Changes to a Civic Guard Portrait

The Technical Investigation of Cornelis Ketel's *Militia Company of Captain Dirck Jacobsz Rosecrans and Lieutenant Pauw*

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Everything changes, nothing is as it was. Viewers standing in front of a sixteenth- or seventeenth-century painting should not be fooled into thinking that they are seeing just what their counterparts would have seen four centuries ago. Many pigments discolour over time, affected by light and climate. The idea that almost every old painting has undergone a certain metamorphosis over the centuries may be unsettling, but it is inescapable. This is simply what happens. Things start to get really exciting, though, when we apply that notion to the work of an artist who was renowned in his own time for his unorthodox method and artistic buccaneering. What will we find?

Cornelis Ketel (1548-1616) was one such innovator. His contemporary Karel van Mander, who wrote a glowing biography of Ketel in 1604, recounts how around 1600 the artist came up with the idea of abandoning his brush and starting to paint with his fingers. Many regarded it as a caprice, said Van Mander, 'a ridiculous, abhorrent craving akin to that experienced by some pregnant women, who hanker after strange, raw or uncooked things to eat.'[1] But Ketel succeeded in his design, and certainly did not produce any 'misshapen offspring'. Not long afterwards, he tried to paint with his toes. His contemporaries thought that this was, if possible, even crazier, but yet again he pulled it off. It would appear, however, that these seemingly bizarre experiments were more than an eccentric flight of fancy: it is likely that Ketel suffered from some form of rheumatic complaint, making it increasingly difficult for him to hold a brush. Be that as it may, the reputation of dauntless experimenter continued to cling to Ketel. The restoration of one of Ketel's best-known works – traditionally known as *The Militia Company of Captain Dirck Jacobsz Rosecrans and Lieutenant Pauw* – painted in 1588, and the associated analytical research, provided an opportunity to investigate whether this reputation is deserved (fig. 1).[2]

Detail of fig. 1

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Fig. 1
CORNELIS KETEL,
The Militia Company of Captain Dirck Jacobsz Rosecrans and Lieutenant Pauw, 1588.
Oil on canvas, 208 x 410 cm.
Amsterdam, Rijksmuseum, inv. no. SK-C-378; on loan from the City of Amsterdam.
Photograph taken after the 2005-07 restoration.

Ketel's painting has been in the Rijksmuseum since 1885 and belongs to the genre of the civic guard portrait, a group portrait of the members of a militia company. Around 1580 the medieval civic guard guilds, which had a predominantly ceremonial role, started to transform into citizens' militias which could provide military support to the city government.[3] Most of the members of these militias were well-to-do burghers. The civic guard portrait as a genre is peculiarly Dutch. The earliest, painted by Dirck Jacobsz, dates from 1529, the latest from the second half of the seventeenth century.

Ketel's civic guard portrait depicts thirteen officers of the crossbowmen's

guild, also known as St George's Militia (fig. 2). The most important figure in the group is the man with the captain's staff, Dirck Jacobsz Rosecrans. He wears a sash in red and white, probably the colours of the regiment. His lieutenant, Pauw, is pictured further to the right. He, too, wears a red and white sash.[4] Between them, carrying a red-and-white striped standard, is the ensign. This is probably the first group portrait in which the guardsmen are pictured life size, full length and standing. This makes it the model for several later civic guard portraits, among them Rembrandt's *Night Watch*.

Research and conservation in any event made it clear that Ketel sometimes used materials in an entirely unorthodox manner, and that the work now appears different in a number of respects from the way it looked when it was first painted.

Support

The Militia Company of Captain Dirck Jacobsz Rosecrans and Lieutenant Pauw was painted on a single piece of linen canvas, which is quite unusual for such a large work.[5] It is one of the earliest civic guard portraits to have been painted on this support. The decision to use canvas was probably prompted by the huge dimensions of the painting: a work this size on panel would have been extraordinarily heavy and difficult to handle. The original canvas is finely woven in a linen weave.[6] The painting currently measures 207.5 x 410 cm, but these are not the original dimensions.

The painting has undergone previous restorations, at which time pieces were probably cut off. It was relined in 1880 by the restorer W.A. Hopman. The dimensions of the painting are recorded for the first time in a letter Hopman wrote in 1879: height 206 and width 407 cm. These measurements correspond more or less exactly with the present size. However, the picture was originally larger.[7] An 1878 inventory in the Amsterdam City Archives reveals that the painting had already been lined before Hopman's intervention in 1880.[8]

It appears that a complete figure has been cut off on the left; a foot, a lower leg and a hand can be seen, while the rest of the figure is missing. The cropping of the shield on the

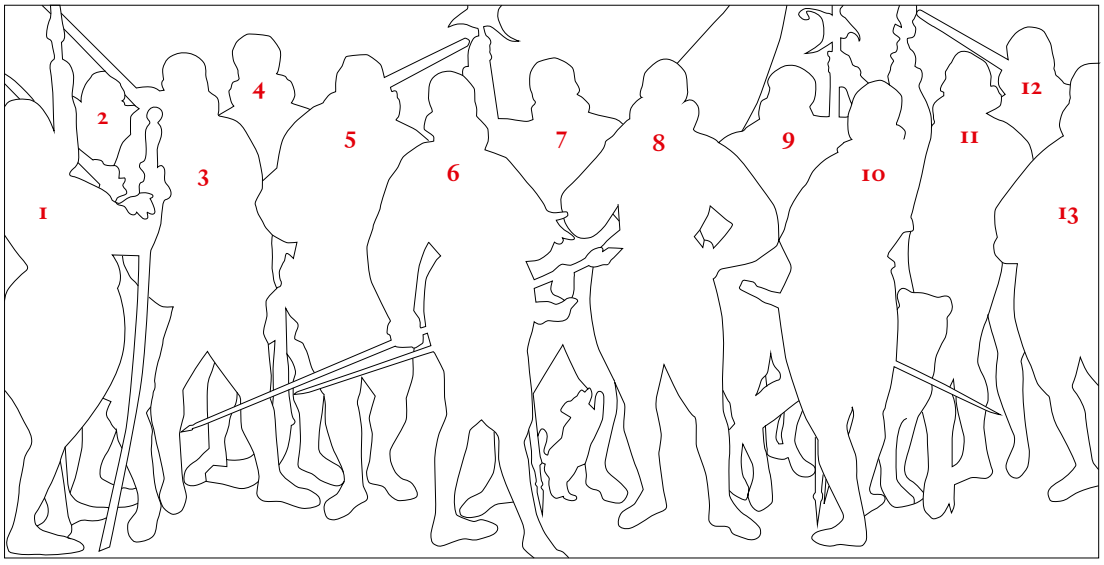


Fig. 2
Schematic drawing with the officers numbered. These numbers are referred to in the text.

right, only half of which is now visible, would also not seem to be original – particularly since on it there is a depiction of a print by Hendrik Goltzius that had been published only two years before. The print depicts Marcus Curtius, the fourth in a set of Roman heroes, all of whom sacrificed their lives to save their country. This is a significant iconographic reference to the heroism of the militiamen in the painting.[9]

On the extreme left of the painting, the '1' of the date has disappeared, possibly along with part of the traces of the signature. In 1864 the city archivist Pieter Scheltema reported that the picture was 'signed Anno 1588, C. Ketel'.[10] This could suggest that it was cut down again after 1864. It seems unlikely that this happened when Hopman relined it. All the indications are that Hopman tried to retain the size, with all the irregularities that existed, as much as he possibly could.[11] Scheltema's comment could suggest that the edges were trimmed again during an earlier lining that took place between his observation of the signature in 1864 and Hopman's treatment in 1880.[12] This seems improbable, however, because a description of the painting in 1841 refers to 'thirteen Militiamen, full length'.[13]

If one or more figures have indeed been cut off, as is suggested several times in the literature, it must have been done before 1841.[14] Regrettably none of the three sources dating from before then (Karel van Mander in 1604, Gerrit Pietersz Schaep in 1653 and Jan van Dyk in 1758) mentions the number of figures portrayed.[15] The painting has been moved more than once. It may have been taken down from its place in 1620, during the renovation of the guards' headquarters.[16] In 1672 it was moved, with a great many other paintings, to Amsterdam Town Hall.[17] After 1808 it hung on the landing between the town clerk's office and the Chamber of the Mayor and Aldermen in the Prinsenhof (the then town hall). On the occasion of the removal of the paintings from the Town Hall in Dam Square – which King Louis Bonaparte commandeered as his palace – to the Prinsenhof, the director of the national art gallery (Nationale Kunstgalerij), C.S. Roos, drew up a list of the works that were to be moved. It emerges from this list, on which the dimensions of the paintings were recorded, that at that time Ketel's group portrait was still the original size.[18] This means that it must have been reduced between 1808 and 1841.

What might the picture originally have looked like? It is possible that the painting was originally the same size as Pieter Isaacsz's 1599 work, *The Militia Company of Captain Gillis Jansz Valckenier and Lieutenant Pieter Jacobsz Bas*. We know from the inventory compiled by Schaep in 1653 that this painting, made eleven years later by Ketel's pupil, hung opposite his master's civic guard portrait in the headquarters of St George's Civic Guard. Pieter Izaacsz's painting measures 218 x 526 cm and is still the original width, as can be deduced from the presence of the original stretched edges with cords.

Ketel's civic guard portrait is organized around a fairly simple central perspective. If we take the perspectival vanishing point of the painting in its present condition (in other words with a considerable part of the original paint surface folded around the stretcher), it appears that about a hundred centimetres are missing from the right-hand side. This space would accommodate at least three more people. That would bring the total width of the painting to more than five metres. It can be deduced from the 1808 list that the original width of the canvas must have been at least 537.9 cm.[19] The work would thus have been slightly, but not much, wider than Pieter Isaacsz's painting. In this

Fig. 3
Reconstruction of the possible original composition and dimensions of *The Militia Company of Captain Dirck Jacobsz Rosecrans and Lieutenant Pauw.*

reconstruction the captain, ensign and lieutenant would be in the centre, emphasizing the hierarchy. The red and white flag, flanked by the officers in their red and white sashes, would have been the central point of the picture (fig. 3).

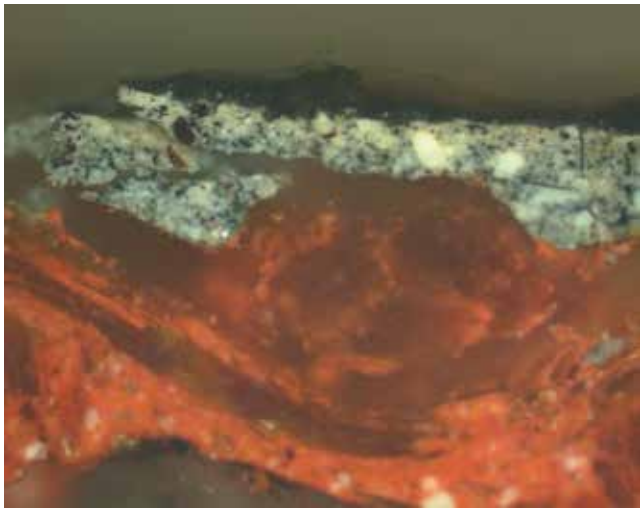
Red Paint on the Back of the Canvas

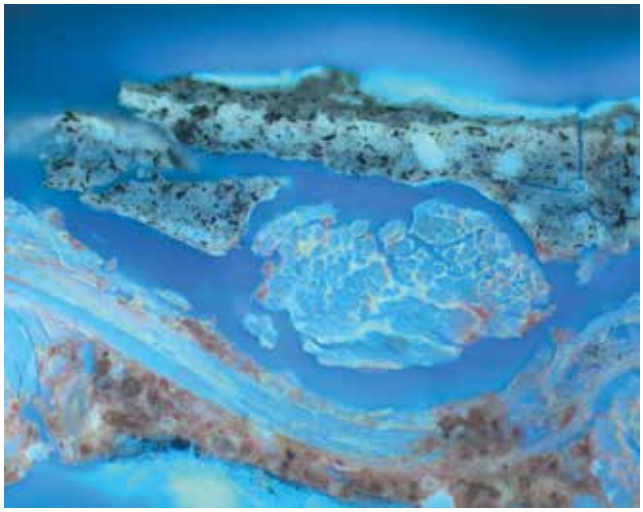
There is a layer of red paint on the back of the original canvas that has penetrated through the canvas fibres, sometimes right to the front. A study of paint cross-sections revealed that this red layer is present not only on the surface of the canvas but also between the warp and weft (fig. 4).[20] In some cases it has penetrated so deep that there are traces on the face of the canvas in direct contact with the priming and paint layers. It sometimes seems as if the canvas was totally impregnated with this material from the back. This layer is present over the whole surface, right to the cut edges of the canvas. We know this because the red layer is still visible in the cross-sections of paint taken along the stretched edges. We cannot say for certain that this layer is original, but it seems likely. The red paint layer on Ketel's painting was analysed using a range of analytical techniques and was found to contain a considerable variety of pigments, with a particularly high level of reddish-orange red lead.[21] The function of this layer is not clear. It may have been applied as protection against damp.[22] Might the painting have been in wainscotting in the civic guard headquarters, and was red lead applied to protect it from a cold or damp wall?

We know of no other examples of layers of red paint on the back of paintings on canvas.[23] Good examples are in any case difficult to find. Original backs of paintings can only seldom be studied because most seventeenth-century paintings have been relined. Without further research it is not possible to pronounce on the dating and function of the red paint layer.[24] Strikingly, Ketel also used red lead in the painting – in the doublet worn by militia officer number 12 (see fig. 2). It is extremely difficult to pick up with a brush, so it is very rarely used when painting in oils.[25]

Ground

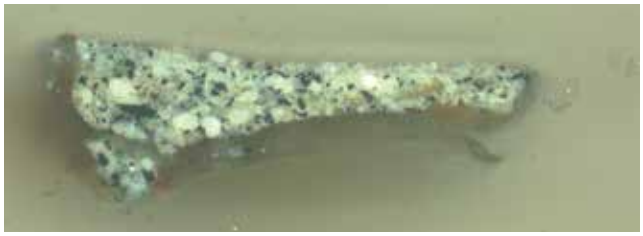
The canvas was primed with a grey ground. In 1979 Miedema and Meijer noted that Cornelis Ketel had used a coloured ground in the civic guard portrait, the first artist in the Northern Netherlands to employ this innovation, which had originated in Italy.[26] There are no obvious visible traces of the

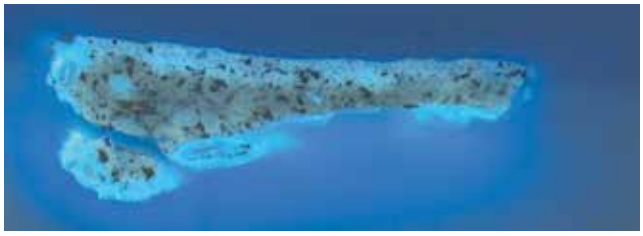




Figs. 4a, b
Paint cross-section (131/?) showing the orange-red paint layer on the back – and in the fibres – of the canvas (200x magnification). Direct polarized light (a) and UV fluorescence (b).

application method.[27] The ground is a mixture of white lead, charcoal black, chalk and a very small quantity of earth pigments.[28] It appears to have been applied in two coats, more or less wet-in-wet. The distinction between the first and second layer is not always very clear, but it can be identified in most of the paint cross-sections. The first layer is a darker grey and contains more black and fewer earth pigments. The second layer is slightly lighter and warmer in tone and contains more white and earth pigments. This is clearly visible in the paint cross-sections (fig. 5). The difference between the first and second layers can also be seen under ultraviolet





Figs. 5a, b
Paint cross-section (131/?) showing two minimally different layers of the grey ground (200x magnification). Transmitted polarized light (a) and UV fluorescence (b).

radiation; the first fluoresces less than the second. In this painting Ketel used the grey ground as a mid-tone in the flesh colours, to create light and shade in an economical fashion. He painted only a thin layer of his flesh-tone mixture over the greyish ground. Where he wanted a shadow, he made the layer so thin that the underlying layer shows through. He also used the colour of the ground for the light tiles by leaving them unpainted. Where Ketel learnt to use a grey ground like this is not clear – in fact he seems to be ushering in a local tradition. Some of his fellow artists in Haarlem also worked with grounds of this kind, but Cornelis Ketel was exceptionally early when he used it in his militia portrait in 1588.[29]

A conventional chalk-glue ground has been found under three portraits that Cornelis Ketel painted on panel in 1579-80. Over this is an opaque grey underlayer composed of drying oil and lead white, charcoal black and red ochre – in other words a blend similar to the one on the civic guard portrait.[30] In these much earlier portraits Ketel was already using the grey in the same way – for the mid-tone in the flesh colours. He painted the three portraits around 1580, when he was in England. The Rijksmuseum also has an even earlier portrait by Ketel, which he painted in 1574 soon after he arrived in England. In this tondo, a *Portrait of a Man, with a Putto Blowing Bubbles on the Verso,* the method seems to be more traditional.[31] In this early work the paint was applied directly on to the white ground, without any intermediate tonal layers.[32] It would therefore seem that Ketel first started to exploit the possibilities of a grey underlayer for flesh tones at some time between 1574 and 1580, while he was in England. This is noteworthy because there is a general consensus that the use of coloured grounds originated in Italy. At this time, however, England – and more particularly London – was an important artistic centre. Many artists, from Flanders and elsewhere, settled in the city – some of them permanently. The practice could have been introduced to the English court in London by painters who had been to Italy.

Underdrawing and Preliminary Sketch

Infrared reflectography examination revealed no traces of an underdrawing.[33] It is similarly impossible to detect an underdrawing with the naked eye, and that is remarkable because the paint was applied so thinly and has become transparent and/or abraded in many places. There are no known sketches or drawings of the painting at a preliminary stage. It would, though, seem safe to assume that the artist made a drawing before he started to paint, even if only to get some idea of the overall layout on the canvas and to establish the positions and poses of the many figures relative to one another.

It is possible that he used a drawing medium that does not show up with infrared reflectography or the composition was prepared with a material that was wiped away during the painting process. Given the dark grey ground of this painting, white or red chalk would be the most likely choice.

The three portraits discussed above do have visible preparatory sketches.[34] For the tondo, Ketel used an underdrawing in a dry material, possibly graphite.[35] The many reserves in the militia portrait tell us that the concept must have been worked out beforehand; the figures are often reserved in the architecture, which was painted first.

Some dark grey lines can be seen with the naked eye, but they appear to have been put in on top of the paint layer or, in the case of the tiles, on the ground. They are also present in the outlines of officer number 9's white stockings and the outline of his breeches on the left. These lines look as if they could have been made with graphite, but could not be analysed.

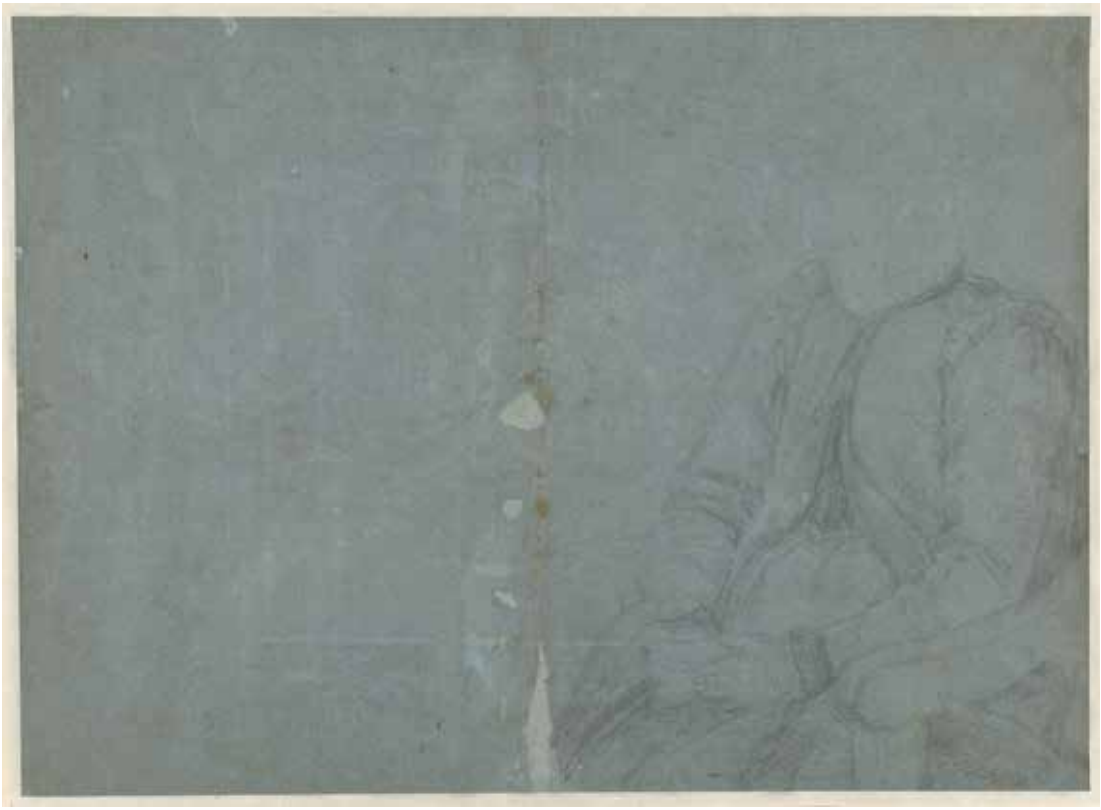


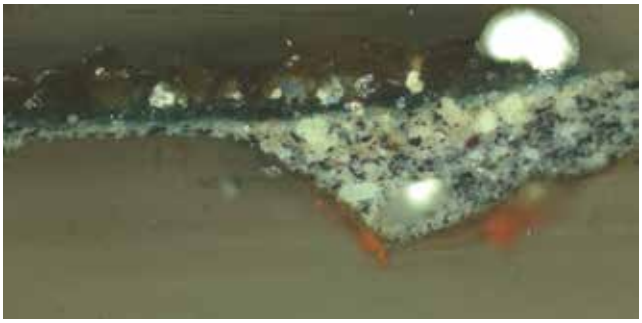
Fig. 6
CORNELIS KETEL, *Study of a Seated Woman, without a Head*, c. 1589-94. Black chalk on blue paper, 51.5 x 37.6 cm. Amsterdam, Rijksmuseum, inv. no. RP-T-1888-A-1423(V).

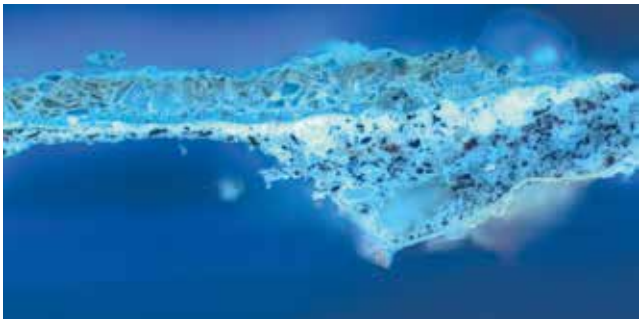
The lines in the tiles appear to have been drawn with a ruler.

In his *Schilder-boeck* Van Mander tells us that Ketel made portrait drawings, so it would seem self-evident that he would have used preparatory sketches when making paintings – and one such drawing by him has indeed survived. In black chalk on tinted paper, it depicts a woman sitting in an armchair. The fascinating thing about this drawing is that the figure, the chair, the dress and the hands have been drawn – but the face has been left blank (fig. 6). This sketch was used as the model for a portrait painted by Cornelis Ketel, now in the Thyssen-Bornemisza Museum.[36] It has been suggested that Ketel kept a number of drawings like this in his workshop to show prospective clients a selection of poses.[37]

It is also very possible – and in fact even more likely – that these drawings were made in an endeavour to find a more efficient working method. With a drawing like this to hand, workshop assistants could do the preliminary work, painting the body in the required position. The master, Cornelis Ketel, only had to concern himself with making an accurate likeness of the sitter's face, which meant that a high turnover could be achieved. This practice was by no means unusual.[38]

Although it is impossible to demonstrate with absolute certainty that Ketel used this method for the militia portrait, it is unlikely that he would have undertaken a commission of this magnitude without some assistance. Looking at the picture itself, it is noticeable that the heads of some of the officers are rather small relative to their bodies; sometimes the heads appear to have been stuck virtually straight on to the torso, without the transition of the neck.



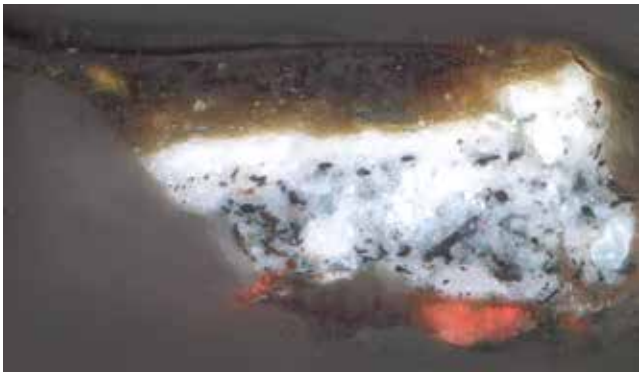


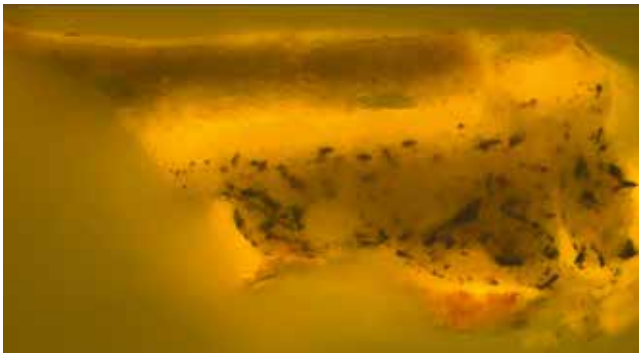
Figs. 7a, b
Paint cross-section (131/2) showing paint containing smalt underpainted with very fine indigo blue (200x magnification). Transmitted polarized light (a) and UV fluorescence (b).

Underpainting

As a rule the paint layers were applied directly on to the grey ground, but underpainting was used in some places. There is beige and, locally, white underpainting in officer number 11's colourful doublet. This intensifies the brightness and colour saturation of the overlying paint layer, which contains smalt and red lake, creating the effect of a shot silk fabric. The same man's breeches, in which the top layer of paint includes smalt, appear to have been underpainted with a thin layer of blue paint that contains fine particles of pigment. Indigo may have been used for the underpainting. The same applies to the ensign's outfit. Here again there appears to be underpainting containing indigo beneath the thicker top layer of paint, which contains smalt and red lake (fig. 7).[39]

The lieutenant's black doublet is underpainted with a layer of grey paint that also contains a small amount of red lake. And officer number 12's hose, where the top paint layer consists of a cupriferous green that has browned over time, are underpainted with a layer of white paint (fig. 8).





Figs. 8a, b
Paint cross-section (131/11) showing a layer of white paint as underpainting for a (discoloured) cupriferous green (200x magnification). Transmitted polarized light (a) and UV fluorescence (b).

Paint Layers

Pigments

Ketel's colourful palette was achieved with a relatively simple series of pigments. The most important pigment on Ketel's palette, for both the grey ground and the flesh tones – and also, of course, for the officers' starched white ruffs – was lead white. Ketel used it in various ways, both to cover[40] in the ruffs and in scumbles in the flesh tones.[41] This was an ingenious way of suggesting transparency; instead of diluting the paint, he applied it very sparingly. By tipping the canvas and the underlying paint layers in very lightly with the lead white paint – mixed with a trace of red ochre and vermilion – he created an open structure where the underlying dark paint layers show through. This enabled Ketel to imitate a lifelike flesh tone in the men's faces (fig. 9). Even the underlying blue veins are visible under the skin. Not all pigments are suitable for this technique, but it works particularly well with lead white. This is because lead white and drying oil that react in a particular way to form a 'short' – stiff – manageable paint.

Smalt and indigo were used for the blue; vermilion, red ochres and an organic red cochineal lacquer for the red. Red lead was used – very sparingly – for the orange-red, and the yellows were obtained from yellow ochres and lead-tin yellow, and possibly also an organic yellow lake. The greens came from verdigris, a synthetic copper pigment. Charcoal black was used as the black, but there is also a crystalline black, possibly of mineral origin, that has not yet been identified with certainty. To identify the pigments we studied paint samples with the aid of various forms of microscopy,

Figs. 9a, b
Captain Rosecrans's face, during varnish removal (a) and after restoration (b). The flesh tones are scumbled, so that the dark grey ground shows through a very thin, transparent layer of lead white, red ochre and vermilion.

microchemical analysis, spectrometry, chromatography and X-ray diffraction.

The flesh tones were built up with lead white, chalk, earth pigments, black and vermilion. A copper green was usually used for the green. Smalt and indigo were often mixed with lead white. Down through the centuries almost all these pigments have undergone changes – usually irreversible – so that they no longer look as they were originally intended to.

Paint Structure

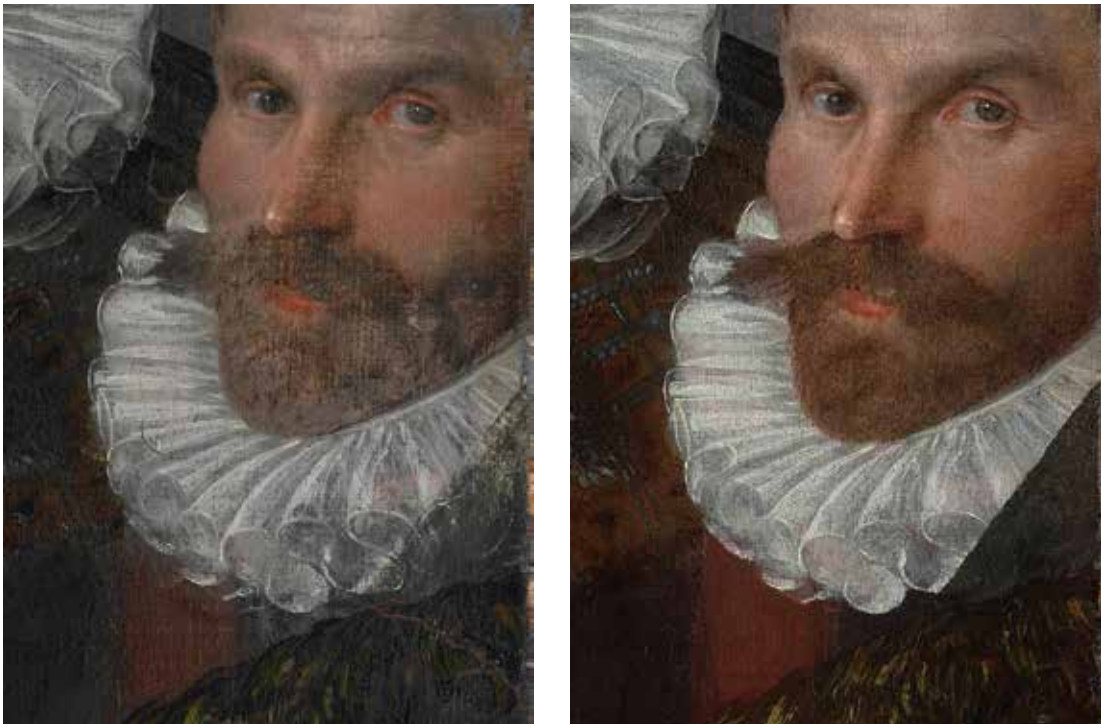
The structure of the paint layers in Ketel's civic guard portrait is relatively simple. The paint was generally applied thinly and in a few layers *alla prima* (wet-in-wet). The artist worked from back to front and from dark to light. Areas in the architectural background were reserved for the columns and the figures. The outlines were sometimes changed, and arms, legs and weapons were moved, which meant that parts of figures were painted over the background. There was little use of impasto. The light parts of the faces and ruffs were painted with a more pastose brushstroke, as were the highlights in lead-tin yellow, for example in the tassel on the captain's pike, in the gilded decorations on the shields and in the gold buttons sported by the captain and the ensign. The green of the sleeve of the missing figure on the left and of the fringe on the shield on the right was likewise applied quite thickly. The paint is a copper green, which shows as white on the X-radiograph. The lead white in the flesh tones and the ruffs also looks lighter on the X-ray, but there is relatively little contrast because the paint was applied so thinly.[42]

Ketel painted the picture fluently and swiftly with a great sureness of touch. The structure is economical and the brushstrokes are varied; coarse and broad in the architecture and tiled floor, and fine and narrow in the faces, hair and details of the clothes. The paint was usually applied opaquely and in some places Ketel used scumbles, where the underlying paint layers or ground are covered with a semi-transparent top layer, for example in the shadows in the flesh tones, as we described above. The paint was also often applied wet-in-wet and the outlines in officer number 11's hands were softened by subtly pulling the almost dry paint of the fingers into the darker outline with short hatching strokes done with a brush. In officer number 12's face, the shape of the eyebrow was scratched into the still-wet paint with the tip of a brush handle. In some places, particularly around the fingers, an outline has been reinforced with reddish-brown paint. The captain's hands are a case in point.

The Drying of Oil Paint and the Effects of Increasing Transparency

Oil paint dries in a specific manner. It dries in two different stages. To begin with, oil dries by oxidation, not by evaporation as watercolour does. A drying oil can do this because it contains sufficient unsaturated fatty acids.

In the second stage the interaction with different pigments, particularly lead white, red lead, lead-tin yellow, verdigris, malachite and azurite, plays an important role. While the oil molecules oxidize further, aldehydes and highly unstable hydroperoxides are formed.[43] This process enables the free reactive products to form compounds with metal cations given off by lead, cobalt, manganese, and cupriferous pigments. Gradually the product of the first stage – an apolar polymer network – is replaced by the product of the second stage: a much more polar structure based on metal compounds: the rock-hard paint of old paintings. Because the overlying paint layers, the pink scumbles of lead white and vermilion, have become more transparent over time, the ground is now more visible than originally



Figs. 10a, b
Details of the face of officer number 13: stripped state (a), the increased transparency of the paint and abrasion of the surface has revealed a previously planned face under the present one (the eyes are visible in the current beard); the officer's face after restoration (b).

intended. The newly-formed paint becomes more transparent than the paint that was applied in the first place.[44] The mechanical abrasion of the upper paint layers compounds this cool, greyish effect.

The abrasion, coupled with the increased transparency of the lead white, making the underlying paint layers more visible, means that the pentimenti are also more evident (fig. 10).

Discolouration

Smalt

There are a great many discoloured passages in Ketel's civic guard portrait. As early as 1876 it was remarked of the painting, '… although the colours are rather faded'.[45]

One of the most obtrusive discolourations is that of the smalt used in the men's garments. Smalt was a relatively recent addition to the seventeenth-century palette – it was not used as a pigment in the Low Countries until around the end of the sixteenth century.[46] This makes Cornelis Ketel one of the earliest users of smalt, which is actually nothing more than glass coloured blue with cobalt salts. The cobalt is responsible for the blue colour in the glass matrix. The splinters of blue glass were ground to a homogeneous pigment powder. The best quality was a very dark purplish blue; the lesser grades were a pale greyish blue. Large quantities of potash were often added as a flux to lower the melting point of the glass. This means that smalt almost always contains a lot of potassium, and this makes the glass less stable. As the paint ages, the excess potassium can be leached out of the glass matrix.[47]

A remarkable aspect of the militia portrait is that not all the smalt passages have discoloured to the same degree. The blue of the cords trimming officer number 7's leather cuirass is still fairly strong. The blue thread woven into the breeches of officer

Fig. 11
Detail of the lieutenant's breeches, which contain discoloured smalt (see also fig. 7).

number 9 has also retained its colour, as have the slashes in his white shirt. His garters, however, are severely discoloured and flaking. Officer number 11's breeches and the ensign's outfit – probably originally bright blue – are badly degraded. The caffa breeches worn by the lieutenant are another passage that has seriously discoloured because of the presence of smalt in the paint (fig. 11).[48] The background colour of this fabric was probably originally purple, created with a mixture of red lake and smalt. Because the smalt has discoloured, the fabric is now predominantly grey with a hint of pink from the red lake.

The blue glass itself is not the only thing that discolours; the pigment also forms all sorts of other undesirable compounds with the drying oil with which it is applied, and this results in browning. Here again, the presence of potassium is an important factor.[49] This process is somewhat similar to the saponification of the lead ions in the lead white we saw before.[50] Potassium soaps are far more problematic, however, because they are much more soluble in water. As a consequence, parts of the binding medium become water soluble.

Where there is poor quality smalt, we see that it is not only the colour of the pigment itself that changes; the saponification process causes the binding medium to discolour, too, and it increasingly loses its binding capacity. The sound, sealed surfaces of passages painted with smalt have often been compromised, and these areas are cracked, rough and friable.[51]

The blue sleeve of officer number 1 is a passage that has not so much discoloured as changed in terms of structure. Red lake and smalt were used for this sleeve. The red lake was used predominantly in the lowest paint layer and the blue was applied on top of it. Red lake is a pigment that dries poorly. Smalt, on the other hand, because of its cobalt content, and more particularly because of the lead that is present in relatively large quantities, dries extremely well. So well, in fact, that it was sometimes recommended that a little of this smalt or another powdered glass containing lead should be mixed with poorly-drying paints. This is probably the cause of the drying cracks. The open effect that saponification of the smalt paint caused is further confirmed by the crocodile craquelure in a relief-like, open texture, which makes the surface highly absorbent and gives it a very mat appearance.

There is no discernible fixed pattern or regularity in the discolouration and saponification. The blue in officer number 11's breeches has clearly suffered more than the blue in officer number 9's, but it is not clear why this

should be the case (fig. 12). The degradation mechanisms of smalt are still shrouded in uncertainty.

Indigo Blue

The indigo used in the hose worn by officers numbers 4 and 8 has probably faded. Indigo is known to lose colour intensity under the influence of light. Photo-oxidation is the generally accepted cause of colour changes in organic pigments, particularly indigo.[52] There is also, though, a strongly expressed suggestion that a reaction with substances in the binding medium, in other words the oil, plays a role in the fading of indigo. The argument is that aldehydes released as a consequence of the oxidation of polyunsaturated fatty acids in the oil could easily react with indigo.[53]

Green

The green passages are also severely discoloured. A striking colour change can be seen in the copper green. The discolouration is not the same everywhere. The green slashes in the colourful doublet worn by officer number 11 are still green (fig. 13), but number 12's hose have turned brown and the tassels and fringing around the shield are green in places but have discoloured to brown in others. Officer number 12's hose were not analysed, but in ultraviolet light it can clearly be seen that the topmost paint layer contains copper, because the copper completely extinguishes the fluorescence (see fig. 13b). The hose look light on the X-radiograph. This is a clear indication that there is an underpainting at this spot done with a heavier material that absorbs more radiation. Further analysis revealed that there is lead white in the underpainting.

In the sixteenth and seventeenth centuries, verdigris, a copper acetate, was usually used for a green pigment. Ketel used it, too. The pigment was made by exposing copper plates to the effect of organic acids. The copper

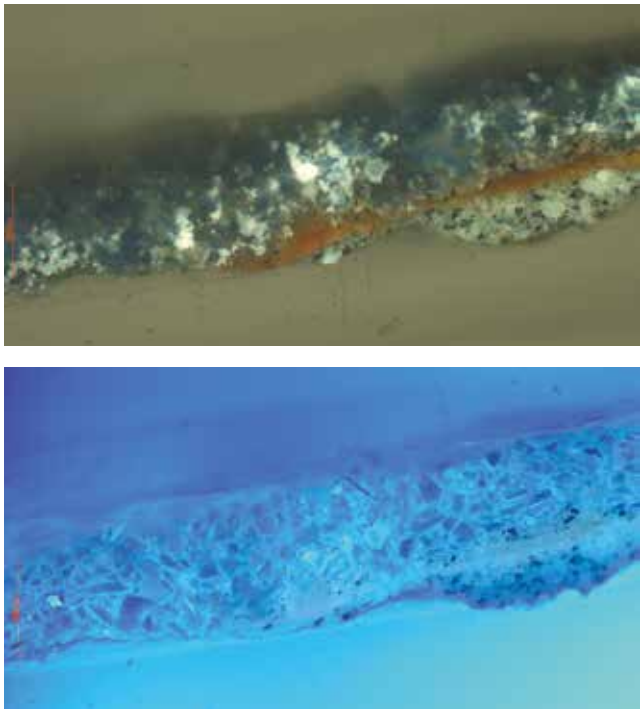
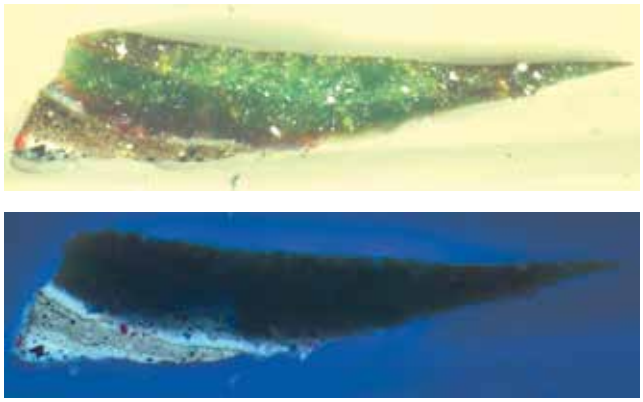


Fig. 12
Paint cross-section (131/24) showing that the smalt for the blue flecks in officer number 9's breeches is in slightly better condition (200x magnification). Transmitted polarized light (a) and UV fluorescence (b).



Figs. 13a, b
Paint cross-section (131/6) showing the green in the colourful doublet worn by officer number 11 (200x magnification). This colour is still reasonably intact here, in clear contrast to the green in fig. 7. Transmitted polarized light (a) and UV fluorescence (b).

acetate consists of relatively fine crystals which, ground with oil, produce an easily worked, nicely pastose paint. Because of the relatively low refractive indices of the verdigris, which are very close to that of the drying oil, the paint is almost always very transparent.[54] Ketel took advantage of this property by putting in a bright white underpainting on the dark grey ground in some places. The stockings worn by officer number 12, for instance, were underpainted first with a layer of white paint, and then a fine glaze of transparent verdigris green was laid over the top. White underpainting was also used in other transparent green passages. The reflective underpainting intensifies the power and brightness of the overlying paint layer.

When old layers of paint with verdigris are examined under a microscope, it is often noticeable that the original crystalline copper acetate particles are barely, if at all, visible. The verdigris has dissolved in the oil.[55] The result appears as a fine, smooth transparent green film.

In a great many old master paintings, including this civic guard portrait, this bright, fresh green is no longer present and has largely turned into a dull, unattractive brown. The green appears to have been preserved fairly well in officer number 11's doublet, but the stockings of the figure standing beside him have discoloured completely and are now a dark brown. Something of the original green can still be made out under the brown in the tassels and fringe around the shield.

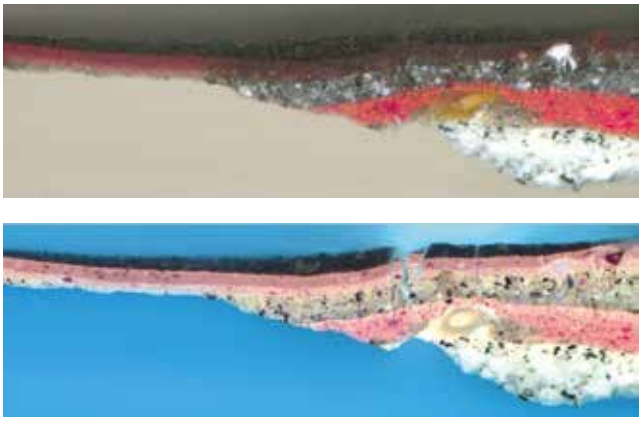
The discolouration of the green paint to brown appears to be the consequence of a chemical reaction under the influence of light, which happens over a long period. As a result, the green copper compound is replaced by the reddish-brown copper(I) oxide, particularly on the surface. Because of this extreme increase in oxidation, not only does the copper discolour, the originally colourless oil quite quickly takes on an intense brownish or yellowish shade.

Red

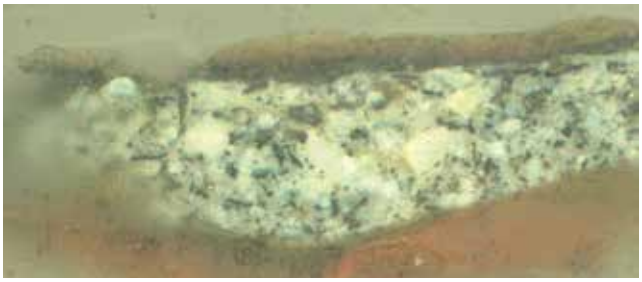
The transparent deep red lake used in the flag, the sashes and some of the stockings and shoes also appears to have changed colour. This is particularly evident in the captain's sash, because the colour of a section that was for a long time covered by a layer of black paint is brighter than the adjacent passages (fig. 14). The most unsightly is the fading in the flag, which looks washed-out and rather flat. This is the consequence of the fading of the fugitive organic red lake. The organic colours artists had at their disposal at this time were lakes made from madder, cochineal or red wood.

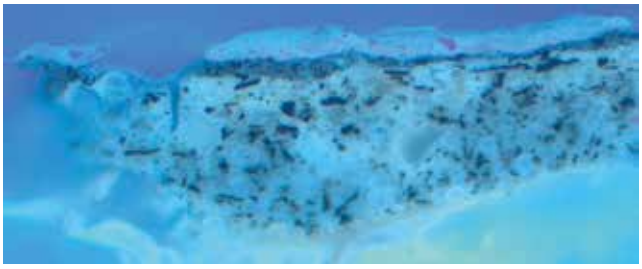
The organic red found in the militia portrait was obtained from cochineal. The substance that gives cochineal its colour is carminic acid. It is a red dyestuff, obtained from the insect *Dactylopius coccus,* a scale insect indigenous to South and Central America.[56] In the seventeenth century these red dyes were used primarily for dyeing textiles. In economic terms, processing them to make lake pigments for painting was at most a derivative, a by-product.

These dyestuffs could not be used for painting just as they were. A solid pigment had to be made from the dye first. The colouring substance was attached by a chemical trick to colourless inorganic particles: the



Figs. 14a, b
Paint cross-section (131/29) showing an organic red lake that had been covered with a layer of black paint (200x magnification). Because it was protected by the black paint, the red is well preserved. Transmitted polarized light (a) and UV fluorescence (b).





substrate. The most frequently used substrate was chalk and aluminium hydroxide.[57] The refractive indices of both chalk and aluminium hydroxide are rather low. Because of these relatively low refractive indices, which come very close to that of the drying oil, organic red lakes are always quite transparent.[58] Ketel made very efficient use of this property. In many places in the militia portrait he put a reflective white underpainting on the grey ground first. Beige and locally white underpainting was used in officer number 11's brightly coloured doublet, over which he painted a fine glaze of transparent red lake and smalt. This suggested a shot silk fabric with great brilliance, because reflection from the underpainting increased the colour intensity of the overlying paint layer and produced a shimmering effect.

Many of these effects have become less prominent over time. These natural organic reds are what is known as fugitive – they have a tendency to fade when exposed to light (fig. 15).[59] The light conveys energy to the structure of the dyestuff, and this breaks down the ring structure that gives the molecule its colour.[60] Organic red lakes are best preserved when they are covered with an opaque paint layer and no longer exposed to light at all (see fig. 14).

Figs. 15a, b
Paint cross-section (131/27) showing that the cochineal lake in the lieutenant's breeches, which were originally deep crimson, has seriously discoloured (200x magnification). Transmitted polarized light (a) and UV fluorescence (b).

Figs. 16a, b, c
Detail of Captain Rosecrans's sash (a): remnants of a layer of black paint; detail of the remnants of black paint on the flag and the pentimento of officer number 9's right shoulder (b); detail of the flag (c): the red and orange stripes do not match up properly with the white stripe below, but they do tally with the remnants of the black paint.

Remnants of Black Paint on Red Passages

Remnants of a layer of black paint were found on the central red stripes of the flag and the sashes worn by Captain Rosecrans and Lieutenant Pauw (fig. 16). This black paint was in any event still present on the painting in 1905, as can be seen in a black and white photograph dating from that year (fig. 17). The work was restored by P.N. Bakker and W.F.C. Greebe in 1924, and it is thought that they took the black paint to be an overpaint and consequently removed the greater part of it. The documentation kept at that

Fig. 17
A photograph of the militia portrait taken in 1905, in which the black stripes can be seen on the sashes and the flag.

time was always extremely brief, so it is particularly remarkable that the removal of overpaints was explicitly recorded: 'overpaints to be removed'.[61] Aside from the relining in 1880, the only other intervention described in the documents is 'to be varnished'.[62] The fact that the black paint in the flag is still intact along the stretched edges tallies with this. The 1905 photograph tells us that the layer of black paint was still present when the canvas was relined in 1880. In 1924 there was no reason to remove the black paint from the stretched edges because it could not be seen anyway.

All the investigations into the authenticity of the black paint layer during the 2005-07 restoration point to the conclusion that the black paint is original. No dirt or varnish was found between the black paint and the underlying paint layers. This is evident from a number of cross-sections of the black paint taken from various places in the painting: from the captain's sash (see fig. 14), along the stretched edge in the flag where the black paint layer is still intact and from the lieutenant's sash.

The strongest argument, however, is the nature of the paint itself. Although the pigment has not yet been identified with certainty, it appears to be a fairly rare black pigment – a high-sulphur, ground mineral – that has so far only been found in a few sixteenth- and seventeenth-century paintings.[63] The SEM-EDX spectra (fig. 18) indicate many mineral elements and a high level of sulphur (S). Its composition is otherwise predominantly organic. However, the black also proves to have a specific crystal structure, identifiable in the

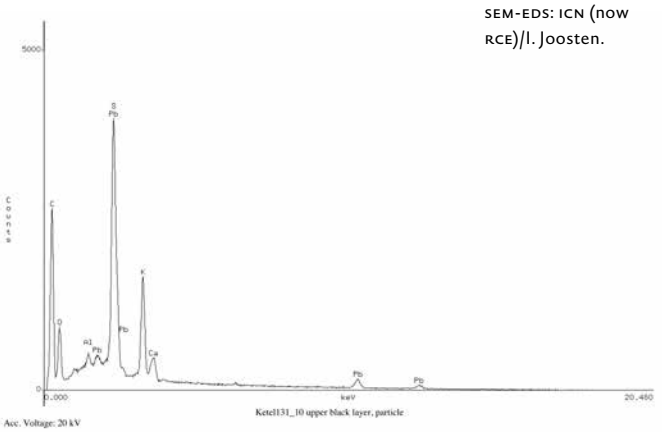


Fig. 18
This EDS spectrum of a black particle from the sash of the Captain may refer to the sulphur-rich coal-type black, because sulphur, calcium, aluminium and potassium were detected. SEM-EDS: ICN (now RCE)/I. Joosten.

X-ray diffraction pattern (appendix). This pattern is identical in both sashes and in the lieutenant's black doublet, which is certainly original.

There are also several indications in the structure of the paint layers. It has been found, for instance, that the white of the lieutenant's ruff overlaps the black on the sash at one point. There is another clue in the pentimento in officer number 9's shoulder. The position of his shoulder, which was originally higher, was reserved in the red of the first version of the flag. Ketel only decided to move the shoulder down at the same time as he added the black stripe, for the red stripe does not continue under the black at the level of the shoulder pentimento (see fig. 16b). There is another pentimento at the junction between the red and orange stripes and the white stripe, which Ketel painted half black later in the painting process. The red and orange do not join properly to the first white version, but they do appear to match up with the later black version (see fig. 16c).

Although no historical evidence that might explain the change to the colours of the flag and the sashes has been found, it is nevertheless most likely that there was an iconographic reason for it. It would seem obvious to associate this addition with a symbol of mourning. However, there is no mention of this in any historical sources, and Rosecrans, in any event, was still alive in 1603.[64] The multiple layers of paint in both the sashes and the flag are another striking aspect in this context. They reveal that Ketel changed the colours several times from red, to white, to black and vice versa.

In Conclusion

In the final analysis, the question as to whether Ketel proves to be an innovator in both his technique and his use of materials can be answered with a cautious 'yes'. Ketel was the first Northern Netherlandish artist to use a dark ground. He also used his materials in an economical, not to say parsimonious way: the pigment in the ground returns in the paint layer, in the shaded parts of the flesh tones and in the floor tiles. In contrast to the often complex paint structure with multiple layers that his predecessors used, Ketel adopted a simpler method

Fig. 19
Officers 4 and 5 during the removal of the varnish: the original colours, damaged areas and abrasion all emerged from under the yellowed varnish.

Fig. 20
The militia portrait shortly after the removal of the varnish began: a small strip from which the yellowed varnish has been removed can be seen on the left. It is still present on the rest of the painting.

in which passages were chiefly painted *alla prima*. He also used pigments that were relatively new in his day: smalt, red lead and the unusual black pigment described above.

Although many of the colours no longer look as they once did, the overall impression of the painting is still surprisingly powerful and lifelike. The recent restoration, in which various layers of yellowed varnish and discoloured retouches and overpaints were removed from the original paint surface (see figs. 9, 10, 19-21), has brought the colours back to life again in so far as that is reasonably possible (see fig. 1). Clarity, depth and detail have increased considerably after the treatment. The restoration also presented the opportunity to undertake in-depth research into the changes that the painting has undergone over time. We have seen how these changes may have come about – in part as a result of human intervention and in part through natural ageing. This knowledge is of great importance to conservation, and it gives viewers a better idea of what the painting originally looked like.

Fig. 21
The militia portrait during restoration ('stripped state').

APPENDIX X-RAY DIFFRACTION DATA OF BLACK PIGMENT

Cu anode λ=1.5418, 40kV, 30mA, Ni-filter, no He-flush, 5:30 hrs.
Sample (131-30) of black paint from painting by Cornelis Ketel.

I/I*	4 Θ	Θ	d
3	25,040	6,260	7,070
2	33,040	8,260	5,366
18	39,740	9,935	4,468
20	41,460	10,365	4,285
100	49,120	12,280	3,625
90	54,300	13,575	3,284
10	57,380	14,345	3,111
12	65,620	16,405	2,730
95	68,520	17,130	2,617
16	72,160	18,040	2,489
18	80,880	20,220	2,230
30	85,780	21,445	2,109
22	88,560	22,140	2,046
1	94,740	23,685	1,919
40	98,320	24,580	1,853
1	103,880	25,970	1,760
14	108,120	27,030	1,696
2	111,900	27,975	1,643
25	116,380	29,095	1,585
7	120,640	30,160	1,534
5	124,940	31,235	1,487
4	137,940	34,485	1,362
6	144,060	36,015	1,311
7	152,260	38,065	1,250
5	159,020	39,755	1,205
4	163,300	40,825	1,179

NOTES

1 'eenen belachlijcken wanschapen lust, gelijck gemeen is by eenige bevruchte Vrouwen, die vreemden, rouwen oft ongekoockten cost tot spijse te gebruycken gelusten.' Karel van Mander, H. Miedema (ed.), *The Lives of the Illustrious Netherlandish and German Painters, from the First Edition of the Schilder-boeck (1603-1604)*, 6 vols., Doornspijk 1994, vol. 1, pp. 370-71; 1998, vol. 5, p. 149.

2 The painting was restored by Erika Smeenk-Metz and Barbara Schoonhoven between October 2005 and March 2007.

3 P. Knevel, 'De kracht en de zenuwen van de Republiek. De schutterijen in Holland, 1580-1650', in M. Carasso-Kok and J. Levy-van Halm (eds.), *Schutters in Holand, kracht en zenuwen van de stad*, Zwolle/Haarlem 1988, pp. 36-53.

4 S.A.C. Dudok van Heel, *De jonge Rembrandt onder tijdgenoten. Godsdienst en schilderkunst in Leiden en Amsterdam*, Nijmegen 2006 (*Nijmeegse Kunsthistorische Studies*, vol. 14), p. 367, note 8, on the identity of the two officers. Dudok van Heel identified Lieutenant Pauw, with slight reservations, as Pieter Pauw (1552-1611). The names of the other men are unknown.

5 *The Meagre Company* (209 x 429 cm) of 1637 by Frans Hals and Pieter Codde (Rijksmuseum, inv. no. SK-C-374) is another example of a large work painted on a single piece of canvas. Ketel's civic guard portrait probably hung opposite Pieter Isaacsz's *The Militia Company of Captain Gillis Jansz Valckenier and Lieutenant Pieter Jacobsz Bas* (218 x 526 cm) of 1599 (Rijksmuseum,

inv. no. SK-C-455). The linen was identified with polarized light microscopy (PLM). Microscopy in transmitted polarized light was undertaken with a Zeiss Standard 17 microscope. Refractive indices were determined in relation to the standard mounting medium (Cargille Meltmount n = 1.662).

6 We counted 22/23 threads per cm vertically (along the right-hand stretcher edge) and 19 threads horizontally (in an abraded area on the front). The threads are approximately 0.5 mm thick. The original canvas is clearly visible in the X-radiographs. Digital X-rays were taken by the Röntgen Technische Dienst (RTD) under the supervision of A. van den Biggelaar. Method: Contour Radiography. Equipment: GE-AGFA CR Tower with GE-AGFA-IPC imaging plate, 35 x 43 cm and Andrex Beryllium tube, 32 kV, 5 mA, 5 min., distance 600 cm.

7 The original paint continues over all the turned-under edges: right 3.5 cm (max.), left 2.8 cm (max.), bottom 3.5 cm (max.) and top 3.1 cm (max.). The edges are irregular and severely damaged. The painted surface – including the turned-under edges – is 214.1 cm high and 416.3 cm wide. No traces of an unpainted edge or original stretching were found. There is no cusping to be seen, either with the naked eye or on the X-rays. The impression of a corner bar in the lower right corner (approx.50/55 cm from the bottom) does not correspond with the current stretcher dating from 1880 and probably came from a previous stretching.

8 Amsterdam, City Archives, no. H85 001, records from 1864, March 1878 and before 1880: 1878, on inventory: 'Very poor condition (old on new canvas that is coming loose again, or also "patched up" …)'. ('Zeer slechte staat (oud op nieuw doek dat weer loslaat, of ook "bijgepleisterd" …)'.); 1879, Advies der Subcommissie van Voorbereiding, B&W Amsterdam: 'The interesting work by Ketel (No 35 landing) which is already in a very bad state, perhaps as a result of former incorrect or poorly executed conservation measures.' ('Het interessante stuk van Ketel (No 35 overloop) welks toestand al zeer slecht is, misschien ten gevolge van vroegere verkeerde of slecht gelukte maatregelen ter conservatie.'); 1880: 'to be relined' ('te verdoeken') (wax/resin relining carried out). In a letter dating from 1879 W.A. Hopman wrote of this picture: '… height 206 width 407 cent.: This work has suffered very badly and is still very suitable for relining.' ('… hoog 206 breed 407 cent.: Dit stuk heeft zeer veel geleden en is nog zeer goed te verdoeken'.) With thanks to To Schulting, who led a working group of University of Amsterdam students who found this material.

9 T. Schulting, 'Hendrick Goltzius en Cornelis Ketel: "hertsen vrienden"?', *Nederlands Kunsthistorisch Jaarboek* 42/43 (1991-92), p. 162.

10 P. Scheltema, *Historische beschrijving der schilderijen van het Stadhuis te Amsterdam*, Amsterdam 1879, cat. no. 35, p. 22.

11 Hopman even took pains to transfer loose pieces of the original canvas to the lining linen.

12 This could mean that another relining was undertaken in the brief period between 1864 and 1880. It is difficult to make an accurate assessment of the truth of Scheltema's assertion on this point.

13 'On the landing from the town clerk's office to the chamber of the burgomasters and aldermen. A very old painting with thirteen militiamen full length, in the centre a small dog, the artist unknown.' ('In de overloop van de secretarie naar burgemeester en wethouderen kamer. Een zeer oud Stuk met dertien Schutters ten voeten uit, in het midden een Hondje, de Meester onbekend.') From Jeronimo de Vries, *Beschrijving der schilderijen en zeldzaamheden op het stadhuis der stad Amsterdam aanwezig*, Amsterdam 1841, p. 11.

14 Some authors believe that the figures were arranged symmetrically, with the captain, lieutenant and standard-bearer as the principal figures in the centre. De Jongh suggests that it is not impossible that the flag was the central point of the composition. This ties in nicely with the perspectival centre formed by the pattern of the floor tiles and the architecture with the great door and the columns in the background. E. de Jongh, 'Cornelis Ketel (1548-1616): Corporaalschap van kapitein Dirck Jacobsz. Roosecrans en luitenant Pauw', *Openbaar kunstbezit* 7 (1963), p. 1b.

15 Karel van Mander, op. cit. (note 1); Gerrit Pietersz Schaep, *Manuscripts by Gerrit Pietersz Schaep, Regarding the History of Amsterdam*, undated [1653] (Amsterdam, City Archives, Manuscripts, nos. 41–44); Jan van Dyk, *Kunst en historiekundige beschrijving en aanmerkingen over alle de schilderijen op het Stadhuis te Amsterdam*, Amsterdam 1758.

16 M. Carasso-Kok and J. Levy-van Halm (eds.), *Schutters in Holland: kracht en zenuwen van de stad*, exh. cat. Haarlem (Frans Hals Museum) 1988, p. 92: no fewer than six civic guard portraits of similar dimensions were commissioned between 1623 and 1633. It seems likely that a considerable amount of

space had to be found to accommodate these new paintings.

17 In 1760 Van Dijk described the painting there, '… in the corner opposite the windows, beside the place where the colonels sit.' ('… in de hoek tegenover de glaazen, naast de zitplaats van de heeren colonellen.')

18 N.E. Middelkoop, 'Schuttersstukken kijken met Jan van Dyk. Een reconstructie van de plaatsing in het Stadhuis op de Dam', *Maandblad Amstelodamum* 96 (2009), no. 2, pp. 76 and 78. For C.S. Roos's list see H. Brugmans, *Van Raadhuis tot Paleis. Documenten betreffende den overgang van het Amsterdamsche Stadhuis tot Koninklijk Paleis*, Amsterdam 1913, pp. 59-65, esp. p. 63.

19 Cf. also the reconstruction in H. Miedema and T. Schulting, 'Het schuttersstuk van Cornelis Ketel (1588)', *Bulletin van het Rijksmuseum* 39 (1991), pp. 355-62, esp. pp. 359-61.

20 This layer – or traces of it – was found in a great many of the paint samples we took. Observations of paint cross-sections were obtained with a Leica DMLM microscope (magnifications 50x, 100x, 200x, 500x and 1000x). Exposures in direct transmitted light (bright field) and ultraviolet light (filter cube BL/V10 C105) were made with a digital Leica DFC 420 C camera. 2,7 dichlorofluorescein (DFC), Rhodamine B (RHOB) and Sudan Black B stains were used to study the distribution of fatty acids in the binding medium (linseed oil).

21 PLM was also carried out with a Zeiss Standard 17 microscope. The refractive indices were likewise determined in relation to the standard mounting medium (Cargille Meltmount n = 1.662) for the identification of the pigments. W.C. McCrone, 'The Microscopical Identification of Artists' Pigments', *Journal of IIC-Canadian Group* 7 (1982), nos. 1-2, pp. 11-34. The classical wet microchemical analyses (MCA) were done in accordance with H. Behrens and P.D.C. Kley, *Mikrochemische Analyse*, vol. 1, Leipzig 1915. See also K. Groen and A. Wallert, *Microscopie en microchemische analyse*, Amsterdam 2001 (course reader Netherlands Institute for Cultural Heritage [Instituut Collectie Nederland]). X-ray diffraction analyses (XRD) were conducted by means of Debye-Scherrer powder diffraction patterns, obtained with 57.3 mm Gandolfi cameras. The length of exposure ranged from 4 to 7 hours. CuKα radiation (λ = 1.542Å) was used at 40kV, with a tube voltage of 30mA. Scanning electron microscope (SEM) analysis with energy dispersive spectrometry of X-rays (EDX) was carried out with a JEOL JXA-840A electron probe microanalyser, usually at 10nA, 25kV, at a working distance of about 40 mm. The samples (paint cross-sections) were generally studied without any coating in a low vacuum. EDX analyses were carried out on a number of points on the cross-sections by measuring the emitted X-rays using the Noran Vantage EDS system with a Pioneer Norvar detector. Raman spectroscopy on different layers of paint in cross-sections was done with a Renishaw inVia Raman microscope using 514nm and 785nm lasers. With thanks to Michel Belleil and Dr Matthew Bloomfield, Renishaw SAS, Champs-sur-Marne, Belgium.

22 Although unusual, the use of red lead to protect the back of the canvas has been recommended in American literature. R. Mayer, *The Artists' Handbook of Materials and Techniques*, New York 1970. This red layer on the back of the painting caused problems when it came to taking the X-radiographs. The layer, which is moreover distributed quite irregularly in – and over – the fabric, contains quite a high proportion of lead, which caused extra absorption in the X-ray image.

23 Martin Bijl (freelance conservator in Alkmaar) knows of a few examples of seventeenth-century canvases that have had layers of red paint applied to their backs later. Maartje Stols-Witlox (lecturer in conservation at the University of Amsterdam), who researches historic sources about grounds, informed us in conversation that she has not come across any recipes for layers of paint – protective or otherwise – on the back of the canvas.

24 There is also a layer of red paint on the back of *The Meagre Company* (see also note 5), but this one is certainly not original because it does not run under the stretcher bars, which are also not original. Moreover, the composition of this paint is different. It was analysed by the RCE (then the Centraal Laboratorium) and consists primarily of starch and red ochre.

25 Red lead ground into oil has to be used within a few hours. The lead ions released from this oxide react with the fatty acids in the oil, and the mixed paint rapidly thickens and becomes an unworkable 'soap'. H. Kühn, 'Farbmaterialen. Pigmente und Bindemittel', in H. Kühn et al., *Reclams Handbuch der Künstlerischen Techniken*, Stuttgart 1988, p. 22. J.J. Mattiello, *Protective and Decorative Coatings. Vol. 2: Raw Materials, Metallic Powders and Metallic Soaps*, New York 1942. L. Robinet and M.-C. Corbeil, 'The Characterisation of Metal Soaps', *Studies in Conservation* 48 (2003), pp. 23-40.

26 H. Miedema and B. Meijer, 'The Introduction of Coloured Ground in Painting and Its Influence on Stylistic Development, with Particular Respect to Sixteenth-Century Netherlandish Art', *Storia dell'arte* 35 (1979), p. 94. On the development of coloured grounds see H. Kühn et al., op. cit. (note 26), p. 303. P. Noble, 'Technical Examinations in Perspective', in Q. Buvelot (ed.), *Portraits in the Mauritshuis*, Zwolle 2004, p. 330.

27 The ground has an average thickness of 50-60 µm.

28 The structure and composition of the ground was studied using paint cross-sections under the light microscope and with the aid of SEM-EDX in combination with PLM and MCA.

29 A cool grey ground is also found in Goltzius's *Mercury* and *Minerva* of 1611 (Haarlem, Frans Hals Museum, inv. nos. OS-I-95, 96). There, too, the ground appears to have been applied in a number of layers that are almost imperceptibly different; sometimes it seems that there is a little more charcoal in proportion to the lead white, sometimes a little less. Goltzius likewise used a double grey ground for his 'pen painting' *Sine Cerere et Libero friget Venus* of 1599 (Philadelphia Museum of Art, inv. no. 1990-100-1). In 1591 Cornelis van Haarlem used a cool grey ground for his *Massacre of the Innocents* (Rijksmuseum, inv. no. SK-A-128).
E. Hendriks et al., 'The Painting Techniques of Four Paintings by Hendrick Goltzius and the Introduction of the Coloured Ground', *Nederlands Kunsthistorisch Jaarboek: Goltzius-studies*, vol. 42-43, Zwolle 1991-92, pp. 481-97.

30 R. Jones, 'The Methods and Materials of Three Tudor Artists', in K. Hearn (ed.), *Dynasties. Painting in Tudor and Jacobean England 1530-1630*, London 1995, pp. 238-40. It is not clear whether this layer was applied as an imprimatura over the whole surface or only locally under the flesh tones (ibid., p. 238).

31 Panel, diam. 43 cm. Amsterdam, Rijksmuseum, inv. no. SK-A-4046.

32 B. Schoonhoven et al., 'Becoming a Virtuoso Painter: Cornelis Ketel's Portrait of Adam Wachendorff and Homo Bulla', www.npg.org.uk/research/programmes/making-art-in-tudor-britain/workshops/workshop-3-abstract-11.php.

33 For infrared reflectography (IRR) we used a Hamamatsu C2400-07 camera with an N2606 IR vidicon, a Nikon Micro-Nikkor 1:2.8/55mm lens and a Heliopan RG850 (or RG 1000) filter. The monitor was the screen of the Asus laptop computer on which the digital documentation was also done using a Pinnacle PCTV frame grabber, at a resolution of 768 x 574 pixels. The montages were made with the PanaVue ImageAssembler and Adobe Photoshop 7.0.

34 A preparatory sketch in light brown oil paint was found; see R. Jones, op. cit. (note 30).

35 Cornelis Ketel, *Portrait of a Man*. A putto blowing bubbles on the verso. Amsterdam, Rijksmuseum, inv. no. SK-A-4046. See note 32.

36 R. Heinemann (ed.), *Sammlung Thyssen-Bornemisza*, cat. Madrid (Thyssen-Bornemisza Museum of Art) 1971, pp. 202-03, p. 152, fig. 115.

37 J. Richard Judson, 'A New Insight into Cornelis Ketel's Method of Portraiture', *Master Drawings* 1 (1963), pp. 38-41.

38 Anthony van Dyck's workshop practices are a good example of this almost production-line efficiency. His famous double portrait *Lord John Stuart and his Brother, Lord Bernard Stuart* (London National Gallery, inv. no. 6518) appears to have been painted in a similar way. The heads of the two young men are not entirely convincingly attached to their bodies. The drawing of the figure of *Lord Bernard Stuart* (London British Museum, Department of Prints and Drawings, Vey 231) likewise shows only pose and drapery. Here, too, the head has not been drawn. The princes *Charles Louis, Elector Palatine, and his Brother Prince Rupert of the Palatinate* (Paris, Musee du Louvre, inv. no. 1238) also display the anatomical anomalies of assembly-line art. C. Brown and H. Vlieghe (eds.), *Anthony van Dyck 1599-1641*, New York 1999, pp. 312-13, 320-21.

39 Here again, PLM revealed the fairly characteristic very fine particles with low refractive indices that correspond with those of our laboratory standard. The quantities of sample material were too small to demonstrate the presence of indigo by means of a microchemical test. It would be advisable to positively identify this pigment using mass spectrometry (m/z 262).

40 Lead white is a pigment with very good covering power.

41 Scumbling involves muting colours, softening hard lines and blending tints by overlaying with a thin coat of opaque colour. In old Dutch treatises it is called 'schommelen', which means to rock or swing, probably an allusion to the movement used to skim the brush over the surface.

42 This relatively weak contrast is compounded by the strong absorption of X-rays by the lead white in the grey ground and the orange-red layer on the back, which contains lead white and red lead.

43 J.D.J. van den Berg, *Analytical Chemical Studies on Traditional Linseed Oil Paints*, Amsterdam 2002 (PhD thesis University of Amsterdam), pp. 18-23.

44 Because some fatty acids combine with lead ions, lead carboxylates are formed in the paint. This happens particularly readily with lead white because lead carbonate is not the only thing formed during the preparation process; there are also lead oxides and lead acetates, which react even more readily with fatty acids. These reaction products, carboxylate molecules, have lower refractive indices than the lead carbonate particles (i.e. lead white) from which they come. This is probably more likely to be a reaction of the fatty acids with lead from lead oxides (Pb_3O_4, PbO), than with lead from pure lead white ($2PbCO_3 \cdot Pb(OH)_2$).

45 , '… al zijn de kleuren wat verbleekt.' D.C. Meijer, *Wandeling door de zalen der Historische Tentoonstelling van Amsterdam*, Amsterdam 1876, p. 186.

46 H. Stege, 'Out of the Blue? Considerations on the Early Use of Smalt as Blue Pigment in European Easel Painting', Zeitschrift für Kunsttechnologie und Konservierung 18 (2004), pp. 121-42.

47 The discolouration of the smalt is always accompanied by an exchange of K^+ ions in the glass with hydronium ions (H_3O^+). It is generally assumed that this K^+ leaching changes the oxidation state of the cobalt (from $Co^{2+} \rightarrow Co^{3+}$), which could cause the discolouration. Trivalent cobalt compounds, such as $Co(OH)_3$, are often not blue, but actually a drab brownish colour – exactly the sort of brown we found in our paint samples.

48 Caffa was a rich silk cloth. With thanks to Marieke de Winkel for her valuable information on this subject.

49 Potassium is quite hygroscopic, and is easily released from the glass at even low levels of humidity, and it then forms soaps. Potassium salts form compounds with various fatty acids in the binding medium, free fatty acids and glycerol.

50 This saponification mechanism, which is currently at the heart of the conservation problem, was already being discussed at the beginning of the last century. A. Eibner, Über fette Öle, Leinölersatzmittel und Ölfarben. Beitrag zur Normalfarbenfrage, Munich 1922.

51 See also, for instance, the degraded smalt in the sky in *Young Woman in a Broad-Brimmed Hat* of c. 1645-50 by Caesar Boëtius van Everdingen (Amsterdam, Rijksmuseum, inv. no. SK-A-5005). Information about this in E. Smeenk-Metz et al., 'Young Woman in a Broad-Brimmed Hat. Painting Technique and Restoration', *The Rijksmuseum Bulletin* 59 (2011), pp. 222-36.

52 N. Kuramoto and T. Kitao, 'Contribution of Singlet Oxygen to the Fading of Indigo', *Journal of the Society of Dyers and Colourists* 95 (1979), pp. 257-61. N. Kuramoto and T. Kitao, 'Contribution of Singlet Oxygen to the Photofading of Some Dyes', *Journal of the Society of Dyers and Colourists* 98 (1982), pp. 334-40.

53 M. van Eikema Hommes, 'Indigo as a Pigment in Oil Painting and Its Fading Problems', in *Changing Pictures: Discoloration in 15th-17th-Century Oil Paintings*, pp. 91-169, esp. p. 168, note 263.

54 H. Kühn, 'Verdigris and Copper Resinate', in A. Roy (ed.), *Artists' Pigments: A Handbook of Their History and Characteristics*, vol. 2, Washington 1993, pp. 131-58.

55 A.E. Koenig, 'On the Stearates and Palmitates of the Heavy Metals with Remarks Concerning Instantaneous Precipitations in Insulating Solutions', *Journal of the American Chemical Society* 36 (1914), pp. 951-61.

56 R.A. Donkin, 'Spanish Red. An Ethnogeographical Study of Cochineal and the Opuntia Cactus', *Transactions of the American Philosophical Society*, vol. 67, part 5 (1977), pp. 1-84.

57 J. Sanyova, 'Spectroscopic Studies (FTIR, SIMS, ES-MS) on the Structure of Anthraquinone-Aluminium Complexes', *Dyes in History and Archaeology* 21 (2008), pp. 208-13.

58 Chalk ($\varepsilon = 1.48$, $\omega = 1.64$-1.66). Aluminium hydroxide ($n = 1.56$). Drying oil ($n \approx 1.55$).

59 D. Saunders and J. Kirby, 'Light-Induced Colour Changes in Red and Yellow Lake Pigments', *The National Gallery Technical Bulletin* 15 (1994), pp. 79-97. P.C. Crews, 'The Influence of Mordant on the Lightfastness of Yellow Natural Dyes', *Journal of the American Institute for Conservation* 21 (1982), pp. 43-58.

60 H. Neevel, *The Biacetyl-Azo Dye System: A Model to Investigate Dye Fading*, Delft 1992 (diss. Delft University of Technology), pp. 4-8.

61 See the restoration history file in the Amsterdam Museum.

62 Ibid.

63 M. Spring et al., '"Black Earth": A Study of Unusual Black and Dark Grey Pigments Used by Artists in the Sixteenth Century', *National Gallery Technical Bulletin* 24 (2003), p. 97.

64 Dudok van Heel, op. cit. (note 4), p. 367, note 8.