter, with Her Maid* (ca. 1670; National Gallery of Ireland, Dublin), establishing a group of four paintings from the same bolt of fabric, painted over a period of roughly eight years (Johnson and Sethares, Appendix 2: *Matches*, Match 5, *Counting Vermeer*, [HTTPS://COUNTINGVERMEER.RKDSTUDIES.NL/APPENDIX-II-MATCHES/MATCH-5](https://countingvermeer.rkd.nl/appendix-ii-matches/match-5)).
- 26 Maartje Stols-Witlox, *A Perfect Ground: Preparatory Layers for Oil Paintings, 1550–1900* (London: Archetype, 2017), 140–41. Evidence for the use of commercially prepared canvases by high-life genre painters includes statistical analysis that shows that Jan Steen (1626–79) must have used locally prepared grounds as he moved among various cities during his peripatetic career; see Maya Albrecht et al., “Discovering Trends in Jan Steen’s Grounds Using Principal Component Analysis,” in *Ground Layers in European Painting 1550–1750*, proceedings of Centre for Art Technological Studies and Conservation conference 5 (“Mobility Creates Masters”), June 2019, ed. Anne Haack Christensen, Angela Jager, and Joyce H. Townsend (London: Archetype, 2020), 118–31.
- 27 The buff-colored ground on *Woman Holding a Balance* is composed of lead white, calcium carbonate, umber, and minor amounts of a black pigment (identified by PLM and EDS). The warm gray ground on *A Lady Writing* is composed of lead white, calcium carbonate, an isotropic earth pigment, and minor amounts of a black pigment (identified by PLM and EDS). According to comprehensive studies by Kühn (“Study of the Pigments and Grounds,” 176–202) and Nicola Costaras (“A Study of the Materials and Techniques of Johannes Vermeer,” in Gaskell and Jonker, *Vermeer Studies*, 151–52), as well as the more recent studies on individual paintings cited below, the range of light-colored



- grounds may include white, off-white, pale gray, warm gray, gray-brown, and brownish-white. See Libby Sheldon and Nicola Costaras, “Johannes Vermeer’s ‘Young Woman Seated at a Virginal,’” *The Burlington Magazine* 148, no. 1235 (2006): 92–93; Abbie Vandivere, Jørgen Wadum, and Emiliene Leonhardt, “The Girl in the Spotlight: Vermeer at Work, His Materials and Techniques in *Girl with a Pearl Earring*,” *Heritage Science* 8, no. 20 (2020), accessed May 2, 2022, [HTTPS://DOI.ORG/10.1186/S40494-020-0359-6](https://doi.org/10.1186/S40494-020-0359-6); Ige Verslype, “The Restoration of ‘Woman in Blue Reading a Letter’ by Johannes Vermeer,” *The Rijksmuseum Bulletin* 60, no. 1 (2012): 18; Robert Wald, “The Art of Painting: Observations on Approach and Technique,” in Sabine Haag, Elke Oberthaler, and Sabine Pénot, *Vermeer, Die Malkunst: Spurensicherung an einem Meisterwerk*, exh. cat. (St. Pölten: Residenz in association with the Kunsthistorisches Museum, Vienna, 2010), 313; and Mahon et al., “Johannes Vermeer’s *Mistress and Maid*.”
- 28 *Girl with the Red Hat* is an outlier in Vermeer’s extant oeuvre insofar as it is the only work executed on an oak panel. In a past conservation treatment, the reverse of the panel was planed down and cradled and the panel inset within a wooden collar that covers all the original edges. Because of this structure, it has not been possible to carry out wood analysis of the support; however, the panel is visually typical of oak.
- 29 Nico Van Hout groups all preparatory stages of the painting applied by brush under this term, exploring the history and etymology of “dead color” with a particular focus on the work of Rubens. See Nico Van Hout, “Functies van Doodverf: De onderschildering en andere onderliggende stadia in het werk van P. P. Rubens” (PhD thesis, Katholieke Universiteit Leuven, 2005), accessed April 24, 2022, [HTTPS://LIRIAS.KULEUVEN.BE/RETRIEVE/66039](https://lirias.kuleuven.be/retrieve/66039). Ernst van de Wetering distinguishes between a monochrome (brown) painted sketch and a colored underpaint stage used by Rembrandt and his contemporaries; see Ernst van de Wetering, “Painting Materials and Working Methods,” in Josua Bruyn et al., *A Corpus of Rembrandt Paintings*, vol. 1, 1625–1631 (The Hague: Martinus Nijhoff, 1982), 20–24.
- 30 Carol Pottasch, “Underdrawings in the Paintings of Frans van Mieris,” in Quentin Buvelot et al., *Frans van Mieris 1635–1681*, exh. cat. (Zwolle: Waanders in association with the Royal Cabinet of Paintings Mauritshuis and the National Gallery of Art, 2005), 62–68. Although that study used the term “brush drawing,” this seems to be equivalent to “painted sketch” as we define it here; during research for the 2017 exhibition *Vermeer and the Masters of Genre Painting* (Gifford and Glinsman, “Collective Style and Personal Manner”), microscopic examination of a number of paintings by Van Mieris occasionally gave evidence of design strokes below the surface in black or brown paint. Pottasch describes a third stage of the heavier brushstrokes that may relate to what we call here the underpainting stage (described there as “undermodelling”).
- 31 Visualizing chalk-based drawings, once covered with oil paint, presents a unique challenge. White chalk would be invisible to the naked eye once covered with oil paint. While black chalk can often be seen with IRR, fine lines of white or red chalk are more challenging to visualize using this technology. However XRF element mapping was used recently to visualize a painted sketch (beige paint with a high chalk content) that Rembrandt used to prepare *The Night Watch*; see “Preparatory Sketch Discovered Beneath *The Night Watch*,” press release, Rijksmuseum, Amsterdam (December 7, 2021),



accessed July 23, 2022, [HTTPS://WWW.RIJKSMUSEUM.NL/EN/PRESS/PRESS-RELEASES/PREPARATORY-SKETCH-DISCOVERED-BENEATH-THE-NIGHT-WATCH](https://www.rijksmuseum.nl/en/press/press-releases/preparatory-sketch-discovered-beneath-the-night-watch).

What appear to be dark drawn lines have occasionally been observed in Vermeer's paintings, primarily used for constructing the interior spaces: Costaras, "Materials and Techniques," 153; Wald, "Art of Painting," 198, 313–14.

- 32 The present study has found new evidence that some version of each of the stages described here appear in all four paintings at the National Gallery. In the case of *Girl with the Red Hat*, Vermeer seems to have repurposed an unfinished painting below to offer his final composition some of the visual qualities of a painted sketch and underpaint. Based on magnified surface examination and a limited number of paint samples, an earlier study had concluded that Vermeer sometimes omitted steps in the process described here (Gifford, "Painting Light," 189–90). During research for the 2017 exhibition *Vermeer and the Masters of Genre Painting* (Gifford and Glinsman, "Collective Style and Personal Manner"), examinations of a number of paintings by Vermeer from throughout his career found evidence of a brown or brown-black painted sketch—in, for example, *Girl Reading a Letter at an Open Window* (ca. 1657–59; Gemäldegalerie Alte Meister, Staatliche Kunstsammlungen, Dresden), *The Milkmaid*, *A Lady at the Virginal with a Gentleman (The Music Lesson)* (early 1660s; Royal Collection Trust); *Woman with a Pearl Necklace*, *The Geographer* (1669; Städel Museum, Frankfurt am Main), and *Woman Writing a Letter, with her Maid*. Published reports of technical studies of paintings by Vermeer sometimes describe dark underlayers that may correspond to a painted sketch, without using this term and not always characterizing the sketch as a distinct phase of the painting process. In three of these cases, Gifford and Glinsman's examinations confirmed that the published report of a dark underlayer in a specific painting is consistent with our understanding of a painted sketch applied directly over the ground layer (*Girl Reading a Letter at an Open Window*, *Lady at the Virginal with a Gentleman*, and *Woman with a Pearl Necklace*). See Costaras, "Materials and Techniques," 153; Elmer Kolfin, Carol Pottasch, and Ruth Hoppe, "The Metamorphosis of Diana," *ArtMatters: Netherlands Technical Studies in Art 1* (2002): 96–98; Karin Groen, "Painting Technique in the Seventeenth Century in Holland and the Possible Use of the Camera Obscura by Vermeer," in Wolfgang Lefèvre, ed., *Inside the Camera Obscura: Optics and Art under the Spell of the Projected Image* (Berlin: Max-Planck Institute for the History of Science, 2007), 206; Helen Howard, "Vermeer and Technique: Paint Application," in "Research: The Meaning of Making," The National Gallery (London) website, accessed May 10, 2022, [HTTPS://WWW.NATIONALGALLERY.ORG.UK/RESEARCH/ABOUT-RESEARCH/THE-MEANING-OF-MAKING/VERMEER-AND-TECHNIQUE/PAINT-APPLICATION](https://www.nationalgallery.org.uk/research/about-research/the-meaning-of-making/vermeer-and-technique/paint-application); Claudia Laurenze-Landsberg, "Neutron-Autoradiography of Two Paintings by Jan Vermeer in the Gemäldegalerie Berlin," in Lefèvre, *Inside the Camera Obscura*, 214, 216, 222; Walter A. Liedtke and Arthur K. Wheelock Jr., "Young Woman Seated at a Virginal: Technical Summary," in *The Leiden Collection Catalogue*, accessed May 2, 2022, [HTTPS://THELEIDENCOLLECTION.COM/ARTWORK/YOUNG-WOMAN-SEATED-AT-A-VIRGINAL](https://theleidencollection.com/artwork/young-woman-seated-at-a-virginal); Petria Noble and Epcó Runia, *Preserving Our*

- Heritage: Conservation, Restoration and Technical Research in the Mauritshuis* (Zwolle: Waanders, 2009), 164; Christoph Schölzel, “On the Restoration and Painterly Technique of *Girl Reading a Letter at Open Window* by Johannes Vermeer,” in Stephan Koja, Uta Neidhardt, and Arthur K. Wheelock Jr., eds., *Vermeer: On Reflection*, exh. cat. (Dresden: Sandstein in association with Staatliche Kunstsammlungen, Gemäldegalerie Alte Meister, 2021), 209–11; Sheldon and Costaras, “Johannes Vermeer’s ‘Young Woman Seated at a Virginal,’” 93; and Wald, “Art of Painting,” 201–2, 315.
- 33 PLM analysis of sample T1138 shows isotropic dark brown particles consistent with umber, and almost no black pigment.
- 34 UMBER pigment is composed of iron oxide (goethite) with 5 to 20 percent manganese minerals, which lend it a darker brown color; sienna pigment, which is closely related, is composed of primarily of goethite with a lower proportion of manganese compounds (under 10 percent). See Nicholas Eastaugh, Valentine Walsh, Tracey Chaplin, and Ruth Siddall, *The Pigment Compendium 2017*, rev. ed. (e-version), s.v. “Umber,” “Sienna” (London: The Pigmentum Project, 2016).
- 35 Libby et al., “Experimentation and Innovation in Vermeer’s *Girl with the Red Hat*” (via [THIS LINK](#)).
- 36 Vermeer’s use of colored underpaint has been previously discussed in the literature (sometimes using other terminology); see Gifford and Glinsman, “Collective Style and Personal Manner,” 66; Groen, “Possible Use of the Camera Obscura,” 205; Howard, “Vermeer and Technique: Paint Application”; Kolfin, Pottasch, and Hoppe, “Metamorphosis of Diana,” 96–97; Noble and Runia, *Preserving Our Heritage*, 164, 174; Mahon et al., “Johannes Vermeer’s *Mistress and Maid*” (sections titled “New Sampling” and “Discussion”); Schölzel, “On the Restoration,” 209–15; Wald, “Art of Painting” 202, 315; Vandivere, Wadum, and Leonhardt, “Girl in the Spotlight” (section titled “What can we find out about layers beneath the surface?”).
- In addition to the paintings at the National Gallery, Gifford and Glinsman’s examinations of paintings by Vermeer (“Collective Style and Personal Manner”) found colored underpaint in at least ten of Vermeer’s paintings, confirming a published report in five of these cases.
- 37 Literature references for Vermeer’s use of a textured and brushmarked underpaint include Costaras, “Materials and Techniques,” 154; Laurenze-Landsberg, “Neutron Autoradiography,” 216; Mahon et al., “Johannes Vermeer’s *Mistress and Maid*” (section titled “The background”); Abbie Vandivere et al., “Revealing the Painterly Technique beneath the Surface of Vermeer’s *Girl with a Pearl Earring* Using Macro- and Microscale Imaging,” *Heritage Science* 7, no. 64 (2019), accessed May 2, 2022, [HTTPS://DOI.ORG/10.1186/S40494-019-0308-4](https://doi.org/10.1186/S40494-019-0308-4) (section titled “Underlayers, outlines and pentimenti revealed by multispectral infrared reflectance imaging”); Vandivere, Wadum, and Leonhardt, “Girl in the Spotlight” (section titled “Which techniques did Vermeer use to create subtle optical effects?”).
- Gifford and Glinsman’s examinations of paintings by Vermeer (“Collective Style and Personal Manner”) found that every example of Vermeer’s colored underpaint had been applied with a brushmarked texture; in two cases this observation confirmed a published report of textured underpaint.

- 38 Jørgen Wadum, "Contours of Vermeer," in Gaskell and Jonker, *Vermeer Studies*, 210–23; Annelies van Loon et al., "Beauty is Skin Deep: The Skin Tones of Vermeer's *Girl with a Pearl Earring*," *Heritage Science* 7, no. 102 (2019), accessed May 2, 2022, [HTTPS://DOI.ORG/10.1186/S40494-019-0344-0](https://doi.org/10.1186/s40494-019-0344-0).
- 39 Gifford, "Painting Light," 190–92.
- 40 Particle size measurement during PLM analysis of pigment samples found that Vermeer's lead-tin yellow particles in his underpaint ranged from 3 to 7  $\mu\text{m}$ ; lead-tin yellow in his final paint measured 2 to 4  $\mu\text{m}$ . It is possible that Vermeer used different types of lead-tin yellow in his underpaint and final paint; where this pigment was used in the underpaint it typically shows evidence of lead soap formation (which probably also contributed to the texture seen in fig. 35), while in the final paint there is almost no evidence of lead soap formation associated with lead-tin yellow. In the seventeenth century, lead-tin yellow was available in various grades; see Johannes Alexander van de Graaf, "Het De Mayerne manuscript als bron voor de schildertechniek van de barok. Brit. Mus., Sloane 2052" (PhD thesis, Rijksuniversiteit te Utrecht, 1958), 144–45, nos. 23, 24. Two types of lead-tin yellow also have been observed in at least one other painting attributed to Vermeer; see Sheldon and Costaras, "Johannes Vermeer's 'Young Woman Seated at a Virginal,'" 93.
- 41 The underpaint is also somewhat more apparent where the final paint has been slightly abraded. Similar colored underpaint below flesh tones has been observed in *Girl with the Pearl Earring* (Van Loon et al., "Beauty is Skin Deep").
- 42 Textured underpaint is visible in other paintings, such as *Mistress and Maid* (The Frick Collection, New York). Brushmarked underpaint is visible in the IRR throughout the original tapestry design, below the now-dark background; see Mahon et al., "Johannes Vermeer's *Mistress and Maid*," fig. 2, for IRR image.
- 43 It is possible that small amounts of pigments of high atomic weight (such as lead white) in the overlying paint layer can suppress the signal from the layers below (the matrix effect) and so modify the appearance of the underlayer in element maps. In this case, however, the difference between the smooth application pattern of lead white in the final paint (seen in the M-line map for lead) and the brushmarked pattern of lead-tin yellow in the underpaint (seen in the tin map) seems clearly related to a difference in paint handling between the final paint and underpaint.
- 44 Lead white was used only sparingly in upper paint layers, primarily in the lighted folds, so in this case it is unlikely that this dense material would interfere with the signal from underlying layers, except for a few brighter highlighted areas.
- 45 XRF mapping stopped just short of the painting's edge, but the vigor of the brushwork seen in the map suggests that these horizontal strokes must have continued across the few centimeters that were not mapped. If Vermeer worked on a canvas stretched trampoline-fashion on a working strainer, what is now the tacking edge would have been empty grounded canvas just outside the image area.
- 46 In addition, there are mixtures of white lead in the highlights of the tabletop and yellow ochre in some limited areas (pigment identifications based on PLM, SEM-EDS, XRF, FORS).
- 47 Van de Graaf, "De Mayerne," 71–73, 147–48, 153–54, 164–65, nos. 27a, 34b, 41.

- 48 Gifford and Glinsman, "Collective Style and Personal Manner," 69–70. A copper-based drier can be inferred from high levels of copper seen in XRF analysis of the paint surface and in SEM-EDS analysis of paint cross sections. In these cases, individual verdigris particles are rarely observed by magnified examination or in paint cross-sections, as the pigment can dissolve in the oil medium, especially if finely ground.
- 49 Dark underpaint based on verdigris has been observed elsewhere in Vermeer's paintings below now-blue final paints, perhaps hinting that these areas might originally have had a greener hue: below the tablecloth of *Mistress and Maid* and the tapestry in *The Art of Painting*. See Mahon et al., "Johannes Vermeer's *Mistress and Maid*," 6–7, 9–10; and Robert Wald, "The Art of Painting," 202, 230 (fig. 48), 315.
- 50 The appearance of the tablecloth in *Woman with a Pearl Necklace* is similar to that seen in the XRF copper map of *Woman Holding a Balance*, with brushmarking that plots folds, shadows, and highlights. Using autoradiography, Claudia Laurenze-Landsberg concluded that in the Berlin painting Vermeer used a copper-based pigment, presumably azurite, in the carbon black-containing underpaint of the tablecloth, though no pigment analysis confirming this identification was published; this publication also notes the surprising freedom of the underlayers (Laurenze-Landsberg, "Neutron-Autoradiography," 214, 216). Copper was also detected in the underpaint of *Mistress and Maid*, in the patterned "tapestry" detected beneath the upper paint layers, representing an earlier version of Vermeer's intended background for the painting. This layer, which is not green, contains black, earth pigments, and copper. Considering that the elaborate design is visible in the XRF copper map, it is plausible this layer is the underpaint, to which Vermeer added a copper drier. See Mahon et al., "Johannes Vermeer's *Mistress and Maid*," fig. 3e, for the XRF copper map. In *The Art of Painting*, however, a visibly green underlayer below the tablecloth was observed through losses in the final paint; see Wald, "Art of Painting," 202, 230 (fig. 48), 315.
- 51 Use of a drier would not be the only factor that influenced the texture of the brushwork; factors that were not analyzed in the present study, such as the preparation of the oil medium and the pigment-binder ratio, also come into play. In some of Vermeer's paintings from earlier in his career, the final paint is far more textured than in his later works (see, for example, *The Milkmaid* and *Girl Reading a Letter at an Open Window*); comparative analysis of the paint medium and driers in the under- and final paints in those works could be informative in tracing the evolution of Vermeer's practice over his career.
- 52 Gifford, "Fine Painting and Eloquent Imprecision," 169; Gifford and Glinsman, "Collective Style and Personal Manner," 73, 80. Previously, Rembrandt had used a much bolder blackish resketching as an independent stage in the painting process, in which he reemphasized and revised much of the composition; see E. Melanie Gifford, "Evocation and Representation: Rembrandt's Landscape Painting Technique," in Christiaan Vogelaar and Gregor J. M. Weber, eds., *Rembrandt's Landscapes*, exh. cat. (Zwolle: Waanders in association with Gemaldegalerie Alte Meister, Staatliche Museen Kassel/Stedelijk Museum De Lakenhal, Leiden, 2006), 126–29. Jan Lievens similarly used black paint to revise and emphasize features of the brown painted sketch, as in *Pilate Washing His*

- Hands* (ca. 1625–26; Stedelijk Museum De Lakenhal, Leiden) and *Christ at the Column* (ca. 1625–26; Kremer Collection).
- 53 Occasional fine black lines that may lie over the underlayers have also been observed in *Girl with a Pearl Earring*, but it has not been noted whether these lines might include a copper drier (Vandivere et al., “Revealing the Painterly Technique”).
- 54 Pigments in various paint mixtures of the yellow jacket were identified using a combination of PLM, FORS, and XRF-IS. See Dooley et al., “Comparing Vermeer’s Painting Techniques,” by Delaney / Dooley for detailed XRF maps. The use of yellow lake is inferred from the presence of high proportions of calcium carbonate, identified in all the samples taken from the jacket. A combination of lead-tin yellow and a yellow lake on a calcium-based substrate has also been identified in the yellow cloak of *Young Woman Seated at a Virginal* (The Leiden Collection, New York) (see Valerie Sivel et al., “The Cloak of *Young Woman Seated at a Virginal*: Vermeer, or a Later Hand?,” *Art Matters, Netherlands Technical Studies in Art 4* {2007}: 92–93) and in the yellow jacket of *The Guitar Player* (Helen Howard, “Vermeer and Technique: Vermeer’s Palette,” in “Research: The Meaning of Making,” The National Gallery {London} website, accessed March 10, 2022, [HTTPS://WWW.NATIONALGALLERY.ORG.UK/RESEARCH/ABOUT-RESEARCH/THE-MEANING-OF-MAKING/VERMEER-AND-TECHNIQUE/VERMEERS-PALETTE](https://www.nationalgallery.org.uk/research/about-research/the-meaning-of-making/vermeer-and-technique/vermeers-palette)).
- 55 Van Hout, “Functies van Doodverf,” 69.
- 56 Gifford and Glinsman’s examinations of paintings by Vermeer (“Collective Style and Personal Manner”) observed that Van Mieris’s underpaint was at most slightly more brushmarked than his extremely smooth final paints.
- 57 See, for example, *A Nurse and a Child in an Elegant Foyer* (1663; National Gallery of Art, Washington, DC) and *A Woman Standing at a Harpsichord, a Man Seated by Her* (ca. 1675–1680; National Gallery, London).