Vermeer's Secrets

his exhibition unveils the often surprising results of recent research into the National Gallery's four paintings by and attributed to Johannes Vermeer—as well as two 20th-century forgeries. For two years, an interdisciplinary research team studied the works intensively and collaboratively to understand how Vermeer achieved his paintings' unique visual effects.

The paintings were examined using a variety of techniques, including magnified examination of the surfaces, analysis of microsamples, and the latest advances in scientific imaging. The findings expanded—and in some cases, completely altered—the understanding of Vermeer's working process.

Pairing luminous paintings with detailed technical images, *Vermeer's Secrets* celebrates the sophistication of Vermeer's palette and the controlled finesse required to create the smooth and delicate surfaces of his genre paintings. Yet beneath these polished surfaces, a different image emerges: of an impetuous, even impatient artist. This exhibition reveals how Vermeer created some of his characteristic visual effects, and how other artists sought to imitate those effects—whether during Vermeer's own lifetime or centuries later.

Johannes Vermeer

he Dutch painter Johannes Vermeer was born in Delft in 1632 and lived there until his death in 1675. Only about 35 paintings by him are known today—mostly intimate scenes of everyday life or images of serene young women—and he probably did not paint many more than that. Vermeer carefully crafted each painting, selecting his materials and applying them in specific ways to achieve precise effects of light and mood. Although many aspects of his artistic practice were typical for the time, his paintings also display an independent approach to materials and technique.

Vermeer's work was widely admired during his lifetime by collectors in Delft and by his fellow artists, but the small number of paintings he produced undoubtedly limited the extent of his fame. Not until the late 19th century did Vermeer's quiet, evocative images begin to achieve the global recognition and appreciation they enjoy today.

Exploring the Surface

lose examination of *A Lady Writing* reveals how Vermeer manipulated his materials and techniques to achieve subtle and specific surface effects. In the woman's face, Vermeer applied the paint with delicately interwoven brushstrokes to achieve smooth gradations of light and shadow.

Zooming in on the sleeve of the woman's yellow jacket, the close-up view at right reveals the thoughtfulness of Vermeer's technique. He used comparatively fluid paints, which allowed individual brushstrokes and dotted highlights to settle as they dried, creating the painting's smooth surface. Analysis of microscopic paint samples and maps obtained from imaging spectroscopy show that Vermeer used four different yellow pigments: two types of lead-tin yellow, yellow ochre, and likely yellow lake. The map at right shows that bright highlights on the lit side of the sleeve have a higher proportion of lead-tin yellow, whereas shadows contain more yellow ochre.

Compositional Changes

Scientists and conservators often use cameras sensitive to infrared light to look for features beneath a painting's surface. Refinements in infrared imaging technology and digital processing software have made it possible to visualize an artist's working process more clearly than before. For example, a false-color infrared reflectance image was used to visually separate the pigments in A Lady Writing. The image shown at left reveals that Vermeer first painted the quill pen in a more vertical position to suggest active writing. On the right, the same imaging method reveals that in the initial design for Woman Holding a Balance, Vermeer painted the scale at an angle. In the final painting, he positioned it parallel to the picture plane to represent the two pans in perfect equilibrium.

fter two years of in-depth comparative analysis, curators, conservators, and scientists have concluded that *Girl with a Flute* was not, in fact, painted by Vermeer. The artist who created this work was intimately familiar with Vermeer's unique working methods, and used the same materials and techniques, but was unable to achieve Vermeer's level of delicacy or expertise. Until now, scholars have never believed that Vermeer had pupils or studio assistants. Yet the material and technical evidence suggests otherwise. Who could have made this painting?

There are many possibilities. The mystery artist could have been a pupil or apprentice in training, an amateur who paid Vermeer for lessons, a freelance painter hired on a project-by-project basis, or even a member of Vermeer's family. Although we do not yet know who painted *Girl with a Flut*e, the possibility that Vermeer had a studio is exciting. It counters the long-held belief that Vermeer was a lone genius, instead suggesting that he might have been a mentor and educator, training a future generation of artists.

n the adjacent wall are two paintings—Girl with a Flute and Girl with the Red Hat—that have striking visual similarities. Both are informal, bust-length depictions of women wearing fanciful hats and large pearl earrings. Both include a chair with lion's-head finials, and a background wall hung with a tapestry. The women even vaguely resemble each other: long, slender faces, dark brown eyes, and similar expressions of focused gazes and slightly parted lips. The paintings are nearly identical in size and are both—unusually for Vermeer—painted on wood panels.

Despite these resemblances, scholars have long questioned whether Vermeer painted *Girl with a Flute*. Compared to *Girl with the Red Hat*, the brushwork in *Girl with a Flute* is blocky and the figure is awkwardly positioned. To better understand the relationship between these two paintings, researchers analyzed them with the same technical methods used to study Vermeer's paintings in the first gallery. They discovered that many, but not all, of the materials used in *Girl with a Flute* are consistent with those used by Vermeer, but the paint handling is very different.

Similar Materials

In addition to the compositional similarities shared by *Girl with the Red Hat* and *Girl with a Flute*, there are also material similarities: evidence of the same pigments in both paintings.

In each painting, broad hats cast a dull, greenish shadow across the women's faces. Analysis of the pigments in these areas reveals that the paint mixtures include a green earth: a highly unusual pigment choice for flesh tones in Dutch paintings. In fact, its use in flesh-tone shadows has not been observed in works by any of Vermeer's contemporaries.

The images on the left show that the lips of both women were blocked in using the mercury-containing red pigment vermilion on the lit side of their faces. Vermilion is also found in the pinkish flesh tones.

Different Techniques

espite the two paintings' similarities in composition and in pigments used, there are key differences in the way each painting was executed. In Girl with the Red Hat, Vermeer created the subtle green shadows by sensitively modulating the color and carefully blending the edges of the paint. In Girl with a Flute, the green shadows were much more heavily applied, creating a blotchy appearance under the nose and along the jawline.

Focusing on the lips, in *Girl with the Red Hat* Vermeer used tiny dots of highlight that incorporate the faint pink color around them. The corresponding highlight in *Girl with a Flute*, however, is a curious blue-green, a color that has no logical place on the inside of a mouth.

Vermeer ground his pigments coarsely for his underpaint, but for the final paint layers he ground them more finely to achieve his delicate surfaces. The artist of *Girl with a Flute* inexplicably reversed this order: the pigments used in the final paint are so coarsely ground that the surface has an almost granular character. The images at left show that the coarsely ground paint contains a mass of broken bristles, indicating either an old or poorly made brush, or that the artist used unusual force in applying the paint.

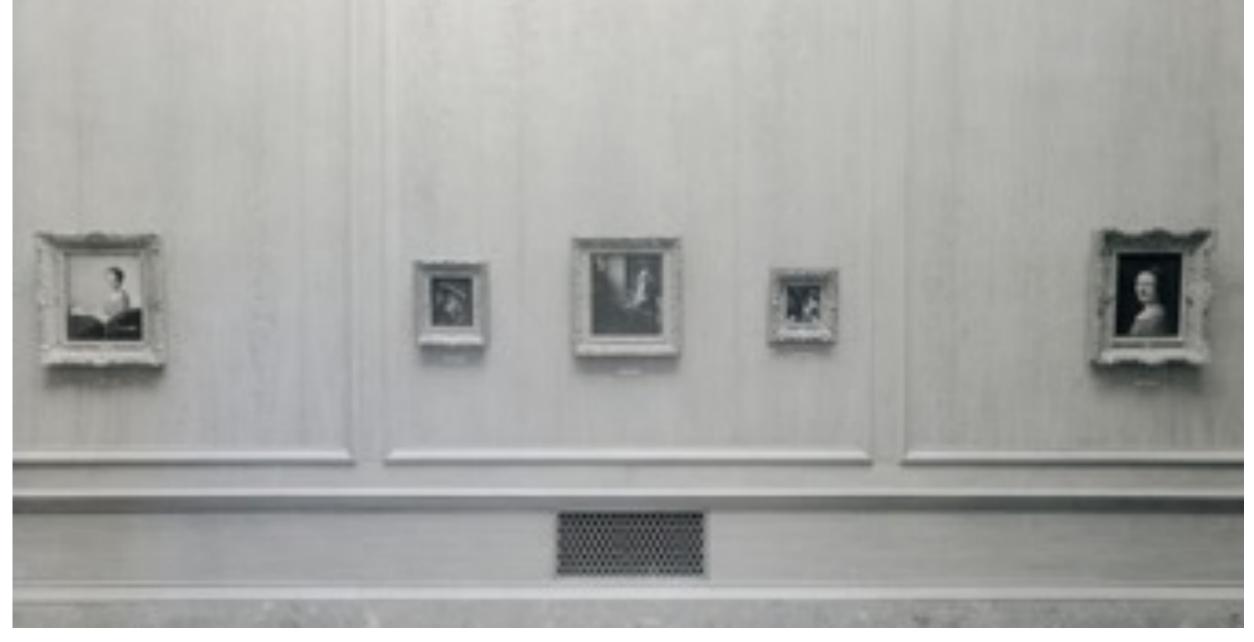
In the early 1970s, an x-ray image revealed that Vermeer painted Girl with the Red Hat on top of a partially completed portrait of a man in a black hat. Rather than scraping away the image or applying a covering layer over it, Vermeer painted directly over the portrait after simply rotating the panel 180 degrees.

Over the last 20 years, newer and more advanced imaging and processing methods have allowed curators, conservators, and scientists to gain a deeper understanding about the composition hidden below the surface. The complementary imaging modalities shown here help to visually separate paint on the surface and in layers below, making it possible to see the man in greater detail than ever before. One day, it may even be possible to identify the man—or the artist who painted him.

hen *The Lacemaker* and *The Smiling Girl* first appeared on the art market in the mid-1920s, they caused a sensation: unseen masterpieces by Johannes Vermeer! In the 1920s, Vermeer was a newly rediscovered artist. Eager to identify and own paintings by him, scholars and connoisseurs were sometimes uncritical in accepting works as his—and collectors were uncritical in acquiring them. It was in this climate of "Vermeer fever" that Andrew W. Mellon purchased these two paintings, which became part of the National Gallery of Art in 1937.

Almost as soon as the paintings arrived at the National Gallery, critics began to express doubts about their authenticity. The paintings' stiff, awkward figures, clumsy brushwork, and inattention to anatomical

proportions were inconsistent with Vermeer's work. It was not until 1973, however, that a scientific research study showed that not only were these paintings not Vermeers, but they were in fact forgeries.



Dutch paintings in the National Gallery, c. 1945 (Image courtesy of the National Gallery of Art Archives)

A Forger's Tricks

The Lacemaker is heavy and rounded—quite different from the fine, angular pattern characteristic of an aged oil painting like Woman Holding a Balance. Pigment analysis of both The Lacemaker and The Smiling Girl reveals synthetic ultramarine, a pigment unavailable before the 19th century, and lead chromate, a yellow pigment first produced in 1811.

It seems likely that Theodorus van Wijngaarden (1874–1952), a Dutch painter, restorer, and art dealer, was the forger of *The Lacemaker* and *The Smiling Girl*. He was a friend and associate of the most notorious Vermeer forger, Han van Meegeren (1889–1947), and was known to purchase old canvases at thrift stores and "restore" them for sale. To give his forgeries a more authentic look, he seems to have let them dry quickly in the sun to expedite the cracking. He then enhanced the cracks by pressing the canvases against a beach ball. The paintings were further "aged" by giving them a yellow tint to imitate the look of old, discolored varnish.

Beneath the Surface

ermeer began *Woman Holding a Balance* with a monochrome painted sketch, then quickly applied a bold underlayer to plot out forms, colors, and patterns of illumination within the composition. The false-color infrared reflectance detail at left shows that in his underpaint, Vermeer applied thick strokes of lead white to suggest a splash of sunlight on the back wall, which in the final paint he smoothed and modulated to a soft glow. Using the same imaging method, researchers also identified the presence of a black underlayer in the tablecloth.

On the right, a different imaging method, used to map the chemical element copper, suggests that Vermeer added a copper-containing material to hasten the drying of the black. The copper map shows vigorous brushstrokes, and folds in the tablecloth that are different from those on the surface. It seems Vermeer was eager for this underlayer to dry so that he could proceed to the painting's final stages.

Conservation & Science

he National Gallery's conservation division includes departments that specialize in the treatment, preservation, and scientific research of paintings, works on paper, photographs, objects, and textiles. Paintings conservators, who often train as visual artists, work to preserve a painting's structural stability and aesthetic appearance. To understand a painter's working process and guide treatment decisions, they closely study paintings in visible and ultraviolet light and with stereo microscopes. They then compare their observations with information gleaned from technical images.

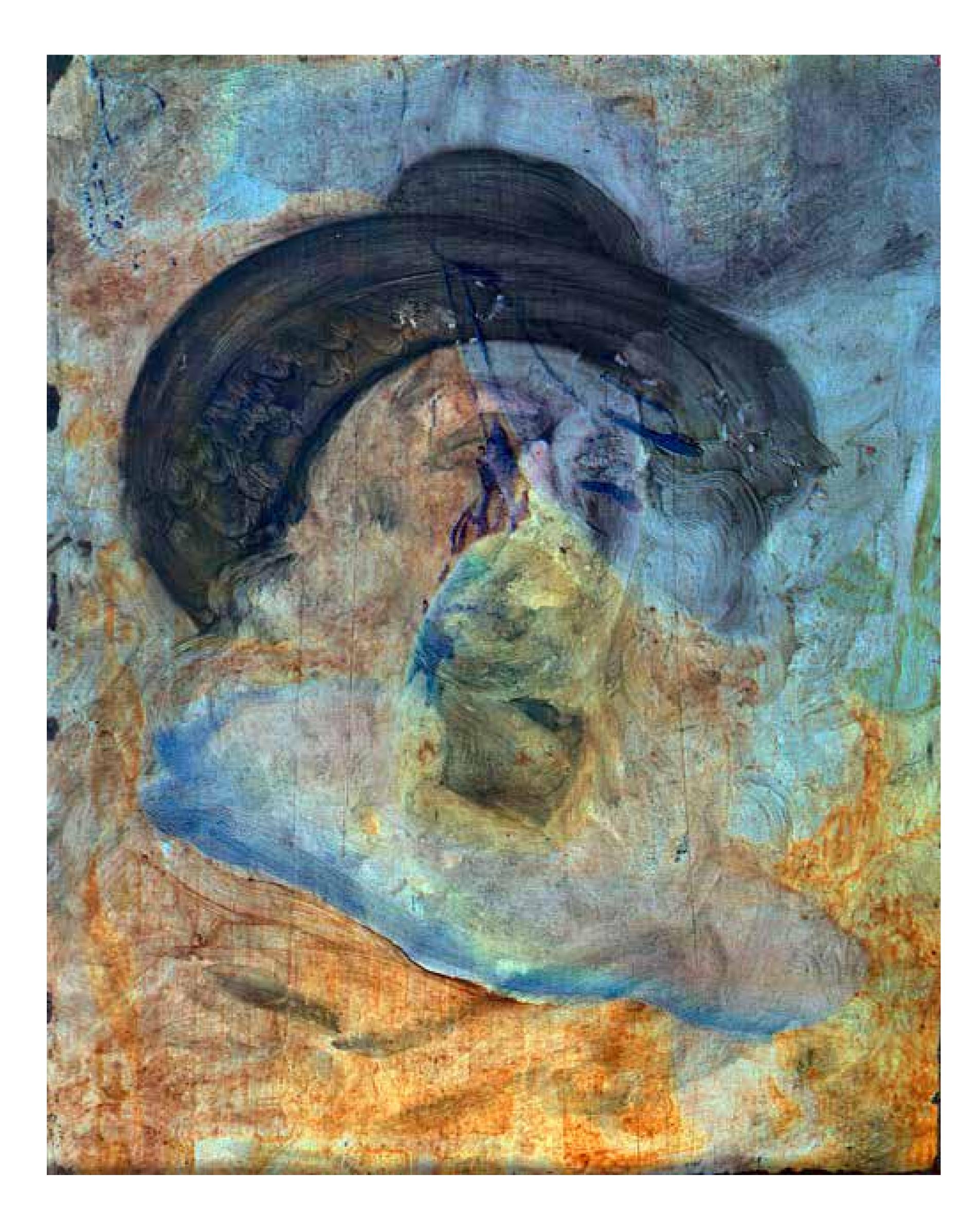
The scientific research department uses analytical techniques drawn from the fields of chemistry, material science, and even optics to investigate the working methods and materials of artists. Imaging scientists, who typically have a background in the physical sciences, collect hundreds of images in different parts of the electromagnetic spectrum, spanning the x-ray, visible, and infrared spectral regions. This method is known as imaging spectroscopy. When combined with insights gathered from conservation findings, these images and results from spectral analysis help scholars from different disciplines construct a fuller picture of an artist's materials and techniques.



An image collected with x-rays, rotated 180 degrees

X-ray imaging is often an initial step to understanding how the paint layers were applied, by visualizing pigments that contain elements with a high atomic weight, like lead or mercury.

Here, the x-ray image helps reveal the man's face, white collar, and collar tie (all painted with substantial amounts of lead white pigment), in addition to portions of the woman's face and costume.



Digitally processed false-color image derived from the infrared reflectance images, rotated 180 degrees

Reflectance imaging spectroscopy exploits the way in which artists' materials reflect visible and infrared light to identify and map chemical features. This technique can also distinguish details of the underlying painting different from those seen in an x-ray image.

Here, digital processing of infrared reflectance images revealed the black pigment used for the man's broad-brimmed hat, the locks of his long, curling hair, and the brushstrokes defining his eyes, his chin, and the cape across his shoulder.



Digitally processed image derived from the x-ray fluorescence lead maps, rotated 180 degrees

X-ray fluorescence imaging spectroscopy uses emitted x-ray radiation to identify and map chemical elements such as iron, copper, or lead, which are commonly found in artists' pigments.

To obtain this view of the hidden man, scientists mapped the use of lead and processed the image to remove most of the forms associated with the woman. The man's face and costume are now more visible than ever before. It is also possible to discern long brushstrokes in the lighted background, where they curve around the brim of the hat, and the short, diagonal strokes that describe the garment draped over the man's shoulder.

[Room 1, G34]

Johannes Vermeer

Dutch, 1632–1675

A Lady Writing

c. 1665

oil on canvas

National Gallery of Art, Washington, Gift of Harry Waldron Havemeyer and Horace Havemeyer, Jr., in memory of their father, Horace Havemeyer

From gleaming pearls to soft flesh, a gentle illumination caresses each form and contour within this painting. Elegant attire and opulent writing accessories—including a silver inkstand and a decorative box for storing supplies—suggest this woman is a member of the educated elite. Although her disarming outward gaze and slight smile seem to encourage our approach, whatever thoughts she has inscribed on the paper remain private, revealed only to their intended recipient. On the wall is a painting with a bass viol, a reminder of the traditional association of music with love and a clue that the letter concerns matters of the heart.

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Johannes Vermeer

Dutch, 1632-1675

Woman Holding a Balance

c. 1664

oil on canvas

National Gallery of Art, Washington, Widener Collection

In this quiet interior, a young woman holds a balance suspended from her outstretched hand. On the table, glittering in the low light, are objects to be weighed. A painting of the Last Judgment on the wall behind the woman offers a potential clue to the painting's meaning: faithful Christians were encouraged to live a life of moderation, to examine their consciences and weigh their sins as if facing Judgment Day. Vermeer positioned the woman midway between the image of eternal judgment and the earthly riches on the table to stress the importance of making wise choices in life.

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[Room 2, G_{32}]

Johannes Vermeer

Dutch, 1632–1675

Girl with the Red Hat

c. 1669

oil on panel

National Gallery of Art, Washington, Andrew W. Mellon Collection

Dressed in a lush blue robe, a young woman stares out at the viewer from beneath a broad, feathery, cherry-red beret. She seems to radiate energy—a feeling that stems as much from the vibrant color combinations as from the directness of her gaze. Her distinctive features may seem portraitlike, but the painting is a *tronie*: an informal head study modeled on a real person, yet primarily intended to study expression, texture, costume, and accessory. The unusual hat is a key part of what makes this painting a *tronie*. It served as a vehicle for Vermeer to contrast the shadow cast by its brim with the light glistening on the woman's moistened lips.

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Studio of Johannes Vermeer *Girl with a Flute*

c. 1669/1675
oil on panel
National Gallery of Art, Washington,
Widener Collection

A woman sits before a tapestry-hung wall in a chair with lion's-head finials, wearing a fur-trimmed jacket and a shallow conical hat. Resting her arms on a ledge and holding a recorder in her left hand, she leans forward with parted lips and an open gaze. Light streaming from the right wraps her figure in a bold pattern of light and shade. The formal similarities with Vermeer's *Girl with the Red Hat*, and the paintings' nearly identical sizes and wood panel supports, have led many scholars to view them as companion pieces. Close analysis, however, reveals that this painting was likely executed by a studio associate of Vermeer's who understood the Dutch artist's process and materials but was not able to master them.

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Imitator of Johannes Vermeer *The Smiling Girl*

c. 1925 oil on canvas

National Gallery of Art, Washington, Andrew W. Mellon Collection

Imitator of Johannes Vermeer *The Lacemaker*

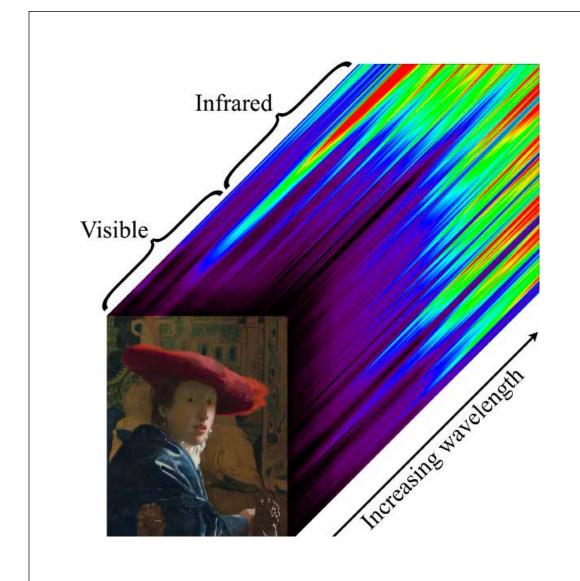
c. 1925

oil on canvas

National Gallery of Art, Washington, Andrew W. Mellon Collection

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The instrument in this case is an infrared hyperspectral reflectance imaging system. It consists of illumination lamps, an imaging lens, and an imaging spectrometer that functions like a prism, dispersing light into narrow spectral bands that are collected with an infrared camera. Hundreds of infrared spectral images are collected when a painting is scanned by the imaging system. A reflectance image cube, like the one pictured, can be generated when a visible hyperspectral reflectance system is used along with the instrument shown here.

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Compositional Changes



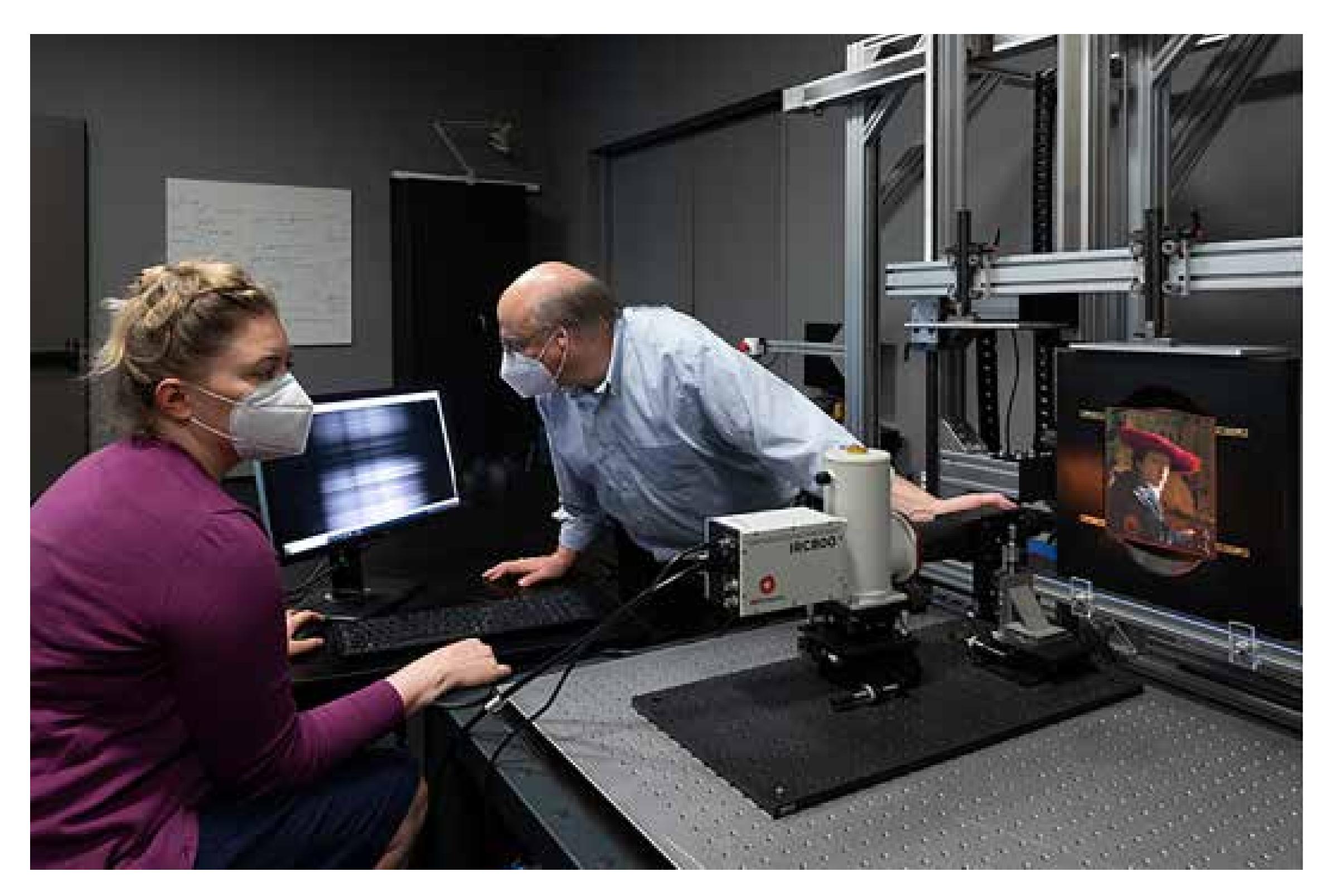
Detail of A Lady Writing

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Conservation and Scientific Research



Paintings conservator Dina Anchin examines a painting through a stereo microscope.



Imaging scientists Kate Dooley and John Delaney use infrared reflectance imaging spectroscopy to analyze *Girl with the Red Hat*.

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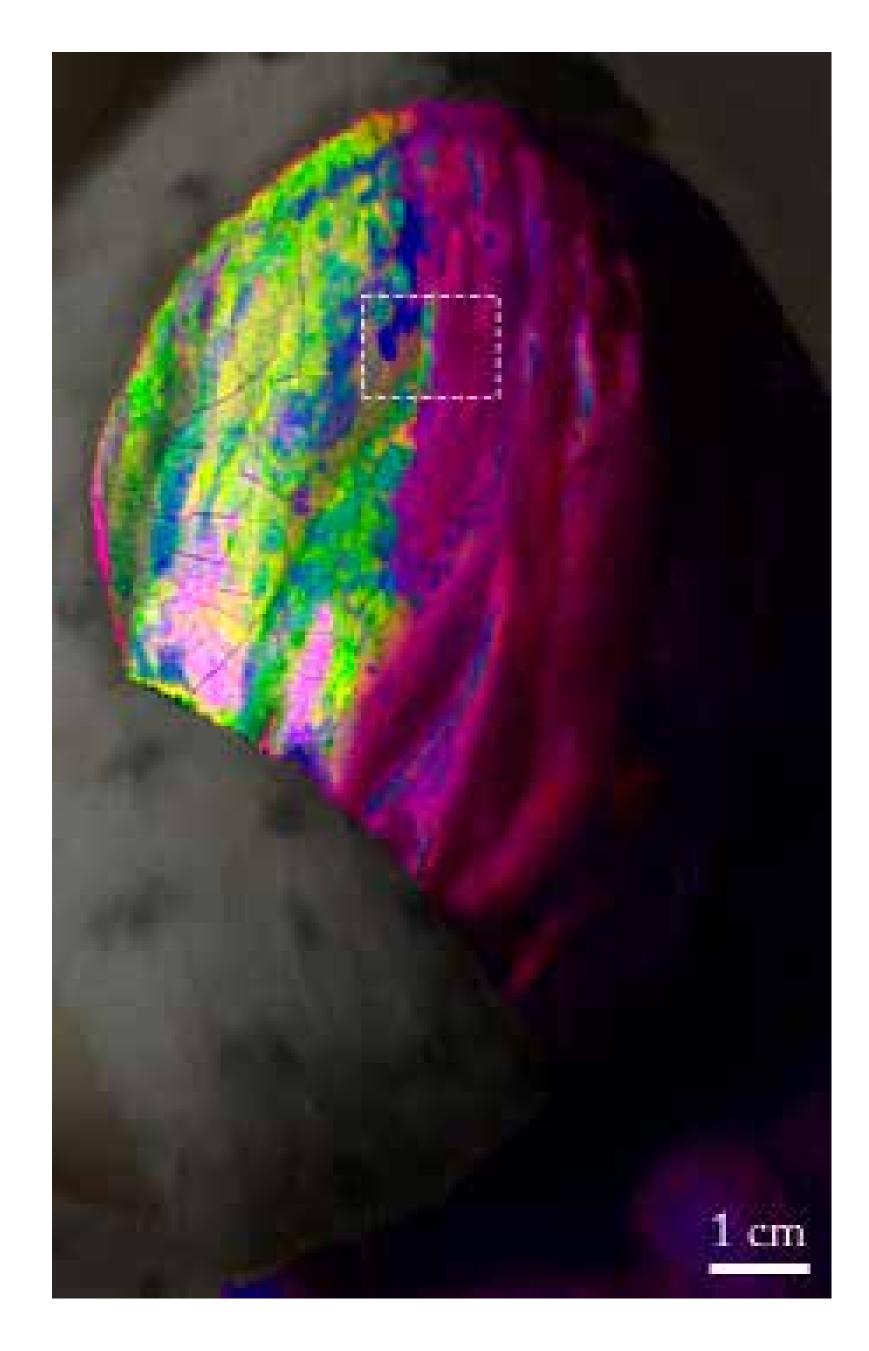
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Detail showing the subtle color variations in the yellow sleeve



Detail of A Lady Writing



Colorized map of final paints
lead-tin yellow (color 1)
lead-tin yellow (color 2)
yellow ochre

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Compositional Changes



False-color infrared image of A Lady Writing



Detail of A Lady Writing



Detail of false-color infrared image of A Lady Writing

Compositional Changes

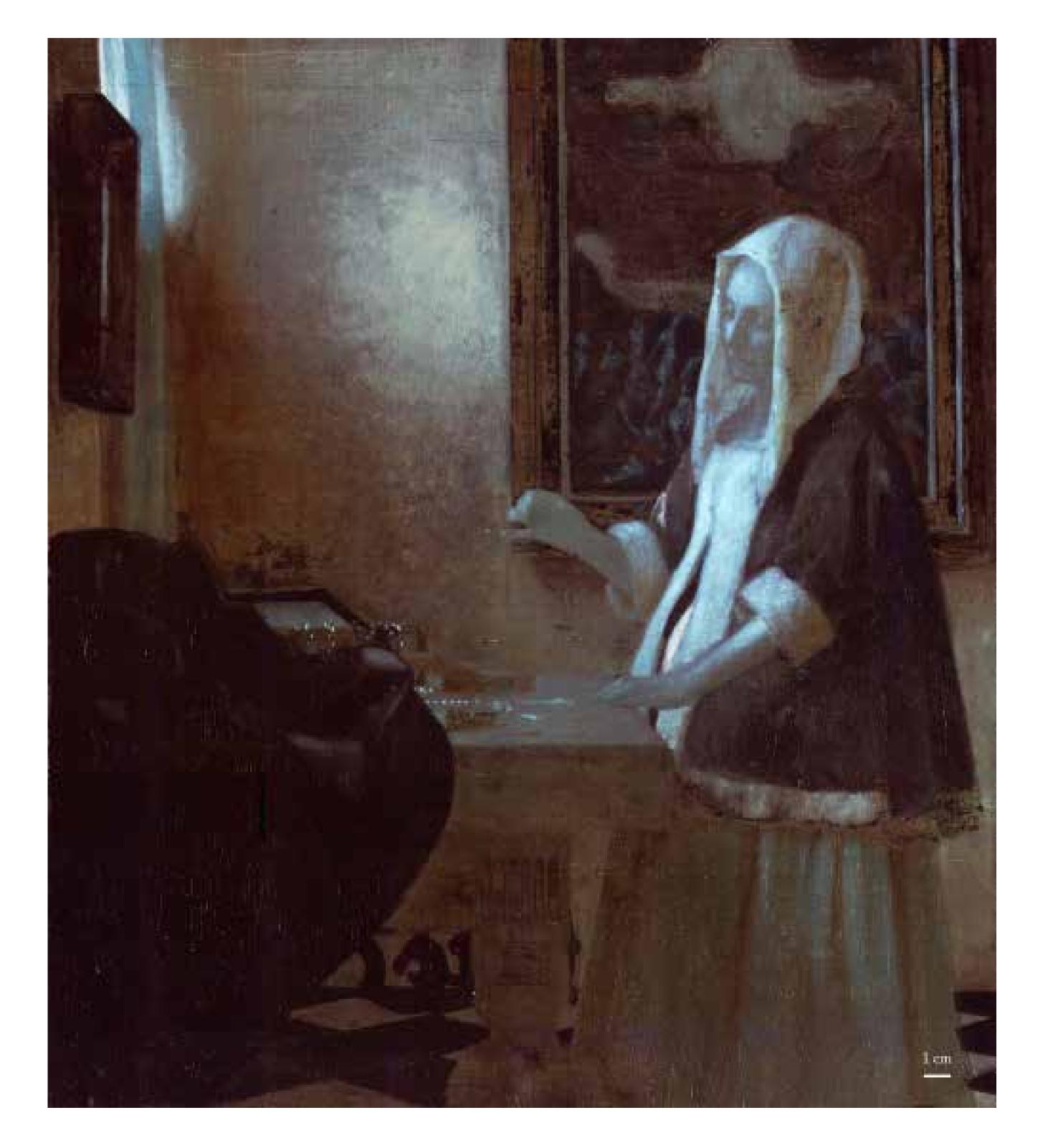
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Detail of Woman Holding a Balance



Detail of false-color infrared image of Woman Holding a Balance



False-color infrared image of Woman Holding a Balance

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Detail of false-color infrared image of Woman Holding a Balance showing brushstrokes beneath the surface on the back wall



Map of the chemical element copper in Woman Holding a Balance. Lighter areas of the image indicate a higher amount of copper.



Detail of copper map showing area in white box (left). The copper-containing brushstrokes in the area of the tablecloth differ significantly from the painting's visible surface.

A Forger's Tricks





Digitally processed detail images showing crack pattern in *The Lacemaker* (above) and *Woman Holding a Balance* (below)



Detail of *Girl with a Flute* showing areas with embedded brush bristles



Photomicrograph of area in white box (left) showing embedded bristles

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Different Techniques

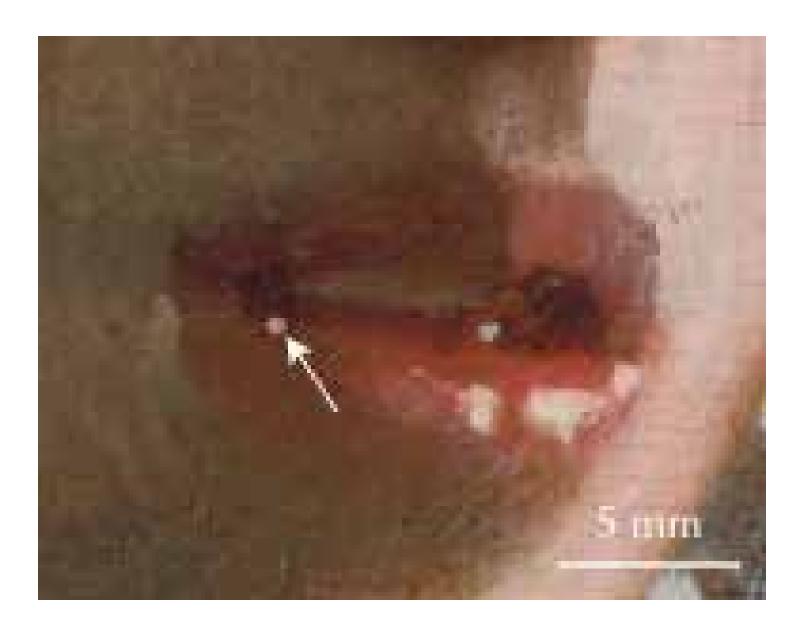
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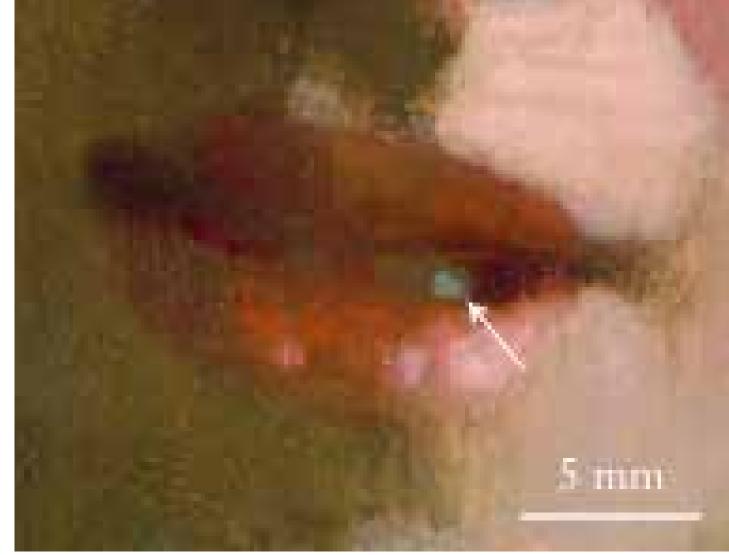
Detail of *Girl with the Red Hat* showing finely blended paint



Detail of *Girl with a Flute* showing paint applied with heavy brushstrokes



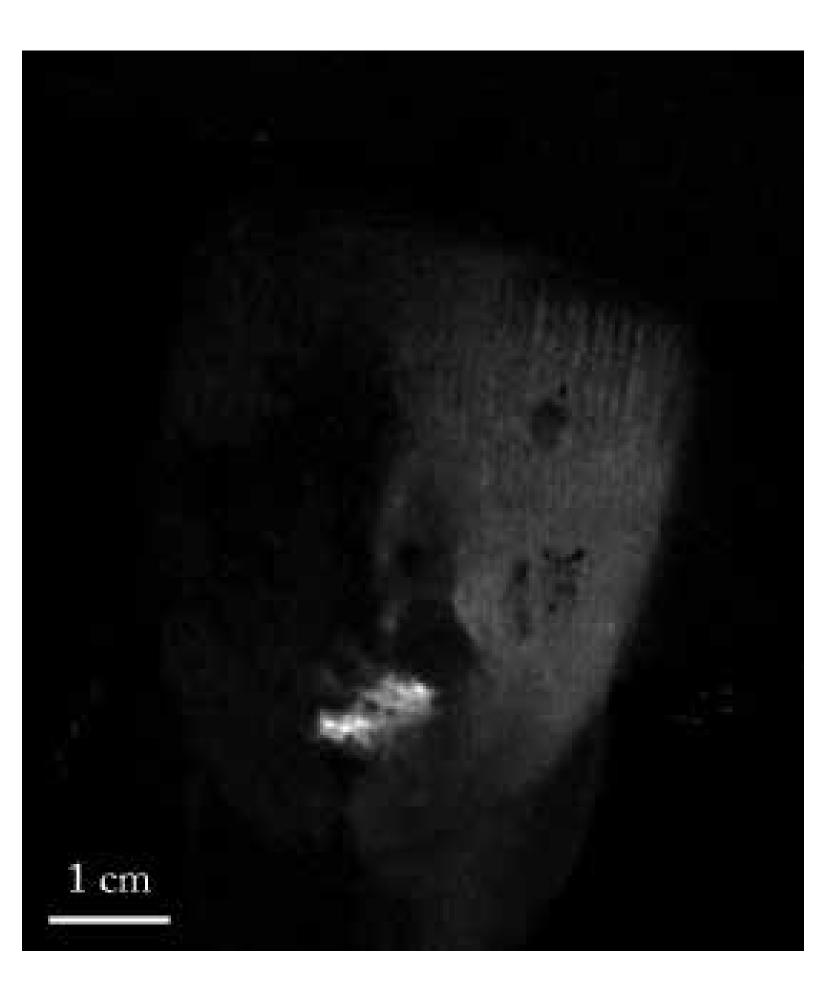
Detail of *Girl with the Red Hat* showing a pink highlight



Detail of *Girl with a Flute* showing a blue-green highlight

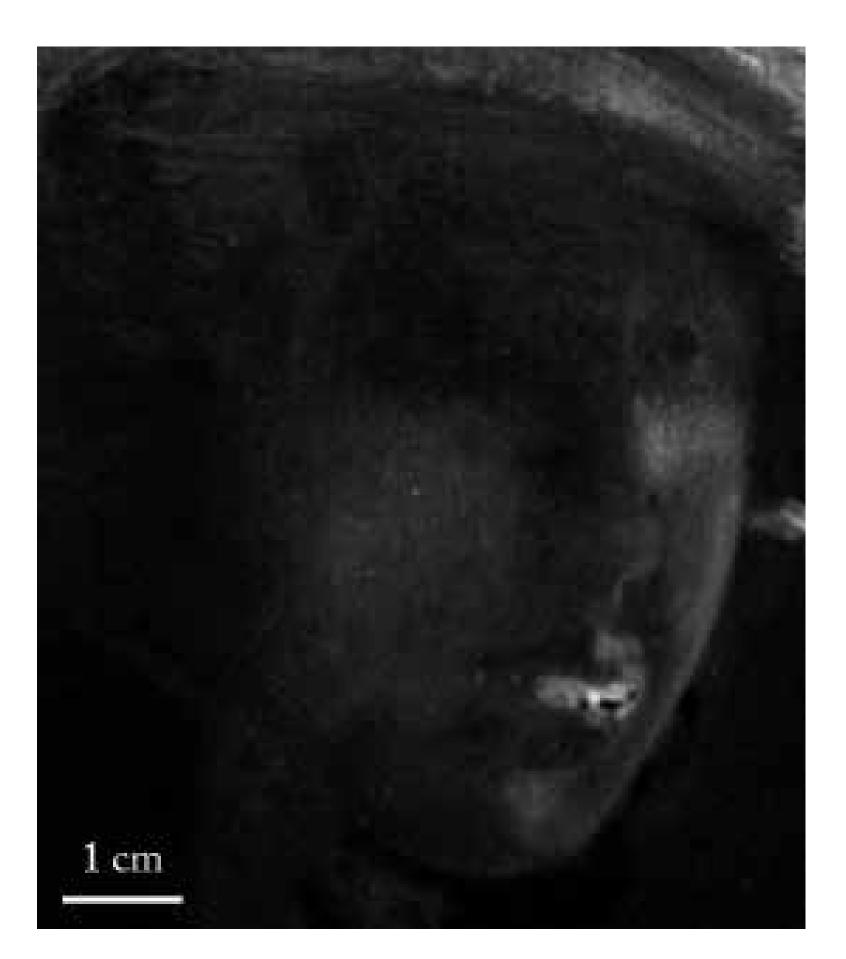
Similar Materials





Details of *Girl with a Flute* comparing paint surface with map of the chemical element mercury





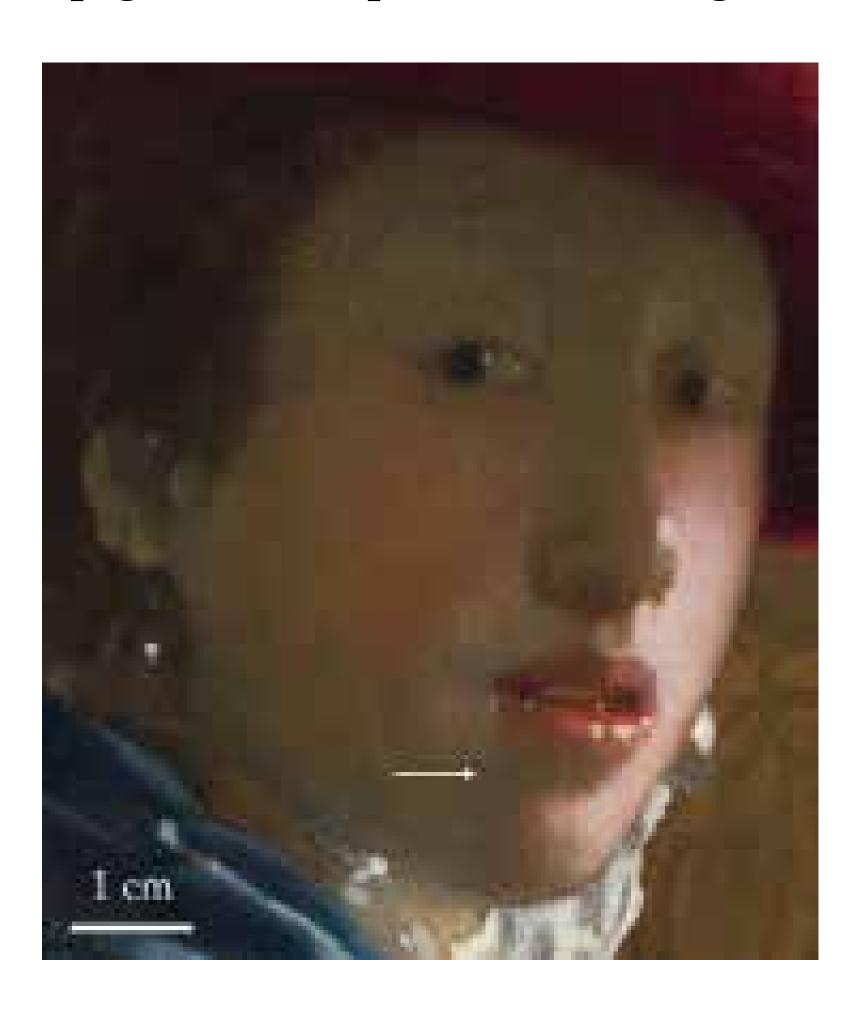
Details of *Girl with the Red Hat* comparing paint surface with map of the chemical element mercury

Similar Materials



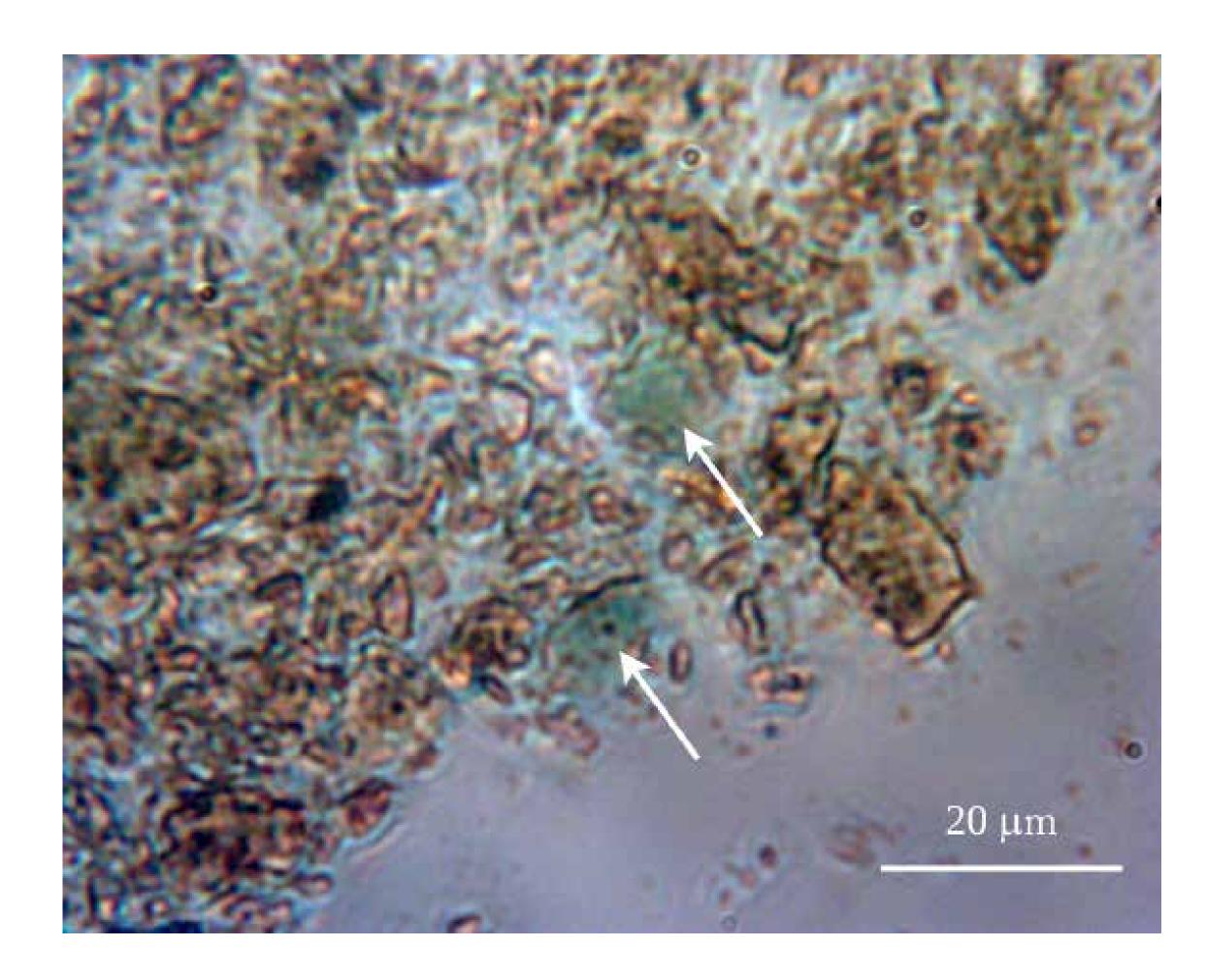
Detail of *Girl with a Flute*.

Arrow indicates location of pigment sample shown at right.

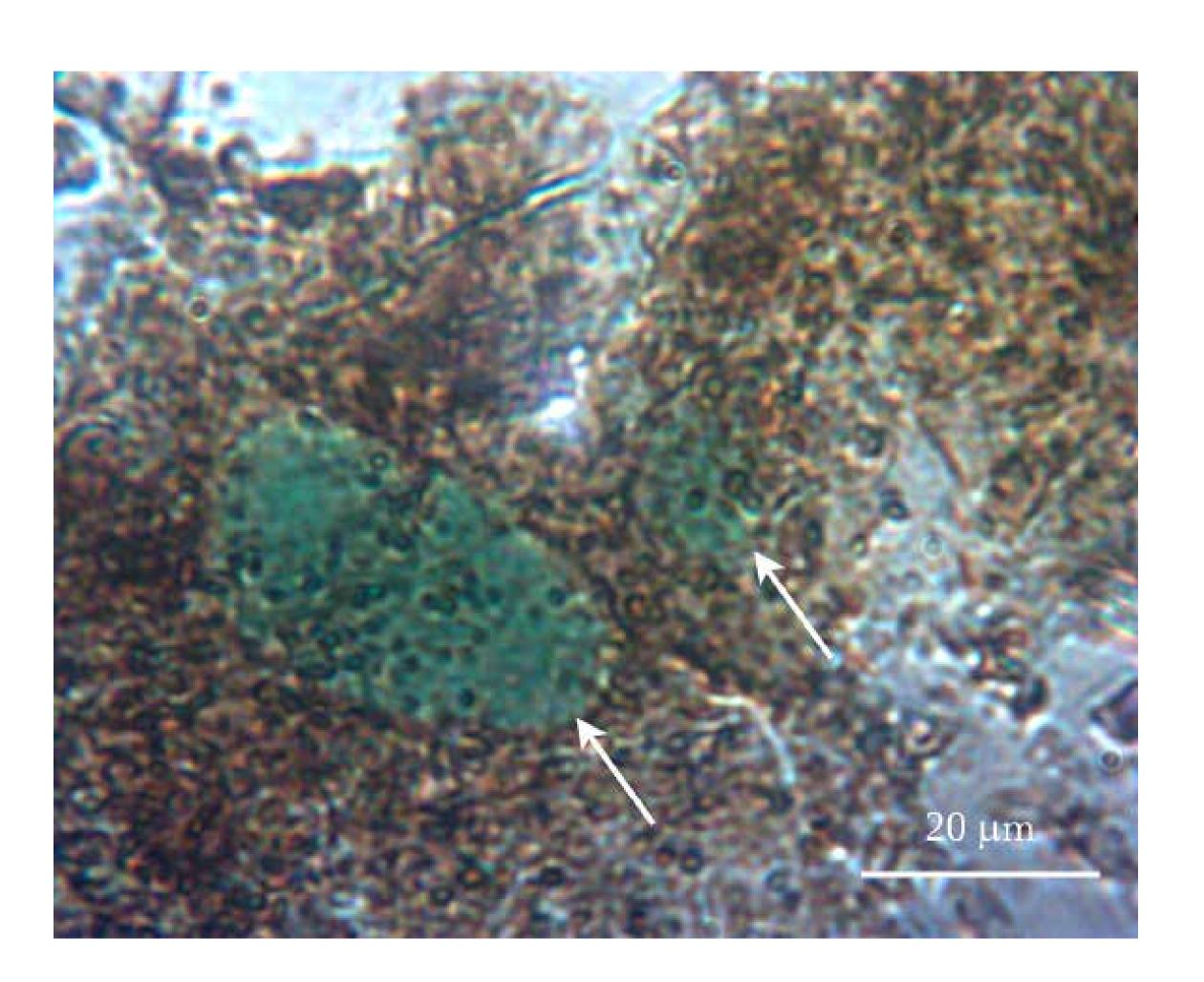


Detail of *Girl with the Red Hat*.

Arrow indicates location of pigment sample shown at right.

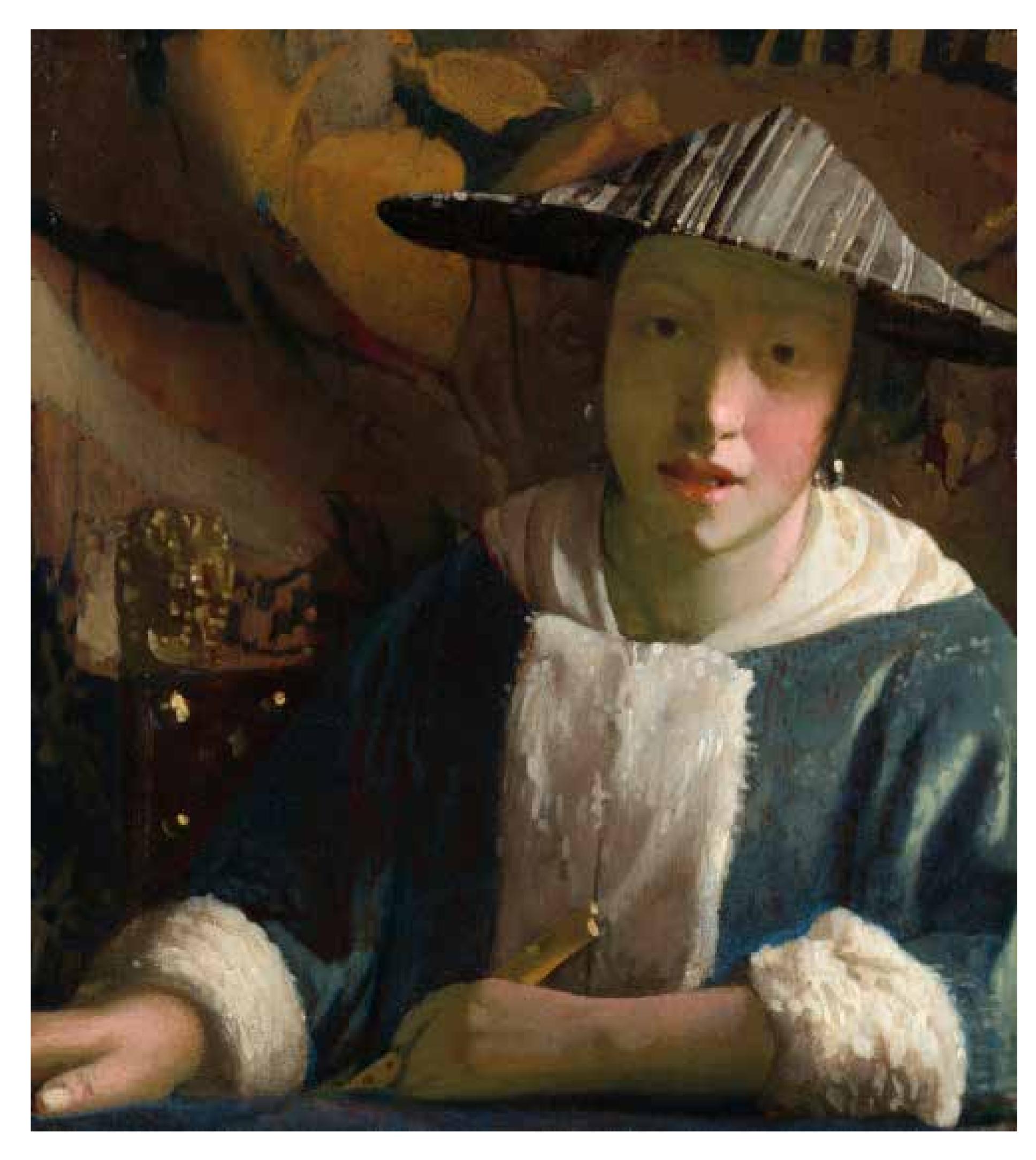


Photomicrograph of dispersed pigment sample showing green earth pigment

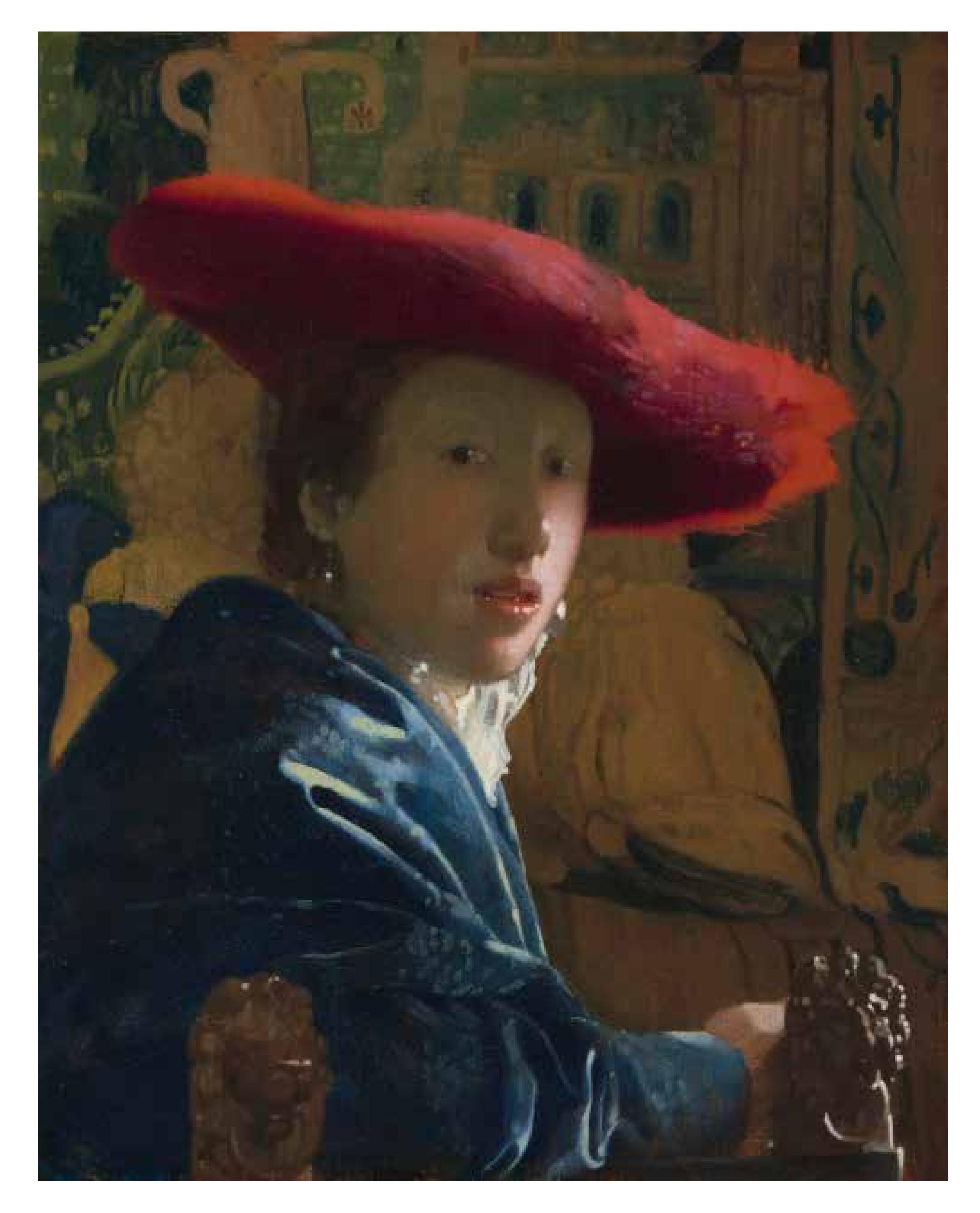


Photomicrograph of dispersed pigment sample showing green earth pigment

Two Paintings, Two Artists



Girl with a Flute, c. 1669/1675



Girl with the Red Hat, c. 1669

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