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THE BRUEGEL SUCCESS STORY

Papers Presented at Symposium XXI for the Study of Underdrawing and Technology in Painting, Brussels, 12–14 September 2018

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Fig. 2.1 Pieter Bruegel the Elder, *Dulle Griet*, signed and dated 1563, oil on oak panel, 116.4 × 162.1 cm, Antwerp, Museum Mayer van den Bergh (inv. 788). After treatment, front (a) and reverse (b)

All the images show the painting after treatment, unless mentioned otherwise.

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Lifting the Veil: The *Dulle Griet* Rediscovered through Conservation, Scientific Imagery and Analysis

Christina Currie, Steven Saverwyns, Livia Depuydt-Elbaum, Pascale Fraiture, Jean-Albert Glatigny and Alexia Coudray

Abstract: The conservation of Pieter Bruegel the Elder's *Dulle Griet* (Antwerp, Museum Mayer van den Bergh) at the Royal Institute for Cultural Heritage (KIK-IRPA) in Brussels was accompanied by scientific research of its original techniques and materials. Dendrochronology gives 1548 as the earliest possible date for the felling of the trees used in the panel's manufacture. Infrared imagery reveals a sparse, functional underdrawing, suggesting that Bruegel had carefully planned out the composition prior to painting. Indeed, few changes were made during execution and any such adjustments are minor. Cleaning brought to light Bruegel's exquisite brushwork. However, the paint layer is more translucent than at the outset and analysis shows that several colours have faded or darkened, including smalt and azurite-based blues and copper resinate greens. Infrared photography also helped reveal the signature and remains of the date, but it was only during cleaning that the full date was exposed: 1563.

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Introduction

In January 2017, Pieter Bruegel the Elder's *Dulle Griet* (fig. 2.1) left the Museum Mayer van den Bergh in Antwerp for the first time in more than seventy years for restoration at the Royal Institute for Cultural Heritage (KIK-IRPA) in Brussels. The momentous decision to carry out a comprehensive conservation treatment was stimulated by the request from the Kunsthistorisches Museum in Vienna to include it in the great *Bruegel* exhibition of 2018–19. The conservation campaign, supported by the Baillet Latour Foundation and the Topstukkenraad (Masterpieces advisory board) of the Flemish Community, took one and a half years.[1] The restoration went hand in hand with scientific research on the painting's techniques and materials, and was closely followed by an international advisory board of conservators, curators and art historians.[2]

The initial aim of the technical research was to support the restoration. But as well as helping with treatment decisions, the scientific investigation reassessed the work's techniques and materials and considered how the painting might have looked when it first left Bruegel's studio. Technical analysis and cleaning also settled a long-standing debate on the painting's date, which had lain hidden behind dark retouching. This contribution explores the most significant findings of the conservation treatment and technical investigation, building on previous research by Maximiliaan Martens.[3]

The Panel Support

The *Dulle Griet* is painted on an oak panel made up of four wide planks, butt-joined with the aid of wooden dowels. The planks are all high-quality

Fig. 2.2 Unpainted lateral edges with *barbes* (a and b), and diagram showing channel edge supports (c)

radial cuts, which probably explains the panel's stable condition. The support no longer retains its original thickness as it was planed down prior to cradling, which exposes the original wooden dowels in places on the reverse. Four dowels bridge the central and lower joins and three the upper join. The dowels are neatly sliced in half, which means that the panel is about half its original thickness of around 1 cm. At the front side, there are vertical traces of planing from the smoothing down of the panel surface prior to application of the ground.

The lateral edges of the panel are unpainted and show a *barbe* of ground (fig. 2.2). On the reverse there are traces of corresponding rebates. The unpainted edges, *barbes* and rebates are witness to the former presence of channel edge supports, which would have been attached to the sides of the panel at right angles to the wood grain prior to application of the ground layer, and removed shortly before framing. These wooden battens facilitated handling and would have prevented warping during painting. Such supports were used on Bruegel's panels from both his Antwerp and Brussels periods, so signs of their use cannot help

decide whether a painting was produced in Antwerp or in Brussels.[4] Furthermore, there are no sources that tell us if Bruegel bought his panels from a professional panel-maker, box-maker or joiner.

Through dendrochronology, we know that the panel-maker for the *Dulle Griet* used planks from three different trees, with the top and bottom boards sourced from the same tree.[5] All of the planks were imported from the Eastern Baltic regions, which is to be expected for such long straight quarter-cut boards.[6] The panel includes seven sapwood rings on the second plank from the top, which helps narrow down the period of manufacture.[7] The most recent sapwood ring is dated 1548, which represents the earliest possible felling date for the trees. There are therefore 15 years to account for between 1548 and 1563, the date painted in the lower left (see fig. 2.12). These years include possible further years of tree growth (sapwood), transport of the timbers, seasoning, storage of the planks and storage of the final panel before use by Bruegel.[8]

The comparisons of the dendro-data from this panel with other paintings by Bruegel the Elder led to an interesting new finding: one of the boards, the second from the bottom, derives from the same tree as one plank of the *Gloomy Day* from the Kunsthistorisches Museum, Vienna (fig. 2.3).[9] This painting is dated 1565 by its inscription. This means that these two planks, which originated from a single log, were used in two supports with a two-year interval. While this discovery has no direct impact on the dendrochronological dating of the *Dulle Griet*, it changes the conclusions for the *Gloomy Day* published in 2019.[10] Indeed, this plank was undated at the time. Its correlation with the *Dulle Griet* plank now allows us to place its last ring in 1541, giving a *terminus post quem* of 1547 for the felling of the tree and the manufacture of the *Gloomy Day* panel.[11] There is therefore 18 years between the dendro-result and the date of the painting, 1565.

Preparation Layer

The *Dulle Griet* has a classic white chalk ground, followed by a much thinner slightly off-white *imprimatura* (see analysis, below), a layer structure typical of Bruegel's paintings.[12] This light-coloured priming can be made out through translucent areas of paint.

Fine striations in the upper right sky may have been caused by the use of a fine-toothed comb or scraper, perhaps from scraping down the ground layer in this particular area. However, these markings may also have been made into the paint layer while it was still soft, to render it even and to provide a certain texture.[13]

'Dul': Inscription?

Maximiliaan Martens previously spotted the word 'dul' in infrared in the lower left of the composition and interpreted it as an original pen and ink inscription alluding to the subject matter of the painting, written on the ground before painting (fig. 2.4).[14] This marking, together with several others like it near the lower edge, was inspected in normal light, ultraviolet fluorescence (UV), infrared (IR) and infrared reflectography (IRR) at the start of the

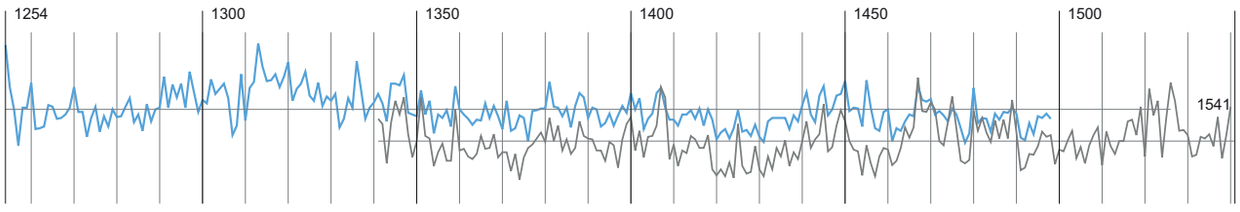


Fig. 2.3 Visual comparison of the ring series recorded on one plank of the *Dulle Griet* panel (in blue; second plank from the bottom) and one plank of the *Gloomy Day* (in grey; bottom plank). Their sequences in relative position match perfectly, leading to the conclusion that both planks come from the same tree

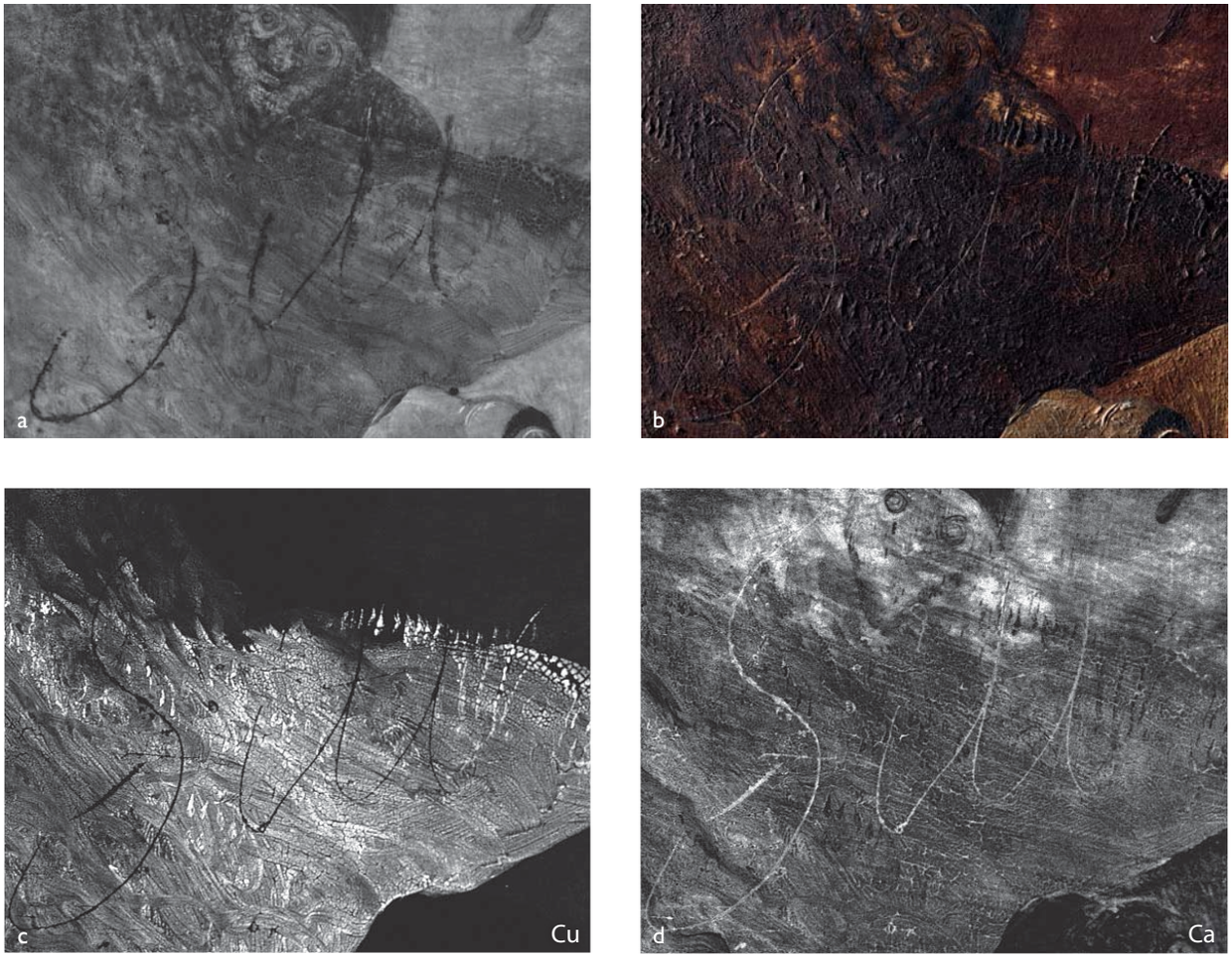


Fig. 2.4 'dul', scratched into paint layer, probably years after the painting was completed
IR, before cleaning (a); raking light after cleaning (b); MA-XRF scan for copper (c); MA-XRF scan for calcium (d)

present cleaning campaign. The goal was to establish whether or not it was an original inscription or a later damage.

All the markings seem to have been made in the same sweeping style. All were retouched, which was particularly clear in IR. Close examination and raking light photography reveal that the lines are in fact scratches, not inscriptions. This was confirmed by macro X-ray fluorescence mapping (MA-XRF, fig. 2.4). A high-resolution MA-XRF scan for the element copper,[15] which characterizes several green and blue pigments, reveals an absence of copper in the 'dul' scratch. The corresponding MA-XRF map for calcium, however, identifies calcium in the scratch. Since the ground is made of calcium carbonate, this means that the paint layer is missing from the scratch and that the ground layer is exposed, proving that 'dul' was scratched into the paint and not into the ground. It seems likely that this supposed 'word' was simply the result of accidental damage, like the other random markings.

Underdrawing

Both IRR and IR reveal lively underdrawing for the buildings in the top right and for the fish-like representation of the entrance to Hell on the left (fig. 2.5).[16] The burning buildings are loosely drawn and represent the only place where there are visible hatching strokes for tone. The drawing lines in this

zone are thicker, softer and looser than those used for drawing the figures. Their visual appearance suggests charcoal or black chalk.

In the figural composition, only traces of underdrawing can be made out and where visible they appear sparing, precise, lacking in liveliness and strictly functional. For reasons unknown, the underdrawing in the figures is easier to detect in IR than in IRR: for example the handle of Dulle Griet's dagger, whose more rounded end in the underdrawing is only visible in IR (fig. 2.6). Underdrawing can also be made out in IR for the drapery folds in the pink dress of the woman binding a creature to a cushion (fig. 2.7). The fact that the underdrawing seems to remain in the dips of the texture of the ground layer in this dress may suggest the use of a liquid medium, but this is somewhat ambiguous. A small sample from the underdrawing of the woman's sleeve was analysed by Raman spectroscopy and it proved to be a non-graphite carbon-containing material.

Maximiliaan Martens postulated in 2012 that the underdrawing was carried out in two phases, first in a dry medium and then in a liquid medium.[17] He states that both phases are carbon-based, but that the second stage is often difficult to distinguish from reinforcements of forms during painting. Indeed, in the infrared images, we find it hard to distinguish any distinct stages. Martens observes that Hell's mouth and eyes seem to show traces of a liquid phase, but we find these markings somewhat ambiguous and think that they could perhaps have been carried out in a dry medium.[18]

The reason for the spare and functional quality of the underdrawing in the *Dulle Griet* is probably because Bruegel had carefully worked out his design prior to painting. This is supported by the fact that there are almost no modifications during underdrawing and painting. Prior to underdrawing, the artist would have worked out his ideas through sketches as well as making a detailed preparatory model drawing of the whole composition. He may even have used a pricked cartoon or set of cartoons for the transfer of all or parts of the figural composition to panel, as he did with some of his other large-format compositions.[19] The loosely drawn buildings in the upper right and Hell, on the other hand, would have been sketched in following a model drawing.

Application of the Paint Layer

Having transferred his design to panel, Bruegel proceeded in the time-honoured manner, beginning with the background sky and leaving spaces for motifs still to be painted. He would have known that by painting in reserve directly on the light priming, his paint layer would retain its brilliance over the centuries. Reserves were retained for the vast majority of motifs, with the exception of small figures in the background such as Adam and Eve and the group sitting down to a meal in the green egg.

Bruegel's system of reserves is easily demonstrated through IR and X-ray imagery and can be spotted with the naked eye in areas of paint that has become translucent over the years. The pink flag with a cooking pot motif to the centre right, for example, was reserved in the background paint, which spills over slightly into the space allocated for the flag. Again, the hand of the giant figure on the roof, painted in reserve in the dark grey paint of his boat, is overlapped slightly by the boat's brushwork (fig. 2.8).

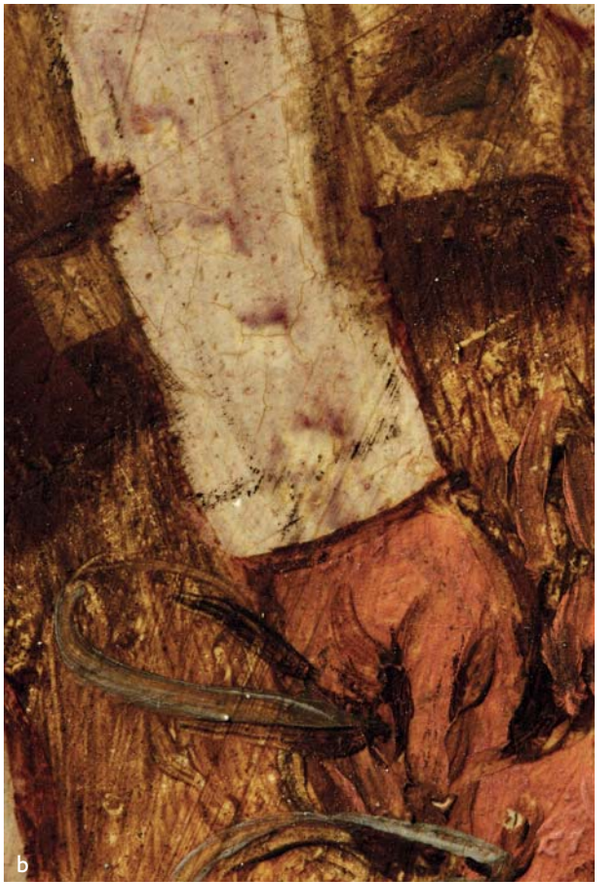
Evolution of the Design during Painting

Bruegel's composition did not evolve much during painting, probably because he planned his design carefully from the start. Minor adjustments clarify the appearance of forms or add a little more meaning: for example, the fish creature with a ring round its middle in the foreground. The X-radiograph shows that Bruegel planned the fish, the ring and the front legs, but not the back legs, which he added later. Radiography also reveals that he extended the toes of the giant on the roof beyond their reserve, using thicker paint than for the rest of the foot. The bowl of the Bosch-like bodiless monster with a spoon in its anus was originally set

Fig. 2.5 Detail, upper right, showing underdrawing
Normal light (a); IR (b)

Fig. 2.6 Detail, Dulle Griet's dagger
Normal light (a); IRR (b); IR, showing a wider, more rounded handle in the underdrawing (c)

Fig. 2.7 Detail, woman binding a creature
IR, showing underdrawn outlines for folds (a); detail of sleeve showing underdrawing through the faded pink paint (b)



straight, but Bruegel later decided during painting to put it at an angle, giving a sense of instability (see fig. 3.5 in Currie, Allart, Brink and Saverwyns, Chapter 3 in the present volume). We can also see that Bruegel planned to put something in the bowl, but changed his mind.

Just one monster seems to have been added as an afterthought during painting. This is the small bodiless creature with a long cap below Hell's ear (fig. 2.9). The infrared image shows that the creature is not underdrawn or reserved. The increased transparency of the paint layer on ageing has meant that the background paint now shows through, to the extent that it is now difficult to decipher the motif.[20] Furthermore, since the black background paint was slow to dry, the monster itself has suffered premature micro-drying cracks, exacerbating the problem of darkening.

Revelations during Cleaning: Colour and Brushwork

During cleaning,[21] many of Bruegel's original colours were brought to light, although some have altered over time (see 'Analysis of the Pigments', below).[22] Prior to its restoration, hints of colour peeked through the general gloom, but it was impossible to make out the full variety of hues. The painting now has passages of colour that were previously completely masked: for example, the patch of blue in the centre part of the sky, which was covered with red overpaint. Dulle Griet's dress is now clearly blue rather than a nebulous grey, if not as intense a hue as originally intended. Overall, the whole scene has become brighter and the sense of perspective has increased, highlighting Griet's dominant position on a small hillock at the front of the composition.

Nuances of Bruegel's brushwork were also revealed through cleaning, including the helmets of soldiers in the lower right, where Bruegel's fluid and buttery handling of the paint can now be better appreciated. In the metal gauntlet of the fish warrior, we can see how Bruegel brushed on the line of the knuckles wet-in-wet and drew the separations between the fingers in fluid black paint (fig. 2.10a). Deft wet-in-wet white in black brushwork is also used to give the impression of shine in Hell's eye (fig. 2.10b).

Bruegel's convincing portrayal of glass, textiles and metal is more impactful after cleaning and we can work out the sequence of his brushstrokes. To evoke the fragile and ephemeral quality of the glass sphere in the boat held aloft by the giant, for example, he first applied a soft grey outline, merged it imperceptibly into a black shadow to the right, and completed the illusion with a single highlight of pure white. He painted Dulle Griet's red velvet sleeve in loose strokes of just black and red and animated her metal breast plate with criss-crossing white and grey brushstrokes. He applied decorative details on her treasure chest with tiny, precise dabs of yellow.

Fig. 2.8 Detail, hand of giant, reserved in dark paint of boat Raking light (a); IR (b)

Bruegel's handling of animals and birds is rapid, yet accurate, combining loose strokes with precise highlights. The movement of the lizard with a little red tongue near Hell is captured with just a few deft strokes, and the Boschian helmet monster to its right is loosely but convincingly painted. A tiny white dot indicating the highlight of the eye of the large bird in the lower left corner is testament to Bruegel's precision and keenness for detail.

In the red paint of the sky, Bruegel seems to have first applied the paint and then dabbed it with a brush to impart a sense of movement. In the lower right, he painted the absurdly comic head of a drowning figure with a few sparing brushstrokes and precise white highlights (fig. 2.11).

Bruegel's pictorial handwriting has become altogether more legible after cleaning: his wiry, precise outlines, the play of contrasting textures and materials, the juxtapositions of transparent and impastoed paint, and the final deft white touches that give a sense of precision and three-dimensionality to objects and figures. At the same time, it is now apparent that Bruegel's paint layer has become more translucent over time, causing certain motifs to almost disappear from view – for example, Dulle Griet's white veil.[23]

The Signature and the Date: 1563

We can now make out Bruegel's original signature and date in the lower left corner of the painting (fig. 2.12). Prior to cleaning, only the date was partially visible. The inscription was, however, previously discernible in infrared, although the X-ray alerted us to its poor condition. Most of the first 'E' of Bruegel is indeed missing and the last digits of the date are damaged. There have been various proposals as to the reading of the date, ranging from 1561 to 1564.[24] Two previous technical studies read it as 1561 using infrared reflectography.[25]

Prior to cleaning, we could make out the date in IR and IRR[26] as '• M • D • LXII', the 'I's being dotted as in other signatures by Bruegel the Elder.[27]

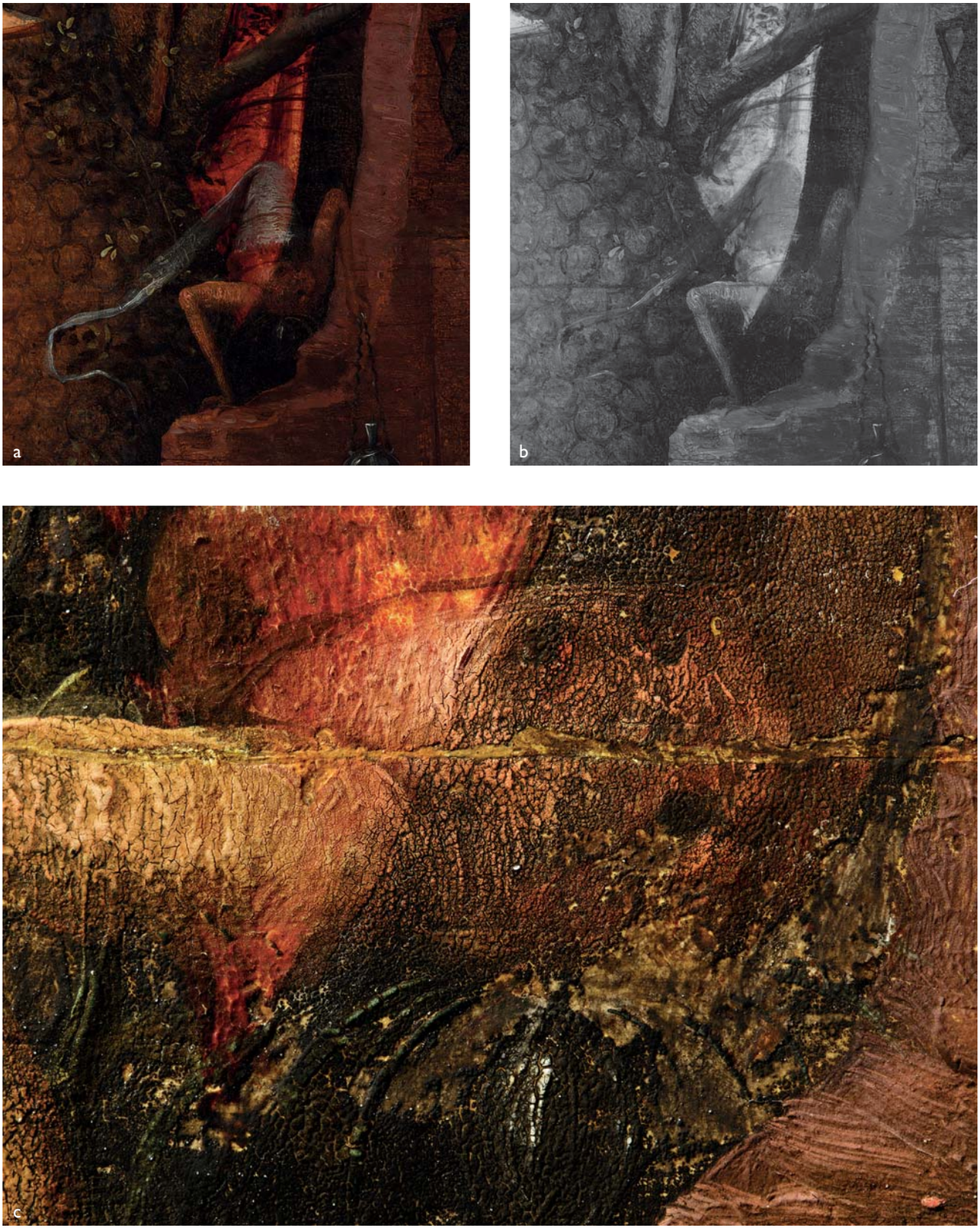


Fig. 2.9 Detail, bodiless monster with cap below Hell's ear, applied as an afterthought
Normal light (a); IR (b); close-up detail, during treatment, showing drying cracks to the right due to the lack of a reserve (c)

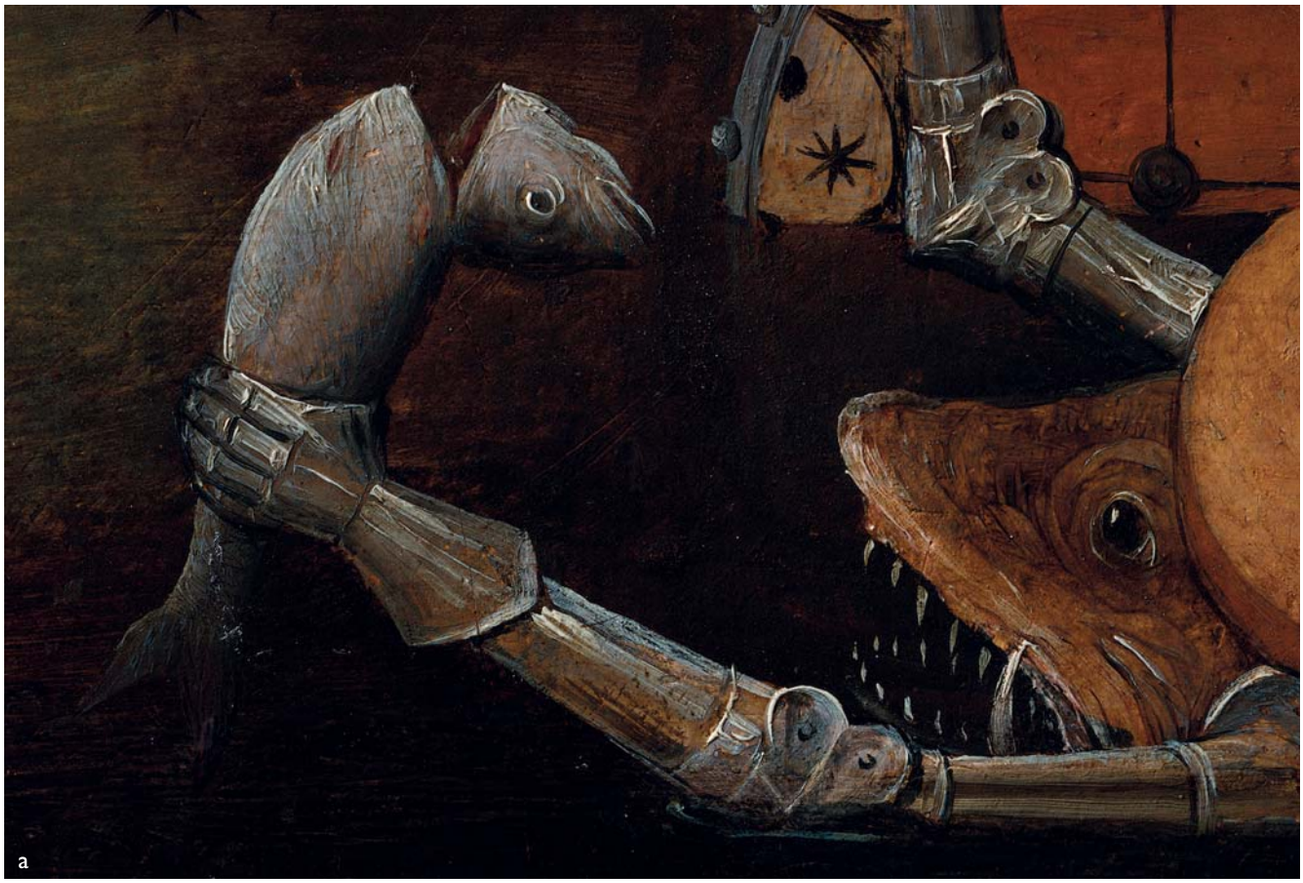


Fig. 2.10 Wet-in-wet brushwork
Fish warrior (a); Hell's eye (b)

Fig. 2.11 Detail, drowning figure, showing Bruegel's precise, sparing brushwork

There was also a possible third 'I' with a painted dot above it, but this was ambiguous due to paint loss and dark overpaint. The dots were examined closely with the microscope and analysed with MA-XRF scanning prior to carrying out any cleaning. The finishing dot and dots separating name and date were difficult to establish in their entirety; however, certain of them did indeed appear to be present.

During cleaning, the signature and date were gradually uncovered, plus the dots on the 'I's and a finishing dot: 'BRV[E]GEL • M • D • LXİİİ •'. There does not appear to be a starting dot, although a paint loss to the left of the 'B' may explain this. The style of the letters and digits is typical of Bruegel's inscriptions. In the painted date of the *Sermon of Saint John the Baptist* (1566), for example, he uses the same type of serifs on the top and bottom of the 'I' digit and uses similar separation and finishing dots.[28] The fact that the inscription is not entirely straight in the *Dulle Griet* is also typical of Bruegel.

There is a tonal difference between the lettering for 'BRVEGEL' and the digits of the date. Both are black, but the name is painted with a less loaded brush than the date and appears paler in tone. The name and the date may therefore have been applied at different moments. Neither has been painted wet-in-wet into the underlying paint.

Analysis of the Pigments

The aim of the laboratory analyses was two-fold: on the one hand, to give support to the restoration by revealing the true condition of the original paint layer prior to treatment; on the other hand, to understand which pigments were used, and whether they have changed colour. This was to help envis-

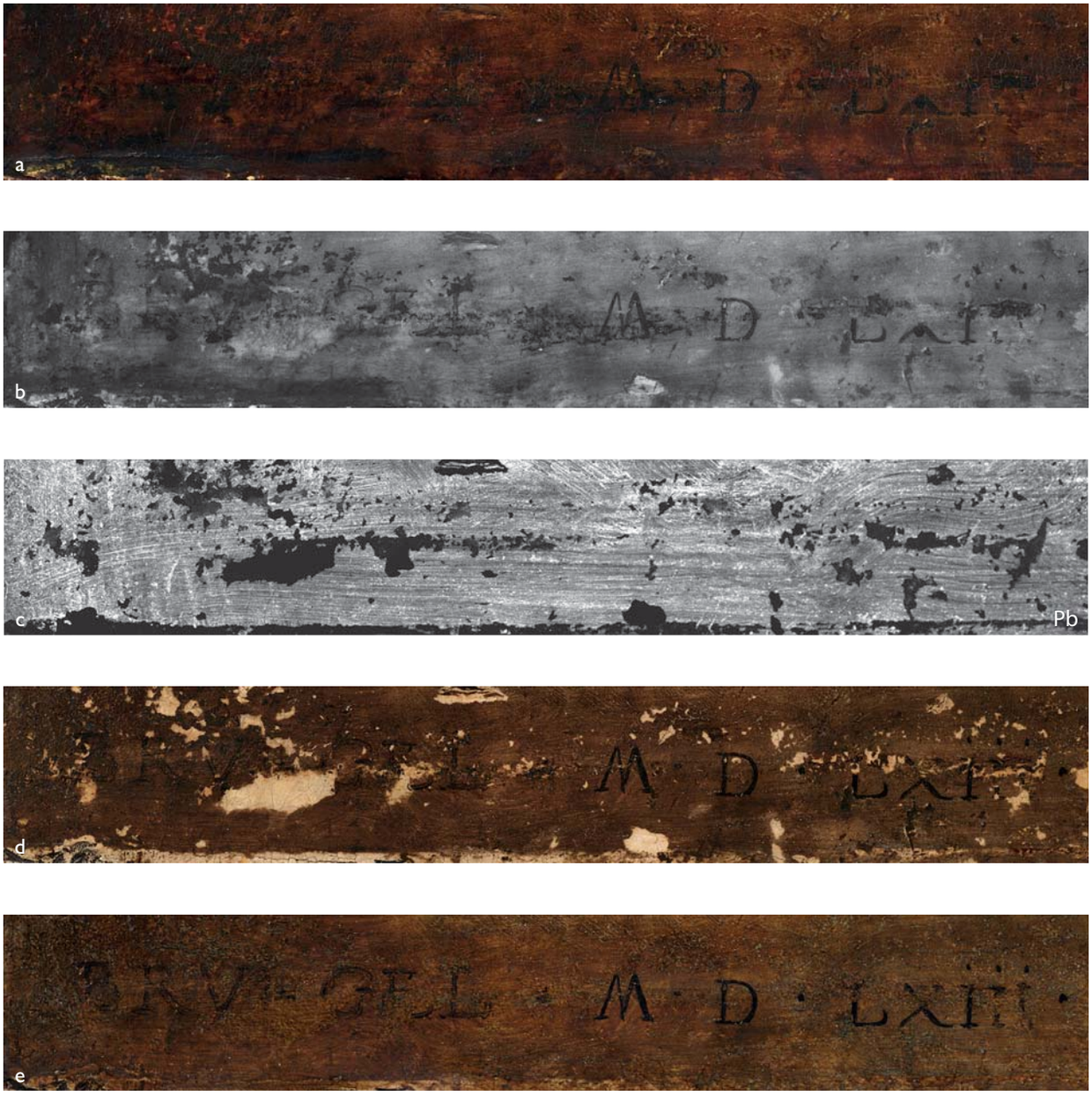


Fig. 2.12 Inscription
Before cleaning (a); IR, before cleaning (b); MA-XRF scan for lead (c); after cleaning before retouching (d); after retouching (e)

age how the painting might have looked when it was freshly painted.

In the first phase, non-invasive analyses were carried out using MA-XRF. With this technique an X-ray beam is focused on the surface. Inorganic pigments produce characteristic secondary X-rays, which means identifications or assumptions can be made on the pigments present. In comparison to classic X-ray fluorescence, MA-XRF scans the painting surface, which in the case of the *Dulle Griet* required several days and the collection of just over 10 million data points.[29] Results are presented as so-called elemental distribution maps. The whiter the area in the map, the higher the

signal intensity of the element under consideration. The scans were carried out at the beginning of the conservation campaign, when most of the varnish and all the overpaint were still present. In a second phase, samples were taken at well-defined places to refine or confirm some of the MA-XRF results. Samples were converted into cross-sections, digitally photographed[30] and analysed by scanning electron microscopy coupled to energy dispersive X-ray detection[31] and micro-Raman spectroscopy,[32] and in a few cases also with Fourier-transform infrared spectroscopy.[33]

The map of lead indicates the use of lead-based pigments (fig. 2.13a). Places where no lead is present show up as black patches. Damage around the joins can clearly be seen, as well as local losses. MA-XRF, being an elemental technique, does not distinguish between different lead-containing pigments. Much of the lead signal must come from lead white, a basic lead carbonate, the only white pigment available in the sixteenth century. It was used pure as white, but also mixed with other pigments to influence the final tonality of the colour and to help in the drying of the oil paint. Lead can, however, also originate from red lead or lead-tin yellow. The tin map indicates that tin and hence lead-tin yellow is indeed present, not only in yellow parts of the painting, such as at the top of the sky to the right, but in some green parts as well, as in the giant egg and the cloak of the giant on the roof (fig. 2.13b). Raman measurements on the cross-sections did not confirm the presence of red lead; hence it is likely not present.

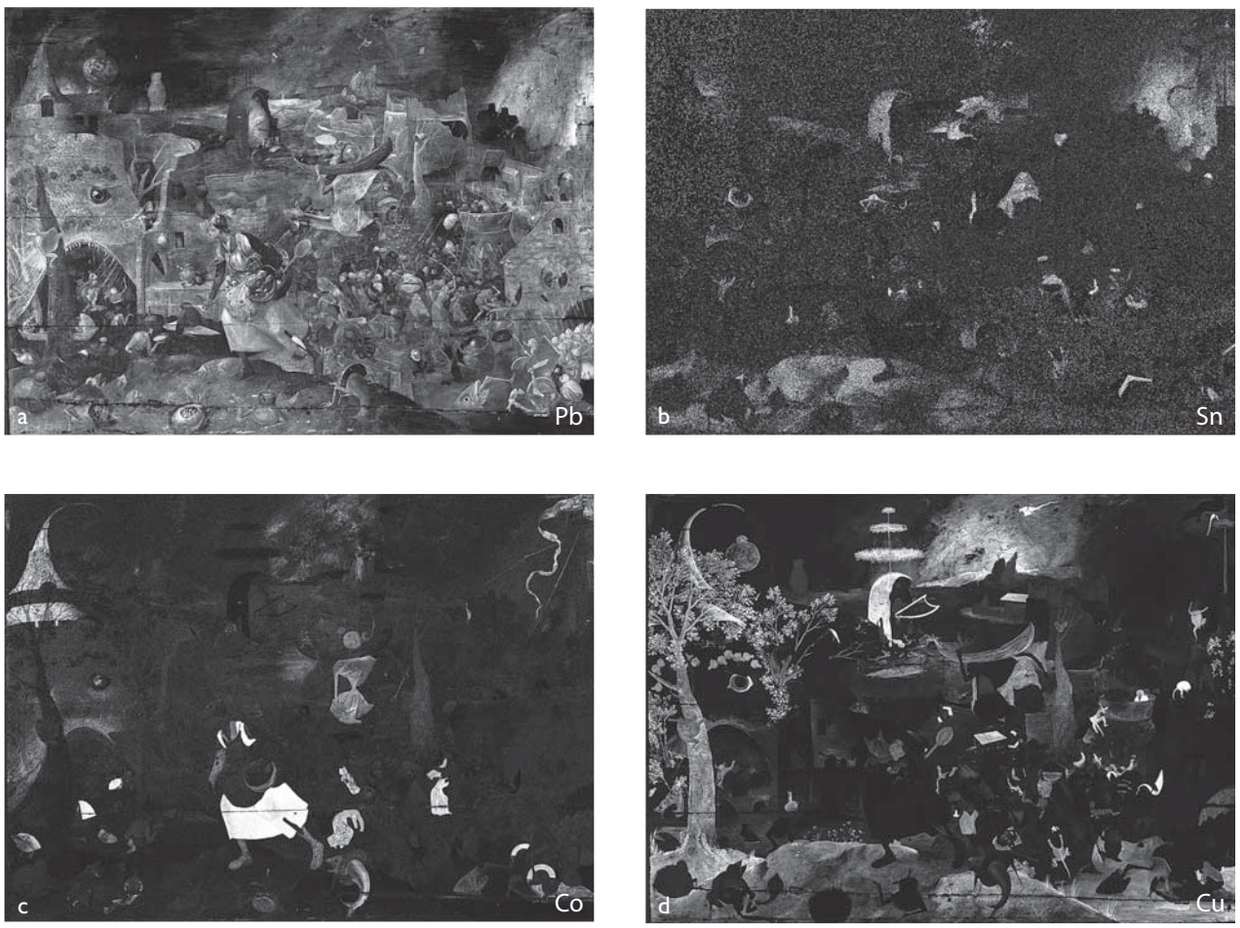


Fig. 2.13 MA-XRF scans for lead (a), tin (b), cobalt (c) and copper (d)

The main red pigment used is vermilion, the only mercury-based pigment, as shown by the mercury map. It is found in all bright red zones, sometimes mixed with other pigments. The back of the toad on the tree also shows up in the mercury map, indicating that it was originally reddish, which could hardly be seen prior to restoration.

The darker red colours are rich in iron, indicating the use of red ochre. Based on the distribution of iron, other ochre pigments must also be present, varying in colour from pale yellow to dark red.

The element cobalt corresponds with areas of pale blue paint, such as the robe of Dulle Griet, but also with greyish colours such as in the left part of Hell's cap (fig. 2.16). Cobalt, together with potassium and traces of nickel and arsenic, can be considered as a marker for smalt, a potassium-rich cobalt glass. The presence of smalt was also suggested in previous studies of the painting.[34] It is notorious for fading, changing from blue to a greyish transparent hue. Different qualities of smalt exist, with different colour hues, but the pigment can be an intense bright blue. Pigment grain size also influences its colour in the paint matrix, so the original appearance of the blue dress of Dulle Griet is difficult to determine. It is notable that where the blue is best conserved, such as in a highlight on the right knee of Dulle Griet, it is also the richest in lead white. It has been reported that lead white can stabilize or slow down the discolouration of smalt.[35]

The MA-XRF scan of the left side of Hell's cap confirms the presence of smalt, but here it is completely discoloured (fig. 2.16c). Originally the cap must have had a bluish hue. There are many more examples of zones where smalt has partially or completely faded. In the large flag in the upper right corner and in the dress of a woman fighter cobalt is detected, but only a light blue tinge remains. In the dress the zones richer in lead white – the highlights – are bluer than the rest. The dress of another woman has a more purple hue. The smalt here must have been mixed with a red pigment, likely a red lake as no inorganic red pigments are detected in that area, which has to a large extent faded as well. The wagon wheels near the bottom right corner must also have been blue based on the cobalt map, but as the lead concentration is fairly low, the blue colour has completely faded. The discoloration of smalt can be visualized in a sample from a partially faded blue dress of the woman fighter (fig. 2.14). Large particles are still blue while smaller ones have turned grey and become transparent (layer 3). Bruegel's chalk ground (layer 1) and thin *imprimatura* (layer 2) are also clearly visible in the cross-section.

The fading of smalt has been observed in other paintings by Bruegel the Elder, as in the *Sermon of Saint John the Baptist*, where smalt-rich clothing

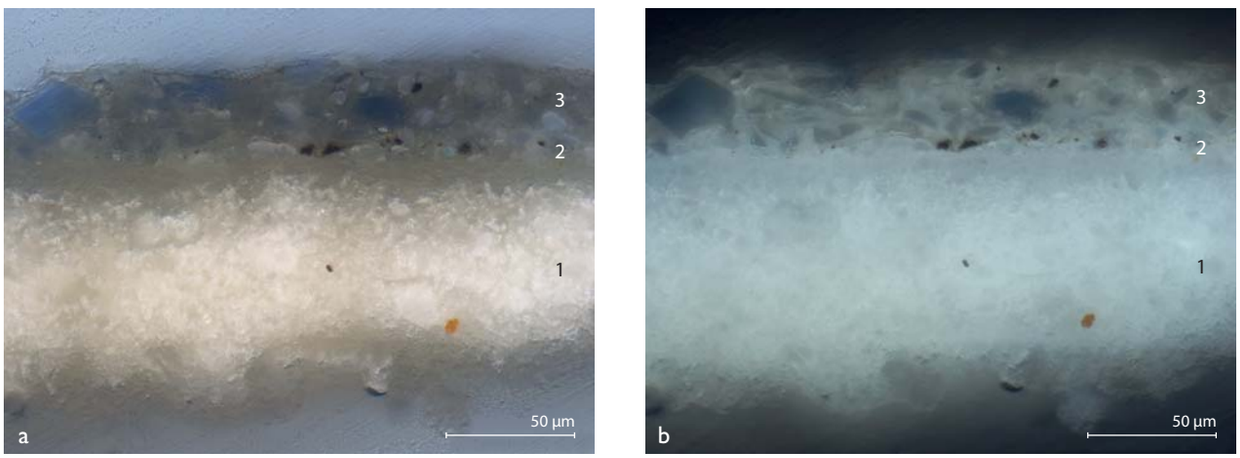


Fig. 2.14 Cross-section, woman fighter, discoloured blue dress
Reflected light (a); UV illumination (b)

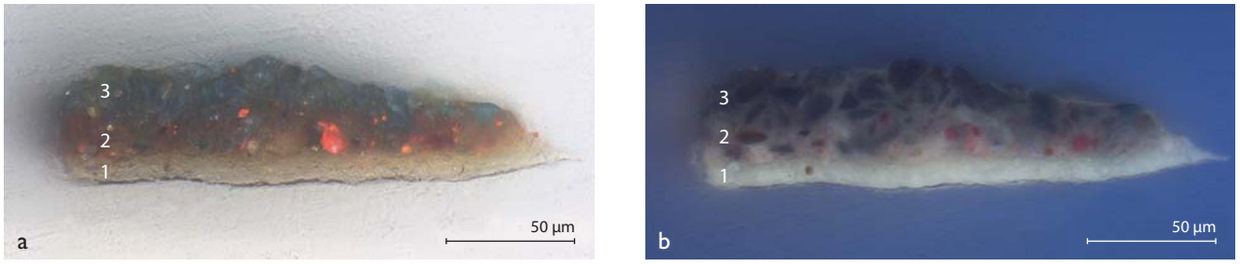


Fig. 2.15 Cross-section from flying insect-like creature
Reflected light with back light illumination (a); UV illumination (b)

motifs have completely faded.[36] In the copies by Pieter Brueghel the Younger and Jan Brueghel the Elder, the same areas are intensely blue, which suggests that the sons saw their father's painting before discoloration of the smalt took place.

Not all blue or supposedly blue pigments are cobalt based. In the blue parts of the sky, copper, rather than cobalt, was detected, as can be seen in the copper map. The sky may therefore contain azurite, a copper-based blue. A flying insect-like creature, very dark blue but appearing almost black, was also very rich in copper. To confirm the presence of azurite and to better understand why the blue of the insect is so dark, a tiny sample was taken from the edge of the insect and converted into a cross-section (fig. 2.15). The ground is missing, but the *imprimatura* can clearly be seen (layer 1), followed by a red transparent layer (layer 2) representing the burning sky. This layer is composed of a mixture of different pigments, including lead white, red ochre, vermilion, a red lake, lead-tin yellow and azurite. The dark blue top layer (layer 3) is composed of densely packed azurite, as confirmed by micro-Raman analyses. No signs of blackening of azurite, the formation of copper oxide (tenorite), can be seen, and no degradation compounds are detected by scanning electron microscopy (SEM-EDX) or Raman spectroscopy measurements.[37] The dark appearance seems to be due to the application of the azurite on a dark background in combination with the increased transparency of the top paint layer, likely due to the formation of lead soaps (although with ATR-FTIR on the small cross-section only weak indicative signals were obtained).

The combination of discoloured smalt and darkened azurite has resulted in drastic colour changes in the cap of Hell (fig. 2.16). MA-XRF results clearly show that the lighter left side of the cap was painted with smalt, while azurite was used for the darker shadow to the right. The smalt must have

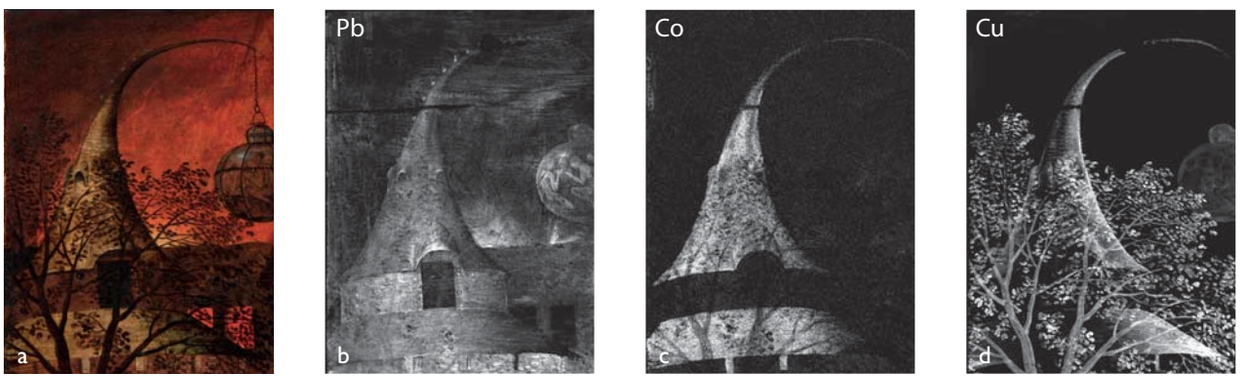


Fig. 2.16 Cap of Hell
Normal light (a); MA-XRF scans for lead (b), cobalt (c) and copper (d)

had a paler blue tone than the azurite, but the blue appearance of the cap is now completely lost.

In the copper distribution map, there are other zones rich in copper but coloured green, such as the egg (fig. 2.13d). A cross-section reveals that the green hue is made of azurite mixed with lead-tin yellow; we found no true copper green such as verdigris or malachite. There is only a single paint layer on the *imprimatura*. The leaves of the tree are also rich in copper but appear dark brown. A sample converted into a cross-section (fig. 2.17) reveals the use of azurite in the top paint layer (layer 3), explaining the high copper signal in the XRF copper distribution map. However, for the leaves to have been green originally, the paint would have had to be mixed with a yellow pigment, but based on the MA-XRF measurements no yellow ochre nor lead-tin yellow is present. This may be explained by the SEM-EDX map of the cross-section, which shows, besides copper, a high concentration of calcium, identified as chalk by Raman spectroscopy. Chalk is sometimes used as substrate for a yellow lake, which could explain the presence of chalk in this layer. Any yellow lake, if originally present, has now completely faded. This hypothesis is strengthened by the fact that underneath the frame, protected from light, some leaves are still green. The confirmation of the presence of a yellow lake unfortunately requires too large a sample for analysis. The current dull brown appearance of the tree leaves is thus due to the direct application (without underlayer) of the paint onto the dark background, in combination with an increased transparency of the paint layer, the fading of a yellow lake and the use of azurite, as observed in the flying insect-like creature.

Finally, there are also zones in the copper map that are less intense, corresponding with dull green or brown semi-transparent zones. The MA-XRF maps of the creature with brown mantle on the bottom right side reveal some copper, but no iron-based ochre pigments, suggesting a discoloured copper resinate (fig. 2.18). The cross-section reveals the thin *imprimatura* layer (layer 1), followed by a white underlayer (layer 2) and several translucent glaze layers (layers 3–5), perhaps not all original (layers 4 and 5 are thought to be later additions as a thin calcium-rich layer is seen above layer 3, the latter also displaying vertical cracks filled with calcium-rich material). In the lower original paint

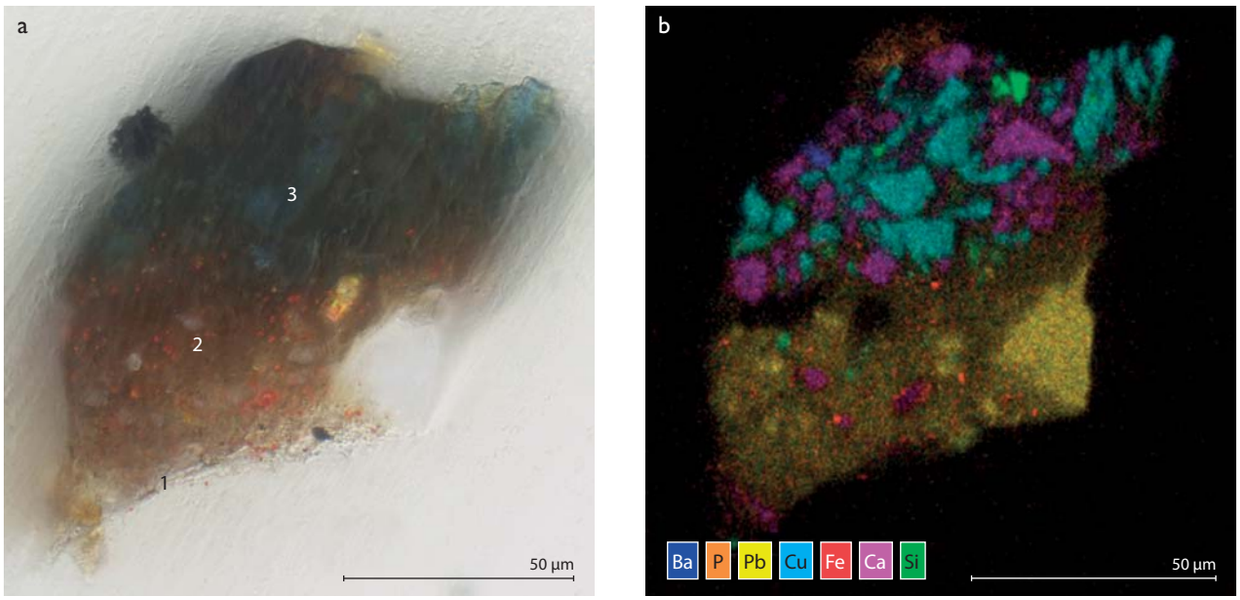


Fig. 2.17 Cross-section from leaf of large tree to left
Reflected light with back illumination light (a); SEM-EDX map with false colours to show elemental distribution (b)

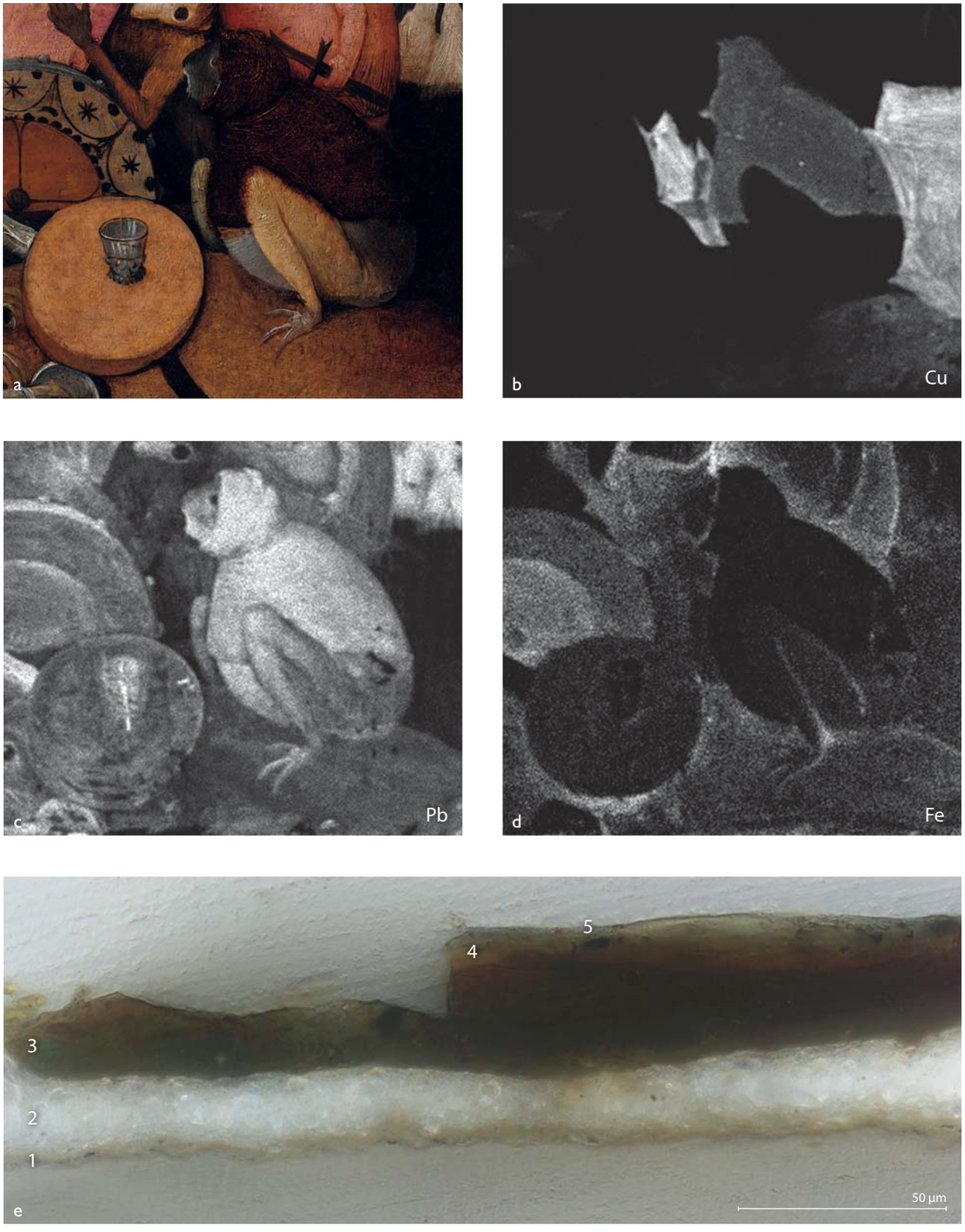


Fig. 2.18 Creature with brown mantle (a)
MA-XRF scans for copper (b), lead (c) and iron (d); cross-section (e)

layer, some green parts can still be seen, while the upper side has turned brown. The green grains still visible, and the brownish top part of layer 3 points in the direction of the application of a green translucent copper resinate glaze, that has now largely changed colour from green to brown. In another zone, a transparent green basket with brown spots, the presence of a copper resinate could be proven by FTIR analysis. The brushwork in the creature with brown mantle resembles closely that seen in a coat in the *Sermon of Saint John the Baptist*. In both, the brownish paint seems to be blotted by a cloth, and spills over the edges of the motif.[38] Tellingly, this brownish coat is vivid green in some of the copies by Brueghel the Younger, strengthening the hypothesis of Bruegel the Elder using green copper resinate that has now turned brown.

Finally, red lake pigments are also used in the painting, as the analysis of a cross-section earlier discussed shows (the red burning sky underneath the dark-blue insect-like creature; fig. 2.16). These organic lakes, however, are not identifiable with MA-XRF analysis, nor is the aluminium-based carrier on which they are often precipitated. But the lack of MA-XRF results on the giant's pinkish coat or the pinkish shield near the bottom right corner suggests the presence of organic lakes. Since only destructive analysis can provide more information on their exact composition, no further research on these pigments could be conducted.

Digital Reconstruction of the Original Colour Scheme

A digital reconstruction of the original colour scheme of the painting (fig. 2.19), based on the scientific analyses and to some extent on an early coloured drawing of the *Dulle Griet* (Düsseldorf, Kunstpalast; see fig. 3.1b in Currie, Allart, Brink and Saverwyns, Chapter 3 in the present volume), gives a glimpse of Bruegel's original intentions, although cannot recreate the lost opacity of the original pigments and the work's original relative tonal values.[39]

Conclusion

The technical study of the *Dulle Griet* reveals the artistic procedures, techniques and materials that Bruegel adopted in the making of this great masterpiece. The oak panel, with its dowels and channel edge supports, is entirely characteristic of his production, as is the light-toned priming consisting of a chalk ground and thin *imprimatura*. The sparseness of the underdrawing and the absence of significant changes during drawing and painting betray Bruegel's careful planning in the preparation of the composition and presuppose the making of detailed preparatory sketches and a model drawing. Indeed, it is even possible that he used cartoons to transfer the figural design to panel. The build-up of the paint layer, using the long-established system of reserves, is further evidence of his preliminary planning. In the one motif where he broke the rules – the bodiless monster below Hell's ear – the motif is no longer fully legible.

The removal of discoloured varnish and overpaint enables us to appreciate once more Bruegel's exquisite brushwork. The painting also has a greater sense of perspective, establishing Dulle Griet more firmly as a dominant figure in the foreground. The sky has more dynamism and is again multihued. Nonetheless, pigment analysis shows that many colours are irreversibly altered and that certain of them have faded or darkened. This particularly affects smalt and azurite-based blues, red and yellow lakes, thinly painted whites and copper resinate greens. The impact of Dulle Griet herself is considerably reduced today owing to the fading of her blue skirt and the increased transparency of her white veil.

Finally, the conservation treatment brings to light the signature and true date – BRV[E]GEL • M • D • LXIII • – obscured for years under discoloured varnish and retouching.

Fig. 2.19 Hypothetical reconstruction of the original colour scheme

Annex 1: Conservation Treatment[40]

Panel Support

The pine cradle on the reverse of the panel was most likely applied in Stockholm, prior to the painting's sale at a Cologne auction to Fritz Mayer van den Bergh in 1894. Its removal was deemed unnecessary for the future stability of the panel and a minimum intervention treatment plan was adopted, following consultation with the advisory board.[41] A thick layer of wax was removed and the blocked sliding vertical members of the cradle were taken out, planed and put back again.[42] Wooden battens attached during the early 1950s were completely removed and the cracks they had concealed were glued with fish skin glue and reinforced by small, square oak blocks.

Paint Layer

Following the removal of surface dirt, the varnish layers were progressively cleaned off with solvents. Ultraviolet fluorescence examination during cleaning revealed that there were four vanish layers present, each markedly different and with their own appearance in UV, and sometimes interlaid with layers of dirt. Chemical analysis with pyrolysis gas chromatography mass spectrometry (Py-GC/MS)[43] successively identified four types of varnish. From the most recent to the oldest, these layers comprised mainly isobutyl methacrylate (Paraloid™ B-67), colophony resin, and shellac (likely two layers). Dammar resin and drying oil were detected in all layers. The origin of the dammar is less clear. It could have been added to the older varnishes to modify their characteristics, but this seems less likely for the modern varnish. The application of dammar varnish during a more recent conservation treatment might also account for its presence. It could have penetrated through old cracks, and therefore be found in the different varnish layers.

The removal of later overpaint and localized scumbles perceptibly improved the appearance of the composition. In several places, original paint reappeared, the most spectacular example being the patch of green-blue sky in the upper centre. This had been foreseen in the MA-XRF scan for copper, which suggested that blue, azurite-based paint could be hidden beneath the chrome-containing overpaint (fig. 2.13d). A corresponding blue zone also features in the Düsseldorf drawing of the *Dulle Griet*, which is dated to the late sixteenth or early seventeenth century (see fig. 3.1b).The sky area now has a more nuanced colour scheme ranging from black, brown, orange-red, intense yellow to green-blue. Rediscovered smaller details include the armoured elbow of the fish warrior in the lower left (fig. 2.10a) and the colours of the toad in the lower left, now green with a patch of red rather than dark brown. Removal of dark, granular overpaint from the architecture to the right brought to light the fluid, translucent character of the original paint layer.

The cleaning was mainly carried out using solvents in liquid form. Occasionally, for certain types of overpaint, solvent gels were applied in order to soften the paint prior to its removal with a scalpel under the binocular microscope. Extremely resistant oil-based retouching was thinned using a scalpel, avoiding solvents, given the thinness and fragility of the original paint layer. Some of the overpaint along the old crack in the lowermost plank was left in place as there was no original paint underneath: for example, the chicks in the foreground. For the signature and date in the lower left, the removal of the old retouching was mostly carried out dry using a scalpel and working under the microscope.

After taking off the overpaint, synthetic fillings applied during the 1950s intervention were removed. These included fillings that extended onto the original paint at the extreme right of the lowermost join and along the crack in the lowermost plank. There were at least four different types of filling present, resulting from four separate interventions. Much original paint was recovered at the edges of the panel, where fillings concealed irregularities in the panel support. Overlapping fillings were also removed in the zone around the

signature and the date. Losses were then filled locally with chalk bound in animal glue.

Retouching was carried out progressively. The Düsseldorf drawing proved extremely useful during this stage, as sometimes motifs that are no longer clear in the painting are more legible in the drawing. Losses and abrasion damage were first retouched in watercolour to match as closely as possible the tonality of the painting. A very thin layer of dammar varnish was then rubbed on with a cloth. This was followed by the second phase of retouching using dry pigments bound in a synthetic resin (Paraloid™ B-72). This stage included the integration of old, darkened retouching that could not be removed during cleaning, principally along the crack in the bottom plank. The painting was then brush-varnished with dammar varnish. The reintegration of the losses was completed with Gamblin Conservation Colors. To finish, a thin layer of dammar varnish was applied with a spray gun.

Notes

The conservation and technical research of Bruegel's *Dulle Griet* could not have been carried out without the full support of Dr Claire Baisier, former director of the Museum Mayer van den Bergh, and her dynamic staff: Rita Van Dooren, Tonia Dhaese, Harlinde Pellens, Margit Didelez, Nicole Van Triel and Karen Werkhoven. We also thank the advisory board for their participation in the decision-making process during the conservation treatment (see note 2).
We are also indebted to our colleagues in the Imagery section at the KIK-IRPA, who provided high-resolution photographs, infrared reflectography and radiography: Stephane Bazzo, Sophie De Potter, Jean-Luc Elias, Catherine Fondaire and Katrien Van Acker. Finally, we thank Dr Frederik Temmermans of Universum Digitalis, who carried out the stitching of the high-resolution images after treatment.

1 The conservation treatment was carried out by Livia Depuydt-Elbaum (paint layer) and Jean-Albert Glatigny (panel support). See Annex 1 for summary.

2 We warmly thank Dr Claire Baisier, former director of the Museum Mayer van den Bergh, for convening and taking part in the advisory board meetings, which met on three occasions, the first time just after the start of cleaning (23 March 2017), the second time prior to the treatment of the wooden support (22 June 2017) and the third time during the removal of the overpaint (19 September 2017). We also thank the board for their advice: Professor Dominique Allart (University of Liège), Dr Véronique Bücken (Royal Museums of Fine Arts of Belgium [KMSKB], Brussels), Dr Lorne Campbell (emeritus, National Gallery, London), Aline Genbrugge (KIK-IRPA), Nicole Goetghebeur (emeritus, KIK-IRPA), María Antonia López de Asiaín (Museo Nacional del Prado, Madrid), Professor Maximiliaan Martens (Ghent University), Ray Marchant (panel conservator, London), Dr Hélène Mund (advisor, Museum Mayer van den Bergh, Antwerp), Elke Oberthaler (Kunsthistorisches Museum, Vienna), Françoise Rosier (KIK-IRPA), Dr Manfred Sellink (Ghent University), Professor Anne van Grevenstein (Topstukkenraad), Régine Guislain-Wittermann (emeritus, KIK-IRPA).

3 Martens 2012a. See also Van de Voorde et al. 2014.

4 For Bruegel's use of channel edge supports as well as their use in the work of Brueghel the Younger and his contemporaries in Antwerp, see Currie and Allart 2012, vol. 1, pp. 246–8, and vol. 3, pp. 732–3, and Oberthaler 2018, pp. 371–3. In addition to the paintings mentioned in these publications, Bruegel's undated *Triumph of Death* and the Detroit *Wedding Dance* (1566) also show signs of their use (see Currie and Allart, Chapter 6, and You, Hanspach-Bernal and Bisulca, Chapter 9, in the present volume). Rembrandt also uses some sort of channel edge support on a painting in a self-portrait from around 1628 (*Artist in his Studio*, 24.8 × 31.7 cm, oil on panel, Boston, Museum of Fine Arts).

5 See Fraiture 2017.

6 For example, Fraiture 2012, Fraiture 2017 and Fraiture and Haneca 2017.

7 This is one more ring than the minimum found for oaks from the Baltic countries (Lithuania, Latvia, Estonia) and southern Finland, according to Sohar, Vitas and Läänelaid 2012.

8 See Fraiture and Haneca 2017 and Fraiture 2019, for more details on this topic.

9 Pieter Bruegel the Elder, *The Gloomy Day*, signed and dated 1565, oil on panel, 117.6 × 162.2 cm, Kunsthistorisches Museum, Vienna, inv. 1837.

10 Fraiture 2019, pp. 214 and 218.

11 Minimum sapwood estimate (6 rings), according to Sohar, Vitas and Läänelaid 2012.

12 For Bruegel the Elder's ground and *imprimatura* layers and their context in Flemish painting, see Currie and Allart 2012, vol. 1, pp. 251–8. See also Oberthaler 2018, pp. 375–6.

13 Similar, comb-like markings made into soft paint are also observed in the work of Pieter Brueghel the Younger. See Currie and Allart 2012, vol. 3, p. 769, fig. 539.

14 Martens 2012a, p. 27, ill. 1.

15 High-resolution setting for MA-XRF scan: spot size 150 µm, pixel size 150 µm, dwell time 20 ms.

16 Infrared photography: Hasselblad H4D-200MS (before treatment) and a Hasselblad H6D-100c (after cleaning and after treatment) with a BW 093 infrared filter. Infrared reflectography: Lion systems near infrared digital camera, fitted with an InGaAs sensor, 512 × 640 pixel FPA; 50 mm Nikkor lens, and narrow bandwidth filter (1.5–1.73µ). IRR images stitched using Adobe Photoshop.

17 Martens 2012a, pp. 30–31.

18 See also the *Triumph of Death* in Currie and Allart, Chapter 6 in the present volume, which has both dry and liquid underdrawing.

19 On Bruegel the Elder's use of cartoons in certain paintings, see Currie, Chapter 5 in the present volume, and Currie and Allart 2012, vol. 3, pp. 882–4.

20 This motif is clearer in the Düsseldorf drawing of the *Dulle Griet* (see Currie, Allart, Brink and Saverwyns, Chapter 3 in the present volume).

21 On the cleaning process, see Annex 1.

22 On the original colours in the painting, see also discussion of an early coloured drawing of the *Dulle Griet* in Currie, Allart, Brink and Saverwyns, Chapter 3 in the present volume.

23 On increased transparency in other paintings by Bruegel, see Oberthaler 2018, pp. 398–400.

24 For example, Marijnissen 1988: 1562 or 1563; Van Bastelaer and Hulin de Loo 1907: 1564.

25 Van Schoute, Verougstraete and Garrido 1995 (infrared vidicon); Martens 2012a, p. 33, ill. 14, and note 4 (Osiris camera).

26 For infrared equipment used, see note 16.

27 For samples of Bruegel's signatures, see Currie and Allart 2012, vol. 1, pp. 76–7, fig. 10a–m.

28 Ibid., vol. 1, p. 145, fig. 54.

29 MA-XRF, Bruker M6 Jetstream, Rh-tube, 50kV acceleration voltage, spot size 500 µm, pixel size 450 µm, dwell time 10 ms.

30 Cross-sections were photographed with an Axio Imager M1 microscope from Zeiss equipped with an InfinityX high resolution CCD camera from Deltapix. They were recorded under visible and ultraviolet light with magnifications up to 500×.

31 Zeiss EVO 15LS instrument equipped with a backscattered electron four quadrant-BSE detector and EDX-detector (X-MAX^{N}80 silicon drift detector, Oxford Instruments); measurements under vacuum of 15Pa and voltage of 15kV.

32 Raman spectra were acquired with a Renishaw inVia Micro-Raman spectrometer with a Peltier-cooled (203 K), near-infrared enhanced, deep-depletion CCD detector (576 × 384 pixels) using a high power 785 nm diode laser (Innovative Photonic Solutions, New Jersey, USA) in combination with a 1200 l/mm grating. Samples were analysed at 500× magnification in a direct-coupled Leica DMLM microscope with enclosure.

33 FTIR spectra were acquired with a Bruker Hyperion 3000, coupled to a microscope and equipped with an ATR crystal of Germanium with a diameter of 150 µm.

34 Martens 2012a, Van de Voorde et al. 2014.

35 Spring, Higgitt and Saunders 2005.

36 Currie and Allart 2012, vol. 1, pp. 160–65, and Currie and Allart 2017, pp. 217, 223–4 and fig. 20.

37 Mattei et al. 2008.

38 For the brown coat in Bruegel the Elder's *Sermon of Saint John the Baptist*, see Currie and Allart 2012, vol. 1, fig. 68.

39 On the Düsseldorf drawing and its relevance to the conservation and study of Bruegel's *Dulle Griet*, see Currie, Allart, Brink and Saverwyns, Chapter 3 in the present volume.

40 Summary of treatment reports by Jean-Albert Glatigny and Livia Depuydt-Elbaum (KIK-IRPA file: 2016.13203).

41 The advisory board meeting of 22 June 2017 dealt specifically with the question of the treatment of the wooden support. During this meeting, Jean-Albert Glatigny laid out his findings on the examination of the support and possible options for treatment. The board also considered alternative treatments developed by Ray Marchant (†), a former private practice conservator affiliated with the Hamilton Kerr Institute in Cambridge, and José de la Fuente Martínez, panel conservator at the Museo Nacional del Prado.

42 A letter from the Regents of the Museum Mayer van den Bergh to the City of Antwerp, dated 9 September 1953, requests permission for the *Dulle Griet* to be moved out of the museum for cleaning and restoration from 15 September to 15 October 1953. A short report by the restorer C. Bender, dated 13 May 1954, states that he added two slats at the reverse to consolidate open joins. He also removed darkened retouching from these joins, applied new retouching, removed old blanched varnish and applied a new layer of varnish. He adds in his report that on the return of the painting from an exhibition of Flemish painting in England [London, Royal Academy of Arts, *Flemish Art, 1300–1700: Winter Exhibition*, 1953–4], the new varnish layer had to be removed and a fresh one applied due to problems with humidity. The thick layer of wax on the reverse was also most likely applied during Bender's conservation treatment, as such a layer is present on many paintings treated by the Bender family in the Royal Museum of Fine Arts Antwerp (KMSKA). We are grateful to Rita Van Dooren for supplying these details from the files in the Museum Mayer van den Bergh.

43 Pyrolysis was performed in a He-atmosphere at 480 °C (Frontier Lab pyrolysis unit model 3030) in the presence of 2.5% tetramethylammonium hydroxide (TMAH) in methanol as a derivatization mixture. A Supelco SLB-5ms column (length 20 m, internal diameter 0.18 mm, film thickness 0.18 µm) was used for chromatographic separation. Compounds separated were detected with a mass spectrometer (PolarisQ mass spectrometer, scanned between 35 and 650 amu). The chromatographic column was connected directly to the pyrolysis unit, without using the classical injector.