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The Wall Paintings at St Stephen's Chapel, Westminster Palace: Recent Imaging and Scientific Analysis of the Fragments in the British Museum

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Abstract

Recent imaging, examination, and analysis of the few surviving fragments of wall painting from St Stephen's Chapel have revealed new data relating to the original technique and aspects of workshop practice in the production of these important mid-fourteenth-century wall paintings. Infrared imaging of the paintings provides clear evidence for the presence of an under-drawing and of extensive modification of the design *in situ* at an advanced stage of the painting process. There are marked differences in the character of the under-drawing on the various fragments studied, which are likely to relate to different hands and may be indicative of workshop practice. In addition, the presence of an original varnish is strongly suggested, the red dyestuff employed for the red lake pigment has been identified, and the complexity of pigment mixtures and stratigraphy of the paint layers has also been elucidated. This information will be discussed in the context of the documentary sources and of analytical results from the investigation of contemporaneous polychromy.

Introduction

When the Society of Antiquaries donated the painted and architectural fragments from St Stephen's Chapel to the British Museum in 1814, its collection of medieval antiquities was practically non-existent.[1] There was little desire on the part of the

museum to collect and display European medieval material; the acceptance of the donation can be seen to be at odds with the prevailing—or at least developing—institutional *Zeitgeist*.[2] Why the museum accepted the fragments, and why the society gave them away needs addressing. It is the aim of this short introduction to set out the evidence for the removal of the fragments from St Stephen's after 1800, their donation to the British Museum in 1814, and the context of their first public redisplay in 1852.[3]

The Department of Antiquities had been set up in 1807 and it was not until 1831, with the purchase of the Lewis Chessmen, that another substantial and important group of medieval objects would be added to the collection. The St Stephen's fragments are therefore the first considerable group of medieval objects to enter the museum. Their collecting history offers a glimpse into the status and perception of the medieval past at the British Museum.

Recording the Fragments at Westminster

John Carter was the first artist to record systematically the medieval interior of St Stephen's Chapel. Between 1790 and 1794, he drew portions of the fabric still partially hidden beneath later architectural iterations.[4] Further paintings were uncovered on 11 August 1800, but Carter was barred from entering due to a long-running dispute with the architect James Wyatt.[5] Carter recorded this visit in *The Gentleman's Magazine*, lamenting that he "saw some of the most rare works of art that this or any country ever produced falling beneath the workmen's hammers."[6] Following Carter's rejection, J.T. Smith was granted access to the chapel in order to record the paintings for his co-authored publication, with J.S. Hawkins, titled *Antiquities of Westminster*.[7] Smith's volume contains drawings of the wall paintings at the east end, produced *in situ*, and including the large number of painted and architectural fragments scattered in Cotton Garden. Smith worked at St Stephen's from 14 August until 24 September, after which Richard Smirke—illustrator to the Society of Antiquaries—was granted access in order to produce drawings for an updated version of Carter's 1795 publication.[8]

Prior to the publication of *Antiquities of Westminster,* there was a public disagreement between Hawkins and Smirke, played out across the pages of *The Gentleman's Magazine* in 1803. The issue at stake was whether Smirke had made his drawings *in situ*, or from fragments that had previously been removed from the walls. This mattered because a drawing made *in situ* was thought more likely to be accurate; removal created loss of paint and stone. Clarifying this will help in tracking when the fragments now at the British Museum might have been moved from St Stephen's and taken to the Society of Antiquaries. In his description of 1800, Carter mentions portions of the chapel "falling beneath the workmen's hammers".[9] Smith gives further evidence for the destruction of the interior in a description of his own working practices. He would begin at first light and work until nine o'clock, when those arriving to work on the renovation would start to remove what he had recorded earlier that morning.[10] Further, Smith's drawing of Cotton Garden shows it as a site filled with fragments from the chapel. It is a document for the removal of substantial fragments from the interior, including "a part of an inscription which was over one of the pictures, and another has on it a painting of two men, one of them in the inside of a gilt bull."[11] In a letter promoting his and Smith's publication, then in progress, Hawkins wrote to defend Smith's methods against Smirke's, suggesting that the latter had made his drawings after the fragments were removed from the walls.[12] Smirke refuted this statement and went on to clarify that certain fragments were moved subsequently into the best light, so that he was able to "make corrections, and discover many parts which, but for the removal, could never have been seen."[13]

The Removal of the Fragments to the Society of Antiquaries

Several letters in *The Gentleman's Magazine* provide further evidence that a number of painted fragments had already been removed and taken to the Antiquaries before Smirke began his recording. Hawkins informs us that paintings from the first window "were taken down; some of them were conveyed into Mr. Groves's room, others into Cotton Garden among the rubbish, and others presented to the Antiquarian Society, long before Mr. Smirke was engaged."[14] His account that numerous fragments had already been taken down and transferred to the

Antiquaries is corroborated by a letter from R. Wynne, who recalled a visit to Cotton Gardens on 21 October 1802. Wynne provides a description of the condition of the fragments still present in the garden: "This inscription is similar to the fragments in the possession of the Antiquarian Society, which were mostly taken down from the South side of St Stephen's chapel long before Mr. Smirke began his drawings."[15]

By 1803, the Society of Antiquaries had possession of at least some of the paintings from St Stephen's Chapel, which it must be assumed are the pieces that were eventually donated to the British Museum. If the letters by Hawkins, Smith, and Wynne are correct, then the Antiquaries would have received them between 11 August and the 23 September 1800. There is unfortunately no information in their council meeting minutes to confirm this suggestion. The bulk of the antiquarian effort was dedicated towards preserving the paintings via drawing and publication. It would seem that little effort was made to salvage the majority of the fragments remaining in Cotton Garden. It was surely not a question of time, as Wynne's letter makes clear that the Cotton Garden fragments were still there in 1802, and were being taken by members of the public to be reused as building material. A fragment showing Queen Philippa was preserved and drawn by John Carter, but its whereabouts are now unknown.[16] Other architectural fragments do survive, although some in poor condition. Two fragments from a moulded mullion were acquired by the British Museum in 1883;[17] and Sir John Soane's Museum holds four heavily weathered stone architectural fragments and a cast from a heraldic shield.[18]

Donation to the British Museum and Redisplay

At a meeting of the Society of Antiquaries held on Thursday, 15 February 1814, it was:

> *Ordered, on the motion of the Rev. Dr. Burney, seconded by Mr Carlisle, that the six cases and three fragments of the original paintings brought from St. Stephen's Chapel, and now in the Meeting Room, be presented to the Trustees of the British Museum.*[19]

On 12 March 1814, the donation book of the British Museum records: "Different Fragments of Paintings from St Stephen's Chapel, from the Society of Antiquaries."[20] There is no mention of the donation in the British Museum trustees' minutes, nor is there any record of the fragments having been accepted by the Department of Antiquities in the officers' reports for the same period.[21] As there was no public or national collection of British antiquities, the Society of Antiquaries was busy intermittently collecting objects—often received as donations from fellows—for a museum of their own.[22] It was therefore an exceptional act to give away the St Stephen's Chapel fragments to the British Museum.[23] The most likely reason for this donation was space. The Antiquaries did not move into Burlington House until 1874, and although framed paintings could be hung on its walls, large stone fragments such as those from St Stephen's were problematic to store and display.[24] The growing British Museum might well have seemed the most logical place to deposit the items.

After the fragments were moved from the Antiquaries to Bloomsbury, there is little evidence to track their location within the British Museum. It is highly unlikely they were placed on public display. It was not until 1852 that they were first described in a British Museum guide book, and located within the earliest incarnation of a permanent British and Medieval Gallery: "Cases 98–101. Paintings from St. Stephen's Chapel, Westminster, of the time of Edward III. They represent scenes from the book of Job and the history of Tobit."[25] An image of the fragments on display in this room—albeit in a slightly later incarnation—is recorded in a photograph by Frederick York, taken in 1875 (fig. 1). There was no chronological or thematic organisational structure. The display was arranged as is stated in the *Synopsis of the Contents of the British Museum*, "with regard to the material and workmanship of the objects".[26] The redisplay of the fragments from St Stephen's coincided with the appointment of Augustus Wollaston Franks, the first permanent employee of the museum responsible for British antiquities.[27] Before 1852, several British and European antiquities were on view in the Ethnographic Room, but the earlier versions of the *Synopsis of the Contents of the British Museum* make no mention of what types of objects constituted the display.

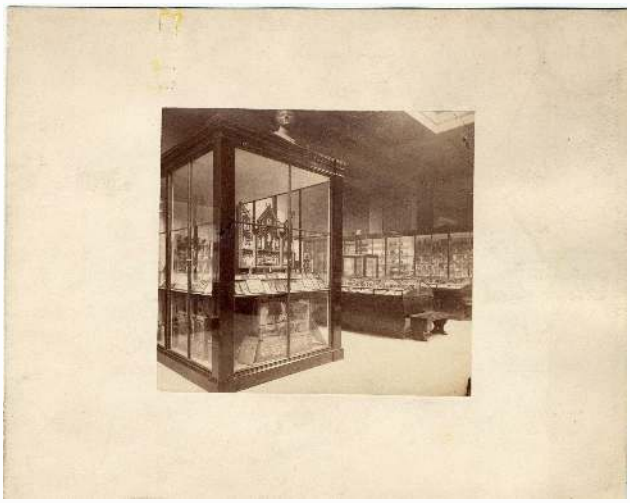

Figure 1

Frederick York, *The wall painting fragments on display in the British Museum*, 1875, photograph. Digital image courtesy of Trustees of the British Museum (CC BY-NC-SA 4.0).

The history of these objects illuminates the slow birth of interest in medieval objects at the British Museum. If the paintings at St Stephen's Chapel had been discovered half a century later—at the time of their display in 1852—the story of their preservation would be completely different.[28] The history of the acquisition and presentation of the St Stephen's fragments serves as a counterpoint to the presentation of other cultures at the museum.[29]

Technical Examination and Analysis of the Fragments

Although the British Museum's development of an interest in medieval antiquities was protracted, the work of Carter, Smith, and Smirke was pioneering. This innovation was mirrored in the analytical investigations undertaken on the St Stephen's Chapel fragments by the London doctor John Haslam in 1800.[30] His work on the fragments included the first recorded analysis of paint samples ever undertaken, and marked the beginning of an interest in this field by leading scientists in Europe at the turn of the century.[31]

Haslam's ground-breaking work provided a remarkably accurate preliminary overview of the pigments and binding medium employed in the scheme of

fourteenth-century wall painting. It was another 170 years before further examinations and analysis were carried out, in advance of the conservation and remounting of the surviving fragments at the British Museum in 1973.[32] Aside from these instances, a few other minor phases of analysis have been undertaken to answer particular technical queries, and a summary of the previous studies is given in the Appendix below.[33]

Following discussions with researchers on the AHRC-funded project 'St Stephen's Chapel, Westminster: Visual and Political Culture, 1292–1941' (2013–17), and with other scholars at a seminar hosted at the British Museum, the decision was made in 2015–2016 to undertake a limited phase of further examination.[34] In light of more recent research on related material, this set out to resolve a small number of outstanding technical questions and included undertaking technical imaging, some further sampling, and re-examination of the 1973 samples with analytical techniques which were not available at that time. Primary research questions focused on: the evidence for the setting out of the paintings, such as the use of incision or under-drawing; the type of dyestuff used in the preparation of the red lake pigment; evidence for original finishes, including further investigation of the mordant gilding; and whether there are any remains of original varnish.

Constrained by the restricted access afforded by the fixed display of the majority of the fragments in glass-fronted cases, only a limited amount of infrared and ultraviolet imaging, examination, and sampling was possible in 2015. Despite the constraints, much useful new information relating to the painting methodology and workshop practices has been assembled, and these results are detailed below. However, perhaps the single most significant advance, which has been made as part of the recent study, is the production of a new set of high-resolution images of the paintings, undertaken by the British Museum in 2017. These images will make detailed study of the fragments possible for all and thus revolutionise the accessibility of these important fourteenth-century wall paintings by exploiting a system of display appropriate for the twenty-first century.

Infrared Examination

Infrared reflectography (IRR) was undertaken on those fragments accessible in the 2015 examination to investigate the possible presence of under-drawing.[35] The resulting infrared images have provided new information relating to the preparatory methods used in setting out the paintings. Although only a portion of the original scheme survives, the few remaining fragments provide clear evidence that a number of different hands were involved in both the drawing and painting phases of the production of this once-extensive cycle of images.

A scene from the *Book of Job*, reveals an under-drawing in a fluid medium, but rather thickly and stiffly applied (fig. 2). Both the exterior outline and interior folds of the drapery are indicated, but they are rather awkwardly and crudely drawn, with broad stiff lines.

Figure 2

The Book of Job (detail), in visible and infrared light, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2c). The IRR image reveals a rather awkward and stiffly drawn preparatory drawing. Images courtesy of the Trustees of the British Museum (CC BY-NC-SA 4.0).

The infrared image from the *Turret Scene* reveals a drawing that is similar, in that all of the folds of the drapery are suggested, but here the drawing is much less stiff, with more confident and flowing brushwork. This can be seen particularly clearly in the fluid freehand drawing of the female figure's hair (fig. 3), and in the flowing curly interior details of the drapery at the bottom left (fig. 4). It is also apparent that the lines setting out the architecture have been ruled, as evidenced by the overrun

of the line at the bottom of the scene. Ruling against a straight edge would explain this type of overshoot (fig. 4). The infrared image also shows that the architecture was very carefully planned out in advance of painting, and that the drawing was followed very closely in the subsequently applied paint layers.

Figure 3

The Book of Job (detail), in visible and infrared light, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2c). The IRR image shows the turret scene, revealing the confident and fluid freehand drawing of the female figure's hair. Images courtesy of the Trustees of the British Museum (CC BY-NC-SA 4.0).

Figure 4

The Book of Job (detail), in visible and infrared light, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2c). The IRR image shows that the architecture was very carefully planned out in advance of painting with many of the lines being ruled against a straight edge, the preparatory drawing was followed very closely in the paint layers, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2c). Images courtesy of the Trustees of the British Museum (CC BY-NC-SA 4.0).

In the *Destruction of Job's Children*, a rather different character of under-drawing is evident, and again this is likely to relate to the various hands present in the workshop (fig. 5). For the preparatory drawing of this fragment, only the external outlines of the drapery are indicated, none of the internal folds are shown. Further,

it is clear that the architecture was drawn in first, and then followed by the horizontal lines of the table. The position of the front of the table was subsequently altered considerably, indicating that the planning of the overall composition was still relatively fluid at this stage, and that certain major compositional changes were made to the drawing on the wall. The drawing of a spoon extends over the first line of the table front, suggesting that at least some of the items of tableware were added after changes in its position were made. However, other objects had already been sketched in at an earlier stage, and so were moved forward at the same time as the table front, such as the platter (just to the left of the glass, in the centre of the image in Figure 5), which was repositioned and refashioned as a dish.

Figure 5

The Destruction of Job's Children (detail), circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2a). Images courtesy of the Trustees of the British Museum (CC BY-NC-SA 4.0).

A number of objects are more distinct in the infrared image than in the painted fragments, such as the knife and bread roll on the left side of the table (fig. 5). Examination of Smirke's drawing of this scene, made in 1800, confirms that a row of three bread rolls was originally positioned along the front of the table, as it was still visible then (fig. 6). The IRR image also shows that the glass vessel at the centre of the scene was initially drawn in an upright position. It is clear that the repositioning of this object was made at a very advanced stage of the painting

process, as the tumbled vessel has been painted over the final flesh paint of the hands of the figures on the right side of the scene (fig. 7).

Figure 6

Richard Smirke, *The Destruction of Job's Children*, 1800, watercolour. Collection of Society of Antiquaries of London. Digital image courtesy of Society of Antiquaries of London (all rights reserved).

Figure 7

The Destruction of Job's Children, (1814,0312.2b detail fragment), circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2a). Digital image courtesy of Trustees of the British Museum (CC BY-NC-SA 4.0).

By comparison with the crude and stiff under-drawing of the first fragment described, which may suggest copying, here the drawing has been refined and developed *in situ* and, like the *Turret Scene*, was undertaken in a fluid, confident

freehand technique. By contrast, with the *Turret Scene*, this draughtsman did not indicate the inner drapery folds.

Figure 8

The Blinding of Tobit (detail), circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2e). Images courtesy of the Trustees of the British Museum (CC BY-NC-SA 4.0).

Examination of the IRR image of the *Blinding of Tobit* (Fig. 8) reveals a drawing that is different in character to those described above. The features of the bearded figure of Tobit on the right-hand side of the scene have been carefully and skilfully drawn with minute attention to detail. The final flesh painting partially masks the preparatory drawing, but examination of a detail taken at high magnification in

normal incident light shows that the preparatory drawing has been undertaken in brown paint, rather than the black fluid material used elsewhere. In the IRR image, we see through the overlying paint, allowing the under-drawing of the face and beard to be easily seen. The final paint layers of this particular fragment have also been exceptionally finely painted. Here, we have a very skilled hand, evident both in the brown under-drawing and in the fine detail of the final paint layers (figs. 9, 10 and 11).

Figure 9

The Blinding of Tobit, photomicrograph of Tobit's left proper eye and hand, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2e). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

Figure 10

The Blinding of Tobit, photomicrograph of Tobit's face, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2e). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

Figure 11

The Blinding of Tobit, photomicrograph of Tobit's beard, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2e). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

Examination of the *Blinding of Tobit* reveals another significant change in the composition—again undertaken at an advanced stage of the painting process (fig. 12). Here, a broad vertical architectural feature in the original background goes directly through the body of Tobit's wife. Further, the green paint of the original background is evident beneath the pink of her drapery, and shows through where the pink paint is worn or damaged, indicating that Tobit's wife was painted in her present position after the completion of the green background (fig. 13). It appears likely that this figure was originally shown emerging from a doorway, or was partially masked behind an architectural feature, but was subsequently moved to a more dominant position in the composition. This new finding has been significant in relation to Jane Spooner's recent interpretation of the iconography of this scene.[36]

Figure 12

The Blinding of Tobit (detail), showing Tobit's wife. IRR image, ca. 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2e). Images courtesy of the Trustees of the British Museum (CC BY-NC-SA 4.0).

Figure 13

The Blinding of Tobit, photomicrograph of Tobit's wife's drapery showing that where the pink paint layer is worn or damaged, the underlying green background is visible, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2e). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

The IRR images suggest that a number of painters drew freehand *in situ*, developing their compositions on the wall. This is consistent with the evidence of the fabric accounts.[37] They confirm that Master Hugh of St Alban himself was involved in the drawing process, since the entry for the week beginning 27 February 1352 records that he was paid for two days' working, "on the drawing of images in the same chapel".[38] The stiffness of some other areas of drawing may suggest that subsidiary artists were copying from models (perhaps on paper), which in all likelihood were also prepared by the master painter, as suggested by an entry in the accounts for the week beginning 30 April 1352, in which Master Hugh of St Alban is paid for "directing the drawings for the said painters".[39] The accounts also provide evidence for the purchase of paper, which may have been used for this purpose, in the week beginning 2 January 1352, "To John Lambard for two quires of royal paper bought for the designs of the painters 20 d.".[40]

In addition to the use of preparatory drawing, lines were finely incised into the lead white paint layer for setting out the inscriptions (fig. 14). Ruled or snapped vertical and horizontal lines for guidance in the overall setting out are also visible in one case below the white paint layer (see fig. 21).

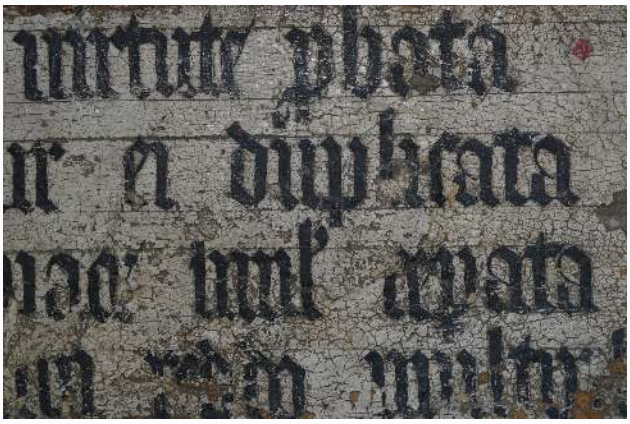

Figure 14

The Blinding of Tobit (detail), photomicrograph showing the incised lines used to set out the text on fragment 1814,0312.2b, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2b). Digital image courtesy of British Museum and the National Gallery, London (all rights reserved).

Mordant Gilding

Examination of the surviving painting fragments at high magnification revealed that many of the fine linear details, which now appear white, for example, the decorative borders of drapery and the edging of the tablecloths, were once gilded. Remnants of the original gold leaf remain on the surface in the *Blinding of Tobit*, and traces are evident on other fragments, such as the *Destruction of Job's Children* (see figs. 15, 16, 17, 31 and 32). The published antiquarian sources confirm that more extensive remains of gold leaf were evident at the end of the eighteenth century. Describing the *Destruction of Job's Children*, it is stated that "the borders and ornaments of all the dresses are gilt".[41]

Figure 15

The Blinding of Tobit (detail), photomicrograph showing traces of gold leaf on Tobit's wife's veil, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2e). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

Figure 16

The Blinding of Tobit (detail), photomicrograph of a detail of Tobit's headdress showing craquelure of the blue paint and linear detailing in white with traces of mordant gilding, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2e). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

Figure 17

The Blinding of Tobit (detail), photomicrograph showing the remains of the white mordant for gold leaf on the border of Tobit's wife's gown, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2e). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

Although very little of the gold leaf itself now survives, the fine white lines that are the remains of the original white mordant used to adhere the metal leaf to the surface are still apparent. This new finding is significant, since white mordants were generally reserved for the application of silver leaf. The only other roughly contemporary example of a white mordant for gold leaf is that used for the fine linear details on Christ's drapery in the late fourteenth-century *Judgement* scene in the Chapter House of nearby Westminster Abbey (figs. 18, 19, and 20).[42]

Figure 18

Feast of Job (detail), circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2d). Digital image courtesy of Trustees of the British Museum (CC BY-NC-SA 4.0).

Figure 19

The Last Judgement (detail of Christ's brooch showing fines lines of mordant gilding), 1390, a secco wall painting on stone. Collection of Chapter House, Westminster Abbey. Digital image courtesy of Courtauld Institute of Art (all rights reserved).

Figure 20

The Last Judgement, photomicrograph of paint cross-section showing the use of a white mordant for gold leaf, used for the fine linear details, 1390. Collection of Chapter House, Westminster Abbey. Digital image courtesy of Courtauld Institute of Art (all rights reserved).

The use of a warm-coloured mordant to lend a deeper golden tone to the subsequently applied gold leaf is far more common and has been found elsewhere on the St Stephen's fragments, for example, for the borders of text (fig. 21), and also on the tin-relief (background) decoration, which was mordant gilded after being applied to the surface of the painting (figs. 22 and 23).[43] In 1800, Haslam noted the presence of a yellow, ochre-containing oil-based mordant for gold leaf of the greatest purity.[44] In 1973, scientists from the National Gallery confirmed the presence of a drying oil in samples, which contained yellow mordant for gilding, although they did not isolate this layer for separate analysis.[45]

Figure 21

St Stephen's Chapel Wall Paintings, photomicrograph of the border for text on fragment 1814,0312.2.f showing the warm yellowish brown mordant for the gold leaf, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2f). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

Figure 22

St Stephen's Chapel Wall Paintings, photomicrograph of the tin-relief decoration on fragment 1814,0312.2.f, showing traces of gilding which remain on the surface and the warm yellowish brown mordant for the gold leaf, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2f). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

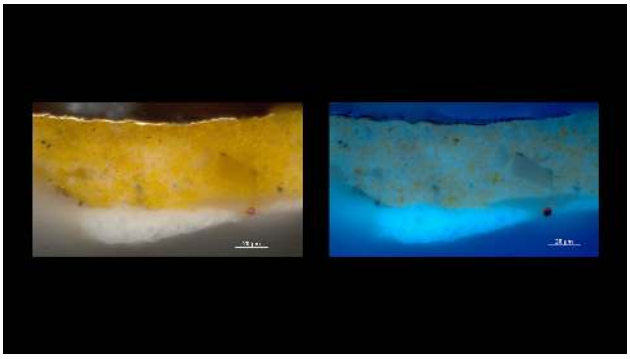

Figure 23

St Stephen's Chapel Wall Paintings, paint cross-section (in visible and UV light) of the sample taken from the mordant gilding of fragment 1814,0312.2.f shown in Figure 21, circa 1355–1363, photomicrograph. Collection of British Museum (1814,0312.2f). Digital image courtesy of National Gallery, London (all rights reserved).

Recent instrumental analysis of the constituents of the yellow-coloured mordant reveal that it comprises a drying oil,[46] combined with a yellow earth pigment, a

lead pigment (lead white or red lead, or both), a few large inclusions of chalk and quartz, and a few particles of a brilliant red earth and vermilion (fig. 23).[47] A mordant closely comparable in overall colour and constituents was used in late fourteenth-century wall paintings in the Byward Tower, Tower of London (fig. 24).[48] Analysis suggests that the oil did not have much chance to dry before the gold leaf was applied, and this of course is the whole point, that the mordant was sticky enough to hold the metal leaf on the surface.[49]

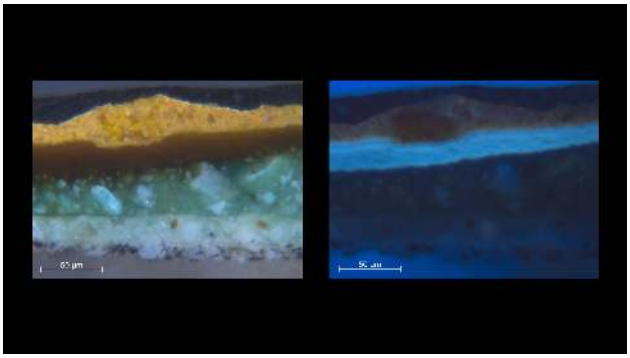

Figure 24

St Stephen's Chapel Wall Paintings, paint cross-section of a sample (in visible and UV light) taken from the mordant gilding used on the late fourteenth-century wall paintings, fourteenth century, photomicrograph. Collection of Byward Tower, Tower of London. Digital image courtesy of National Gallery, London (all rights reserved).

There is little doubt that the two different coloured mordants, white and yellow, were used with the intention of producing distinctive and different optical effects in the subsequently applied gold leaf.

It seems likely that silver leaf itself was employed elsewhere, as it is mentioned in the accounts for the chapel—although entries for it are much less frequent than for gold leaf and tin foil.[50] Haslam's analysis confirmed that silver leaf was used,

> *the specimen of painted glass you lately sent me consists of verdigrise prepared with varnish, painted to the glass; immediately over which silver-leaf is laid, and upon that a cement, to fasten it to the niche wherein it was laid.*[51]

Examination of the surviving fragments, suggested that silver leaf was used for a number of items of tableware, such as the two goblets, cutlery, and platters in the *Destruction of Job's Children* (see figs. 5 and 7). Indeed, they are described as such in the early nineteenth-century accounts.[52] Unfortunately, due to limited access, it was not possible to sample any of these areas to confirm the nature of the metal leaf, or to determine the constituents and overall colour of the mordant employed. Though silver leaf would originally have been glazed or varnished to prevent tarnishing, the metal leaf in these areas now appears dark and degraded.

Examination of the surface at high magnification also suggests that silver leaf may have been employed to render the tumbled glass vessel at the centre of this scene. A green glaze seems to have been applied over metal leaf to produce the appearance of liquid in the type of greenish transparent glass that would have been available at the time (see fig. 7).[53]

Red Lake Pigment

Two samples of red lake paint were analysed: one from the pink robe of the female figure at the far left side of the *Destruction of Job's Children* (1973/S7) (see figs. 5, 25, and 26) and the other from the red drapery of the female figure in the *Blinding of Tobit* (fig. 12). High-performance liquid chromatography (HPLC) analysis in both cases confirmed that the lake pigment was made from dyestuff extracted from the lac insect *Kerria lacca* Kerr. The presence of erythrolaccin, an alkali-soluble dyestuff component suggests that the lake was prepared by alkaline extraction of sticklac.[54]

Figure 25

Destruction of Job's Children, unmounted fragment of the sample taken from the pink robe of the female figure at the far left side, circa 1355–1363, photomicrograph. Collection of British Museum (1814,0312.2). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

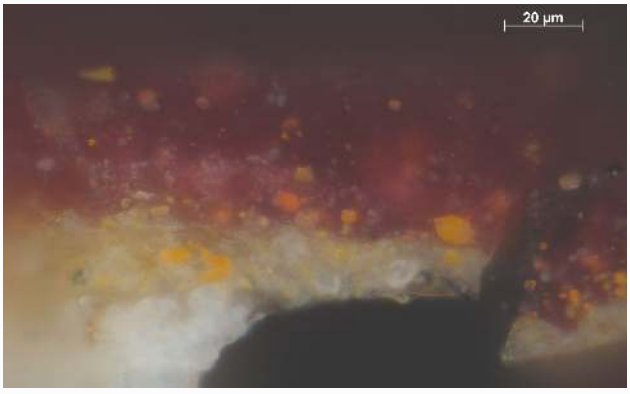

Figure 26

Destruction of Job's Children, paint cross-section of a sample taken from the pink robe of the female figure at the far left side, circa 1355–1363, photomicrograph. Collection of British Museum (1814,0312.2). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

Gas chromatography–mass spectrometry (GC-MS) analysis of the sample taken from the *Destruction of Job's Children* (1973/S7) suggests that the dry lake

pigment was combined with a heat-bodied drying oil, likely to be linseed or walnut oil, a mixture of the two, or indeed different oils in the different layers.[55]

The paint cross-section prepared from this sample shows that the red lake pigment was applied in two layers over an underpaint of lead white combined with red lead, yellow earth, and a few black particles (fig. 26). The lower of the two red lake-containing layers contains particles of red lead and lead white, which would not only have increased the opacity of the layer, but would also have aided drying. Over this, a translucent red lake glaze layer has been applied to model the drapery. This layer additionally contains a few particles of red lead and lead white, probably incorporated to function as driers.

In other areas, the red lake pigment was combined with ultramarine to produce a purple colour, as shown in the sample taken from the drapery below Tobit's wife's veil in the *Blinding of Tobit* (see figs. 12 and 27). Here the red lake pigment has partially faded; it is now clearly visible only at the base of the paint layer.[56]

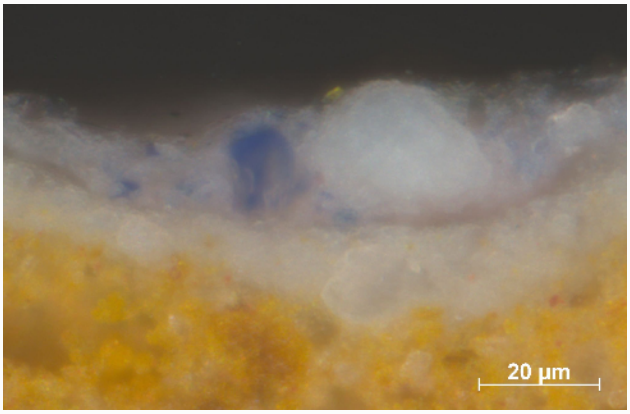

Figure 27

The Blinding of Tobit, paint cross-section of a sample taken from the drapery below Tobit's wife's veil, showing where the red lake pigment has faded and is only visible at the very base of the once purple paint layer, circa 1355–1363, photomicrograph. Collection of British Museum (1814,0312.2). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

Lake pigments were expensive. Indeed, records of the purchase of pigments for the chapel indicate that red lakes were among the most expensive materials a painter

could buy.[57] The accounts for 1351–1352 include an entry for 1 lb *cynople* for 30s., while 2 lbs of vermilion—the most costly of all the other red pigments—was 3s. 4d., or about one-twentieth of the cost.[58]

The documentary evidence suggests that several different types of red lake pigment may have been purchased for the St Stephen's Chapel scheme. One *cyneple* was priced at 17s. 3d. for 1½ lb, another *cynople* 20s. for 1 lb, while 2 lbs *cynopre* of Montpellier (de Monte Pessalono) cost 16s.[59] This price differential, with one of the lakes at twice the price of the others, must be due to a substantial difference in the quality, or to the lake having been prepared using a more expensive variety of dyestuff (such as lac or kermes lake, as opposed to madder, which would have been cheaper).[60] However, in the two samples taken, only lac lake has been identified. Indeed, recent analyses of lake pigments from Westminster of about this period have indicated that lac lake is the *only* red organic colorant employed in these high-quality commissions.[61] It seems likely that it was the only high-quality lake pigment available (though at a high price) until the last quarter of the fourteenth century, when the use of kermes lake (extracted from the insect *Kermes vermilio* Planchon) is confirmed in paintings for the first time.[62]

Perhaps the earliest example of the use of kermes lake is in a sample taken from the frame of the tester over the tomb of the Black Prince in Canterbury Cathedral (d. 1376). Here, both kermes and lac have been identified in the same paint sample, along with a tiny trace of madder.[63] Among the other early identifications of kermes lake in England are the *Apocalypse* and *Old Testament* cycles (1375–1404) in the Chapter House of Westminster Abbey, as well as the portrait of Richard II, also in Westminster Abbey (dated to the last decade of the fourteenth century). On this, it was used in a mixture with a small amount of madder as a glaze over vermilion for the king's robe.[64]

Original Varnish

A final question of this phase of analysis concerned the presence of original varnish. The documentary sources suggest that varnish was used in the original painting scheme, since the accounts for the decoration of the chapel mention the

purchase of both red and white varnishes. For instance, between 15 August 1351 and 13 February 1352 white varnish is supplied three times and in much larger quantities than the red, which was supplied only once.[65]

While the purchase of varnish is documented, the manner in which it was employed is less certain, although the sources again provide some information. Haslam's report begins with a description of the separation of the varnish layer and the media (that is, paint layers). It states:

> *In order to examine these colours, I was obliged, after having carefully scraped them from the stone, to employ a quantity of impure aether (spiritus aetheris vitriolici of the London Pharmacopeia), to dissolve the varnish which had been laid over them, and also to separate the oil with which the colours had been prepared.*[66]

He went on to separate out the "oleaginous" matter, and noted that it, "had the peculiar smell of varnish and adhered as such to the sides of the phial. What the composition of this varnish may be, I can not precisely determine".[67]

Haslam clearly describes a layer of varnish "laid over" the colours. However, it is not possible to be absolutely certain that the varnish he removed from the surface of the paintings was original. It could, for example, have been applied to protect the surface of the paintings before they were lost from view, some time before 1651. [68] Nonetheless, the notion of a later overall varnish layer seems unlikely in the light of Haslam's observation of two different types of varnish on the paintings. He states that the gold leaf was, "covered with a white or transparent varnish" and goes on to note that, "in some instances a brilliant lacker had been employed, the lustre of which is undiminished in the specimens before me". In an appendix to his analysis, Haslam also mentions the presence of verdigris in varnish over silver leaf.[69] The use of a translucent layer to modify the appearance of the surface in particular areas is supported by Smirke (1800), in his account of *The Adoration of the Magi; St George, and Edward III with his sons*, he describes what is likely to have been a varnish or a glaze for the purpose of making the floor recede: "it is glazed with transparent brown, which increases in strength as the floor approaches the diaper work" (fig. 28).[70]

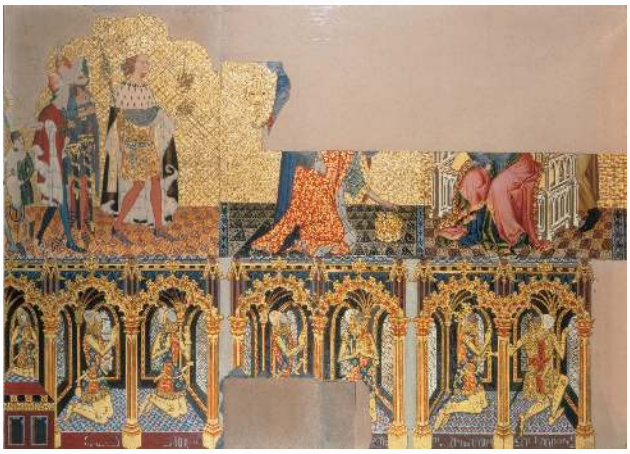

Figure 28

Richard Smirke, *The Adoration of the Magi, St George and Edward III with his sons (copy)*, 1800–1802, tempera and gold leaf on paper, 82.5 × 116.5 cm. Collection of Society of Antiquaries of London. Digital image courtesy of Society of Antiquaries of London (all rights reserved).

The accumulated documentary evidence certainly seems to confirm the presence of a translucent layer, which varied in colour from area to area, and which functioned to modify the appearance of the surface. This layer may have been a varnish or a glaze layer, or potentially both. While a glaze is generally a translucent (usually) oil-based layer containing pigment (often a lake pigment), an oil-based medieval varnish would also have contained a resinous component.[71] The type of resin employed may have contributed to the overall colour of the varnish.[72]

Broadly speaking, fourteenth- and fifteenth-century recipes for oil-based varnishes are of two types. In the first, the resin constituent(s) are heated together with the oil. In the second, the oil and resin are heated separately, and the resin is melted before the hot oil is added (for less easily soluble resins, this is a far more efficient method).[73] Whichever method was chosen for manufacture, analysis of their constituent components can be extremely challenging.

Examination of one of the paint samples taken in 2015 at high magnification suggested the presence of an original varnish or glaze layer on the surface of the green paint (fig. 29). This yellowish translucent layer is approximately 20 microns thick and exhibits strong fluorescence when viewed in ultraviolet light. There are

drying cracks that go through both the green paint and the translucent layer on the surface, suggesting that they are likely to be coeval; if the uppermost layer had been applied later, it would be present within the drying cracks.

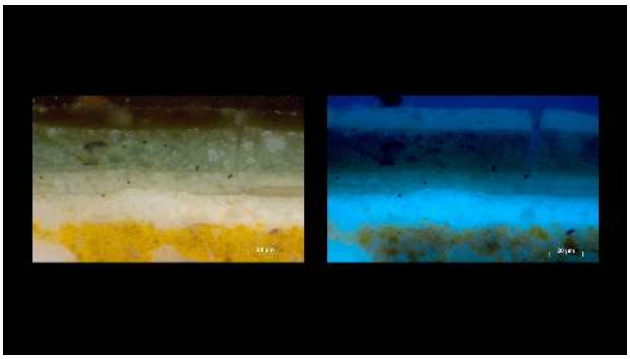

Figure 29

St Stephen's Chapel Wall Paintings, paint cross-section (in visible and UV light) of a sample taken from the green painting on fragment 1814,0312.2.f (the yellowish translucent layer on the surface exhibits strong fluorescence when viewed in ultraviolet light), circa 1355–1363, photomicrograph. Collection of British Museum (1814,0312.2f). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

The translucent upper layer was carefully separated out and analysed by GC-MS analysis, which confirmed the presence of a drying oil, but no resinous components could be detected. In case a polymerised resin, such as sandarac or amber had been used in the varnish, pyrolysis GC-MS was also performed. The analysis of the resinous components of original varnishes has generally proved extremely challenging, and it was not possible to detect any resin in this case.[74] This may be due to the fact that the proportion of resin dissolved in the oil to make these early varnishes was always rather low, but it may also reflect the changes undergone by these materials, both during the preparation of the varnish and in its subsequent ageing.

Though the layer is mainly composed of organic material, analysis in the scanning electron microscope with energy-dispersive X-ray analysis (SEM/EDX) did confirm the presence of a few calcium-rich and silicon-rich particles (likely to be chalk and quartz), a little lead (likely to have been originally added as lead white,

to function as a dryer), and a trace of copper. Copper salts are very mobile within oil-based paint layers and the small quantity present here is likely to have originated from the verdigris-based paint layer below. There is certainly insufficient evidence to suggest that this was a copper green glaze. Attenuated total reflectance-Fourier transform infrared spectroscopy (ATR-FTIR) analysis was also undertaken, which confirmed the presence of metal oxalate and carboxylate salts, suggestive of a reaction between the lead and copper salts and the oil in the layer.[75]

Re-examination and analysis of one of the samples taken in 1973, taken from an area of blue drapery in the *Destruction of Job's Children*, suggests the presence of a varnish layer over the ultramarine paint layer, although it was not possible to confirm the presence of a resinous component (fig. 30).[76]

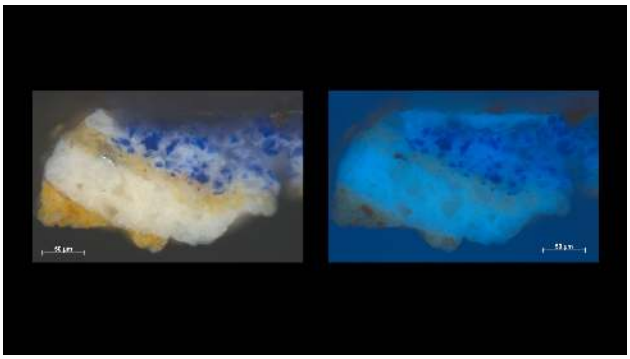

Figure 30

Destruction of Tobit's Children, paint cross-section (in visible and UV light) of a sample taken in 1973 from an area of blue drapery (the analysis suggests the presence of a varnish layer over the ultramarine paint layer), circa 1355–1363, photomicrograph. Collection of British Museum (1814,0312.2). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

In addition, the sample taken from Tobit's wife's veil in the *Blinding of Tobit* also seems to provide evidence of an original varnish, here used as an intermediary layer before the application of fine surface details. Figure 31 shows the fine linear details of the veil in white mordant, with a few tiny traces of the original gilding remaining on the surface. The paint cross-section shows the white mordant on the

intermediate layer, it seems likely that it is a varnish which was applied over the pale purple of the drapery before the fine linear details of mordant gilding were added on the surface. A varnish layer such as this would have provided a smooth and evenly absorbent surface on which to paint the final delicate details.[77]

Figure 31

The Blinding of Tobit (detail), photomicrograph of Tobit's wife's veil showing the fine white linear details which were once gilded, circa 1355–1363, a secco wall painting on stone. Collection of British Museum (1814,0312.2e). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

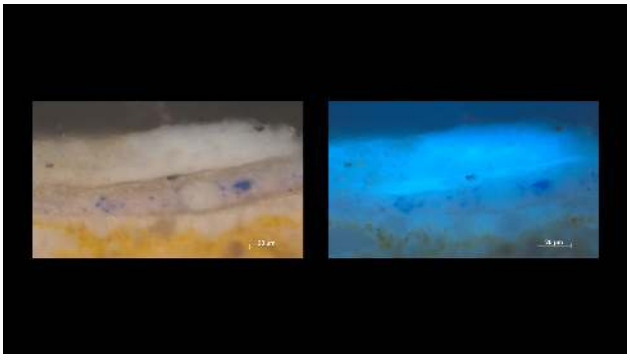

Figure 32

The Blinding of Tobit, paint cross-section (in visible and UV light) of a sample taken from the fine linear detail in white mordant of Tobit's wife's veil , circa 1355–1363, photomicrograph. Collection of British Museum (1814,0312.2). Digital image courtesy of Trustees of the British Museum and the National Gallery, London (all rights reserved).

Varnishes that are considered to have belonged to the original paint schemes have already been identified at Westminster Abbey: on the Retable; on the Crouchback tomb; on the south transept figure of St Christopher; and possibly also on the

sedilia. The type of resin incorporated in an original varnish has been characterised in only two cases in medieval English polychromy: an amber-containing varnish has been identified on the late fourteenth-century wall paintings in the Byward Tower, Tower of London; and a sandarac varnish has been detected on a mid-thirteenth-century engaged column with a stiff-leaf capital from Wells.[78]

Both contemporary financial accounts and later descriptions of two differently coloured "varnishes" on the surface suggest the presence of an original varnish layer. The material evidence, when considered together (for instance, the drying crack that passes through both the paint and the translucent surface layer, the fluorescence of the surface layer, and its thickness and colour), all points to the presence of an original varnish on the St Stephen's Chapel wall paintings (fig. 29). The fact that we have not been able definitively to confirm the presence of the resin here is likely to be a function of the difficulty of identifying the resinous component of such an aged material in the tiny sample available for analysis.

Conclusion

The red lake pigment has now been characterised as lac lake and a white mordant for gold leaf has been identified. In addition, the presence of an original varnish is strongly suggested.

Infrared imaging of the paintings has provided clear evidence for the presence of an under-drawing and of extensive modification of the design *in situ* at an advanced stage of the painting process. There are marked differences in the character of the under-drawing on the various fragments studied, which are likely to relate to different hands and may be indicative of workshop practice. The exceptionally high quality of a precious few sections of the under-drawing have been made visible for the first time. By revealing the quality of the drawing hidden underneath the paint layers, we have gained new insights into the delicacy and care with which this scheme was created, from the initial preparatory stages all the way through to the final paint layers, which points towards the overall quality of the scheme.

The present, damaged appearance of the many areas of the paint surface merely reflects their violent physical history. Perhaps the most significant outcome of this study is that the new high-resolution images will make the surviving fragments of one of the finest schemes of English medieval wall painting accessible to all.

About the authors

Catherine joined the National Gallery in 1999 as an organic analyst, specialising in the study of paint binding media and other amorphous organic materials, having previously completed a PhD in chemistry. In 2007–2015, she was Head of Science at the British Museum. In 2015, she returned to the National Gallery as Principal Scientific Officer, building on her previous research and helping to extend the range of analytical and imaging approaches available within the department for the study of paintings. Her role has included introducing the use of MA-XRF scanning into institutional practice and helping to develop cutting-edge visible-nIR-SWIR hyperspectral imaging equipment for use at the Gallery. She has a particular interest in the ageing and deterioration of organic materials, and on the interactions between inorganic and any associated organic materials, or between inorganic and organic materials and the environment.

David is an Honorary Research Fellow at the British Museum, having been Keeper of Conservation and Scientific Research at the Museum for ten years until 2015. After postdoctoral research in chemistry, he began his conservation career in the Scientific Department at the National Gallery in London, where he worked for twenty years. His main research interests lie in the study and prevention of deterioration in museum collections and in the use of non-invasive analytical techniques for the study of artefacts, particularly imaging-based methods. He is a fellow of the Society of Antiquaries of London and a member of the Council of the International Institute of Conservation, whose journal—*Studies in Conservation*—he edited for many years. He serves on a number of conservation advisory boards and has been a syndic of the Fitzwilliam Museum since 2015. He was a guest scholar at the Getty Conservation Institute in Los Angeles in 2015–2016 and the Getty-Rothschild Fellow in 2017. He was Praska visiting professor at the Conservation Center of the Institute of Fine Arts, New York University in 2018.

Working in collaboration with conservators and curators at the National Gallery, Helen undertakes research into the original materials and techniques of paintings, investigating how these materials may have deteriorated over time and whether this may affect the current condition and appearance of the painting. The analytical results inform conservation treatments and art-historical research. Before joining the National Gallery in 2006, she completed her PhD, “Pigments of English Medieval Wall Painting”, at the Courtauld Institute

of Art, University of London. This followed a Postgraduate Diploma in the Conservation of Wall Paintings, from the Courtauld Institute/Getty Conservation Institute, and an MA in Fine Art from Oxford University. Her main research interests include historical painting technology, pigment alterations, and original vanishes.

Lloyd de Beer is Curator: Medieval Britain and Europe in the department of Britain, Europe and Prehistory at the British Museum, where he has worked since 2012. He recently curated the blockbuster exhibition *Thomas Becket: Murder and the Making of a Saint*. In January 2022 Lloyd began a three-year fellowship, jointly funded by the British Academy and the Wolfson Foundation, working on a project called *The Age of Copper, Ivory and Gold: England and West Africa in the Middle Ages*.

Footnotes

1. For a synopsis of Sir Hans Sloane's collecting of medieval objects, see John Cherry, "Medieval and Later Antiquities, Sir Hans Sloane and the Collecting of History", in Arthur MacGregor (ed.), *Sir Hans Sloane: Collector, Scientist, Antiquary, Founding Father of the British Museum* (London: British Museum Press, 1994), 198–221.
2. For the most up-to-date survey, see David M. Wilson, *The British Museum: A History* (London: British Museum Press, 2002), 58–93.
3. A small architectural fragment was retained by the Society of Antiquaries and is still held there (SOA cat.). It is recorded in Beatrice de Cardi's inventory as "Fragment of wall plaster showing paint and gilding, c. 1349–60, from St. Stephen's Chapel, Westminster, rescued by the Soc. of Antiquaries; the rest in the British Museum".
4. John Topham, *Some Account of the Collegiate Chapel of St Stephen, Westminster* (London: Society of Antiquaries, 1795). For an overview of Carter's life, see Joseph Mordaunt Crook, *John Carter and the Mind of the Gothic Revival* (London: W.S. Maney & Son, in association with the Society of Antiquaries, 1995). Rosemary Hill, "'Proceeding like Guy Faux': The Antiquarian Investigation of St Stephen's Chapel Westminster, 1790–1837", *Architectural History* 59 (2016): 253–279.
5. *The Gentleman's Magazine* 73 (1803), I: 31–32.

6. *The Gentleman's Magazine* 70 (1800), II: 736.
7. John T. Smith, *Antiquities of Westminster; The Old Palace; St. Stephen's Chapel, (Now the House of Commons) &c. &c., Containing Two Hundred and Forty-Six Engravings of Topographical Objects, of which One Hundred and Twenty-Two no Longer Remain* (London: T. Bensley, 1807).
8. *The Gentleman's Magazine* 73 (1803), I: 31–32.
9. Smith, *Antiquities of Westminster*, vi.
10. Smith, *Antiquities of Westminster*, vi.
11. Smith, *Antiquities of Westminster*, 252.
12. *The Gentleman's Magazine* 73 (1803), I: 31–32: "the drawings for the Society were not begun till after the 24th of September, as I am well informed; at which time the originals had been removed from their first station; so that the artist never saw them as they stood placed in the House of Commons, but was obliged to copy them as so many detached subjects".
13. *The Gentleman's Magazine* 73 (1803), I: 204.
14. *The Gentleman's Magazine* 73 (1803), I: 423–426.
15. *The Gentleman's Magazine* 73 (1803), I: 317–318.
16. John Cherry and Neil Stratford, *Westminster Kings, and the Medieval Palace of Westminster*, British Museum, Occasional Papers, 115 (London: Department of Medieval and Later Antiquities, British Museum, 1995), 48. The drawing is P&D G,3.259.
17. British Museum, inventory numbers: 1883,0310.1, 1883,0310.2. These fragments were donated by Charles Baker-King, but had been previously in the possession of Sir George Gilbert Scott.
18. Sir John Soane's Museum, inventory numbers: MY44, MY45, MY46, M652, MP182.
19. Society of Antiquaries, Council Minutes 15 February 1814, IV/269.
20. British Museum, Central Archive: Book of Donations, 17 July 1766 to 11 January 1823.

21. These reports are usually very informative and report on the monthly work undertaken in the departments. This includes acquisitions, displays, and publications.
22. Joan Evans, *A History of the Society of Antiquaries* (London: Society of Antiquaries, 1956), 218–219.
23. Evans, *A History of the Society of Antiquaries*, 218–219.
24. Bernard Nurse, "Collecting for Britain", in David Gaimster, Sarah McCarthy, and Bernard Nurse (eds), *Making History: Antiquaries in Britain 1707–2007* (London: Royal Academy of Arts, 2007), 70.
25. *Synopsis of the Contents of the British Museum* (London: G. Woodfall and Son: 1852), 229.
26. *Synopsis of the Contents of the British Museum*, 229.
27. See Marjorie Caygill and John Cherry, *A.W. Franks: Nineteenth-Century Collecting and the British Museum* (London: British Museum Press, 1997).
28. *Synopsis of the Contents of the British Museum* (London: Woodfall and Kinder, 1850).
29. See Ian Jenkins, *Archaeologists and Aesthetes in the Sculpture Galleries of the British Museum 1800–1939* (London: British Museum Press, 1992).
30. John Haslam, "To Mr. John Thomas Smith, Engraver of the Antiquities of London", in John T. Smith, *Antiquities of Westminster; The Old Palace; St. Stephen's Chapel, (Now the House of Commons) &c. &c., Containing Two Hundred and Forty-Six Engravings of Topographical Objects., of which One Hundred and Twenty-Two no Longer Remain* (London: T. Bensley, 1807), 223–226.
31. Haslam's work was followed by that of Jean Chapel (1809) and Sir Humphry Davy (1814), who analysed pigment samples from excavations in Rome and Pompeii. See Stephen G. Rees-Jones, "Early Experiments in Pigment Analysis", *Studies in Conservation* 35 (1990): 93–101, esp. 95–97.

32. Peter C. van Geersdaele and Lesley J. Goldsworthy, "The Restoration of Wall Painting Fragments from St Stephen's Chapel, Westminster", *The Conservator* 2 (1978): 9–12.

33. Catherine Higgitt, Marika Spring, and David Saunders, "Pigment-Medium Interactions in Oil-Paint Films Containing Red Lead or Lead-Tin Yellow", *National Gallery Technical Bulletin* 24 (2003): 75–95, esp. 82; and Marika Spring and Catherine Higgitt, "Analyses Reconsidered: The Importance of the Pigment Content of Paint in the Interpretation of the Results of Examination of Binding Media", in J. Nadolny (ed.), *Medieval Painting in Northern Europe: Techniques, Analysis, Art History* (London: Archetype Publications, 2006), 223–229.

34. The results of much of the recent research are discussed by Helen Howard and Marie-Louise Sauerberg, "The Polychromy at Westminster Abbey, 1250–1350", in Warwick Rodwell and Tim Tatton-Brown (eds), *Westminster: The Art, Architecture and Archaeology of the Royal Abbey*, British Archaeological Association Conference Transactions 39, Part I (2015), 205–261; Marie-Louise Sauerberg, Helen Howard, Jo Kirby, Rachel Morrison, and David Peggie, "The Final Touches: Evidence from the Study of Varnishes on Medieval Polychromy in England", postprints of the symposium, *Let the Material Talk: The Technology of Late Medieval Painting in Cologne from the Master of Saint Veronica to Stefan Lochner*, Cologne, November 2011, in *Zeitschrift für Kunsttechnologie und Konservierung* 26 (2012/1): 241–258.

35. Infrared radiation passes through the paint until either it reaches something that absorbs it, or it is reflected back to the camera. Carbon black is highly absorbing and so if an artist has begun a painting by drawing the design in black on a white ground, an infrared image can often show this under-drawing. IRR to examine under-drawing and pentimenti was carried out using an OSIRIS infrared camera, based on an InGaAs sensor that is sensitive to radiation in the range circa 800–1700 nm. The panels were illuminated with standard tungsten-halogen photographic lamps positioned

at circa 45 degrees to the focal axis of the camera; see David Saunders, Rachel Billinge, John Cupitt, Nicholas Atkinson, and Heida Liang, "A New Camera for High-Resolution Infrared Imaging of Works of Art", *Studies in Conservation* 51 (2006): 277–290.

36. See Jane Spooner, "The Iconography of the St Stephen's Chapel Painting Fragments" in John Cooper, Caroline Shenton and Tim Ayers (eds), *St Stephen's Chapel and the Palace of Westminster*, forthcoming.
37. See Tim Ayers (ed.), *The Fabric Accounts of St Stephen's Chapel, Westminster, 1292–1396*, transcribed and translated by Maureen Jurkowski (Woodbridge: Boydell, forthcoming).
38. Ayers, *The Fabric Accounts of St Stephen's Chapel*, no. 40, m. 15: "To Hugh of St Albans, painter, working there on Monday and Wednesday on the drawing of images in the same chapel, taking per day, as above: 2s." ("Hugoni de Sancto Albano pictori operanti ibidem per dies lune et mercurij super protractacionem ymaginum in eadem capella capienti per diem ut supra ijs.").
39. Ayers, *The Fabric Accounts of St Stephen's Chapel*, no. 40, m. 19: "To Master Hugh of St Albans, painter, directing the drawings for the said painters for one day within the same period, taking per day, as above: 12d." ("Magistro Hugoni de Sancto Albano pictori ordinanti protractaturas pro dictis pictoribus per j diem infra idem tempus capienti per diem ut supra: xijd."),
40. Ayers, *The Fabric Accounts of St Stephen's Chapel*, no. 40, m. 12 ("Johanni Lambard pro ij quaterniis papiri regalis emptis pro patronis pictorum xxd.").
41. John Topham, *Plans, Elevations, Sections and Specimens of the Architecture and Ornaments of [….] St Stephen's Chapel, Westminster, London;* with added plates by R. Smirke and text by H. Englefield (London: Society of Antiquaries, first published 1795, 1811), pl. XIX.
42. The cross-section shows the white mordant used to adhere the fine linear detailing in gold leaf over the rich red of the drapery in the *Judgement*

scene, in the Chapter House of Westminster Abbey (fig. 20). The style of the brooch visible at the left side of Figure 19 is also closely comparable to that in a *Scene from the Book of Job* (BM 1814.0312.2d; fig. 18), though in the Chapter House painting the brooch is rendered in high relief. For the technique of the Chapter House paintings, see Paul Binski and Helen Howard, "Wall Paintings of the Chapter House", in Warwick Rodwell and Richard Mortimer (eds), *Westminster Abbey Chapter House: The History, Art and Architecture of "a Chapter House Beyond Compare"* (London: Society of Antiquaries, 2010), 184–208. A white mordant was also used beneath the gold leaf of the faux enamels in the earlier polychromy (circa 1300) on the tomb of Edmund Crouchback, and beneath gold leaf glazed with red lake on the late thirteenth-century tomb of Aveline de Forz, Crouchback's wife. See Helen Howard, "Edmund Crouchback: Technique of the Tomb of a Crusader", in Paul Binski and Ann Massing (eds), *The Westminster Retable: History, Technique, Conservation* (Cambridge: Hamilton Kerr Institute, and London: Harvey Miller, 2009), 319–340; and Sarah Houlbrooke, "A Study of the Materials and Techniques of 13th Century Tomb of Aveline, Countess of Lancaster, in Westminster Abbey", *The Conservator* 29 (2005–2006): 105–116, esp. 115.

43. Both white and yellow mordants for gold leaf were employed in the Westminster Chapter House paintings, see note 41.

44. "A coat of ochre with oil was laid on [the stone] over which the gold leaf was placed", Haslam, "To Mr. John Thomas Smith, Engraver of the Antiquities of London", 224.

45. Joyce Plesters and John Mills, "Preliminary Report on the Examination of a Part of the Wall-Paintings from St Stephen's Chapel, now in the British Museum", unpublished report, Scientific Department, National Gallery, London, October 1973. These results were published (unacknowledged) as, "The Structure, Pigments and Medium of some Samples from the St Stephen's Chapel Wall Paintings in the British Museum", Appendix I, in

van Geersdale and Goldsworthy, *Restoration of Wall Painting Fragments*, 11–12.

46. Analysis was undertaken using GC-MS (conventional and following low temperature pyrolysis using a thermal separation probe) and FTIR spectroscopy (transmission and ATR-FTIR imaging), see Catherine Higgitt, "Organic Analyses, St Stephen's Chapel, Westminster Palace", unpublished report, Scientific Department, National Gallery, London, 2017.
47. SEM/EDX analysis confirms the presence of lead (Pb) within the mordant and FTIR analysis indicates the presence of lead carboxylates (lead soaps) within the sample. However, the nature of the lead-based pigment, which may have been added as a drier to the oil or mordant, cannot be determined.
48. Jane Spooner, "Royal Wall Paintings in England in the Second Half of the Fourteenth Century", unpublished PhD thesis, Courtauld Institute of Art, University of London, 2016–2017; Jane Spooner, "An Admonitory Wall Painting at the Tower of London", *Burlington Magazine* 158 (2016): 940–949.
49. The sample examined was small but these results are suggestive of a rather lean oil-based mordant, with a high inorganic content, in which the oxidative drying processes were retarded by application of the gold, and in which metal-soap formation has occurred, see Higgitt, "Organic Analyses".
50. For example, on 22 April 1352, to John Lyghgrave and William Allemand, 400 leaves of silver for painting of the same chapel, at 8d. per hundred; Ayers, *The Fabric Accounts of St Stephen's Chapel*, no. 40, m. 18 (w/b 23 April 1352). It is also possible that part-gold (a composite metal leaf, in which gold and silver are beaten together) or tin foil are present here. Unfortunately it was not possible to sample this area of the painting, but future non-invasive XRF investigation may help to elucidate the elemental components of the metal leaf.
51. Haslam, "To Mr. John Thomas Smith, Engraver of the Antiquities of London", 226. An engraving by Smith of the section of painted glass

(described separately from stained glass), showing a male head in profile set against a green background, is illustrated between pages 156 and 157. This information confirms that faux enamels of the type found elsewhere at Westminster around this time were also present in the chapel, see Howard and Sauerberg, "The Polychromy at Westminster Abbey", 234–237. Also, accounts to John Lightgrave for 300 leaves of silver for the painting a certain window to counterfeit glass, at 8s. per hundred, in Smith, *Antiquities of Westminster*, 220.

52. "The cups and spoons on the table are silver", Topham, *Some Account of the Collegiate Chapel of St Stephen, Westminster*, pl. XIX.

53. This type of glass, known as "forest" or potash glass, due to the use of wood ash as the source of alkali in its manufacture, was typical of north-western European production from around the tenth century. See the analysis by Ian Freestone, published by Sandra Davison, "Glass Elements on the Westminster Retable", in Paul Binski and Ann Massing (eds), *The Westminster Retable: History, Technique, Conservation* (Cambridge: Hamilton Kerr Institute, and London: Harvey Miller, 2009), 260–269.

54. Sticklac consists of the hard brownish substance secreted by and completely enclosing the lac insects. In most recipes for lac lake pigments, the entire raw material was ground and extracted with alkali. Alum, generally potash alum, potassium aluminium sulphate Al.K (SO~4~)~2~.12H~2~O was then added to precipitate the lake pigment. SEM/EDX analysis of the substrate of the lake in this sample detected: Al, S (Pb), O, P, Ca, K (trace Cl, Na), suggesting an alum substrate. For the technology of lake pigments, see Jo Kirby, Marika Spring, and Catherine Higgitt, "The Technology of Red Lake Pigment Manufacture: Study of the Dyestuff Substrate", *National Gallery Technical Bulletin* 26 (2005): 71–88.

55. GC-MS of the binding medium of this sample provided a palmatite/stearate (P/S) ratio of 2.0. This is a little hard to interpret and could imply the use of linseed oil or walnut oil, a mixture of the two, or indeed the use of different oil in the different red lake-containing layers. It also seems likely that the oil

was heat-bodied to promote drying. See Higgitt, "Organic Analyses"; David Peggie and Catherine Higgitt, "Analysis of Lake Pigment, St Stephen's Chapel, Palace of Westminster", unpublished reports Scientific Department, National Gallery, London, 2016.

56. For the fading of lake pigments, see David Saunders and Jo Kirby, "Light-Induced Colour Changes in Red and Yellow Lake Pigments", *National Gallery Technical Bulletin* 15 (1994): 79–97.

57. English accounts refer to red lake pigments as *cinople*, *cynopre*, and *synople* (lake). For example, in Westminster accounts of the late thirteenth century, referring to St Stephen's Chapel and the great chamber, we find *sinople* (1289), *synople* at 2½d. (1292), and *synoplio* at 9d. (also 1292?), J. Gage Rokewode, "A Memoir on the Painted Chamber in the Palace of Westminster", *Vetusta Monumenta* 6 (1885): 11. At Exeter, in 1321–1322, an altar account specifies ¼ lb of *cinople* at 3s. 6d., see Audrey M. Erskine, *The Accounts of the Fabric of Exeter Cathedral, Part I: 1279–1326* (Torquay: Devon and Cornwall Record Society, new series, 24, 1981).

58. Louis F. Salzman, *Building in England down to 1540, a Documentary History* (Oxford: Clarendon Press, 1952), 168–169.

59. Ayers, *The Fabric Accounts of St Stephen's Chapel*, no. 40, mm. 4 (w/b 8 August 1351), 9 (w/b 14 November 1351), 10 (w/b 21 November 1351).

60. Research comparing fifteenth- and sixteenth-century pharmacy price lists in Germany has established that madder lake was considerably cheaper than lake pigments prepared from scale insects. For example, entries for 1505 suggest that madder was 40 times cheaper than *grana*, see Andreas Burmester and Christoph Krekel, "The Relationship between Albrecht Durer's Palette and Fifteenth/Sixteenth-Century Pharmacy Price List", in Ashok Roy and Perry Smith (eds), *Painting Techniques: History, Materials and Studio Practice*, pre-prints of the International Institute for Conservation of Historic and Artistic Works (IIC) International Congress, Dublin, 1998 (London: IIC,1998), 101–105, esp. 102, Table 2.

61. At Westminster Abbey, lac lake has been identified on the Retable (circa 1260–1270); on the tomb of Aveline de Forz, wife of Edmund Crouchback (dated to circa 1295); on the tomb of Edmund Crouchback (circa 1300); in wall paintings in the south transept (circa 1260–1270), and in St Faith's Chapel (circa 1300); and on the painted sedilia (circa 1307), see Howard and Sauerberg, "The Polychromy at Westminster Abbey", 222–223.

62. Lac lake has been found to be the most commonly used colouring matter for lake pigments employed in English and Norwegian panel painting, wall-painting, and sculptural polychromy from the mid-thirteenth to the early fourteenth centuries, see Raymond White and Jo Kirby, "Some Observations on the Binder and Dyestuff Composition of Glaze Paints in Early European Panel Painting", in J. Nadolny (ed.), *Medieval Painting in Northern Europe: Techniques, Analysis, Art History* (London: Archetype Publications, 2006), 215–222, esp. 218. Other red lake pigments have also been identified at this period. For example, brazilwood lake has also been detected on the magnificent choir-screen paintings of 1332–1349 at Cologne Cathedral, where it was applied over gold leaf and also over layers of opaque underpaint, see Elizabeth Jägers and Christa Schulze-Senger, "Zur Maltechnik der Chorschrankenmalereien im Kölner Dom", *Kölner Domblatt* 54 (1989): 187–198.

63. Analysis by high-performance liquid chromatography (HPLC) by Jo Kirby, National Gallery Scientific Department, unpublished analytical report, August 2009. Marie-Louise Sauerberg, Ray Marchant, and Lucy Wrapson, "The Tester over the Tomb of Edward, the Black Prince: The Splendour of Late-Medieval Polychromy in England", in Sally Badham and Sophie Oosterwijk (eds), *Monumental Industry: The Production of Tomb Monuments in England and Wales in the London Fourteenth Century* (Donington: Shaun Tyas, 2010), 161–186.

64. In one of the samples from Westminster Chapter House, a minute quantity of brazilwood lake was also identified but this is probably a residue from

manufacturing the kermes lake in a dye bath of cloth clippings; see White and Kirby, "Some Observations on Binder and Dyestuff Composition", 218.

65. Ayers, *The Fabric Accounts of St Stephen's Chapel*, no. 40: Lowyn de Bruges, for six and an half of white varnish, for the painting of the chapel, price per lb 9d.; Master Hugh of St Albans, 52 lbs of white varnish for painting, at 8d. per lb; John Lighgrave, 136 lbs of white varnish for painting the chapel, at 4½d. per lb; John Lighgrave, 18 lbs of red varnish, at 4d. a lb. The specific use or uses of the two types of varnish are unclear, and whether the terms "red" and "white" may refer to the particular resin or ingredient in the varnish is uncertain. However, this distinction is made quite widely, for example, white varnish is mentioned a number of times in the accounts for work undertaken in the 1380s for Philip the Bold in Dijon. See Sauerberg *et al*., "The Final Touches", 241–258.
66. Haslam, "To Mr. John Thomas Smith, Engraver of the Antiquities of London", 224.
67. Haslam, "To Mr. John Thomas Smith, Engraver of the Antiquities of London", 224.
68. See James Hillson, "War, Politics and Architecture: Iterative Design at St Stephen's Chapel, 1292-1348", in John Cooper, Caroline Shenton and Tim Ayers (eds), *St Stephen's Chapel and the Palace of Westminster*, forthcoming. The paintings were not uncovered from beneath panelling and interior walls until 1800, during James Wyatt's remodelling of the east end.
69. Haslam, "To Mr. John Thomas Smith, Engraver of the Antiquities of London", 224 and 226.
70. See Topham, *Some Account of the Collegiate Chapel of St Stephen, Westminster*, pl. XVI.
71. Spirit varnishes, in which the resin constituents are dissolved in a volatile solvent, were unknown before the very end of the fifteenth century or the early sixteenth century.

72. Certainly, in a later fourteenth-century example where amber resin was employed, the varnish has a rather strong orange/yellow colour, see Sauerberg *et al*., "The Final Touches", 269–270.
73. Recipes for making varnish, pigments, or other craft-related preparations are commonly found within quite heterogeneous compilations, frequently including medical or alchemical recipes and other material. An example of the second type of recipe (where the oil and resin are heated separately) exists in a popular compilation known as the *Secretum Philosophum*, probably compiled in England in the late thirteenth or early fourteenth century. The fifteenth-century *Bolognese Manuscript* frequently mentions *vernice liquida*, and gives three recipes for making it from oil and sandarac resin. For a detailed discussion of these recipes and trade in the constituent materials, see discussion by Jo Kirby in Sauerberg *et al*., "The Final Touches", 241–258.
74. See Higgitt, "Organic Analyses".
75. See Higgitt, "Organic Analyses".
76. See Higgitt, "Organic Analyses".
77. Intermediate varnishes used in connection with glazes and fine detailing have been identified in a number of other cases, such as The Westminster Retable and Tomb of Edmund Crouchback, see Sauerberg *et al*., "The Final Touches", 271.
78. Analysis by R. Morrison, using pyrolysis GC-MS, see Sauerberg *et al*., "The Final Touches", 250–255.

Supplementary Materials

Summary of analytical work undertaken on the St Stephen's Chapel wall painting fragments.

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