Colour matters: Reading the materiality of the Great Bookcase

Foreword

One might think that a material investigation of the colour composition of an artwork has no place in a book that discusses colour primarily from literary, social, historical, and anthropological perspectives. However, I will argue that it is precisely in the context of the artistic and historical significance of a work like Burges' Great Bookcase that an examination of this sort can add vital depth to our understanding of the piece.

The Humanities and the Sciences have long stood apart in academia, each taking certain subjects and methodologies as belonging by right to their particular domain. However, the intrinsic relationship between meaning, traditionally addressed by the Humanities, and matter, traditionally explored by Science, becomes evident when one considers the study of heritage objects. An artist's purpose cannot be brought out into the world as a living thing in the absence of the matter that he or she uses to give it form and shape. As obvious as this statement might seem, we often forget that artists deliberately choose the materials they use to create their artworks. These choices can be directly linked to the meaning they wish to give to their work in specific social, cultural, and economic contexts. This is particularly true for painters' pigments, which have often been overlooked by art historians as if they had little to do with the overall iconography of a piece. And yet, if a painting contains two different blue sections, one painted with cobalt blue and the other with the much more expensive genuine ultramarine, it is likely that the artist considered the latter section to be more important than the former. It is, thus, only by combining a scientific approach to chromatic matter with the more social, cultural, and historical angles explored by the Humanities that we can achieve a comprehensive perspective on our heritage.[1]

In the past few decades, increasing efforts have been made to investigate the materials of heritage objects and to showcase this research to a broad public.[2] In the wake of the 'material turn' that is now transforming the Humanities, scholars working on the arts of the past are becoming more and more interested in creating a dialogue with the conservators and scientists who analyse the materiality of artworks. This interest is reflected in the investigation that has been carried out on the materials of the Great Bookcase, which would not have been possible without the funding that Charlotte Ribeyrol's Chromotope project (of which this book is a key outcome) received from the

[1] I would like to express my deep gratitude to Joyce H. Townsend, Kelly Domoney, and Fiona Mann for fostering an interdisciplinary dialogue that stimulated much of our reflection on the pigments used on the Bookcase.

[2] A recent example of a structured research project of this type was provided by the heritage scientists and conservators working on the project *Operation Nightwatch* at the Rijksmuseum in Amsterdam as they carried out their investigation live in the galleries for the public to see. The project received considerable media attention and demonstrated to a broad and diverse audience the importance of looking at the materiality of our heritage.

European Research Council with the goal of promoting an interdisciplinary dialogue around nineteenth-century colour. This annexe thus rightfully belongs in the present volume, where it has the potential to shed additional light on how deeply colour mattered to the Victorians.

Analysing chromatic materiality

It is possible to achieve various differing levels of specificity when characterizing a pigment.[3] For instance, if the element chromium is detected in a green area of paint, we can be confident that the colour used was produced in the nineteenth century or later.[4] The detection of chromium in a green background allegedly painted by Titian would, for instance, cast doubt on the authenticity of the painting, and would, at minimum, demand an explanation in terms of the history of the restoration of the work. Nevertheless, the presence of chromium is not by itself sufficient to identify the pigment used. Two different chromium-based green pigments were sold by colour suppliers in the nineteenth century:[5] chromium oxide green (Cr_2O_3) and hydrated chromium oxide green, also known as viridian ($Cr_2O_3 \cdot 2H_2O$). In addition, another green colour that contained chromium had become popular by the middle of the nineteenth century, supplied as a mixture of Prussian blue (iron-based) and chrome yellow ($PbCrO_4$).[6] It is clearly not enough to know that a green background contains chromium if one wishes to establish which of these pigments was used in a painting. Rather, the question requires further investigation, demanding that we delve into the pigment's chemical structure to achieve a second level of specificity. To then establish whether pigment from the same paint tube was used in different areas of a painting is another matter altogether. This latter operation requires a much deeper exploration of the chemical composition of the colours, since forensic precision is needed to prove the correspondence of a number of common trace elements.

On a macroscopic level, the analysis of painted surfaces is further complicated by the fact that painting never involves the simple application of a layer of homogeneous pigment upon a support but rather a composite stratigraphy made up of several overlapping layers. The ground layer is often white or lightly coloured and serves as an interface between the support (canvas, wood, etc.) and the coloured stratigraphy above. The more elaborate the system of light and shade depicted—or the more multi-layered the build-up caused by repeated repainting—the more complex the stratigraphy.

[3] For a more detailed discussion of the topic, see Feller, ed., *Artists' Pigments: Vol. 1*, 12–13.
[4] The usefulness of chromium's coloured compounds for pigments was noted just before the beginning of the nineteenth century.
[5] Popular colourmen included Roberson and Winsor & Newton. It is documented that Burges ordered his pigments from Roberson from 1865 onwards.
[6] Harley, *Artists' Pigments c.1600-1835*, 78–79; Gettens and Stout, *Painting Materials*, 105, 107, 173; FitzHugh, ed., *Artists' Pigments Vol.3,* 273–93; Field, *Chromatography*, 233-34; Carlyle, *The Artist's Assistant*, 492–93.

Because paintings are composite objects, the characterization of their pigments is often approached using a multi-analytical methodology: the results obtained using different complementary analytical techniques are cross-linked to serve this purpose.[7] Thanks to progress in Heritage Science, a wide range of *non-invasive* analytical methods can now be used to characterize pigments.[8] These methods have several advantages when applied to museum objects. First and foremost, they do not require the extraction of samples, thus preserving the integrity of the artworks as favoured by curators and conservators. Furthermore, many of these new tools are commercially available as portable instruments. This means that the analysis can take place directly in the museum gallery or storage area, with no need to transport the object to a different facility, with the consequent reduction in risk this entails. For these reasons, portable, non-invasive instruments have become great allies for the material investigation of heritage objects. However, in some cases, they provide only partial insight into their material composition.

The results that portable, non-invasive equipment can achieve when used on a painting depend to a very significant extent on the object's material complexity and condition. In the best case scenario, for a number of pigments a combination of several non-invasive techniques can give access to the second level of specificity described above. But if the identification of mineral pigments using non-invasive methods can be relatively straightforward, organic dyes (i.e., compounds obtained from vegetal or animal matter such as indigo or madder) remain very challenging to characterize and often require the extraction of samples that are typically destroyed in the process. Artworks, like the Great Bookcase, that were produced during and after the industrial revolution tend to present greater material complexity than earlier equivalents for a range of reasons. First of all, a much wider variety of pigments was available to artists by this point. Secondly, the paints of nineteenth-century artists were frequently adulterated with cheaper pigments, extenders, and substituents which resulted in complex material mixtures.[9] This material complexity sometimes limits the insight that can be achieved with any particular analytical protocol involving non-invasive methods. For instance, detecting cobalt on a blueish area of an original 16th-century European painting is enough to determine that the artist used a pigment known as smalt (a ground potassium glass containing cobalt), which for

[7] Hundreds of studies based on multi-analytical methodologies are available in the literature. A recent, very comprehensive, example can be found in Vandivere, ed., 'The Girl in the Spotlight: a technical re-examination of Vermeer's Girl with a Pearl Earring' (2019–2020).

[8] Examples of studies on pigments carried out with non-invasive techniques include: Kogou et al., 'A Holistic Multimodal Approach to the Non-Invasive Analysis of Watercolour Paintings' (2015); Brunetti et al., 'Non-Invasive Investigations of Paintings by Portable Instrumentation: The MOLAB Experience' (2016); Delaney et al., 'Visible and Infrared Imaging Spectroscopy of Paintings and Improved Reflectography' (2016); Janssens et al., 'Non-Invasive and Non-Destructive Examination of Artistic Pigments, Paints, and Paintings by Means of X-Ray Methods' (2016).

[9] Carlyle, 'Authenticity and Adulteration: What Materials Were 19th Century Artists Really Using?' (1993); Townsend et al., 'Later Nineteenth Century Pigments: Evidence for Additions and Substitutions' (1995); Katz, 'William Holman Hunt and the Pre-Raphaelite Technique' (1995).

a long time was the only cobalt-containing pigment available. By contrast, the industrial revolution introduced several cobalt-based colours: cobalt blue (cobalt aluminate) at the beginning of the century, cobalt green (a solid solution of cobalt oxide and zinc oxide) towards the middle of the century, and cobalt violet (cobalt phosphate or cobalt arsenate) and cobalt yellow (potassium cobaltinitrite) in the second half of the century.[10] A more thorough knowledge of the chemical composition of a sample is thus needed to identify pigments on a cobalt-rich area of a painting from the late nineteenth century. The more specific the information required, the more it will evade a non-invasive analytical protocol, especially considering the range of adulterants the coloured mixture is likely to contain.

If non-invasive investigation turns out to be insufficient to answer the questions that curators, art historians, and conservation scientists have, and if there are no significant conservation concerns for the object, the way forward is usually to extract micro-samples. For this reason, the examination of painting materials—and, more generally, any material investigation of our heritage—is often the result of a delicate balance between maintaining the integrity of the object and achieving a more accurate degree if insight through a further level of specificity. The instruments and resources that are available for the investigation significantly impact this quest for an optimal balance.

Carrying out the analyses: Objectives and logistics

The scientific examination of the Great Bookcase aimed to obtain information about its materiality and to interweave this data with the historical and technological context of the 1850s and 1860s in which it was created. With the advent of the industrial revolution at the end of the eighteenth century, the manufacture of colours gradually shifted from the artist's studio to large-scale factories. By the middle of the nineteenth century, the industrial production of artists' materials in Britain had already significantly transformed the nature of the products available, and oil paint tubes were available for a growing number of colours.[11] When work on the Bookcase started in 1859, the market for colour production was facing another radical revolution: the introduction of synthetic dyes obtained from coal tar, a development that was sparked in 1856 by the discovery of mauveine.[12] One of the primary purposes of the present investigation was to unveil the materials and painting processes used on the Bookcase and to observe the ways in which the industrial revolution may have impacted these.

[10] Gettens and Stout, *Painting Materials* (1966); Harley, *Artists' Pigments c.1600-1835* (1970); Carlyle, *The Artist's Assistant* (2001); Roy et al., eds., *Artists' Pigments: Vol. 1–4* (1986–2007).
[11] Townsend, 'Painting Techniques and Materials of Turner and Other British Artists 1775–1875' (1995); Carlyle, *The Artist's Assistant* (2001), Townsend, 'The Materials Used by British Oil Painters throughout the Nineteenth Century' (2001).
[12] Garfield, *Mauve* (2002).

The analyses began in November 2020 and required the collective efforts of scientists, conservators, and museum technicians from the Ashmolean Museum and the Departments of Engineering and Earth Sciences at the University of Oxford, as well as the contributions of Professor Andrew Beeby of Durham University. The collaborative nature of this project proved highly challenging in the context of the Covid-19 pandemic. Travel was restricted during this period, access to buildings limited, and regulations were introduced to cap the number of people who could work closely together in any physical space. The analytical process was heavily affected by these restrictions and as a result took considerably longer than initially anticipated. The area of the Bookcase investigated was thus limited to the eight painted panels whose iconography and historical significance are discussed in detail in the present volume. For these reasons, the results obtained do not provide the complete pigment characterization that was initially envisioned, but they are nonetheless remarkable considering the difficulties faced by the Ashmolean Chromotope team during this period.

The size of the Bookcase—3.17 m tall and 1.73 m wide—posed the most significant challenge during the analytical work. The Bookcase consists of three structural sections assembled one on top of the other. Initially, the Ashmolean conservation and technical teams considered dismantling it into these three parts to carry out the analyses. This would have made the upper part of the middle section and the whole of the top section more easily accessible from floor level. However, the prospect of dismantling the Bookcase caused some concern, in particular given the limited number of people who would have been able to work together on the task due to the restrictions then in place. Instead, a scaffolding tower was built to reach the higher levels, although this reduced the area that was available to set up the equipment and also occasionally introduced analytical complications (fig. 1). The Bookcase was studied in situ using several complementary non-invasive methods. Initially, the painted surface was observed using a low-resolution digital microscope to obtain a preliminary insight into the painting stratigraphy and possible retouches (fig. 2), and under UV light to observe possible fluorescence that would indicate the use of a lake, an organic pigment absorbed on a white inorganic substrate such as alum. The underdrawing made with charcoal was unveiled using an infrared camera (fig. 3 and 5.1), while the coloured underpainting was recovered with a scanning X-Ray Fluorescence spectrometer (scanning or macro-XRF, fig. 4). This instrument provided bidimensional maps that illustrated the spatial distribution of the different chemical elements detected in each panel. For instance, fig. 5.2 shows the comparison between the gold background presently visible between the figures of Edward I and Torrel in Moore's panel (left) and the elemental map made for this portion of the work (right). On the map, the areas containing iron-based pigments are shown in red while those containing gold are displayed in yellow. The spatial distribution of these two elements shows

that beneath the current gilded background lies a decoration depicting vegetal patterns which were made with iron-based pigments. The elemental maps not only revealed hidden underpainting but also provided information on the chemical composition of the colours. These results were cross-linked with the insights obtained using two other complementary methods: Fibre Optic Reflectance Spectroscopy (FORS) and Raman spectroscopy, which typically record spectra that represent the molecular fingerprint of a specific pigment. Finally, in addition to non-invasive analyses, eight micro-samples—collected back in 2016 when the Bookcase underwent conservation treatment—were investigated using optical and electron microscopes available at the Oxford University Departments of Earth Science and Engineering. For conservation reasons, no further samples were taken from the Bookcase.

The analytical work carried out in Gallery 66 created a unique opportunity for public engagement. Museum visitors enthusiastically welcomed the research activities and were offered the chance to engage with the research team and ask questions.[13]

Results

The most striking findings concerned the alternating blue and golden backgrounds that run across the painted panels: the analyses surprisingly showed that there is more to these backgrounds than meets the eye. The underdrawn and underpainted areas that were analysed using the infrared camera and the scanning XRF revealed that the original iconography was in some cases significantly different from the monochrome backgrounds we now see, as illustrated, for instance, in figs 5.1 and 5.2. The images recovered enabled Dr Charlotte Ribeyrol to cast new light on the iconographic program. Jevon Thistlewood, who treated the Bookcase in 2016, noted that the blue backgrounds were characterized by a 'clumsy application and poor finish which is not consistent with the general standard'.[14] It is plausible that, after the Bookcase was completed, Burges himself, rather than one of the artists, painted over the original backgrounds with alternating blue and gold monochrome layers, perhaps to achieve a sense of evenness that was originally lacking across the panels.

The characterization of the colours of each panel showed a very complex material composition, revealing that mixtures of different pigments were often used. To some extent, this was

[13] This provided an ideal opportunity to advertise the forthcoming exhibition *The Colour Revolution*, which will open at the Ashmolean in the autumn of 2023 and will feature the findings about the materials used on the Bookcase. Further engagement actions targeting a broad audience included the creation of a podcast episode for the series *Museum Secrets* (*Beneath the Blue*, accessible at: https://www.ashmolean.org/museum-secrets) and an article for the non-specialist public published in the fall edition of the *Ashmolean Magazine* (Ghigo, 'Where Science Meets Victorian Art,' *Ashmolean Magazine*, 2021).

[14] Thistlewood, 'An Examination of William Burges's Great Bookcase' (2017).

to be expected since nineteenth-century paint colours were frequently adulterated.[15] Furthermore, the artists increased this material complexity by deliberately mixing colours on their palette or overlapping different coloured layers. FORS provided little insight into this complex polychromy due to the intrinsic limitations of this method when applied to pigment mixtures, while Raman spectroscopy led to satisfactory results in very few cases because of the interference of the oil used as a binder. In contrast, the analysis of the samples provided a higher level of precision, as is usually the case. However, the eight samples available were too few to accurately represent all the painted areas on the Bookcase—primarily because only two of them came from the panels. For these reasons, scanning XRF proved to be the most insightful method for investigating the composition of the pigments. This method led to high-resolution maps of almost the entire area of the painted panels and showed the spatial distribution of a broad range of chemical elements—all those listed between aluminium and lead in Mendeleev's periodic table.

The combination of these different methods contributed to the identification of a substantial number of pigments. Table 1 lists in bold the colours introduced to the market during the late eighteenth and nineteenth centuries. While the techniques used sometimes hinted at the presence of organic dyes, only once was it possible to identify one such dye (indigo) since these compounds are notoriously difficult to detect with non-invasive methods. The same challenge applies to synthetic coal-tar dyes such as mauveine, although their use in oil painting seems to have started some years after the Bookcase was painted.[16] Furthermore, the analytical protocol that was deployed provided, in some cases, only partial identification of the inorganic pigments. For this reason, Table 1 lists generic terms such as 'chrome-based pigment' rather than specific pigments such as 'chromium oxide' or 'hydrated chromium oxide'. Finally, lead-containing pigments (with the exception of lead white) proved particularly difficult to detect. The presence of lead in the binder[17] resulted in this element being detected all over the painted surface, thus making it at times difficult to establish its association with a specific area or colour.

Discussion and conclusions

[15] Carlyle, 'Authenticity and Adulteration' (1993); Townsend et al., 'Later Nineteenth Century Pigments: Evidence for Additions and Substitutions' (1995); Katz, 'William Holman Hunt and the Pre-Raphaelite Technique' (1995).

[16] Fiona Mann, who studied the price lists of several colourmen (Winsor & Newton: 1849, 1858, 1863, 1879; Reeves: 1852, 1862, 1879; Rowney: 1852; 1867; Roberson: c. 1840, c. 1870 and J Barnard: 1860) kindly shared with me unpublished information in a personal communication (December 2021). She noted that mauveine (sold as a pigment under the name Mauve) first appears in Rowney's price list only in 1867 and in Reeves' price list in 1879. Furthermore, Carlyle notes in her book, *The Artist's Assistant,* that Mauve, as an *oil paint*, appeared in Reeves' catalogue from 1876 (p. 538); in Rowney's catalogue from 1885 (p. 542) and in Winsor & Newton's catalogues from 1886 (p. 535).

[17] The use of lead as a paint dryer is well documented in 19th-century technical literature. For an overview of this ingredient in different sources, see: Carlyle, 'Paint Driers Discussed in 19th-Century British Oil Painting Manuals' (1999).

Burges' Bookcase served as the centrepiece of the Medieval Court at the 1862 London International Exhibition, providing an example of Gothic Revival painted furniture.[18] The influence of medieval models is well reflected in the iconographic program and chromatic choices, with gold and blue predominant. However, the artists' emulation of medieval styles barely ~~did not~~ extends to the materials used. In reconstructing this fictitious past, Burges and the thirteen artists involved in this project ironically deployed a wide range of pigments that were unavailable prior to the industrial revolution. As a matter of fact, the use of historically accurate methods would have been problematic at that time. During the eighteenth century, the Royal Academy of Art in London increasingly emphasized theory and ideas over teaching the practice of painting. With the exception of channels such as private lessons or personal friendships, workshop secrets regarding specific materials and techniques ceased to be passed on from master to pupil.[19] Furthermore, the preparation of painting materials was industrialized early in Britain and this led to artists slowly losing the material know-how that had formed part of their profession's training in earlier times.[20] In other words, Victorian artists lacked the kind of knowledge that the Old Masters had of their materials and techniques. The Pre-Raphaelite painter William Holman Hunt would later lament this handicap during a Royal Society of Arts lecture given in 1880.[21] It does not mean, however, that artists had no theoretical cognition regarding medieval pigments, notably since Sir Charles Eastlake and Mary Merrifield published their volumes on the historical use of materials in oil paintings towards the middle of the century.[22] The evidence retrieved from the Bookcase suggests that Burges tried, at least in part, to use pigments inspired by the middle ages when he painted the blue backgrounds. This blue colour contains Prussian blue, barium white and ultramarine, the latter being one of the most celebrated medieval pigments. Such complex material composition might well have resulted from industrial adulteration of a colour marketed with the label "ultramarine".

Even if the Bookcase was not a Pre-Raphaelite work per se, many connections to this movement can be detected,[23] including from a material perspective. For instance, emerald green, a bright green containing copper and arsenic that was a particular favourite of the Pre-Raphaelites,

[18] Winterbottom, 'Not Acceptable to Present Taste: William Burges's Great Bookcase' (2017).
[19] James Ayres, *Art, Artisans and Apprentices,* part 4, pp. 434–435; Carlyle, *The Artist's Assistant*, 3; Alison Smith, 'Revival and Reformation: The Aims and Ideals of the Pre-Raphaelite Brotherhood' (2004).
[20] Carlyle, 'Authenticity and Adulteration' (1993); Katz, 'William Holman Hunt and the "Pre-Raphaelite Technique"' (1995); Townsend et al., 'Later Nineteenth Century Pigments: Evidence for Additions and Substitutions' (1995); Jacobi, *William Holman Hunt - Painter, Painting, Paint*, 117–32.
[21] Hunt, 'The Present System of Obtaining Materials in Use by Artist Painters, as Compared with That of the Old Masters' (1880).
[22] Eastlake, *Materials for a history of oil painting* (1847); Merrifield, *Original treatises; dating from the 12th to 18th centuries on the arts of painting, in oil, miniature, mosaic, and on glass; of gilding, dyeing, and the preparation of colours and artificial gems; preceded by a general introduction; with translations, prefaces, and notes* (1849).
[23] Winterbottom, 'Not Acceptable to Present Taste: William Burges's Great Bookcase' (2017). See also the introduction to this book.

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appears extensively on the panels. Similarly, the purple colour used for the garment worn by King Edward in Moore's panel recalls the mixture of cobalt blue and the pinkish madder lake that has been documented in many Pre-Raphaelite[24] and coeval paintings.[25] However, the painting technique used on the Bookcase by Burges' artists is very different from that of the Pre-Raphaelite Brotherhood, who often adopted a method of glazing that involved the distribution of a semi-transparent layer of pure pigment over a white background to maximize the refraction of light and achieve higher brilliancy and saturation. Alternatively, the colours could be juxtaposed rather than mixed to preserve their intensity. Indeed, the Pre-Raphaelites were rather parsimonious when it came to the overlapping of different pigments, showing the influence of contemporary theories concerning colour perception which claimed that mixtures resulted in less vibrant and saturated colours.[26] By contrast, the complexity of the pigment mixtures found on the Bookcase is such that it was extremely challenging to characterize them using the non-invasive methods deployed during this investigation. For this reason, it has not been possible to establish whether the artist working on a specific panel personally selected the pigments they used. The apparent consistency of the colour harmonies used across all sides of the Bookcase seems to suggest otherwise, perhaps indicating that Burges had some influence on the colours used or that he supplied materials for all the artists. Mixtures of different pigments were often observed in areas where the colours now look dark and dull due to chromatic degradation. This suggests that the Bookcase initially displayed a more complex interweaving of coloured lights and shades, resulting in a richer chromatic vibrancy than we can now appreciate. We can imagine that a nineteenth-century visitor at the 1862 International Exhibition would have had quite a different chromatic experience than our own, standing in front of an artwork that offered a more intense spectacle of bright colours.

Earlier material and archival studies of nineteenth-century British painting materials have revealed the regular use of lakes for purple, red, orange, and yellow tones.[27] This suggests that something remains to be discovered regarding the organic dyes used on the Bookcase, which have not yet been thoroughly analysed. Although it was only possible to partially identify the colour palette, the results provide a great example of the wide variety of synthetic materials available to artists in the wake of the industrial revolution. For instance, cobalt blue was introduced in 1802 in France, emerald green was discovered in 1814 in Germany, and chrome yellow was first made in

[24] Townsend, Ridge, and Hackney, *Pre-Raphaelite Painting Techniques*, 62–63.
[25] Personal communication with Joyce H. Townsend, December 2021.
[26] Townsend, Ridge, and Hackney, *Pre-Raphaelite Painting Techniques*, 29–37 and 66–67.
[27] Townsend, 'The Materials of J.M.W. Turner: Pigments' (1993); Townsend, 'Painting Techniques and Materials of Turner and Other British Artists 1775–1875' (1995); Katz, 'William Holman Hunt and the Pre-Raphaelite Technique' (1995); Townsend, Ridge, and Hackney, *Pre-Raphaelite Painting Techniques* (2004); Mann, 'A Born Rebel: Edward Burne-Jones and Watercolour Painting 1857–80' (2014); Mann, 'Opaque with a Vengeance: Burne-Jones's Later Watercolours, 1880–98' (2019).

1809 and commercially introduced in England around 1816-20. Strontium chromate seems to have been introduced by the chemist George Field, who mentions it in his book *Chromatography*, first published in 1835,[28] although innovative artists who knew him had used these yellow pigments in earlier years.[29] In painting the Bookcase, Burges and his artist friends extensively resorted to newly introduced pigments, possibly including mercury chromate, which Field had described as a 'bad pigment', prone to change colour by action of light or pollutants.[30] It is difficult to establish the extent to which the artists were aware of the actual composition of the materials used, since they might have fallen prey to misleading commercial labels, which were very common at the time.[31] However, the number of synthetic industrial pigments highlighted in this investigation suggests that they must have been used intentionally. It is difficult to believe, for instance, that it was a mere accident that emerald green was used in all the panels, especially when one considers the popularity of this pigment throughout the nineteenth century.[32]

In the second half of the century, the toxicity and stability of new synthetic pigments and dyes caused increasing concern within and beyond the artistic community. The press frequently reported cases of accidental poisoning that resulted from exposure to fabrics or wallpapers dyed with formulations of emerald green and anilines that irritated the skin or could be absorbed by breathing vapours, thus contributing to the distrust towards such synthetic products that eventually developed.[33] In his *Elements of Drawing* (1856), John Ruskin warned his readers and pupils about the fugitive, unreliable nature of Antwerp and Prussian blues and advised them to use Field's *Chromatography* as a manual when approaching colouring.[34] From the 1870s, his disciple Hunt initiated a personal crusade against industrial adulteration. He called out the deception engineered by the new colour industry and invited his fellow artists to systematically test and experiment with their materials to ensure their lightfastness.[35] He even claimed that 'the painter's work is not worth the doing if it will

[28] Sources: Field, *Chromatography* (1835); Gettens and Stout, *Painting Materials* (1966); Harley, *Artists' Pigments c.1600–1835* (1970); Roy et al., eds., *Artists' Pigments Vol. 1–4* (1986–2007).
[29] Townsend, 'The Materials of J.M.W. Turner' (1993).
[30] Field, *Chromatography*, 218.
[31] Hunt, 'The Present System of Obtaining Materials in Use by Artist Painters, as Compared with That of the Old Masters' (1880); Carlyle, 'Authenticity and Adulteration' (1995); Townsend et al., 'Later Nineteenth Century Pigments: Evidence for Additions and Substitutions' (1995).
[32] Aside from being one of the favourite colours of the Pre-Raphaelites, emerald green has frequently been found on paintings by other nineteenth-century artists. Ruskin suggests using this pigment in his *Elements of Drawing* and Field describes it as a stable and vivid colour. Sources: Townsend, Ridge, and Hackney, *Pre-Raphaelite Painting Techniques* (2004); Townsend, 'The Materials of J.M.W. Turner' (1993); Townsend, 'Painting Techniques and Materials of Turner and Other British Artists 1775–1875' (1995); Ruskin, *The Complete Works of John Ruskin*, vol. 15, 141–142 (footnote); Field, *Chromatography*, 236.
[33] Matthews David, *Fashion Victims*, chapters 3 and 4.
[34] Ruskin, *The Complete Works of John Ruskin*, vol. 15, 141–142 (footnote).
[35] Katz, 'William Holman Hunt and the Pre-Raphaelite Technique'; Katz, 'Holman Hunt on Himself: Textual Evidence in Aid of Technical Analysis' (1998); Jacobi, *William Holman Hunt - Painter, Painting, Paint*, 117–32.

not last for many generations of eyes and minds'.[36] Other artists showed no interest in the composition of their paints. John Everett Millais, for instance, explained in an interview with *The Times* that 'artists should paint for the ephemeral taste of the day'.[37] Nevertheless, concerns regarding the durability of artworks drove the Committee of Council on Education to ask Russell and Abney to undertake a systematic study of the action of light on watercolour pigments in 1886.[38]

The young artists involved in painting the Bookcase may have had similar concerns in mind as they carried out their work, even if they were not fully aware of what materials they were using. On the other hand, they could not have remained indifferent to the craze for chromatic experimentation that was spurred on by the industrial progress that took place during this period of global transformation.[39] Burges and the artists started their work in 1859, at the height of the 'Mauve mania' that spread across Europe following William Perkin's discovery of mauveine. This discovery caused great excitement and was showcased at the London International Exhibition in 1862, where both the Great Bookcase and coal-tar dyes were presented for the first time to the public.[40] Thanks to Perkin, who led the way, the pavilions of the Exhibition were tinted with a rainbow of coloured fabrics proudly displayed by 28 different dye-making firms from the United Kingdom, France, Germany, Austria, and Switzerland. August Hoffmann—a renowned chemist and Perkin's professor at the moment of his discovery—praised England's recent progress in his *Report to the Juries* of the Exhibition and claimed that the country would soon become the greatest colour producer in the world.[41] While the iconography of the Bookcase pays tribute to the polychromy of the past, its materiality tells a new story, that of the Victorians' enthusiasm for chromatic innovation. Burges' medievalizing Bookcase can thus be read as a paradoxical tribute to the nineteenth-century colour revolution: a toxic and potentially unstable rainbow of mesmerizing coloured matter.

[36] Hunt, 'The Present System of Obtaining Materials in Use by Artist Painters, as Compared with That of the Old Masters' (1880).
[37] *The Times* in 1880.
[38] Russell and Abney, *Action of Light on Watercolours. Report to the Science and Art Department of the Committee of Council on Education* (1888).
[39] On this artistic experimentation, see also: Mann, 'A Born Rebel' (2014); Mann, 'Opaque with a Vengeance' (2019); Townsend, 'Painting Techniques and Materials of Turner and Other British Artists 1775–1875' (1995).
[40] 'The Great Exhibition; about Dyes and Beauty and Coal-Tar Mauve and Magenta How Made Extraordinary Specimen of Aniline Art and New Colours.' (1862).
[41] Garfield, *Mauve*, 77–78.

Table 1. Pigments identified on the different panels. The pigments in bold were introduced to the market during the late eighteenth or nineteenth centuries.

Panel	Colour	Pigments	Areas
Panel 1 *Edward I and William Torrel*	Red	Iron oxides	King Edward's heraldic motif on the chest
		Red lake (?)[42]	Torrel's trousers
	Yellow	Iron oxides	King Edward's crown and heraldic motif on the chest
	Green	Copper-based pigment(s)	King Edward's sleeves
	Purple/violet	Mixture of **cobalt blue** and red lake (?)	King Edward's mantle
	White	Lead white	King Edward's garment and Eleanor's effigy, skin tones
Panel 2 *Fra Angelico painting the Virgin*	Red	**Mercury chromate (?)**	Fruits on the tree
		Vermilion	Red leaves of the plant on the left, painting
		Red lake	Red leaves of the plant on the left (?), bottom of the Virgin's garment, Virgin's lily
		Iron oxides	Painting
	Blue	**Cobalt blue**	Background of the painting
	Yellow	**Lemon yellow (strontium chromate)**	Leaves of the Virgin's branch
		Iron oxides	Hair of the Virgin
	Green	**Emerald green**	Leaves of the Virgin's branch, tree on the left, painting
		Chromium-based pigment(s)[43]	Tree on the left
	White	Lead white	Fra Angelico's garment, skin tones
		Zinc white	Fra Angelico's garment, Fra Angelico's face
Panel 3 *The origin of painting*	Red	Vermilion	Lips and cheeks of the two characters, woman's dress
		Iron oxides	Jar on the left, man's hair
		Organic reds and oranges	Man's toga (?), flamingo's wings
		Lead chromate	Fish held by the flamingo
	Yellow	Iron oxides	Man's hair
	Green	**Emerald green**	Man's toga[44]
		Chromium-based pigment(s)	Salamander's head
		Copper-based pigment(s)	Salamander's body, Man's toga
	White	Lead white	Skin tones

[42] A question mark next to a pigment indicates that the analytical methods deployed suggested its use, rather than identifying it definitively.
[43] Either a chromium-based green pigment or, possibly, chrome yellow (lead chromate), which Pre-Raphaelites used in combination with emerald green for bright yellowish greens (personal communication with Joyce H. Townsend, December 2021).
[44] Cobalt-based pigments were observed in association with emerald green on the man's garment. The blueish hue of the lower section of his clothes suggests that cobalt blue might have been mixed with emerald green, as was the case on Panel 8.

Panel 4 *Pygmalion and Galatea*	Red	Vermilion	Statue's face and neck, clip on Pygmalion's mantle
		Iron oxides	Hair, stool, goat, tree
	Blue	**Prussian blue**	Venus' garment, Pygmalion's mantle
	Yellow	Iron oxides	Hair, stool, goat, tree
	Green	**Emerald green**	Venus' garment, leaves, Pygmalion's mantle (blue area)
	White	Lead white	Statue, dove, skin tones
Panel 5 *The apparition of Beatrice to Dante*	Red	Vermilion	Beatrice's garment, book, Dante's sleeve, collar, and headdress
		Red lead	Dante's headdress
		Iron oxides	Decoration on the vase
	Blue	Mixture of **prussian blue**, barium white and ultramarine	Background[45]
		Cobalt blue	Decoration on the vase
		Cobalt-based pigment	Dante's pillow
	Yellow	Iron oxides	Hair of ladies in the oval medallion, Dante's garment (filling of stripes), desk
	Green	**Emerald green**	Decoration on the vase, Beatrice's mantle and plant's leaves,[47] Dante's garment (borders of stripes)
		Chromium-based pigment(s)[46]	Plant's leaves
	White	Lead white	Beatrice's veil, skin tones
Panel 6 *St. John and the new Jerusalem*	Red	Vermilion	Angel's garment and vial, 2nd, 7th, 8th, and 12th coloured stones (from the top)
		Iron oxides	Eagle, angel's hair, plate with Hebrew script, 3rd and 6th stones
	Blue	Organic pigment	11th stone
	Green	**Emerald green**	Angel's wings, 3rd, 5th, and 9th stones
		Copper-based pigment(s)	Angel's vial, skin tones
	Purple/violet	Organic pigment	1st stone
	White	Lead white	Skin tones, 4th, 8th, and 10th stones
Panel 7 *Rhodopis commissioning a pyramid*	Red	Vermilion	Skin tones, necklace and fringe of the priest-like figure, fan, mattress, Rhodopis' headdress and necklace
		Iron oxides	Mattress, shendyt of the priest-like figure
	Blue	Indigo	Rhodopis' pillow

[45] This mixture was detected on a microsample using visible and electron microscopy. It is very likely the same mixture used for all blue backgrounds (Panels 2, 4, 5, and 7).
[46] See note 44 on the use of chrome yellow in combination with emerald green.
[47] Cobalt-based pigments were observed in association with emerald green in these areas. Cobalt blue might have been mixed with emerald green, as was the case on Panel 8.

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		Cobalt-based pigment(s)	Rhodopis' pillow
		Cobalt blue	Rhodopis' headdress
	Yellow	Iron oxides	Architect's headdress, coins
		Chrome yellow	Shendyt's fringe and belt
	Green	**Emerald green**	Fan, shendyt's fringe, Rhodopis' headdress, necklace and dress
	Purple/violet	Organic pigment	Pattern on Rhodopis' dress
	White	Lead white	Rhodopis' dress
Panel 8	Red	Vermilion	Decoration on boat, sail
Sappho serenading		Iron oxides	Boat, Phaon's hair, sail
Phaon		Red lake	Sail
	Blue	**Cobalt blue**	Sea
		Cobalt-based pigment(s) (blue/violet)	Decoration on sail
	Green	**Emerald green**	Sea,[48] Sappho's garment
		Copper-based pigment	Sail
		Chromium-based pigment(s)	Sea
	White	Lead white	Skin tones, Phaon's garment

[48] The analysis of a microsample showed that cobalt blue was mixed with emerald green in this area.



Figure 1. Scaffolding in front of the Great Bookcase in Gallery 66, Ashmolean Museum.



Figure 2. Examination of the Bookcase with USB microscope.



Figure 3. Infrared camera setup.



Figure 4. Scanning X-Ray Fluorescence equipment in front of the Bookcase.

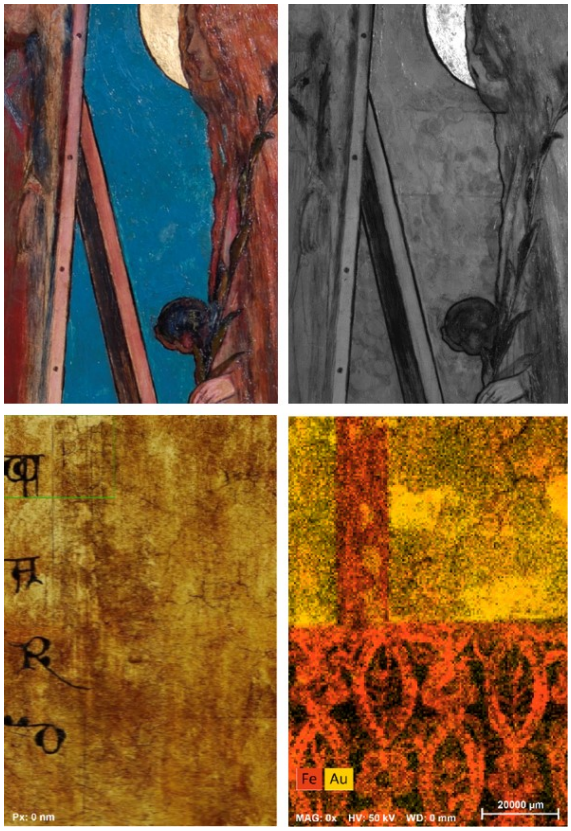


Figure 5. Top: infrared image (close-up) showing the underdrawing on Panel 2. A stone wall with ivy is visible between the canvas and the Virgin. Bottom: XRF elemental map showing the spatial distribution of iron and gold (Fe and Au) beneath the golden background of Panel 1. Iron-based pigments were originally used to create a vegetal pattern decoration.

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