An Exceptional Commission: Conservation History, Treatment and Painting Technique of Rembrandt's Marten and Oopjen, 1634

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The spectacular acquisition in 2016 of Rembrandt van Rijn's wedding portraits of Marten Soolmans and Oopjen Coppit by the Netherlands (Rijksmuseum) and France (Musée du Louvre) from a French private collection, led to a unique collaboration of the Rijksmuseum with the Musée du Louvre and the Centre for Research and Restoration of the Museums of France (C2RMF). For eighteen months, painting conservators, researchers and scientists, guided by an advisory committee, worked together on the research and treatment of these monumental paintings.[1] This article focuses on our search for information about the conservation history of the portraits and the different steps in their treatment.[2] Scientific and computational analyses carried out as part of that process also led to important new insights regarding the genesis of the portraits and Rembrandt's early painting technique.[3]

I The Nineteen-Fifties Conservation History of Marten and Oopjen

In an interview with former Rijksmuseum restorer and liner Dick Middelhoek (1926-2001), Middelhoek mentions that he had worked with the Rijksmuseum's chief paintings restorer Henricus Hubertus Mertens (1905-1981) on two pendant portraits by Rembrandt in the Rothschild collection.[4] At that time, it was not unusual for Rijksmuseum restorers to treat paintings from other collections in the studio. Ever since his successful treatment of Rembrandt's *Night Watch* in 1946-47, Mertens was considered a Rembrandt specialist in the conservation field.[5] The 1956 treatment of Marten and Oopjen seems to have been part of an arrangement between the Rijksmuseum and the Rothschilds to lend the paintings for the Rembrandt exhibition held in the Rijksmuseum from 18 May to 5 August 1956 (fig. 1).[6] The Rijksmuseum conservation files contain ten black-and-white photographs of Oopjen taken before and during treatment (fig. 2).[7] It was thought odd that there were no photographs of Marten, especially given Middelhoek's remarks. When the paintings were examined in Paris for the first time in September 2015, differences were noted in the condition of the two paintings, although the wax-resin linings on the reverse of both pictures looked so similar that they had clearly been lined in the same conservation studio at the same time, if not by the same hand.[8] This mystery was solved by the *Kunstchronik* of May 1957, which reported: 'In the "Soolmans couple", the difference between the two pictures is probably due to a recent restoration.

< *Fig. 1*
The portraits of Marten Soolmans and Oopjen Coppit on display in the Rembrandt exhibition in the Rijksmuseum, 1956. Amsterdam, Rijksmuseum, inv. no. HA-0009456.

< *Fig. 2*
Portrait of Oopjen Coppit, during treatment in the Rijksmuseum in April/May 1956.

> *Fig. 3*
Before treatment 2015.
Left: *Portrait of Marten Soolmans (1613-1641)*, 1634. Oil on canvas, 210 x 136 cm. Purchased in 2016 by the Dutch State for the Rijksmuseum, inv. SK-A-5033. Signed and dated, lower left, on the vertical rise of the lower step, in brown paint: *Rembrandt · Fv: · 1634*
Right: *Portrait of Oopjen Coppit (1611-1689)*, 1634. Oil on canvas, 210.5 x 134.7 cm. Purchased by the French Republic for Musée du Louvre, inv. SK-C-1768. Photo: Copyright C2RMF, Jean-Louis Bellec, 2015.

The man has been restored by W. Suhr in New York, the woman in Holland.'[9] The well-known American restorer William Suhr (1896-1984) worked for more than forty years as the permanent conservator for the Frick Collection in New York, and privately for numerous other museums, collectors and art dealers throughout America and Europe.[10] Suhr's documentation archive at The Getty Research Institute (GRI) in Los Angeles holds fourteen prints of six black-and-white photographs of Marten.[11] All are dated '1952' or '52' on the back, but provide no evidence that Suhr had treated the painting, other than the words 'before treatment' on some of them. Correspondence between Suhr and the art historian and Rembrandt connoisseur Horst Gerson (1907-1978) contains a list of paintings attributed to Rembrandt with notations indicating which ones Suhr had seen and worked on. Suhr confirmed that he had treated the portrait of Marten (B199), remarking that it was in a 'fine state', but that he had not worked on the portrait of the woman (B342).[12] Suhr's conservation ledgers (1938-57) provided the final link, and show that the painting/s were in Suhr's studio in New York between April 1952 and 5 January 1953.[13] We now knew that Marten had been treated by Suhr in 1952, presumably only on the front, as both paintings were lined in the Rijksmuseum just four years later, in 1956. Since Oopjen's portrait had not been treated in New York, it was also cleaned by Mertens. Both linings and the restoration of Oopjen were carried out within a time span of just six weeks; on one of Oopjen's treatment photographs is written: 'April/May 1956'. The exhibition opened on 18 May 1956.

Varnishes Used by Suhr

At this point we knew 'when' and 'by whom', but since neither restorer left a written treatment report, we did not know what treatment each painting received. To determine general trends in Suhr's treatments throughout his career, some thirty-nine treatment reports of Rembrandt paintings that Suhr had worked on, as well as nineteen reports on paintings by other seventeenth-century Dutch artists and relevant correspondence, were examined.[14] Although it is not within the remit of this paper to consider all aspects of his methods and materials, Suhr's use of different varnishes will be discussed. This informed both the recent treatment of Marten, and the interpretation of analytical results of the varnish samples from the painting.

After some experimentation in the nineteen-thirties, Suhr basically settled for four different varnishes. The commercial Dutch varnishes *Talens retoucheer vernis* and *Talens Rembrandt vernis,* and the French *Soehnée frères vernis à tableaux* were used the most, while an unspecified mixture of dammar and copal resin ('D+C' in his notes), which he may have made himself, is mentioned occasionally. Suhr generally began by isolating the original paint layer with a *Talens retoucheer* varnish, on which he added his retouching. In the most straightforward cases, he finished with a layer of *Talens Rembrandt* varnish. But more often he would apply a layer of *Soehnée frères* varnish in between. Sometimes he built up the varnish in several layers of *Soehnée frères* and *Talens Rembrandt* in various orders. Suhr regularly finished with a matting agent in the form of a wax spray. As far as we know, both *Talens* varnishes are based on an early synthetic resin (cyclohexanone), and are described as 'non-yellowing' in a *Talens* catalogue.[15] Even more interesting is the *Soehnée frères* varnish, which contains shellac.[16] Shellac is relatively unknown as a picture varnish in the conservation field, possibly due to lack of documentation regarding its use and the scarcity of analytical research on historical varnishes.[17]

Varnishes Used by Mertens

Unlike Suhr, Mertens only made written treatment reports in exceptional cases.[18] A study of his materials and methods therefore had to be drawn from less direct sources, which nevertheless yielded valuable information. The most important sources for the varnishes Mertens employed – which he might have used on Oopjen – are several questionnaires sent out by the *International Council of Museums' (ICOM) Care of Paintings* group between 1948 and 1957, the Rijksmuseum notebooks in the Louis Pomerantz Papers and a one-page varnish manual Mertens wrote in 1952 with his supervisor and Rijksmuseum curator Arthur van Schendel (1910-1979).[19] It is clear from this information that throughout his career Mertens always made his own varnishes, either with mastic, or with dammar, or a combination of both. He stayed well clear of synthetic or commercial varnishes. The dammar or mastic resin would be dissolved in French turpentine and the jar would be left to stand in the sun between two and six months. If a varnish was deemed too glossy, he would apply a mixture of carnauba wax and bleached beeswax in turpentine. This paste would be rubbed over the surface of the painting, and then polished. It is unclear how often this was done in practice.

II
Research and Conservation Treatment

The research into the conservation history of Marten and Oopjen and the methods of the restorers involved generated crucial information for the pre-treatment investigation of the two portraits. The next stage was non-invasive imaging and scientific analyses, to better understand the condition of the paintings, provide answers to complex questions concerning their past restorations described in section I, and to guide the conservation treatment.

Research and Treatment in Paris 2015-2016

During the initial examination of the paintings in Paris in September 2015, while they were still part of the Rothschild Collection, the paintings appeared in good stable condition, but many areas, especially the dark tones of the background and costumes, were challenging to discern due to the layers of discoloured varnish and dirt (fig. 3). The surface dirt was removed at the Musée du Louvre by Anne Lepage, a paintings conservator appointed by the C2RMF.[20] During this treatment the paintings were lightly varnished and a few tiny areas of raised paint in the background below Marten's outstretched hand were gently flattened.[21] Despite the improvement in saturation, the underlying varnishes appeared cloudy and discoloured, especially in the portrait of Oopjen, where several thick drips of varnish were discernible. During the lead-up to their sale, the Rijksmuseum and the Louvre agreed that future restoration was desirable and that this should take place in Amsterdam, especially since both paintings had been lined in the Rijksmuseum in 1956.

Prior to their acquisition, the new X-radiographs and infrared images made by the C2RMF confirmed the paintings' good state of preservation. The only damage that could be discerned was an old area of restoration in the bottom right corner in Oopjen's portrait, several small losses in Marten's lace collar and an old tear in the lower edge of his jacket right of centre, along with a few localized areas of paint loss at the upper and lower edges of both pictures. The ultraviolet light and infrared images also gave the impression that there were remarkably few retouches.[22]

Continued Research in Amsterdam 2016-2017

After display in Musée du Louvre and the Rijksmuseum, the paintings came to the laboratories of the Rijksmuseum in October 2016 for further research aimed at determining an appropriate treatment plan. The two paintings were then investigated with a range of non-invasive imaging techniques including visible, raking, and ultraviolet light, infrared photography and reflectography, transmitted infrared photography[23] and macro-x-ray fluorescence (XRF) imaging. In order to document each stage of the conservation treatment, the paintings were photographed in visible and ultraviolet light utilizing high resolution (approx. 1250 ppi), to facilitate high-precision stitching and registration of the images. This meant that for each overall photograph, the photographers captured more than two hundred separate images.[24] The stitched and registered images, each exceeding six gigapixels, could then be compared using the 'curtain viewer', an internet-based image viewing technology.[25]

The macro-XRF imaging technique, which makes it possible to examine both surface and sub-surface layers in a non-invasive manner, resulted in a series of black-and-white contrast images showing the distribution of chemical elements in the two paintings.[26] These were then compared with one another and with other types of images to study hidden features in the paintings and to help identify pigments. The XRF maps for lead (associated with the lead white in the upper ground and paint layers) yielded important information about the true extent of paint losses (figs. 4a, d). In comparison with the calcium maps, associated with the chalk fills, it was clear to see that the old fillings often extended over the original paint, beyond the actual losses (figs. 4b, e). The titanium distribution map associated with the twentieth-century pigment titanium white also shows the numerous tiny retouches in Oopjen's face, most likely applied by Mertens in 1956 (fig. 5). It was only in the high-resolution images and under magnification that we could see that these retouches are associated with pin-point paint losses caused by lead soap aggregates, a form of chemical degradation first observed in Rembrandt's 1632 *The Anatomy Lesson of Dr Nicolaes Tulp* (Mauritshuis), and now known to affect thousands of paintings.[27] Examination with the stereomicroscope also confirmed the abrasion in the past described in Oopjen's hair and in the lit area of her lace collar.[28] In contrast, Marten's face and collar are exceptionally well preserved. Apart from these localized areas in the painting of Oopjen, the condition of the paintings was confirmed as being remarkably good.

Characterization of Varnish Layers

The greatest challenge proved to be the investigation of the old varnish layers that not only allowed for a better understanding of the materials used by Suhr and Mertens, but also aided in tailoring the methods for the various steps of the conservation treatment. Right from the start, the heterogenous appearance of the varnishes in high-resolution ultraviolet images raised questions about the possible presence of multiple varnish layers, particularly the brownish fluorescence in the background of Oopjen's portrait. Organic analyses carried out in 2016 by the C2RMF and the Cultural Heritage Agency of the Netherlands (RCE), identified many components in the varnishes, including aged linseed oil, pine resin, cyclohexanone, acrylic, dammar, shellac, mastic, beeswax and starch.[29] This long list suggested the presence, or remains of older coatings/varnishes predating those applied by Suhr and Mertens, along with wax from past surface treatments, as well as the mixture of beeswax and pine resin used to line the paintings in 1956. The starch may be a residue from a facing used to protect the paint surface prior to lining, or from an isolating layer used during a past cleaning (see the section on egg-white varnish). The presence of shellac in the

a

b

d

e

c

< *Figs. 4*
Selected XRF elemental distribution maps, from left to right for both Marten and Oopjen: a, d) lead maps associated with lead white in the upper grey ground and paint layers (Pb-L shell); b, e) calcium maps associated with ivory black, lake pigments and chalk-based fillings (Ca-K shell); c, f) copper maps associated with azurite (Cu-K shell).

f

Fig. 5
Detail of an XRF elemental distribution map for titanium associated with titanium white retouches (Ti-K shell), probably applied during the 1956 restoration.

varnish from Marten, can be explained by Suhr's shellac containing *Soehnée frères* varnish. The cyclohexanone ketone-based resin identified in samples from both paintings is from the varnish applied in Paris in 2016, and in the case of Marten, also from the *Talens* varnishes used by Suhr in 1952.[30]

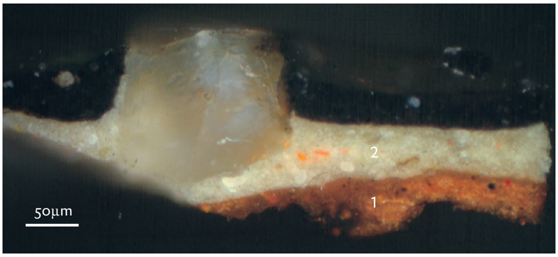
In dialogue with the advisory committee, the varnish layers in paint cross-sections from both paintings were analysed.[31] A combination of UV light microscopy and attenuated total reflection (ATR)-Fourier transform infrared (FTIR) imaging made it possible to distinguish three different varnish layers linked to Suhr's restoration of Marten in 1952: *Talens retoucheer* varnish, followed by an intermediate layer of *Soehnée frères* varnish and a final layer of *Talens Rembrandt* varnish.[32] Below these layers, we identified remnants of older varnishes, including a proteinaceous layer, starch residues and degradation products that had formed over time (figs. 6c, d, e, f).[33]

Figs. 6 a-h
Paint cross-sections from Marten and Oopjen taken before treatment revealed identical 'double grounds', along with evidence of older varnish layers.

a)
Paint cross-section from the dark paint in the upper left background of Marten showing a 'double ground' consisting of a reddish-brown ground (1) followed by a warm grey second ground layer consisting mostly of lead white with a little lamp black, yellow ochre and red lead (2) (SK-A-5033_04 BF).

b)
Paint cross-section from the upper right background of Oopjen showing an identical 'double ground' (SK-C-1768_03 BF).

c)
The left side of the sample from Marten shows three varnish layers associated with Suhr's restoration in 1952: *Talens retoucheer* varnish, *Soehnée frères* varnish (a shellac-based varnish) and a final layer of *Talens Rembrandt* varnish. Note that the lower resin runs into a crack in the paint layer (circle) indicating its modern genesis



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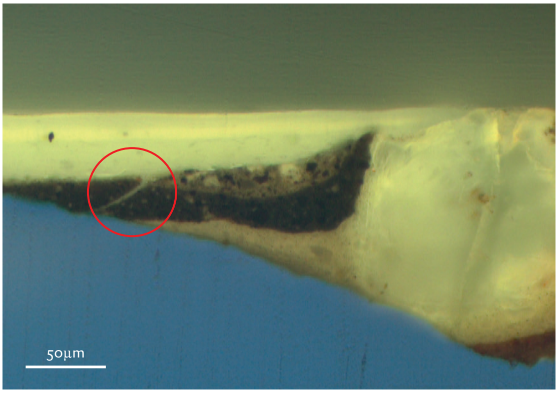

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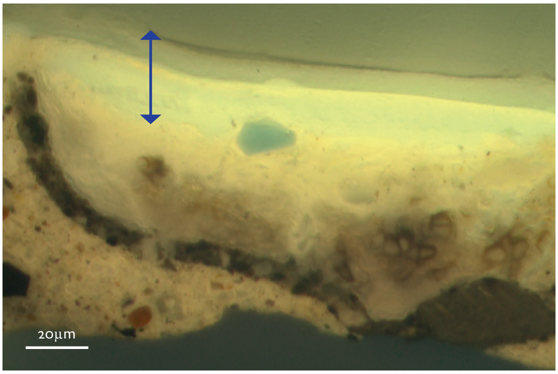

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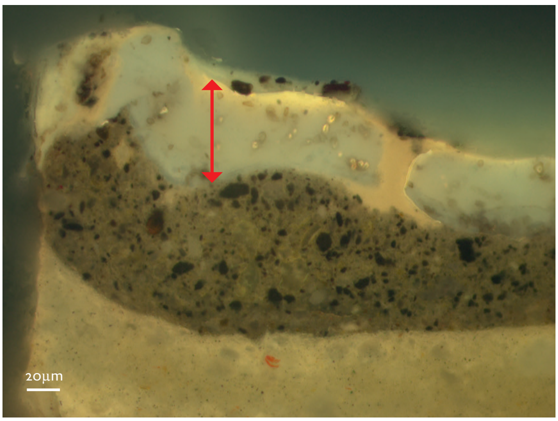

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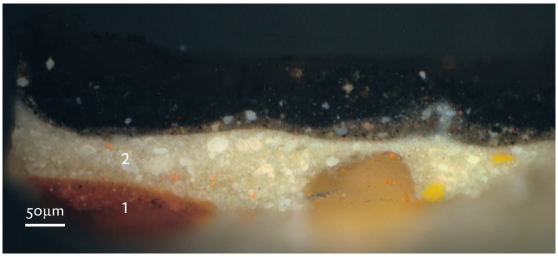

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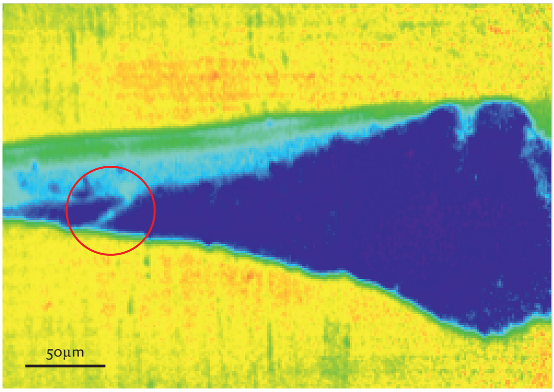

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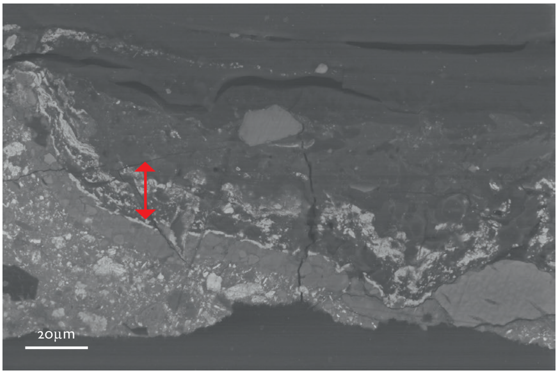

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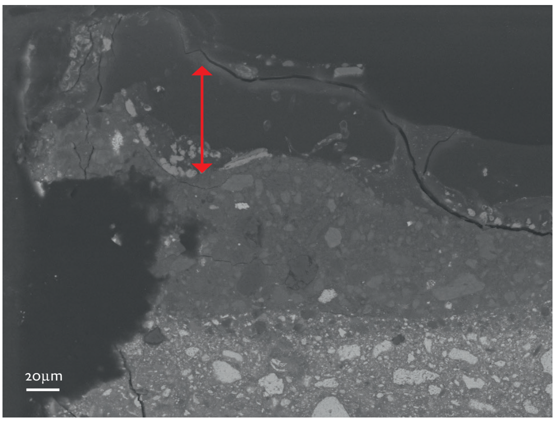


h

(SK-A-5033_04 ultraviolet (365 nm)).

d)
ATR-FTIR imaging of the same part of the sample that helped distinguish the three varnishes used by Suhr by differences in their infrared vibrations (dark blue = low intensity, red = high intensity; SK-A-5033_04 false-colour ATR-FTIR map at 1726 cm-1 (red-yellow area is representative for the embedding medium)).

e)
Ultraviolet light image of paint cross-section from Marten's dark grey cloak showing numerous old varnish layers on top of the cupped paint layers. At the top of the sample, we see the three varnish layers associated with Suhr's 1952 restoration (blue arrow) (SK-A-5033_08 ultraviolet (365 nm)).

f)
Backscattered electron image of paint cross-section from Marten's dark grey cloak showing the numerous varnish layers on top of the cupped paint layers. The egg-white layer along with starch residues, and degradation products that had formed over time were identified directly on top of the paint (red arrow) (SK-A-5033_08 backscattered electron image).

g)
Ultraviolet light image of paint cross-section from the upper right background of Oopjen showing highly fluorescent proteinaceous layers identified as egg white (red arrow); the small oval particles are starch. Missing from this sample are the varnish layers from Mertens's restoration in 1956 (SK-C-1768_03 ultraviolet (365 nm)).

h)
Backscattered electron image of paint cross-section from the upper right background of Oopjen showing a thick egg-white layer on top of remains of another egg-white layer with starch and degradation products, similar to that identified in Marten (red arrow) (SK-C-1768_03 backscattered electron image).

The build-up of the varnish layers in Oopjen was similar, comprising upper layers of mastic/dammar from Mertens's 1956 restoration, on top of remnants of older proteinaceous layers with starch and lead-rich degradation products. The proteinaceous layers identified on both paintings exhibit a strong bluish fluorescence in ultraviolet light and can be interpreted as the remains of an old egg-white varnish.[34]

Egg-White Varnish

Although the use of egg white as a varnish for paper and parchment appears in early sources from the fourteenth to the seventeenth centuries, it was not recommended as a permanent varnish for paintings.[35] In the seventeenth century Théodore Turquet De Mayerne (1573-1655) emphatically warns against it: 'Egg-white on work in oils. It attacks and destroys with time the colours, and attaches itself so stubbornly that, even if you wash the painting repeatedly, some of it will always remain.'[36] Elsewhere in the manuscript he recommends it as a varnish after cleaning that can be washed off and reapplied.[37] In the eighteenth and early nineteenth centuries egg-white varnishes are mentioned in nearly all the painters' and domestic manuals and its use by artists and restorers must have been widespread. Manuals and treatises describe its many uses: to protect the fresh oil paint from dirt or damage, especially during transport, to restore a saturated appearance to the paint surface, as an isolating varnish on which artists could make additions, as a temporary varnish before the application of a final resin varnish, to even out an irregular paint surface appearance, to saturate dark colours and to achieve a matt finish. In *The Handmaid to the Arts* (London 1764), Robert Dossie describes how it can be removed by simply washing the surface of a painting with water and a sponge, but warns it does not last and is prone to cracking.[38] François-Xavier de Burtin (1743-1818), in his *Traité théorique et pratique* published in France in 1808, refers to egg-white varnish as a quick drying intermediate varnish used by restorers.[39] Both egg-white (and starch) layers were also used in restoration as protective isolating layers to facilitate removal of resin varnishes without coming in contact with the original paint. Referred to as 'encollage' in French, this method is described in the 1851 *De La Conservation Et de La Restauration Des Tableaux* by Simon Horsin-Déon (1812-1882), a restorer at the Musées Nationaux in Paris.[40]

Egg-white varnishes, however, were also frequently criticized; problems with cracking and insolubility were described in most of the painting manuals.[41] *A Compendium of Colours, and Other Materials Used in the Arts*, a British oil painting manual published in 1808, states that an egg-white varnish is 'apt to crack the colours of the picture it covers, and therefore should not be used to pictures of value'.[42]

Although the use of egg-white varnishes by restorers in the past was well-intentioned, the danger was that such layers could be forgotten or only partially washed off. This seems to be the case with Marten and Oopjen, as the egg-white layers in both pictures were only partially removed in the past. Apart from minute residues, the layer appears to have been carefully and almost completely removed from the flesh tones, as compared to the hair, costumes and backgrounds in both paintings, where many residues remain. In these paintings the egg-white layer (and starch) clearly seem related to past restoration, and not to an original varnish. Evidence is supplied by the study of paint cross-sections where in one sample, an even older (possibly resin) varnish is visible below the egg-white layer, and in several other cross-sections the egg-white layer was applied on top of damage in the paint layers.

Optical coherence tomography (oct) and macroscopic x-ray powder diffraction (ma-xrpd) were then carried out to better understand the distribution and nature of these residues. Since the oct technique uses light waves to create virtual cross-sections, it is highly dependent on the differences in the optical properties (refractive index) of layers. Because of this, and the imaging resolution, it is not always possible to distinguish all varnish layers; however, in this case we were able to visualize the egg-white layer below the upper varnish layers.[43] oct also revealed variations in the thickness and number of varnish layers. For instance, in the depths of the white impasto in the rosettes on Marten's shoes, areas which would have been overlooked during previous cleanings, oct could distinguish multiple varnish layers pointing to numerous restoration or varnishing campaigns in the past. Several line scans were performed with ma-xrpd on both paintings, the spectra of which identified the degradation products, lead (potassium) sulphates and calcium oxalates.[44]

Treatment

The difference in composition and solubility of the old varnish layers meant that different cleaning methods had to be used. Solubility tests were performed to choose the best solvent for removing the upper, modern resin varnish layers. Then, since the degraded egg-white varnish is not soluble in organic solvents, this would have to be removed with an aqueous gel.

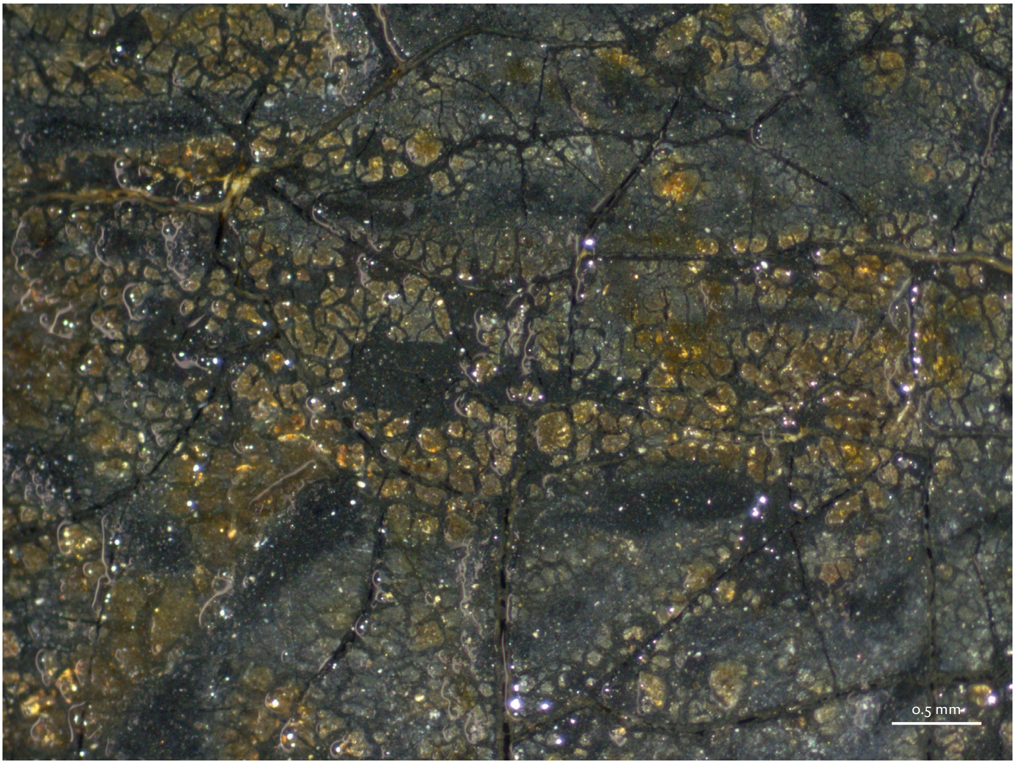
With the permission of the advisory committee, the treatment of both paintings began in the summer of 2017. Using a novel micro-filament fabric, chosen to minimize mechanical action and limit solvent penetration and exposure, the modern upper varnish layers were successfully removed (fig. 7). The retouches applied by Mertens and Suhr, such as we see in fig. 5, were also taken off along with these layers. Not surprisingly the removal of the upper varnish layers revealed the uneven, grey/brown remains of egg-white varnish and starch on both paintings (fig. 8); since these remains are highly fluorescent they could easily be distinguished in the ultraviolet images (fig. 9). It would seem that Suhr and Mertens both removed previous varnish layers down to the old egg-white layer, no doubt because of its insolubility.

Surprisingly, in Marten's cloak the old egg-white layer was still intact, albeit brown and heavily cracked. Seemingly no attempt had ever been made to remove it, or perhaps this area was simply overlooked. Cupping and micro-cracking of both paint and varnish layers, visible in a paint cross-section from this area, are considered to have been caused by the tensions induced by the moisture-sensitive egg-white layer (figs. 6c, d). After systematic testing of various aqueous gel systems, good results were achieved with a polymeric emulsifier.[45] This phase of the cleaning was carried out under the stereomicroscope and could be monitored with ultraviolet light as the proteinaceous layer is strongly uv fluorescent. However, more research is required to remove this layer from areas where the residues are thinner and the underlying paint is more sensitive, and we therefore decided only to reduce the thickest areas of the egg-white layer, namely in Marten's cloak and Oopjen's hair. The results were striking, especially in the cloak, where the cooler grey and striped detailing was revealed (fig. 10).

After the cleaning phase, the coarse texture, anomalous crack pattern and smooth application led us to suspect that several of the darkest black shadow areas in Marten and Oopjen's costumes were later overpaints. Unfortunately, the study of paint cross-sections provided no clear-cut proof as to when the overpaint was applied.[46] Nor could these areas be detected with macro-xrf imaging, since the composition of the overpaint is chemically identical

Fig. 7
Details of Marten's lace collar (top) and Oopjen's cuff (bottom). Digital assemblies of before (left) and after (right) cleaning images, showing removal of the nineteen-fifties resin varnishes.

Fig. 8
Stereomicroscope images of the cracked and degraded egg-white layer in Marten's cloak (top) and in the background of Oopjen (bottom) after removal of the nineteen-fifties resin varnishes.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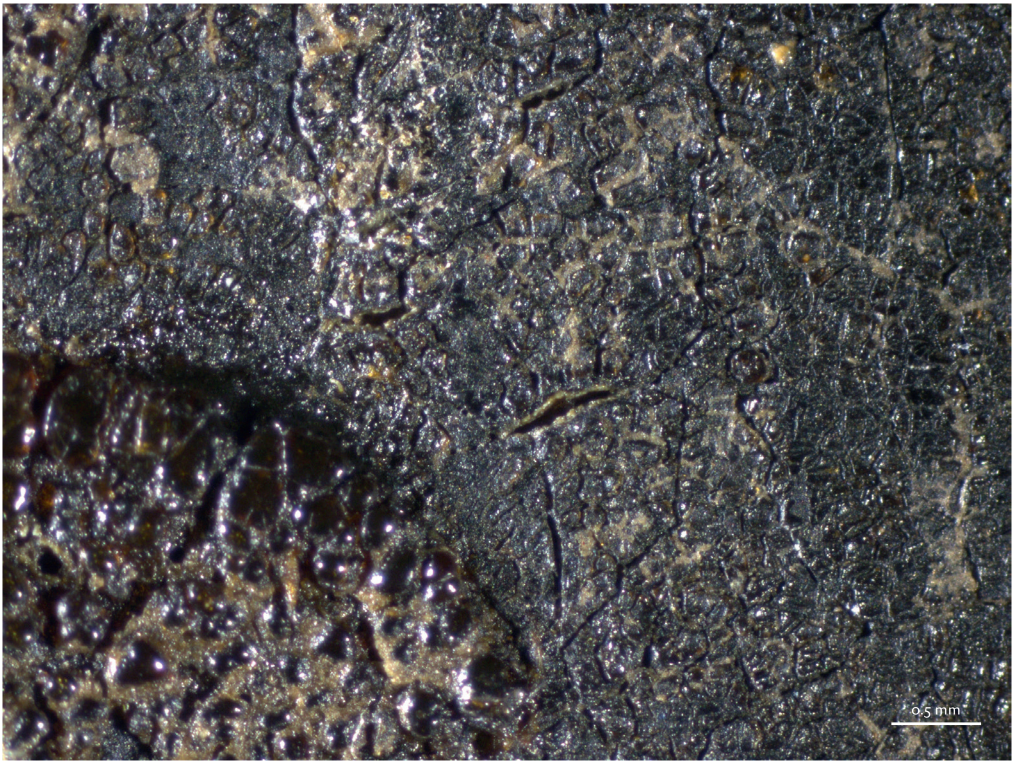
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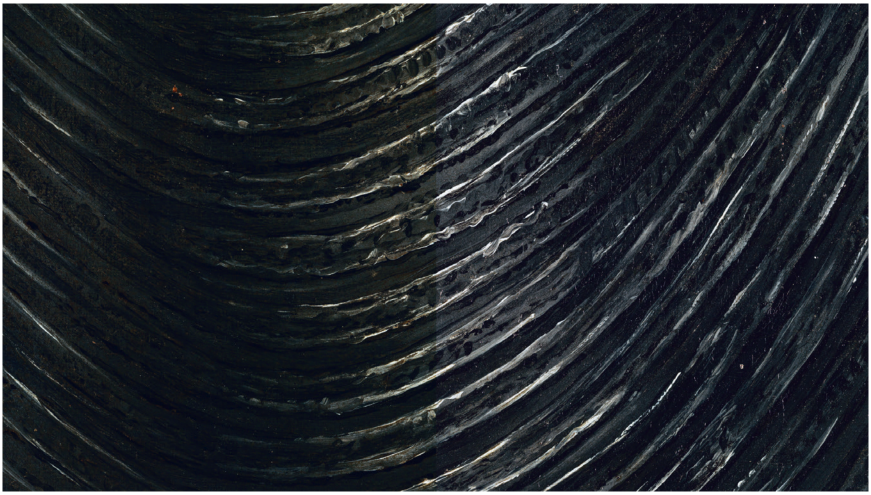
Fig. 9
Ultraviolet light detail of Oopjen showing the strongly fluorescent egg-white residues in the hair and background after removal of the nineteen-fifties resin varnish.

Fig. 10
Digital assembly of Marten's cloak, before (left) and after reduction of the old egg-white layer (right).



to that of the original paint. In places where the slightly greyed overpaint was particularly disturbing, such as the inner contours of Marten's breeches, the overpaint was judiciously thinned, revealing small-scale drying cracks and masses of tiny (decapitated) lead soap aggregates. These were made visible with transmitted infrared photography (IRT) (where the lamps providing IR radiation face the back of the painting) and documented with stereo and digital microscopy (fig. 11).[47] It would seem that these aging defects were the reason for the overpaint, as no other damage in the original black paint could be detected. Many of the deepest shadow areas in the costumes are still covered with old overpaint. Additional investigation is required in future to fully characterize the overpaint and its relationship to the original black paint.

In the final phase of the treatment, the paintings were given a brush coat of dammar varnish, followed where necessary by careful filling of the old paint losses. Retouching was carried out in stages, by first applying a basic tone with gouache and watercolour followed by a mixture of dry pigments

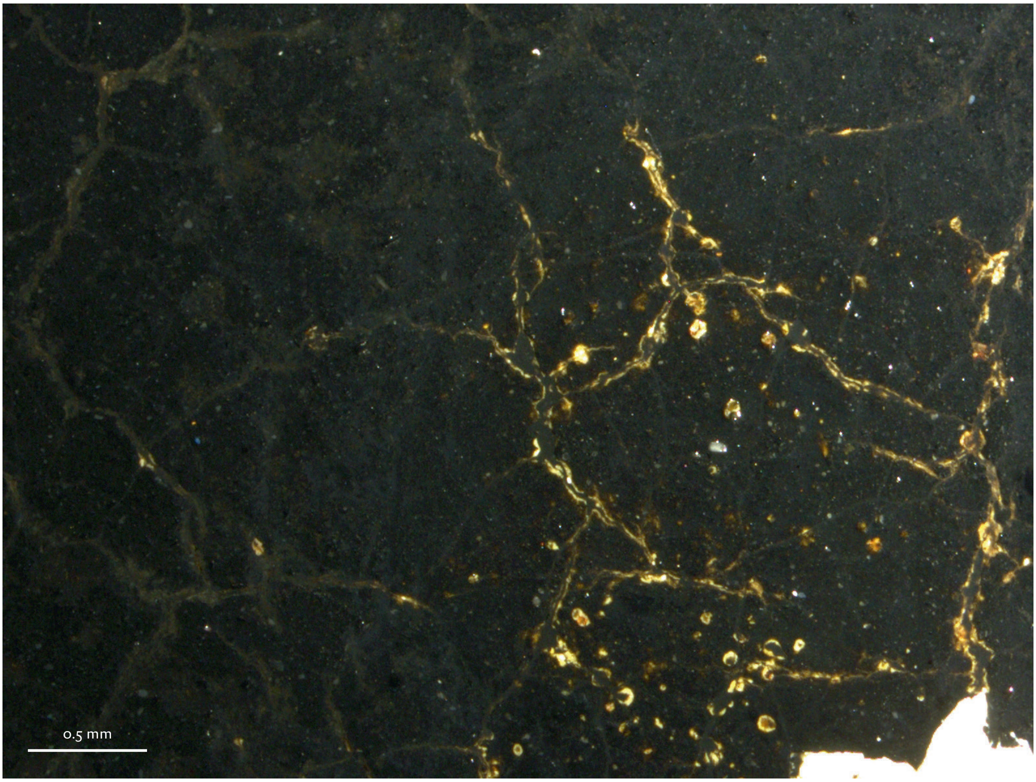


Fig. 11
Stereomicroscope detail of shadow area of Marten's jacket after removal of a tiny area of black overpaint showing exposed drying cracks and tiny decapitated lead soap aggregates.

and stable modern synthetic resin (polyvinyl acetate) to mimic the saturated colours of the original paint. A final dammar varnish was then applied in several thin spray coats in order to achieve an evenly saturated surface with moderate gloss (fig. 12).

III
Initial Results on Painting Technique

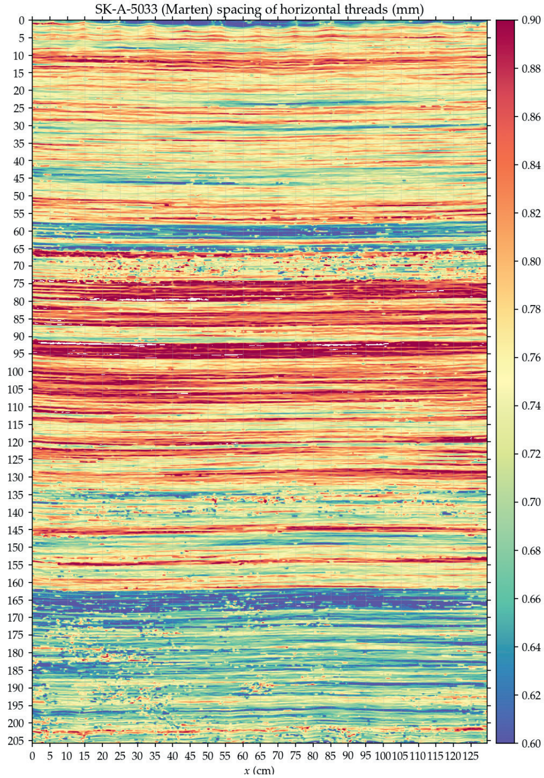
Scientific analyses and imaging also led to new information on the painting techniques and materials Rembrandt used for these exceptional portraits. We will discuss some initial results here.

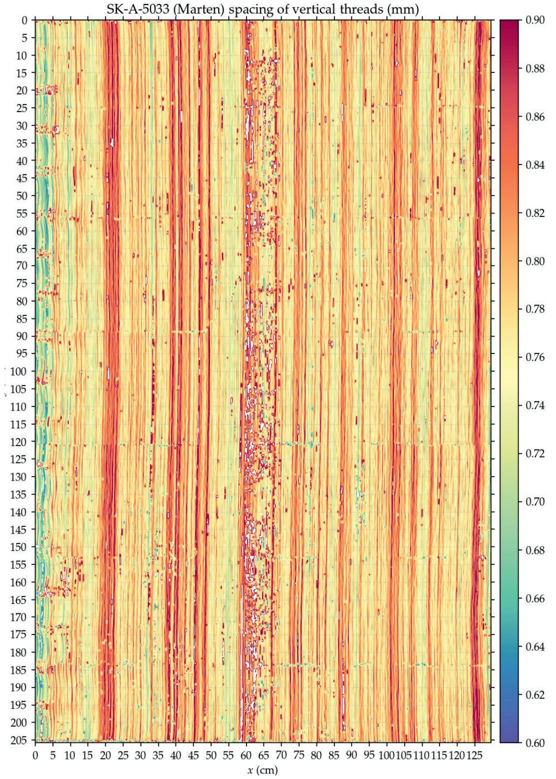
The Canvas Support and Preparation

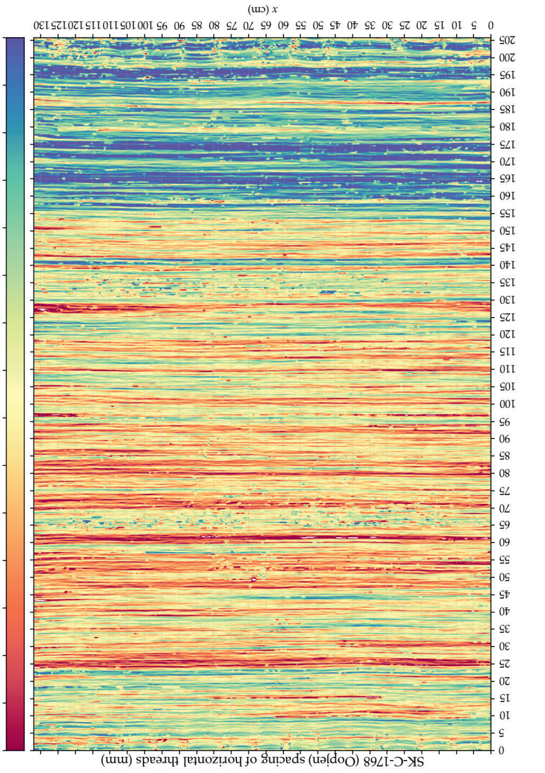
Marten and Oopjen are painted on two single pieces of plain weave medium weight canvas, presumably linen, measuring 210 x 136 cm (Marten) and 210.5 x 134.7 cm (Oopjen). Innovative computational analysis of the canvas weave involving forensic imaging tools developed in the Rijksmuseum reveals that the supports were cut from the same roll of canvas that must originally have been at least 140 cm, or 2 el, wide. This is consistent with Ernst van de Wetering's study of Rembrandt's canvas supports, in which he identified the fact that the majority of the canvas paintings are painted on strip widths of 1.5 el (approx. 107 cm) and 2 el (approx. 140 cm), with just a few paintings painted on very wide strips of 2.5 el (approx. 175 cm) and 3 el (approx. 210 cm).[48]

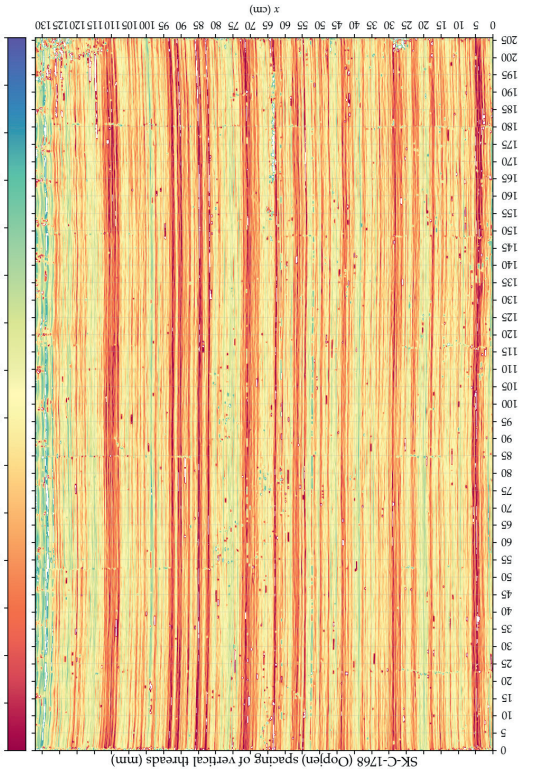
Evidence that the paintings originate from the same roll is provided by their identical thread counts[49] and thread density distributions.[50] The greater variation in thread densities in the horizontal direction, as compared to the more regular densities in the vertical direction, indicates that the

> *Fig. 12*
The portraits of Marten (left) and Oopjen (right) after treatment, 2018. The research and conservation treatment was made possible by the Irma Theodora Fonds/Rijksmuseum Fonds, Philips and the Cevat Fonds/Rijksmuseum Fonds.


SK-A-5033 (Marten) spacing of horizontal threads (mm)
x (cm)


SK-A-5033 (Marten) spacing of vertical threads (mm)
x (cm)


SK-C-1768 (Oopjen) spacing of horizontal threads (mm)
x (cm)

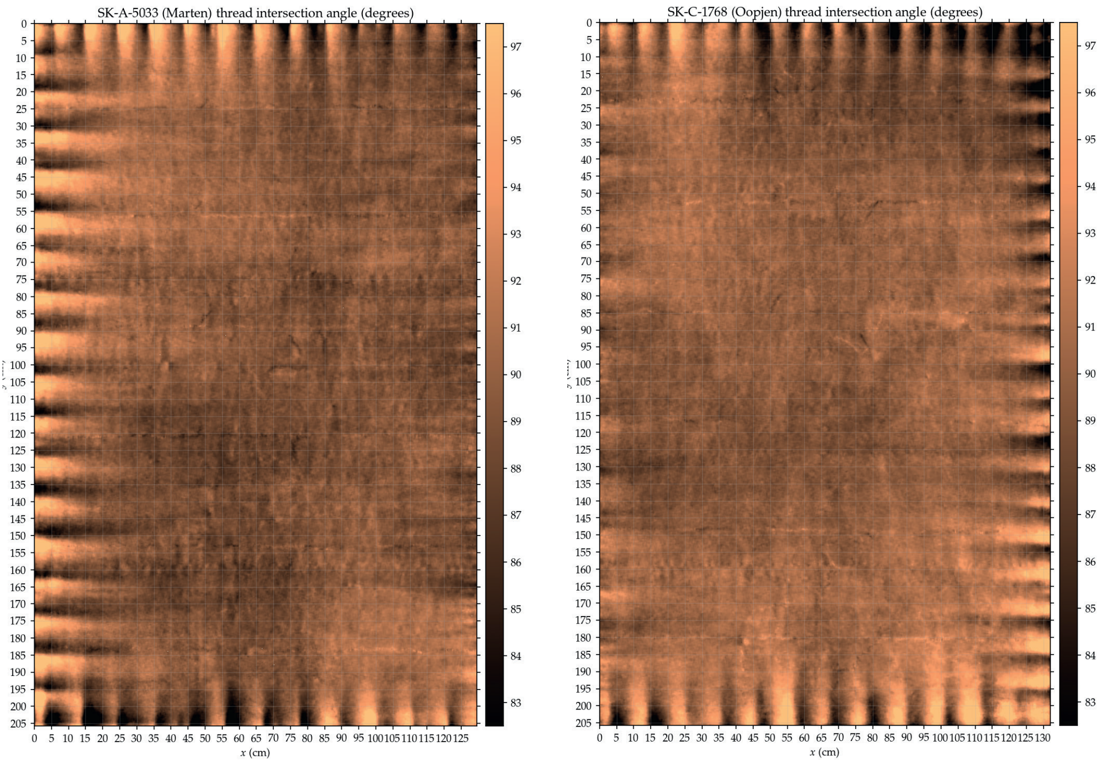

SK-C-1768 (Oopjen) spacing of vertical threads (mm)
x (cm)

< *Fig. 13*
False-colour thread density maps of the canvas supports of Marten (top images) and Oopjen (bottom images) showing the variation of the horizontal/weft thread spacings (left images) and vertical/warp thread spacings (right images) in the canvas supports of Marten and Oopjen. When one of the portraits is rotated 180 degrees, the pattern of the vertical thread densities aligns perfectly.

weft must run horizontally and the warp vertically. In the vertical/warp thread density distribution maps we see a distinctive striped pattern that is identical for both paintings. When the two portraits are placed feet to feet lengthwise, the pattern of the vertical thread densities aligns perfectly (fig. 13).

The cusping patterns caused by distortions of the thread angles around the edges of the two portraits, also suggest that the two supports were joined together when the two canvases were prepared. Primary cusping that extends some twenty cm into the canvas is confined to the three outer edges of each painting, while faint, more closely spaced distortions, are just visible along the right and left edges of Marten and Oopjen respectively (fig. 14).[51] These anomalies in the cusping patterns can be explained if the two lengths of 2-el-wide canvas

Fig. 14
Combined horizontal and vertical thread angle maps of the canvas supports of Marten (left) and Oopjen (right) showing primary cusping on three outer edges and faint distortions along the inner edges.



were stitched together along their selvedges before priming, the faint distortions that we now see caused by puckering along the seam. This suggests that the two pendants may have originally been intended as a double portrait, which for some reason/changes in the commission were then cut apart and stretched onto individual strainers. The practice of joining strips of canvas together for large scale compositions is frequently encountered. *The Night Watch* (Rijksmuseum), for instance, probably consisted of three strips, approximately 140 cm wide. Each of the three canvas supports that make up Gerard de Lairesse's 1672 *Triumph of Peace* (now in the Peace Palace in The Hague) was also found to consist of two lengths of canvas cut from the same roll.[52] One strip was turned 180 degrees and the strips were then sewn together along the selvedges and primed: the same scenario is plausible for Marten and Oopjen.

It was suggested in the past that Oopjen's portrait was painted after 1641, the year Marten died, but the evidence presented here refutes this.[53] Indeed the two paintings may even have originally been a single composition; an exceptional commission fitting for the wealthy young couple. In a dispute in 1642, concerning Rembrandt's full-length, life-size portrait of Andries de Graeff, 1639 (Kassel, Staatliche Museen Gemäldegalerie Alte Meister), which was subjected to arbitration due to the sitter's dislike of the portrait and refusal to pay, the portrait's worth was set at five hundred guilders to be paid to the painter. The portraits of Marten and Oopjen most likely cost at least twice as much; a vast sum at the time.[54] The subtle interaction, with Oopjen seemingly moving towards Marten who reaches out to his spouse with his left hand, holding a glove, does not contradict an original intention of a double portrait. Unfortunately, the tacking edges of both pictures were removed in the past, so we do not know whether the paint extended over the edges. To suggest that Rembrandt initially intended a double portrait on a large single canvas, only to change this to individual portraits during the painting process, would therefore be speculative at this stage of our research. We can, however, be sure that they were painted in the same year.

Both canvases were prepared with an identical double ground. The lower ground layer is reddish brown and consists of red ochre, umber and a small amount of lead white. This is followed by a warm grey layer containing mostly lead white with small amounts of lamp black, yellow ochre and red lead (figs. 6a, b).[55] The ground seems to have been applied while the canvas was still one large piece, as it is the imprint of the canvas in the lead-white containing ground that is seen in the X-radiographs used to determine the thread densities. A double layered ground of identical material composition is found in the 1632 *The Anatomy Lesson of Dr Nicolaes Tulp* (Mauritshuis).[56] So-called 'double grounds', reddish brown followed by grey, were used extensively by Rembrandt in his canvas paintings of the sixteen-thirties and by his contemporaries, and have been found in, for example, Frans Hals's 1637 *Meagre Company*, and Jacob Adriaensz Backer's *Regentesses of the Amsterdam Burgher Orphanage* from 1633/34 (Amsterdam Museum), although in both the Hals and the Backer, charcoal black was identified rather than lamp black.[57]

Sketching and Undermodelling

Examination of cross-sections and macro-XRF distribution maps provided evidence of a painted sketch and undermodelling, as well as significant changes in the background and several pentimenti in the figures. It seems that Rembrandt laid in the composition with a sketch using dilute, ivory black

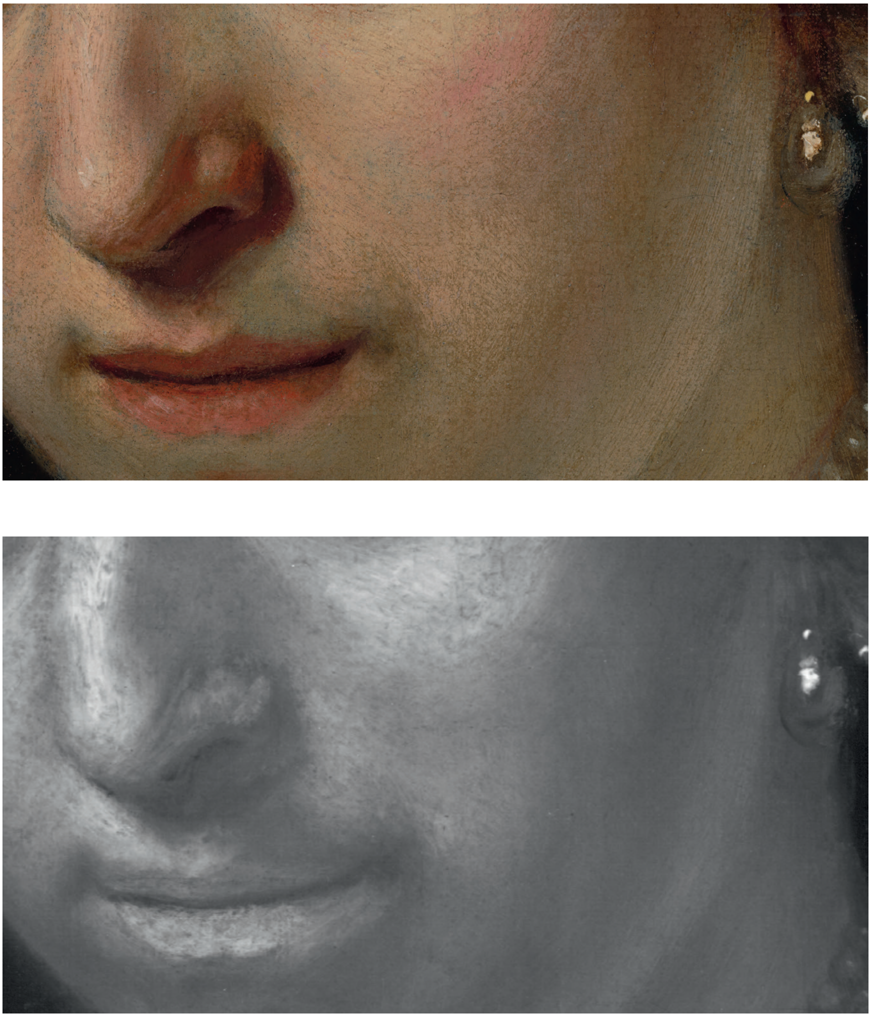


Fig. 15
A thin black underdrawing can be discerned in the lips, nose and earring, with the naked eye (top) and with infrared reflectography 1100-1700 nm (bottom).

paint. In several cross-sections from different areas in the paintings,[58] including those from Marten's costume, there is a very thin, ivory black layer directly on top of the double ground. It is plausible to assume that this black lay-er is part of a painted sketch, similar to that seen in the eighth neutron autoradiograph of *Portrait of a Young Woman with a Fan* from 1633 (The Metropolitan Museum of Art, New York).[59] Since the same pigment is used in the paint layers of the costumes, this painted sketch cannot be distinguished in the calcium map associated with ivory black.[60] However, a faint, thin black line is visible with the naked eye (and infrared imaging) through the translucent paint of Oopjen's earring, and around the contours of her lips and nose (fig. 15), which may belong to this preliminary stage of the painting process.

Another painted sketch or undermodelling, reddish brown in colour, seems to be present in Oopjen and Marten's faces. The XRF maps, especially those for mercury (not illustrated here), calcium and iron (figs. 4b, e and 16) correspond with pigments identified in a reddish-brown layer in a paint cross-section from the shadow side

> *Fig. 16*
XRF elemental distribution maps for iron associated with earth pigments (Fe-K shell) used for the initial lay-in of the compositions, the hair, the chain of Oopjen's fan, Marten's gloves, shadow areas, as well as old retouches.

of Marten's nose: vermilion, red and yellow lakes, some organic brown and small amounts of earth pigments. This layer, which was applied directly on top of the ground, is followed by a thin translucent reddish layer containing a now faded red lake pigment and extra chalk. Further research into the flesh paints and the way Rembrandt employed preliminary paint layers in Marten and Oopjen is ongoing.

Artist's Changes

Rembrandt typically made several small changes. For example, he enlarged Marten's hat, as can be seen by comparing the contour of the hat with the smaller reserve made visible in the iron maps (fig. 16) and manganese maps (not illustrated here), associated with the use of earth pigments/umber for the first lay-in. The iron map of Oopjen showing the yellow earth used for the chain of the fan demonstrates how the chain was originally longer. The contour of her profile, the left edge of her gown and lace collar were also slightly adjusted.

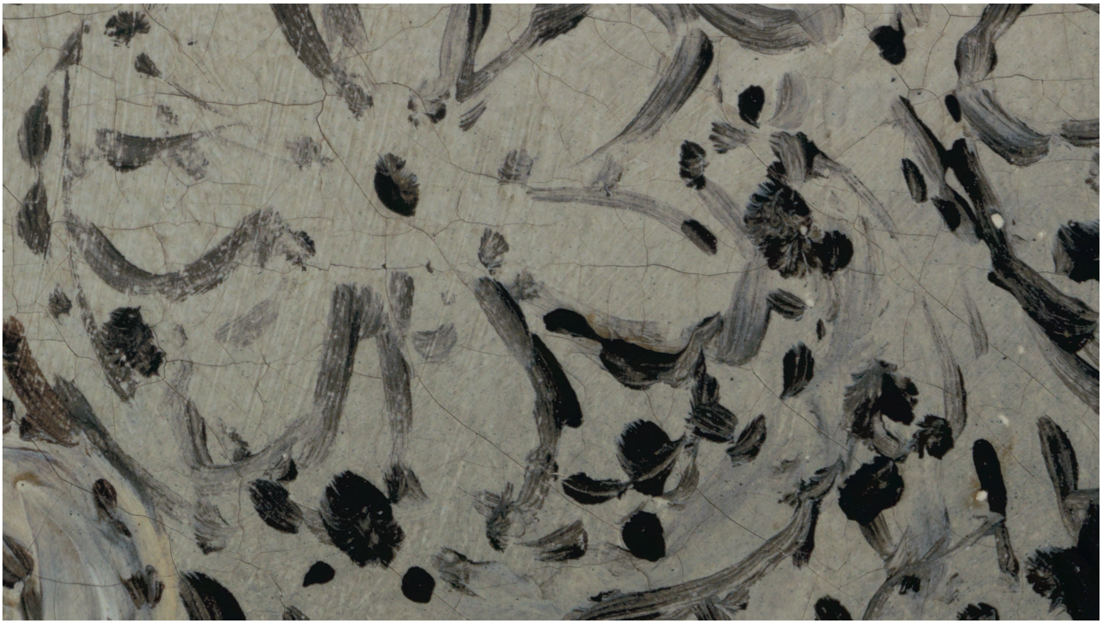
The XRF maps for iron (and manganese) also reveal an important change in the background of both paintings. Rembrandt indicated an arch directly behind Marten, while Oopjen was depicted stepping through an arched doorway. Although further analyses of the scientific data are required, these features are notably similar to those in the background of *Portrait of a Man*, 1633, and *Portrait of Andries de Graeff*, 1639 (fig. 17; both Kassel, Staatliche Museen Gemäldegalerie Alte Meister). Rembrandt, however, added a curtain to cover much of the background behind Oopjen and part of the arch behind Marten, which he then further painted out with a lighter grey. Additional examination of the technical data is needed to establish if this change in the composition, which initially seemed to show a more active entrance of Oopjen into a shared space, to a more monumental portrayal as we see now, could be related to the change in format from a double portrait to two single portraits.

Fig. 17
Portrait of Andries de Graeff, signed and dated 1639. Oil on canvas, 200 x 125 cm. Kassel, Staatliche Museen Gemäldegalerie Alte Meister, inv. no. GK 239.

White

Rembrandt's virtuosity as a painter can be seen in his rendering of the lace in both portraits. He cunningly uses pictorial devices such as curling, foreshortening and projecting in the lobes of lace. The pure white raised contours catching the light, and diminishing detail towards the back, evoke depth and three-dimensionality. In Marten's single-layer lace collar, what seem to be just black specks and dashes painted on the white underlayer, successfully suggest the intricate patterns of the lace (fig. 18). Rembrandt clearly moves away from a traditional method which employed white on top of the black costume to create the lace's design. In portraits by Frans Hals we see a similar technical shift: in Hals's 1631 portrait of *Cornelia Claesdr Vooght* (Frans Hals Museum), the lace cuffs are painted white on black, while in the slightly later *Portrait of a Man* (Rijksmuseum), dated 1635, Hals paints the interstices in the lace with black on top of a white

Fig. 18
Details of Marten's lace collar, showing how Rembrandt deftly applied fluid black lines and dots on a white underlayer to suggest the openings in the intricate bobbin lace.



layer.[61] This change in technique, observed in both Rembrandt and Hals, may be a matter of efficiency but also the result of a change in fashion. The intricate and less linear patterns of bobbin lace, popular at the time when Rembrandt painted his early Amsterdam portraits, would require different technical solutions.[62] According to Bas Dudok van Heel, in 1633-34 both Hals and Rembrandt may have been living and working at at Hendrick Uylenburgh's studio.[63] It was at precisely this time that Hals started painting *The Meagre Company* (Frans Hals and Pieter Codde, Rijksmuseum, Amsterdam), and Rembrandt the portraits of Marten and Oopjen. It is plausible that their contact in Ulyenburgh's studio is the reason why both artists found similar technical solutions for painting the complex bobbin lace patterns.

To resolve the difference in materiality of Oopjen's double-layered collar, Rembrandt extended his technical repertoire. In the lower layer of lace, black was added on top of a smooth, slightly translucent white paint to suggest the pattern of the lace as in

Marten's collar. For the upper layer of her collar, however, he applied the opaque white paint thickly, and here the interstices in the lace were painted with a light warm grey (fig. 19). The scattered light reflected from the highly textured surface, intensifies the lace's luminosity and adds to its three-dimensionality. A similar use of texture is found in the white bows on both costumes and in Marten's lace garters and the rosettes on his shoes, providing extra tactility and brilliance due to the light reflected from their textured surfaces. In both collars Rembrandt even added a little azurite to the white paint to increase its optical whiteness.

Black

Rembrandt painted the costumes with pure ivory black.[64] Both costumes show up in the XRF maps for calcium, since ivory black is essentially composed of calcium phosphate with smaller amounts of magnesium phosphate and calcium carbonate (figs. 4b, e). Marten's dark grey cloak also contains ivory black with some earth pigments and added lead white for the grey detailing. The mercury map of Oopjen (not illustrated) shows that a significant amount of vermilion was mixed in the black and grey tones in the folds around and below her hand holding up her skirt. The addition of red would make the black and grey warmer in tone. Rembrandt seemingly wanted to catch the subtle glow of the flesh tones of Oopjen's hand reflected in the sheen of the black silk of her gown.[65]

Although now barely discernible to the naked eye, Marten's shadow cast onto the curtain on the right can be recognized in the copper distribution map (fig. 4c). Here Rembrandt added a thin layer containing a finely ground azurite on top of the dark grey of the curtain. The small size of the greyish azurite particles is significant, as no doubt Rembrandt chose this grade on purpose since azurite loses much of its intense blue colour when it is finely ground. It is also found along the left (shadow) side of Oopjen's gown, her veil and the area between her black sleeve and fan, creating subtle transitions in tone to distinguish her figure from the background (fig. 4f). The rather unusual addition of a copper

Fig. 19
Detail of Oopjen's double-layered lace collar, showing the difference in the use of pigments in the single and double lace areas.

blue to a dark mixture, is also found in the cool brownish green veil and shadows in *Saskia Ulyenburgh as Flora*, 1635 (National Gallery, London).[66] In the *Introduction to the High School of Painting* of 1678, Samuel van Hoogstraten describes how adding 'some light' in the darkest shadows gives them even more depth.[67] The added greyish blue azurite set against the pure ivory black on the shadow side of the costumes and the dark curtain, would do just that.

Final Remarks

It can be concluded that both pictures are in an excellent state of preservation. Although it is clear that the paintings have been treated numerous times in the past, this article focuses on the search for information on the 1952 treatment by Suhr in New York and the 1956 treatment by Mertens and Middelhoek in Amsterdam. A study of these restorers yielded valuable information on the materials and methods they used and helped explain the differences in the varnish layers between Marten and Oopjen. The inclusion of a thorough examination of the conservation history of these paintings reflects the multidisciplinary character of this research. The results show the significance of such a study, not only for the conservators working on the paintings, but also for scientists and art historians, and will hopefully stimulate future research in this field.

The present conservation treatment of the paintings aimed at removing the discoloured modern varnishes applied in the nineteen-fifties, and selectively removing the degraded old egg-white varnish layers. Although it was not possible at this time to remove all remains of the old egg-white varnish and overpaint, the appearance of the paintings is much improved. Removal of the upper varnish layers gave a better understanding of the modelling and Rembrandt's intended spatial relationships with their cool-warm colour contrasts and subtle transitions. More of Rembrandt's characteristic open brushwork was revealed along with improved saturation of the darks. It is anticipated, however, that with the passage of time it will become increasingly difficult to liberate the paint layers from these old restoration layers and further research is warranted. The knowledge gained from the extensive investigation of the varnish layers was found to be crucial in optimizing the conservation treatment and supporting the decision-making process.

Computational and scientific analyses also provided novel data indicating both canvases were cut from the same roll, which along with the identical ground layers confirm that both portraits were painted at the same time and may even originally have been conceived as a double portrait. Pigments identified in the ground and paint layers correspond with other paintings from that period, and demonstrate Rembrandt's mastery of creating spatial depth through subtle modulations of light and tone created by the unusual additions of pigments. High-resolution imaging revealed Rembrandt's extraordinary skill in creating the illusion and luminosity of lace.

The portraits of Marten and Oopjen are exceptional in every way. They are the only extant full-length, life-size pendant portraits by Rembrandt; a commission befitting the wealthy young couple. Our research reveals the extraordinary way the painter created these marvellous pictures. Our search for information on how best to treat them, and the extraordinary collaboration that followed, was every bit as exceptional.

Acknowledgements

Firstly, our sincere thanks to Sébastien Allard and Blaise Ducos from Musée du Louvre, and Isabelle Pallot-Frossard and Michel Menu from the Centre for Research and Restoration of the

Museums of France (C2RMF) for the rewarding collaboration. For the research into the conservation history we are grateful to Hélène Kat; Nadja Garthoff, Netherlands Institute for Art History (RKD); Anne Woollett, J. Paul Getty Museum, Susan Chore and The Frick Collection. We also acknowledge the many partners who participated in the scientific research: the C2RMF, the Cultural Heritage Agency of the Netherlands (RCE), Delft University of Technology, Shell Research Laboratories, Academic Medical Center (AMC), VU Medical Center, University of Twente, University of Antwerp and University of Bologna. Richard Wolbers, Lora Angelova and Boelo Schuur are thanked for their advice with the testing of aqueous gels. We would especially like to thank Anna Krekeler and Willem de Ridder for their assistance during the last phase of the treatment, and the Rijksmuseum photographers, Rik Klein Gotink and Carola van Wijk. Ige Verslype, Suzan Meijer and René Lugtigheid are also thanked for their fruitful discussion regarding the canvas supports. We are also grateful to the staff of the Rijksmuseum and especially Robert van Langh for their support.

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ABSTRACT

This article focuses on the conservation history and recent treatment (2016-2018) of the newly acquired pendant portraits of Marten Soolmans and Oopjen Coppit painted by Rembrandt in 1634. Much new information is brought to light about the nineteen-fifties treatments by William Suhr in New York and Henricus Hubertus Mertens in Amsterdam, particularly their varnishing methods. An impressive array of scientific analyses gave insight into the nature of the old varnish layers that were found on top of Rembrandt's paint layers. The recent treatment, carried out in the paintings conservation studio of the Rijksmuseum, restored much of the stunning detail and original colour contrasts in the two portraits. This consisted of removal of the 1950s varnish layers, along with (partial) reduction of a degraded and discoloured egg-white varnish. Scientific and computational analyses carried out as part of the conservation process also led to important new insights regarding the genesis of the portraits and Rembrandt's early painting technique. Macro-x-ray fluorescence (XRF) imaging showed significant changes in the composition of the backgrounds that Rembrandt later painted over with a curtain. Novel data gained from forensic imaging analysis of the canvas supports indicate that Marten and Oopjen are painted on two lengths of canvas that were cut from the same roll; however, more research is needed to conclude whether the portraits were initially intended as one composition. High resolution imaging and scientific analyses also reveal Rembrandt's extraordinary skill and inventiveness, for instance in painting bobbin lace using black on top of white, and his mastery in creating subtle modulations of light and tone through unusual additions of pigments.

NOTES

1 Treatment and technical analyses were carried out by Petria Noble (Senior Paintings Conservator), Gwen Tauber (Senior Paintings Conservator), and Susan Smelt (Junior Paintings Conservator). The advisory committee consisted of Taco Dibbits (General Director, Rijksmuseum) and Sébastien Allard (Director of Paintings Department, Musée du Louvre), along with Gregor Weber (Head of Fine Arts and Decorative Arts, Rijksmuseum), Blaise Ducos (Curator Dutch and Flemish painting, Musée du Louvre), Isabelle Pallot-Frossard (Director, Centre for Research and Restoration of the Museums of France (C2RMF)), Petria Noble (Head of Paintings Conservation, Rijksmuseum) and Anne Lepage (Conservation Specialist appointed by the C2RMF).

2 The paintings were investigated by Esther van Duijn as part of her research into the history of conservation in the Rijksmuseum (2015-18).

3 Scientific research in support of the treatment was led by Katrien Keune (Conservation Scientist, Rijksmuseum) in collaboration with the C2RMF, Annelies van Loon (Conservation Scientist, Rijksmuseum) and other partners; Erma Hermens (Senior Researcher Technical Art History, Rijksmuseum) collaborated on the interpretation of the painting technique; computational analyses were performed by Robert Erdmann (Senior Research Scientist, Rijksmuseum).

4 Middelhoek worked in the Rijksmuseum as a *verdoeker* or liner in 1955-64. He was interviewed in 1995 by former Rijksmuseum paintings conservator Hélène Kat. The interview was digitized and transcribed by Esther van Duijn in May 2015.

5 Esther van Duijn and Jan Piet Filedt Kok, 'The Art of Conservation III: The Restorations of Rembrandt's "Night watch"', *The Burlington Magazine* 158, 1355 (2016), pp. 117-28.

6 Middelhoek states: 'Yes, he did help me once with the large Rembrandt exhibition, and there were two canvases, owned by the Rothschild family. And those were lent to the museum on condition that they would be lined here.' See also *Verslagen der Rijksverzamelingen van geschiedenis en kunst 1956*, The Hague 1957, p. 16.

7 Rijksmuseum, Conservation files, External treatments: Rembrandt.

8 Wax-resin lining, a Dutch method developed in the nineteenth century, involved the impregnation of the reverse of a painting with a molten wax-resin mixture. This consolidated the paint layer, and at the same time was used to adhere a second canvas behind the original in order to strengthen it.

9 F. Winkler, 'Echt, falsch, verfälscht', *Kunstchronik* 10 (May 1957), no. 5, p. 142. We are grateful to Nadja Garthoff (RKD) for bringing this to our attention. Both paintings were on display in the Cleveland Museum of Art in 1949-52; see the 1949 Annual Report published in *The Bulletin of the Cleveland Museum of Art* 38 (June 1951), p. 154. Thanks to Jonathan Bikker (Rijksmuseum).

10 Joyce Hill Stoner, 'The legacy of William Suhr: From Berlin to New York', in Isabelle Verger (ed.), *ICOM-CC 14th Triennial Conference Preprints*, The Hague 2005, pp. 1040-45.

11 *William Suhr papers, 1846-2003*, bulk 1928-1982, Research Library, The Getty Research Institute, Accession no. 870697, box 23, folder 2. We are indebted to Anne Woollett (Curator, J. Paul Getty Museum), who generously agreed to look through the Suhr archive. The folder contains one overview photograph of Marten and three details (head, breeches and left hand), and two raking light details of lifting paint below his outstretched hand. The name of the painting on the folder is misspelt: 'Portrait of Maerten Sorlimans (Rothschild)'. In 1952 the portraits were known under the names Maerten Daey and Machteld van Doorn. Suhr wrote 'Rembrandt 1634' on the reverse of all photographs; some bear the inscription 'before treatment'.

12 *William Suhr papers*, Accession no. 870697, box 116, folder 8. On 10 November 1967 Suhr wrote to Gerson: 'Yes, worked for Rothschilds. … Cleaned the Rembrandt and worked on the EYCK now in the Frick.'

13 William Suhr, Conservation Ledgers, The Frick Collection/Frick Art Reference Library Archives, Volume 2, p. 88. Following "Baron Rothschild", are the letters 'R+S', meaning Rosenberg and Stiebel, New York art dealers who probably acted as a go-between. We are grateful to Susan Chore (Frick Art Reference Library) for this information.

14 Suhr allegedly treated 89 Rembrandt paintings. See Edward Grasman, *Gerson in Groningen. Een portret van Horst Gerson, kunstkenner en hoogleraar kunstgeschiedenis (1907-1978)*, Hilversum 2007, p. 87. The *William Suhr papers* at the Getty hold 155 folders with documentation of paintings

by, or attributed to, Rembrandt. Of these, 39 have treatment reports, mostly consisting of handwritten notes on the reverse of photographs.

15 Talens & Son, *Vindingen van den Laatsten Tijd*, Apeldoorn 1931(?), pp. 2-3. See also http://www.conservation-wiki.com/wiki/IV._Low_Molecular_Weight_Varnishes (consulted 17 April 2018). A fax from Talens in 1997, describes the ingredients of *Talens Rembrandt vernis* as cyclohexanone resin (35-40%), castor oil (c. 5%), turpentine (35-40%), white spirit (15-20%). See Mireille te Marvelde, 'Bijlage 10: De geschiedenis van de restauratie van de schilderijen in de Oranjezaal van Huis Ten Bosch', in *De Oranjezaal: catalogus en documentatie*, 1997, p. 30, http://oranjezaal.rkdmonographs.nl/steunbestanden/bijlage-10.

16 Ken Sutherland, 'Bleached Shellac Picture Varnishes: Characterization and Case Studies', *Journal of the Institute of Conservation* 33 (2010), no. 2, pp. 129-45, esp. pp. 141-42, see http://dx.doi.org/10.1080/19455224.2010.495242.

17 Leslie Carlyle discusses the development of bleached shellac varnish, see Leslie Carlyle, *The Artist's Assistant. Oil Painting Instruction Manuals and Handbooks in Britain 1800-1900 with Reference to Selected Eighteenth-Century Sources*, London 2001, pp. 87-93.

18 A report was often written for private clients, although none has been found for Marten and Oopjen

19 For the Rijksmuseum questionnaires: Haarlem, North Holland Archives, Rijksmuseum en rechtsvoorgangers te Amsterdam 1807-1945 (476), inv. nos. 3020-3023, 3037. The notebooks by conservator Louis Pomerantz (1919-1988): Archives of American Art, Smithsonian Institution, *Louis Pomerantz Papers*, 1937-1988, bulk 1950s-1988. The manual was written in 1952 for the Committee of Supervision and Advice for the Care of the Paintings by the City of Amsterdam. See Esther van Duijn, 'Changing Views, Altering Practices – A Brief Overview of Nearly Two Hundred Years of Painting Conservation at the Rijksmuseum in Amsterdam', in Janet Bridgland (ed.), *ICOM-CC 18th Triennial Conference Preprints*, Copenhagen 2017, pp. 1-7, esp. pp. 4-5. Other sources were the treatment reports for external paintings and various archives.

20 16 February-3 March 2016. The paintings were varnished with *Talens retoucheer vernis*. 'Rapport d'intervention concernant les deux tableaux suivants', Anne Lepage (C2RMF), 2016.

21 Areas of raised paint are evident in detailed photographs of both pictures taken in the nineteen-fifties.

22 C2RMF reports nos. 34411 and 34412, for Rijksmuseum and Musée du Louvre: 'Etude avant acquisition': Collection particulière, 'Rembrandt Harmensz van Rijn, Portrait de Marten Soolmans' (4 novembre 2015, revu en octobre 2016) and 'Portrait d'Oopjen Coppit' (9 novembre 2015, revu en octobre 2016), Elisabeth Ravaud, Gilles Bastian and Witold Novik, C2RMF, 2016.

23 Front: Visible (Vis) - before (A), during (B1), (B2), and (C), and after restoration (E), approx. 1250 ppi; Ultraviolet radiation (UV) - (A), (B1), (B2), (C), and (E), approx. 1250 ppi; Raking light - (A); Infrared photography (IR) - 850-1100 nm (A), approx. 1250 ppi; Transmitted (IRT) - 850-1100 nm (A); IR reflectography - 900-1700 nm (A): approx. 250 ppi. Reverse: Vis and UV - (A). Carried out by Carola van Wijk, Rik Klein Gotink, Staeske Rebers and Albertine Dijkema (Photographic Department, Rijksmuseum).

24 Susan Smelt, Robert Erdmann, Rik Klein Gotink, Petria Noble, Gwen Tauber, Carola van Wijk, 'High-Resolution Imaging as a New Research Tool at the Rijksmuseum', *American Institute for Conservation of Historic and Artistic works (AIC) 46th Annual Meeting* (2018). See https://aics46thannualmeeting2018.sched.com/event/Cz5i/imaging-technology-high-resolution-imaging-as-a-new-research-tool-in-the-rijksmuseum.

25 Developed by Robert Erdmann, for the *Bosch Research and Conservation Project*. See http://boschproject.org/#/.

26 *Bruker M6 Jetstream*: rhodium source, 50 kV, 600 µA, 700 µm stepsize, 70 ms/pixel dwell time, 9 scans/painting, c. 20 hrs/scan; in addition, three detail scans (head, hands and collar) of each painting were made at 400 µm stepsize, 220 ms/pixel dwell time, in collaboration with Joris Dik (Delft University of Technology). The spectra acquired were exported and processed using the PyMCa and Datamuncher software.

27 Identified in the upper grey ground of Marten and Oopjen. Lead soap aggregates form as a result of the reaction of lead-containing pigments or driers with fatty acids from the oil binding medium. Jaap Boon, Jaap van der Weerd, Katrien Keune, Petria Noble, Jørgen Wadum, 'Mechanical and Chemical Changes in Old Master Paint-

ings: Dissolution, Metal Soap Formation and Remineralization Processes in Lead Pigmented Ground/Intermediate Paint Layers of 17th Century Paintings', in Roy Vontobel (ed.), *ICOM-CC 13th Triennial Conference Preprints*, Rio de Janeiro 2002, pp. 401-06.

28 Josua Bruyn, Bob Haak, Simon Levie, Pieter van Thiel, *A Corpus of Rembrandt Paintings. Volume II: 1631-1634*, Dordrecht/Boston/Lancaster 1986, nos. A100, pp. 547-52, and A101, pp. 553-57.

29 Pyrolysis gas chromatography-mass spectrometry (py-GCMS) was carried out by the C2RMF and the RCE. C2RMF report nos. 34411 and 34412, 2016 (see note 22), and RCE reports: 'ESCAPE report SKA-5033-05_Marten' and 'ESCAPE report SKC-1768-02_Oopjen', 13 December 2016.

30 The varnish used in Paris in 2016 was a cyclohexanone, the same resin as that supposedly used by Suhr in 1952 (see note 20). For the history of synthetic varnishes, see http://www.conservation-wiki.com/wiki/III._The_History_of_Synthetic_Resin_Varnishes (consulted 30 April 2018).

31 Samples were embedded in *Technovit LC 2000*, dry-polished with Micro-Mesh© and studied with light microscopy (Zeiss AXIO Imager.A2m with AxioCam MRC5 and VIS-LED and LED 365nm filter set EX G 365, BS FT 395, EM LP 420), attenuated total reflection (ATR)-Fourier transform infrared (FTIR) imaging (Perkin Elmer Spectrum 100 FTIR spectrometer combined with a Spectrum Spotlight 400 FTIR microscope and a Perkin Elmer ATR imaging accessory consisting of a germanium crystal, instrumentation belonging to RCE) and scanning electron microscopy combined with energy dispersed X-ray analyses (SEM-EDX, FEI Nova Nano SEM 450 electron microscope coupled with a Thermo EDX system). BF and DF photographs are colour calibrated; for UV 365 nm images a white balance was made using a UV Grey chart from *UV Innovations*, Rijksmuseum, 2016-17.

32 The cyclohexanone ketone-based resins have vibrations at 3350, 2922, 2854, 1705, 1450, 1367, 1230, 1159, 1045 and 755 cm^{-1}, while the shellac-based varnish can be distinguished by its C-O vibration at 1715 cm^{-1} and an extra small band around 1604 cm^{-1}, ATR-FTIR imaging, Amsterdam 2017. Suzanne Quillen Lomax and Sarah Fisher, 'An Investigation of the Removability of Naturally Aged Synthetic Picture Varnishes', *Journal of the American Institute for Conservation* 29 (1990), no. 2, article 6, pp. 181-91.

33 Degradation products consisting of lead (potassium) sulphates and calcium oxalates have been frequently encountered and are considered to form over time from a reaction between lead, potassium or calcium ions from the original paint and gases (SO_2) from the atmosphere, or oxalates possibly derived from the oxidized oil. See Annelies van Loon, Petria Noble, Jaap Boon, 'White Hazes and Surface Crusts in Rembrandt's *Homer* and Related Paintings', in Janet Bridgland (ed.), *ICOM-CC 16th Triennial Conference Preprints*, Lisbon 2011, 1322, pp. 1-10; Letizia Monico et al., 'Non-Invasive Identification of Metal-Oxalate Complexes on Polychrome Artwork Surfaces by Reflection Mid-Infrared Spectroscopy', *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 116 (2013), pp. 270-80.

34 Albumen identified with Chemiluminescent Immunochemical imaging on paint cross-section SK-C-1768_03 from Oopjen by Silvia Prati, Giorgia Sciutto, Rocco Mazzeo, Aldo Roda (University of Bologna) in 2017. The protein was identified as chicken egg by mass spectrometry using a label-free GeLC proteomics workflow, Sander Piersma (VU Medical Center, Amsterdam) in 2018.

35 Renate and Paul Woudhuysen-Keller, 'The History of Egg-White Varnishes', *Hamilton Kerr Institute Bulletin* 2 (1994), pp. 90-140.

36 Theodore Turquet de Mayerne, 'Pictoria sculptoria & quae subalternarum artium' (the 'Mayerne manuscript'), 1620. London, British Library, MS. Sloane 2052, fol. 143r-v.

37 Ibid., fol. 15r.

38 Cornelia Peres, 'On Egg-White Coatings', in Cornelia Peres et al. (eds.), *A Closer Look: Technical and Art-Historical Studies on Works by Van Gogh and Gauguin*, Zwolle 1991, pp. 39-49, esp. pp. 40, 43, and the historical sources listed in the Appendix, pp. 44-49.

39 M. François-Xavier de Burtin, *Treatise on the Knowledge Necessary to Amateurs in Pictures* (Robert White, trans.), London 1845, p. 300. Carlyle 2001 (see note 17), p. 235.

40 Woudhuysen-Keller 1994 (see note 35), pp. 93, 94.

41 Peres 1991 (see note 38), p. 40.

42 *A Compendium of Colours, and Other Materials Used in the Arts*, 1808, p. 48. See Carlyle 2001 (see note 17), pp. 233-36.

43 OCT using a central wavelength of 1060 nm, by Maurice Aalders, Mitra Almasian and

Leah Wilk (Academic Medical Center (AMC), Amsterdam) in 2017.

44 MA-XRDP, a novel, non-invasive imaging technique developed by the group of Koen Janssens (University of Antwerp). Line scans were carried out in the conservation studio of the Rijksmuseum by Frederik Vanmeert, Steven de Meyer and Nouchka de Keyser in 2018. FTIR analyses of small scrapings of the residues from both paintings also identified protein and starch, in addition to lead (potassium) sulphates and calcium oxalates in all samples, Amsterdam, 2017 (see notes 31 and 33).

45 2% *Pemulen TR-2* with triethanolamine (TEA) adjusted to pH 7. This was applied with a small flat brush and moved around for approx. 1 minute. Almost immediately the grey-brown layer began to swell and break up. The bulk of this layer was removed with a dry swab, followed by clearance with mineral spirits (18% aromatics). Gels containing enzymes specific for albumen were tested but were found to be ineffective, most likely due to the presence of lead ions from the lead (potassium) sulphates.

46 Light microscopy and SEM-EDX analyses of paint cross-sections revealed the overpaint is ivory black, although more uniform in its composition than the ivory black of the original paint, suggesting a modern origin. There is no varnish layer between the original paint and the black overpaint.

47 For transmitted infrared photography see note 23. Photomicrographs were made with a stereomicroscope (Zeiss Stemi 508 with Axiocam 105 color and LED using Zen 2.3 (blue edition) software). Digital microscope images were captured using a HIROX RH-200 digital microscope with assistance of Jaap Boon in the Rijksmuseum conservation studio in 2018.

48 Rembrandt's companion portraits were usually painted on canvas from the same bolt, possibly provided by the patrons or sitters. See Ernst van de Wetering, 'The Invisible Rembrandt: The Results of Technical and Scientific Examination', in Christopher Brown et al. (eds.), *Rembrandt: The Master and his Workshop: Paintings*, New Haven/ London 1992, pp. 90-105, esp. p. 90, note 11. At the time, canvas was produced in various standard widths, depending on the size of the loom. See Ernst van de Wetering, 'The Canvas Support', in Bruyn et al. 1986 (see note 28), pp. 15-43; reprinted in Ernst van de Wetering, *Rembrandt: The Painter at Work*, Amsterdam 1997, pp. 124-25, 300 note 48; Michiel Franken, 'Sixty Years of Thread Counting (Chapter 3)', in Richard Johnson Jr (ed.), *Counting Vermeer: Using Weave Maps to Study Vermeer's Canvases*, The Hague 2017, see http://countingvermeer.rkdmonographs.nl/chapter-3-sixty-years-of-thread-counting/strip-widths.

49 Computational analyses established the thread counts of the canvas supports.
Marten: Horizontal 12.3 th/cm (10.2-14.5); Vertical: 11.8 (9.8-13.8 th/cm).
Oopjen: Horizontal 12.7 th/cm (10.7-14.7); Vertical: 12.0 (10.5-13.6 th/cm), Rijksmuseum, 2016, revised 2018.

50 The x-ray films provided by the C2RMF were scanned at 600 dpi resolution to facilitate computerized 'thread counting' and weave comparison, Rijksmuseum, 2016, revised 2018. The seven horizontal films that make up the x-radiograph were digitized in two parts, a left half and a right half. Automated canvas analysis has been instrumental in establishing links between paintings in the oeuvres of Vincent van Gogh, Nicolas Poussin, Velasquez and Johannes Vermeer. For description of the method used, see Robert Erdmann, Richard Johnson Jr, Mary Schafer, John Twilley and Travis Sawyer, 'Reuniting Poussin's Bacchanals painted for Cardinal Richelieu Through Quantitative Canvas Weave Analysis', 2013, https://pdfs.semanticscholar.org/9531/af55182654a34184a218bfbae34fca4784ba.pdf?_ga=2.214997335.1157590304.1497967244-794445577.1497967244. See also Laurens van der Maaten and Robert Erdmann, 'Automatic Thread-Level Canvas Analysis. A Machine-Learning Approach to Analyzing the Canvas of Paintings', *IEEE Signal Processing Magazine*, July 2015, pp. 38-45.

51 Primary cusping derives from a first stretching and attachment of a canvas to a framework with tacks or string. The attachment points create distortions in the canvas around the edges, which become fixed after the application of the glue and ground layers. When the canvas is stretched again and attached to a strainer, new but weaker secondary cusping may occur.

52 The three canvases measure resp. 446 cm x 185/202/232 cm. Margriet van Eikema Hommes, Tatjana van Run, Katrien Keune, Ige Verslype, Arie Wallert, Milko den Leeuw, Ingeborg de Jongh, 'Discoveries During the Technical Investigation of Gerard de Lairesse's Earliest Known Ceiling Painting', in *Painting Techniques.*

History, Materials and Studio Practice, 5th international Symposium Rijksmuseum Amsterdam 18-20 September 2013, Amsterdam 2016, pp. 145-53, esp. pp. 146-47.

53 Remmet van Luttervelt, 'Bij het portret van Oopje Coppit', *Amstelodamum Maandblad* 43 (1956), p. 93.

54 Jonathan Bikker, *Marten and Oopjen: Two Monumental Portraits by Rembrandt*, Amsterdam 2016, p. 39.

55 Pigments identified with SEM-EDX in paint cross-sections of Marten and Oopjen: SK-A-5033_04 (background) and SK-C-1768_03 (background), Rijksmuseum, 2017.

56 Petria Noble and Jørgen Wadum, 'The Restoration of the "Anatomy Lesson of Dr. Nicolaes Tulp"', in Norbert Middelkoop, Marlies Enklaar and Peter van der Ploeg (eds.), *Rembrandt under the Scalpel: The Anatomy Lesson of Dr. Nicolaes Tulp Dissected*, Amsterdam/The Hague 1998, pp. 65-72, esp. p. 65. Further investigation of the grounds in the '*Anatomy Lesson*' and Marten and Oopjen may prove that they were applied by a specialist primer in Amsterdam. For Rembrandt's grounds, see the survey in Karin Groen, *Paintings in the Laboratory: Scientific Examination for Art History and Conservation* (Esther van Duijn, ed.), London 2014, pp. 21-49 ('Grounds in Rembrandt's Workshop and Paintings by his Contemporaries').

57 The ground was analysed by Annelies van Loon, *Jacob Adriaensz. Backer, De Regentessen van het Burgerweeshuis, 1633/34, Amsterdam Museum, Chemische analyse van het tafelkleed*, unpublished report, 2008, p. 10.

58 Identified with SEM-EDX in paint cross-sections of Marten: SK-A-5033_31 and SK-A5033_31b (background) and SK-A-5033_22 (cloak), and in Oopjen: SK-C-1768-09 (skirt).

59 Maryan Ainsworth et al., *Art and Autoradiography: Insights into the Genesis of Paintings by Rembrandt, Van Dyck, and Vermeer*, New York 1982, p. 40, plate 22. Ernst van de Wetering, *Rembrandt's Paintings Revisited: A Complete Survey*, Dordrecht 2017, p. 525, no. 88b, fig. 1. This painting appears to have an identical (double) ground to Marten and Oopjen, see Table 2.3 in Van Duijn ed. 2014 (see note 56), p. 28.

60 Only neutron activation autoradiography (NAAR) can detect the phosphorous in bone or ivory black in a sketch layer deep within the paint build-up. See Matthias Alfeld, Claudia Laurenze-Landsberg, Andrea Denker, Koen Janssens, Petria Noble, 'Neutron Activation Autoradiography and Scanning Macro-XRF of Rembrandt van Rijn's *Susanna and the Elders* (Gemäldegalerie Berlin): A Comparison of Two Methods for Imaging of Historical Paintings with Elemental Contrast,' *Applied Physics A* 119 (2015), no. 3, pp. 795-805.

61 Seymour Slive (ed.), *Frans Hals*, Munich/New York/London 1989, p. 249, no. 42. See for the painting technique of the lace specifically, Karin Groen and Ella Hendriks, 'Frans Hals: A Technical Examination', in ibid., pp. 109-27, esp. 120.

62 Ernst van de Wetering, 'Problems of Apprenticeship and Studio Collaboration', in Bruyn et al. 1986 (see note 28), p. 63, and note 149.

63 Bas Dudok van Heel, 'Rembrandt and Frans Hals Painting in the Workshop of Hendrick Uylenburgh', in Stephanie Dickey (ed.), *Rembrandt and his Circle: Insights and Discoveries,* Amsterdam 2017, pp. 17-43, esp. p. 24.

64 Identified in samples from both costumes with SEM-EDX (ivory black is distinguished by its high magnesium content) and with non-invasive MA-XRPD, carried out by University of Antwerp, in Amsterdam, 2017 (see note 44).

65 Marieke de Winkel, *Fashion and Fancy: Dress and Meaning in Rembrandt's Paintings*, Amsterdam 2006, p. 66.

66 David Bomford et al., *Art in the Making: Rembrandt*, London 2006 (orig. 1989), pp. 45-46, 97.

67 Samuel van Hoogstraten, *Inleyding tot de hooge schoole der schilderkonst*, Rotterdam 1678, p. 307: 'De schaduwen of bruintens zijn ook geen zeekere middelen om te doen + wechwijken. Want schoon de donkerheit in een hol het zelve diep doet achten, zoo zal het zelve noch veel dieper schijnen, wanneer het in zijn waere diepte eenich licht ontfangt'.

> Conservators Gwen Tauber (left), Petria Noble (centre) and Susan Smelt (right) working on Marten and Oopjen in the paintings conservation studio of the Rijksmuseum. Photo: David van Dam