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Technical Note

Raman Spectroscopic Analysis of a Mid-19th Century Reredos by Sir George Gilbert Scott

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Abstract: A painted stone reredos in the Priory Church of St Cuthbert, Worksop, Nottinghamshire, UK, was analysed before recent conservation to determine the pigment scheme employed. The screen was created by the eminent British architect Sir George Gilbert Scott in the middle decade of the 19th Century. The results help inform the wider range of palettes employed by British architects and craftspeople working in the 19th and early 20th centuries which have previously been little studied. The pigments generally were high-quality vermilion (red), chrome yellow (yellow), and ultramarine (blue), and several alternatives were also evident such as red lead and haematite for red, bone black, and carbon black for black. Lightening and darkening agents were incorporated as lead white, barytes, and carbon, and pigment mixtures were used to achieve the colours dark blue-red, and green.

Keywords: Raman spectroscopy; paint; pigments; artwork; nineteenth century; England; Arts and Crafts; Scott; ecclesiastical; analysis

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1. Introduction

A considerable amount of ecclesiastical artwork was undertaken in the United Kingdom by a group of prolific architects of the late Victorian and Edwardian eras, c.1850 to 1914. This form of decorative artwork was frequently applied to church interiors, and especially to fittings commonly in the form of ornate, painted screens, organ cases, reredoses (painted screens), and other exposed stone and timberwork, in the belief that church buildings should shape spiritual experience [1–3]. The study of the paint composition has received little published scientific analysis, unlike wall paintings of all periods that have been the subject of extensive research (see, for example [4–8]).

Although similar objects have been examined and their artistic merits discussed in considerable detail, they generally lack scientific analysis of the pigments employed [9]. The authors have previously examined several objects that fall into this category, and the work presented here represents a further case study in understanding pigment use in this context and period [10,11]. In this study, a reredos created by the well-established Victorian architect Sir George Gilbert Scott (known as Sir Gilbert Scott) has been examined and the composition of the paint used for surface decoration has been determined using Raman spectroscopy.

2. Background, Method, and Materials

The Priory Church of St Cuthbert, Worksop, Nottinghamshire, U.K. is a former Augustinian priory, founded c.1120 and re-endowed c.1140; the earliest parts of the fabric date from this period. At the Dissolution of the priory in 1538 the nave was left standing and became the parish church [12,13]. The east end and most of the claustral buildings were dismantled. Apart from the body of the church, only the gatehouse, a fragment of cloister wall, and the ruined Lady Chapel remained. During the nineteenth century, the interior church walls were plastered and restoration work was carried out, some by Sir Gilbert Scott [14]. In the 1850s this included the creation of a new stone reredos to sit behind the high altar [15]. In 1929 the church was partially remodelled so that the Lady Chapel could be reached from the inside, and the transepts were restored in 1935 [16,17]. It was probably at this time that the reredos was moved into the newly reconstructed north transept where it was set against the north wall as an ornamental 'blind arcade'. From photographic evidence in the 1870s the upper portion of the reredos, studied here, has changed little from the original other than the loss of a larger, central bay, and the finials that capped each bay.

Scott had been instructed in July 1853 by the 5th Duke of Newcastle [under Lyme] to conduct a survey of churches and chapels in the county of Nottingham and elsewhere in which the duke maintained an 'interest' (for example as Lord of the Manor or Patron of the church) [18]. The purpose was to elicit a detailed report on their condition, an account of the extent of repairs needed, and an estimate of the cost of such work. However, for four of these buildings, Scott visited but made no specific report; Worksop Priory was one of the four and the extent of Scott's repairs here is unknown, although he did provide a detailed, later report in 1874 [19]. His sole work during the 1850s may have been confined to the provision of a new reredos at the behest of the 5th Duke of Newcastle. In 1875 the reredos was fully described thus:

> *'The last ornament added to the edifice is the beautiful reredos presented to it by his Grace the late Duke of Newcastle, with his usual generosity. This gives great richness to the east end of the church, and looking from its opposite end, terminates the vista very pleasingly; but when the eye has become accustomed to its varied hues, and can critically trace out all its details, again it becomes a question whether its features accord well with the old fabric it has been placed in; and also whether its really best materials, such as the marble shafts forming a part of the composition, should have been so entirely subdued by the tints emanating simply from the painter's brush aided by gilding. As a work of art, however, it will command admiration; and the difficulty of treating this end of the church must be borne in mind, consisting as it does, simply of a veil of masonry, filling up the original central tower-arch. There can be no doubt as to the genius of the designer, Mr G. G. Scott, nor of the munificence of the noble donor of this reredos.'* [20]

The former reredos comprises six recesses, each with trefoiled and recessed heads topped by a crocketed canopy; the finials are truncated as the termini merge with the string course above, which defines the base of the north wall windows. The recesses of the arcade are each divided by a marble colonnette that terminates in capitals with a gilded, stylized foliate ornament with some naturalistic foliate decoration at the east and west end capitals. The backs of each recess in the arcade have gilded, intertwining, and stylized foliate carving in stone (Figures 1 and 2).

In 2017 extensive repair works were undertaken in the nave of Worksop Priory which included the removal of Victorian plaster from the walls. An inspection of the reredos revealed that conservation work was required, not only due to the recent dust and dirt pick-up as a result of the works, but flaking paint was evident along with the loss of much of the original gilding. A programme of conservation work was proposed, and funding was obtained. At the commencement of this work in 2019 it was decided to analyse the paint using Raman spectroscopy to determine which original colours Sir Gilbert Scott had requested for the surface design.

Figure 1. The reredos from the southeast before conservation.

Figure 2. Detail of the painting on the east side of Bay 2.

Unfortunately, no documentary material has survived to indicate whom Scott employed as his decorator. It was often customary to use local craftspeople and so the unknown painter may have been as local as Worksop itself, though may equally have derived from towns as far afield as Doncaster to the north or Nottingham to the south. However, in the design of a near contemporary reredos for the high altar in Ely Cathedral, Scott employed a Mr Hudson of South Kensington Museum, and it is not beyond possibility that he did so here at Worksop Priory; alternatively, he may have employed the well-known firm Clayton and Bell of London who he also used for decoration [21]. Pigments for the work may have been acquired from Charles Robertson who was a well-respected London artists' colourman from 1820 onwards throughout the 19th Century and who Scott's craftspeople were likely to use [22]. The painted decoration consists of red painted petal ornament around the trefoil recesses with gilded dogtooth projections at the edges. Each canopy contains, within its spandrel, a painted, recessed circle within which is a quatrefoil; the arcades alternate in colour between red and yellow-gold for the decoration. The canopies are adorned with red, blue, and gold outlines and the outer edges have alternating red and blue outlines within which are silver/white pellets. The canopy crockets are gilded. Subsequent conservation work entailed careful mechanical cleaning, starting at the top and working down, using a vacuum and brushes followed by repeated moist swab cleaning using 3–5% non-ionic surfactant in de-ionized water before neutralization with plain de-ionized water swabs. Following treatment, the surface was allowed to dry out and 18 months later a select amount of new gilding was applied, carefully restricted to offer the optimum amount of gilding without making the arcade appear too new (even though it was more heavily gilded originally). The gilding also needed to work with the balance of the remaining colour left on the arcade.

Before the commencement of conservation work, seven samples of paint pigment were extracted by scalpel from the scheme using only the leading edges of flaking paint that could not be re-secured to the surface (WPNA 1–WPNA 7). This resulted in samples that were too small to allow cross-section mounting but preserved the original paint in situ which is in line with conservation ethics. The locations of the samples are given in Figure 3. The extraction of samples was restricted to seven to allow representative data for all the principal colours present without oversampling.

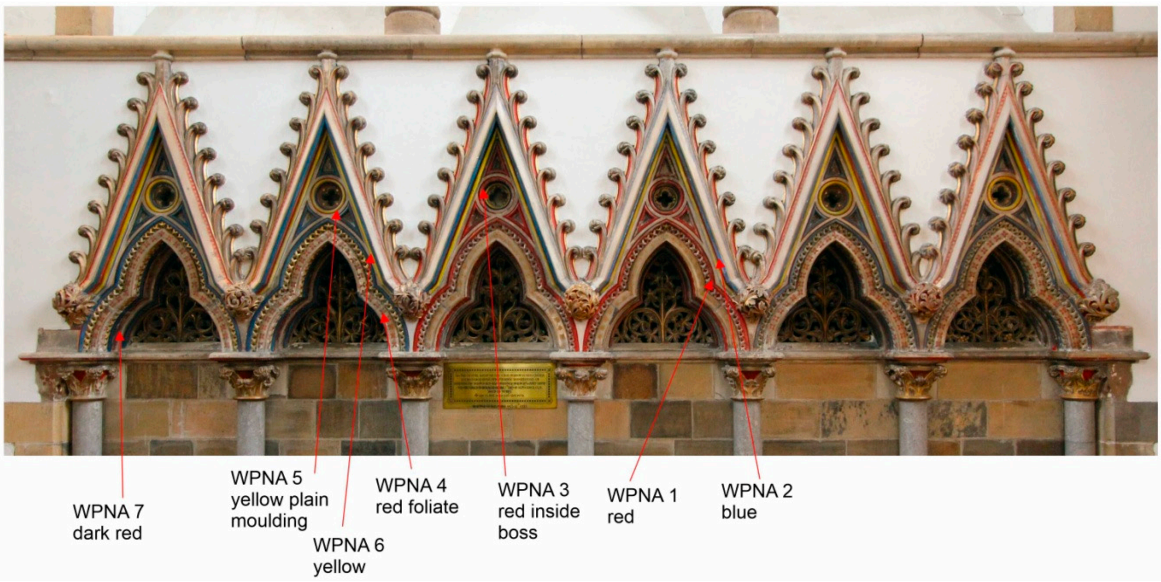

Figure 3. Location of samples taken.

Sample WPNA6, yellow, was intended to be a preparatory paint layer for gilding to be applied. In some cases, gilding was applied, but for large sections of the scheme, it was evident that this had never taken place and the colour was left as the yellow base coat.

The samples were examined using a confocal Raman spectrometer Senterra R200-L, equipped with two lasers: a red diode laser (785 nm) and a green NdYAG laser (532 nm).

An Olympus microscope is coupled to the spectrometer for the visualization of the sample. This microscope has different objective lenses for 5×, 20×, and 50× magnification and a motorized xyz-stage with servo-assisted z-control for line scans and mappings. On top of the microscope, a CCD camera is attached for sample observation. The spectrometer is equipped with a thermo-electrically cooled CCD (1024 × 256 pixels), two gratings, a filter changer consisting of Rayleigh filters, an ND filter wheel for changing the laser power, a slit-type aperture and a pinhole-type aperture. The laser power at the specimen is normally 10% of that at the source and is typically several mW; the objective lens is usually 50× magnification and the spectral range is 80–2600 cm^{-1} for 30 to 60 spectral accumulations, each of 60 s duration, to reduce noise. Each specimen was studied microscopically in replicate to allow for any inhomogeneity. In all some seven specimens were studied (labelled here WPNA 1–7).

3. Results

The seven specimens selected for sampling comprised red, dark red, blue, green, yellow, brown, and grey/black. These gave characteristic Raman signatures for vermilion, ultramarine, chrome yellow, haematite, carbon, and red lead, and details of the composition of each specimen are given in Table 1. Table 1 gives a digest of the Raman microanalyses; however, we often find particulates of a different colour to those that describe the main colour observed, as indicated in the figures (for example Figure 7). This reflects the accumulation of several different coloured pigments comprising the analyses of each specimen in Table 1 which can arise either from a deliberate admixture of colours by the artist or an inadvertent contamination.

Several interesting features of these pigments are revealed and can be summarized as follows:

- Three pigments are adopted for the red colour, namely vermilion (mercury sulfide), haematite (iron III) oxide) and more rarely, red lead; the latter pigment is found in only one specimen (WPNA 3). WPNA 1 curiously comprises two different red pigments, namely vermilion alone and haematite in admixture with carbon—the darker red colour incorporated carbon black and was used with vermilion only in WPNA 3. Generally, the carbon spectral signatures were indicative of a vegetative source of carbon black but WPNA2 and WPNA3 showed the phosphate stretching band at 960 cm^{-1} indicative of a bone black or ivory black pigment: this was preferred for instances where artists desired a glossier tonal black quality [23]. The green pigment is a mixture of chrome yellow and blue ultramarine, and the single mineral alternatives of malachite, green earth, viridian, and verdigris were not used. A visually dark red pigment hue in WPNA4 is also a mixture of red vermilion and blue ultramarine.
- Lighter and darker shades of blue were achieved using ultramarine and lead white or carbon, respectively.
- Calcite and dolomite signals are assigned to the substrate.
- WPNA6 is predominantly chrome yellow but contains some ultramarine, possibly a contaminant.
- A brown colour is seen in WPNA 7 and is a mixture of carbon black, haematite, quartz, lead white, and barytes. The presence of barytes is attributed to a filler and lightening agent.

Figures 4–9 are representative of the analysis.

Table 1. Pigment composition from Raman Spectral Data.

Sample Number	Colour	Pigments Identified	Characteristic Raman Bands/cm^{-1}
WPNA 1	Red	vermilion	257, 353
	Red	haematite	223, 292, 410
	Black	carbon black	1320, 1598
WPNA 2	Blue	ultramarine	548
	White	lead white	1050
	Black	bone black	960, 1320, 1598
WPNA 3	Red	vermilion	257, 353
	Black	bone black	960, 1320, 1598
	Red	red lead	224, 316, 390, 550
	Black	carbon black	1320, 1598
WPNA 4	Blue	ultramarine	548
	White	lead white	1050
	Black	carbon black	1320, 1598
	Red	vermilion	257, 353
WPNA 5	Yellow	chrome yellow	320, 852
	White	lead white	1050
WPNA 6	Yellow	chrome yellow	320, 852
	Blue	ultramarine	548
	Yellow	chrome yellow/ ultramarine	320, 548, 852
	Red	vermilion	257, 353
WPNA 7	Red	haematite	223, 292, 410
	Black	carbon black	1320, 1598
	White	barytes	981

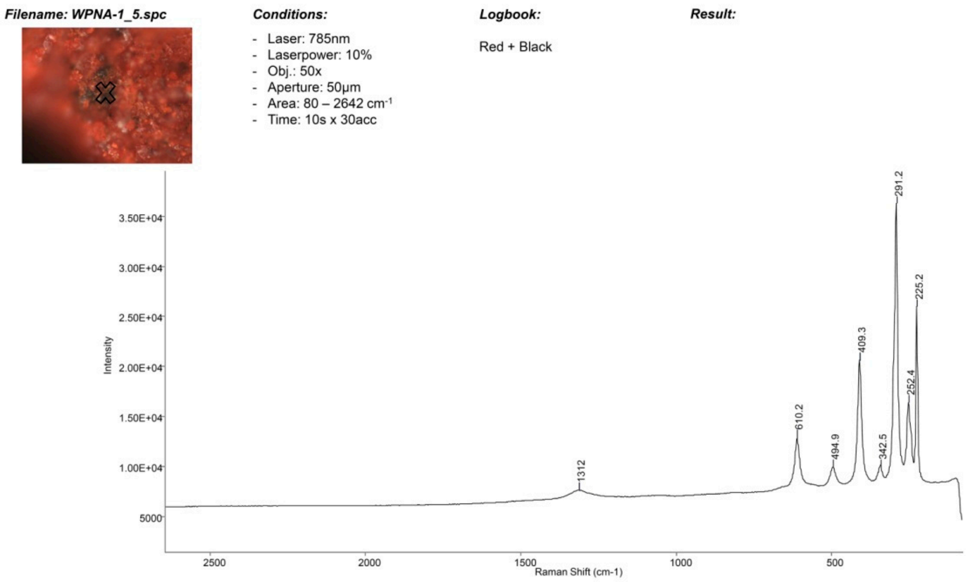

Figure 4. Sample WPNA-1_5 showing very pure haematite.

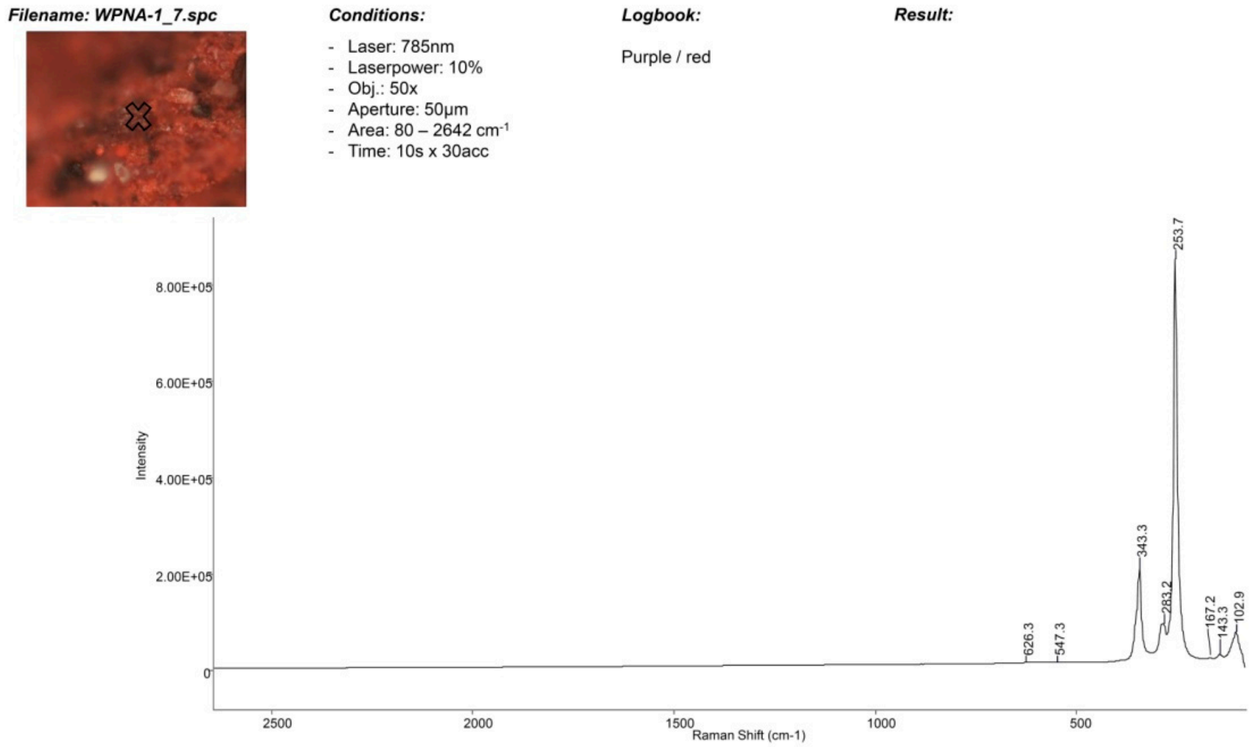

Figure 5. Sample WPNA-1_7 showing very pure vermilion.

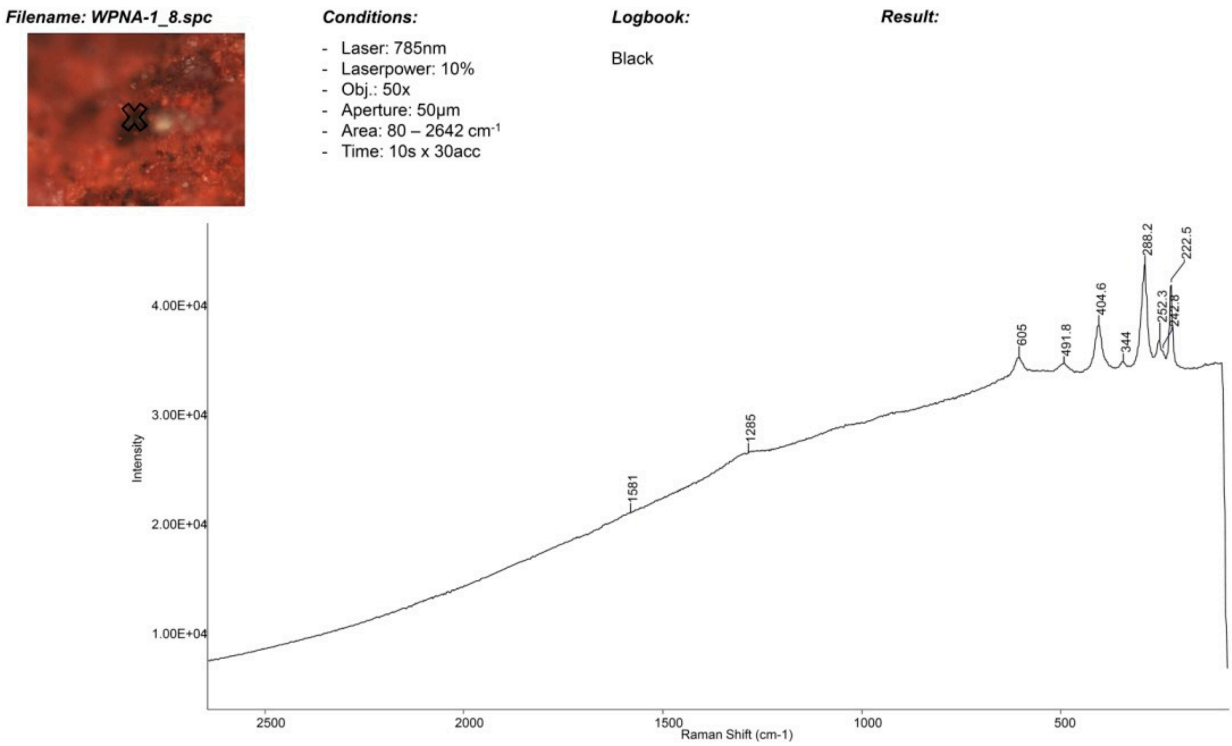

Figure 6. Sample WPNA-1_8 showing a mixture of haematite and vermilion.

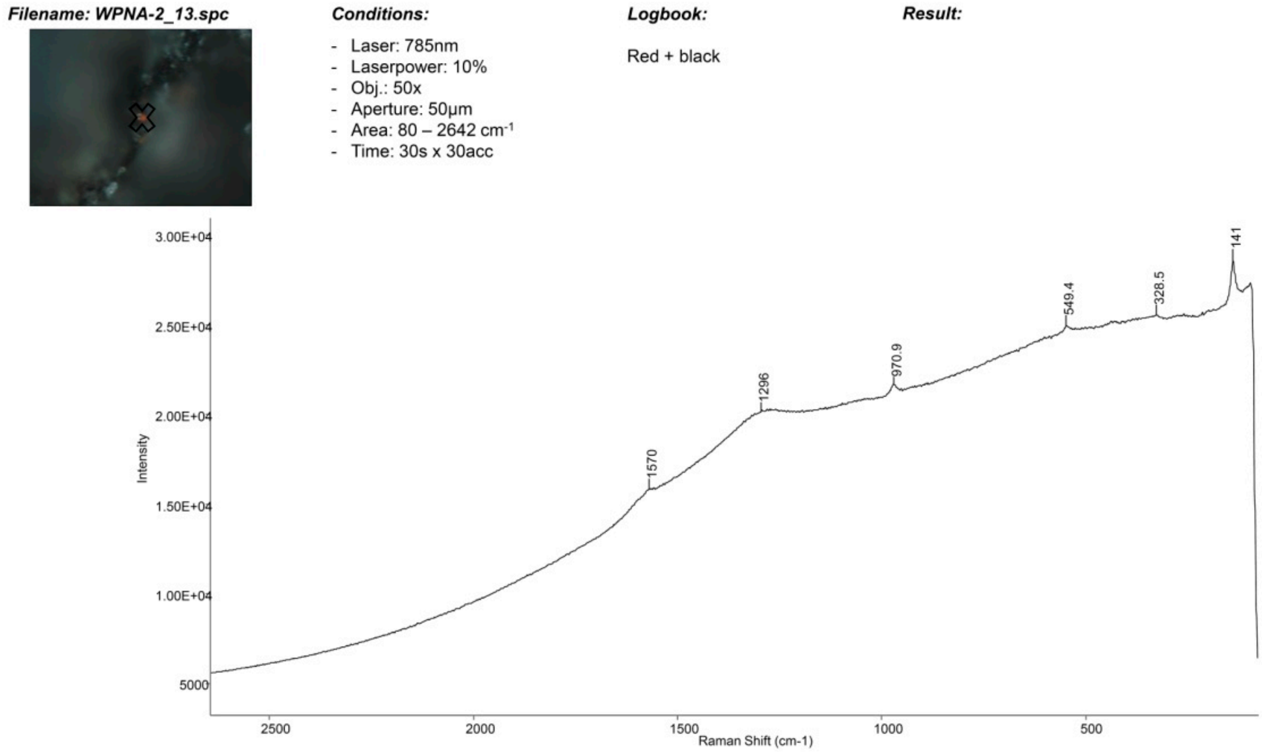

Figure 7. Sample WPNA-2_13 extracted from an area of blue, illustrating the contamination of the visual blue pigment ultramarine with red lead and bone black.

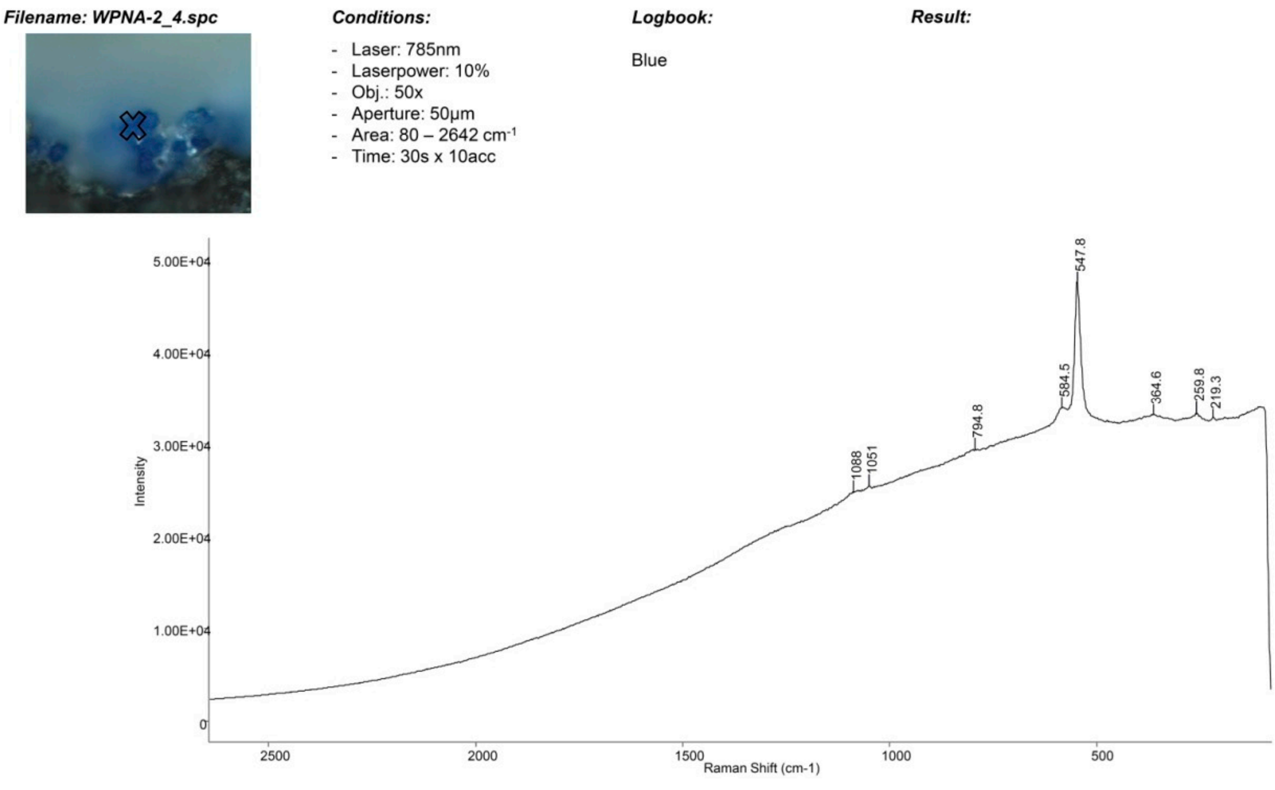

Figure 8. Sample WPNA-2_4 showing ultramarine with traces of lead white and calcite.

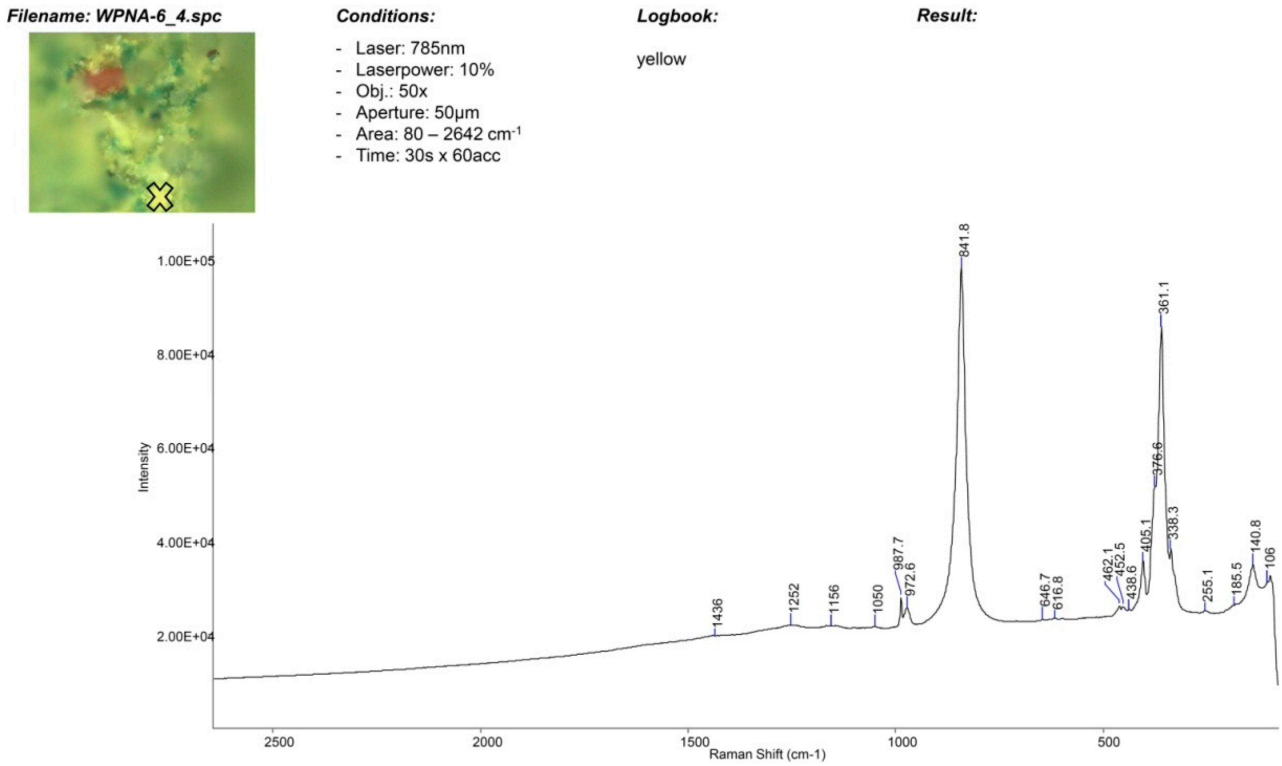

Figure 9. Sample WPNA-6_4 showing chrome yellow.

4. Discussion and Conclusions

The results of the analysis show a rather unremarkable group of pigments that is typical for artistic decoration of the period and for the subsequent several decades [24]. However, it does reveal Sir Gilbert Scott's particular preference for his design in this instance. Writing around the same period as the reredos was created Scott wrote:

> *In the designing or directing of all these [decorative features] the architect should have a primary influence, and even in works of the highest kind the painter should work hand in hand with the architect*. [25]

From this, it is clear that Scott worked very closely with his painters and colourists, and from further remarks made it is clear he had an idea in his mind of exactly the final effects he wished to achieve and did not leave the choice of colours solely to his craftspeople. High Victorian fashion for constructional polychromy commenced during the 1840s [26–28]. This was accelerated by the publication of John Ruskin's considerations of colour in his seminal book *The Stones of Venice*, published between 1851 and 1853 [29]. Scott was influenced by these developments in ideas; however, his use of constructional polychromy (i.e., painting of architectural stonework) ceased in the early 1840s and instead, he focussed his interests in colour on applied and crafted objects [30]. This is ably borne out by his use of polychrome decoration in the Worksop Priory reredos, and to achieve it he used commonly available artists' pigments which, in addition to achieving the visual effect desired, were also durable and could withstand the semi-harsh environment found in large church interiors (large variations in temperature and humidity, exposure to smoke and particulate material, and to occasional handling).

It is useful to compare Scott's colour palette with some of his contemporaries: for example, Sir Ninian Comper [10] effectively used mixtures of pigments that he termed Comper red and Comper green, which he associated with his characteristic strawberry colours adopted in his paintings. Here, we notice that Gilbert Scott used three different red pigments to achieve his desired tonal quality, namely vermilion, red lead, and haematite—the latter is found in a highly crystalline state and has not been diluted as red ochre by the admixture of fine river sand [31], Haematite is occasionally found to have been mixed with carbon black to produce a dark red hue: in contrast, the black pigment itself is seen to mainly comprise bone black, which is formed by the low-temperature calcination of bone and is characterised by the presence of calcium phosphate signatures. It is noteworthy that the cadmium reds and yellows, which are a complex group comprising cadmium sulfide and sulfoselenide, often found in admixture with mercury sulfide [32] do not appear here although they do become very popular with artists and decorators towards the end of the 19th Century. The presence of a signal for ultramarine in a chrome yellow pigment specimen is adjudged to be contamination as otherwise, a greenish colour would have resulted in the overall pigment hue. A notable absence is the signal for Prussian blue, which was certainly a favourite still among artists in the 19th Century and the only blue pigment detected here in Scott's palette was ultramarine; this was synthesised in 1828 and rapidly overtook the supplies of natural semi-precious lazurite, which were always expensive until the cheaper synthetic version became readily available for use as a pigment [33]. The ground colour was lead white, commonly used and admired for its hiding power, but barytes was also detected as an alternative white filler in several specimens. The stratigraphy of the pigment application could not be assessed as the specimens were taken during ongoing conservation work and the established protocols forbade the removal of specimens upon which any depth profiling could be undertaken.

In summary, an otherwise fairly minor, although richly decorated, ecclesiastical fitting of the mid-19th Century has provided a useful insight into the polychrome decoration chosen by a major British architect of the period, Sir Gilbert Scott. The detailed analysis of the pigments employed, and the visual scheme achieved, will prove useful for comparison with other decorative objects of a similar type and period to be analysed in the future.

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