CONSERVATION OF WALL PAINTING DEPARTMENT
COURTAULD INSTITUTE OF ART

Peterborough Cathedral, nave ceiling: Scientific examination of the original decoration of bays 36-39

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September 1998

1 Summary

As part of a major project aiming to ensure the long-term preservation of the ceiling, a preliminary investigation of the original and added materials of the painted surfaces was undertaken in April 1997, in conjunction with a phase of emergency treatment by the Perry Lithgow Partnership. The preliminary investigation focused on the figures of *St. Paul*, *St. Peter* and the *Psaltery Player,* and on surrounding areas accessible from the scaffold.

Results indicate that original paint layers exist in a number of areas, usually beneath layers of rather crude overpaint. It is also evident that some original layers remain exposed, though frequently juxtaposed with cursorily applied overpaint. The original palette includes natural azurite, lead white, verdigris and vermilion, and the binding medium of layers containing lead white and verdigris has been identified as a drying oil.

The investigation revealed that, unusually, green—comprising azurite combined with lead white and yellow iron oxide—was employed as an underpainting for some of the flesh tones. It is significant that azurite was also used to indicate shadows in the flesh tones in the ceiling fragments from the Painted Chamber of Westminster Palace, dating from *c.* 1263-6. These panels, which survive in remarkably good condition, provide perhaps the closest surviving English parallel in terms of original function and date to the original scheme at Peterborough. Natural azurite was also employed for the background of St. Paul's mandorla at Peterborough, and the extensive use of this rather expensive material on a painting which would never have been viewed at close quarters suggests that the original scheme was of high quality.

The results of the preliminary investigation have clear implications for the conservation of the painted ceiling. The presence of calcium sulphate at the wood/paint interface, and also at varying concentrations throughout the paint layers, makes the painting profoundly sensitive to moisture. In addition, some 19th-century paint layers were also found to contain high concentrations of both calcium sulphate and clay-rich minerals, which accounts for their extreme moisture sensitivity. This was dramatically demonstrated by the severe blooming which followed even brief contact with water during the recent emergency conservation testing and treatment.

There is also evidence of pigment alterations in both the original and later phases of painting. These include the transformation of natural azurite to copper oxalate, which indicates deterioration of the original painting, and which may be partly due to an episode of high humidity at some time in the past.

In preparation for the phase of conservation and documentation undertaken in the spring of 1998, further examination and analysis was undertaken to provide additional information about the nature and extent of surviving original paint layers, to further characterise the various phases of later repainting, and to assess the implications these results may have for the conservation treatment. Additional specific samples were also taken in relation to queries arising from the conservation treatment.

Results of this phase of examination and analysis provide further evidence for the presence of original paint layers (dating to *c.* 1220) on the ceiling. These are evident for example in the flesh tones of the *Green Man* and *Janus* (Samples 8 & 12) where, as for St. Peter, azurite combined with yellow ochre and lead white was employed for the green underpainting of the flesh.

Original pigments identified in this phase of analysis include natural azurite, lead white, red earth, yellow earth and vermilion, all of which were also identified in the preliminary investigations. In addition, instrumental analysis of the binding medium confirmed the presence of a drying oil combined with lead white in a sample taken from the original flesh tone of the Janus figure (Sample 12/2358).

In addition, examination of the surface indicated that the raised motifs which are visible in a few discrete areas are likely to be the result of shallow carving into the original oak boards, and may have been employed to assist in setting out the design. This is evident for example in the foliate motifs on boards 37 IV b and 36 IV dd (Plate 14, lower right, and Plate 5, right side) where a distinct raised edge is clearly visible.

Again, it appears that no fresh ground layer was applied generally to the surface in preparation for the 18th- and 19th-century interventions, but that layers of repainting were applied directly over existing paint. For example, in Sample 1/2347, Prussian blue combined with lead white has been applied directly over verdigris and yellow iron oxide, while in Sample 8/2354 repainting of the flesh tones has been executed directly on to the original layers.

However, in a sample taken from the vertical boarding below the ceiling a secondary lead white ground is evident (Sample 10/235). The distinct layer of dirt over the lower layer of red paint and the subsequently applied lead white ground and repainting, also in red, confirm that extensive repainting of this zone was undertaken.

Instrumental analysis of dark stains and drips which are clearly visible in zones such as 37 III suggested the presence of shellac.

2 Introduction

The nave ceiling at Peterborough is the only 13th-century painted wooden ceiling surviving *in situ* in England.[1] Two fragments of the wooden ceiling of *c.* 1263-6 from the Painted Chamber at Westminster Palace have recently been discovered and examined in detail, and the resulting information, together with analytical evidence from some of the few other early medieval English panel paintings, provides important comparative technical information for Peterborough.

Parallels have also been drawn between the Peterborough ceiling and painted examples on the Continent, such as those at Zillis, Switzerland (*c.* 1150); St. Michael, Hildesheim (*c.* 1200); and Dädesjö, Sweden (*c.* 1275). However, technical, structural and other comparisons with these ceilings will only be possible as a result of the present overall study of the Peterborough ceiling, of which this report forms a part.

3 Selected history of the nave ceiling

***c.* 1140**	building of the nave commenced after 1140 under Martin de Bec, and was continued by William de Waterville (1155-75), and completed, up to but not including the W. front, by Benedict (1177-93).[2]
***c.* 1210-30**	painting of the nave ceiling.[3]
early 14th c.	east end was re-fenestrated.
15th c.	all clerestory windows west of the apse, and those in the lower levels of the east and west transepts, were replaced.
1740s	repair, washing and repainting of the ceiling.
1834/5	roof repaired by Ruddle and ceiling again repainted (Charles Layton received £30.00 for the repainting).[4]
1880s	central tower rebuilt by Pearson. This intervention caused some disruption to the east end of the nave ceiling.

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1 Other early medieval wooden ceilings are known to have existed, such as that at Canterbury Cathedral which was destroyed in the fire of 1174.

2 It has been suggested that a stone vault for the nave was intended but later abandoned.

3 Opinion on the dating of the wooden ceiling varies considerably: *c.* 1177-93, Gunton 1686 (see Higham 1995); *c.* 1220 (Cave & Borenius 1937:304-309); 1236-7 (Nordström 1955); and *c.* 1210-30, Dr. Paul Binski, who cites a group of Psalters produced for Peterborough and St. Neots in *c.* 1220 as the closest parallels (lecture by P. Binski at the seminar on Peterborough nave ceiling, 14th April 1998). I am grateful to David Park for discussing the stylistic evidence for the dating with me.

4 Cave & Borenius 1937:304-9.

1890 limewash removed from the walls of the nave. This work is recorded in inscriptions on the frieze below (26 & 27 I).

1926 new roof over nave. The roof and also the ceiling were treated with '*Silvertown*,' an insecticide containing sulphur chloride and carbon bisulphide.[5] Structural repairs were necessitated by infestation of death watch beetle.[6] The upper surface of the boards was covered with hessian and glue at this time.

1994 Pollution tests by Dr. B. Knight of English Heritage indicate much soluble acid present in the wood. Tests for chlorides and sulphates also gave weakly positive results.

1995 Hirst Conservation undertakes cleaning and conservation testing and pigment analysis.

1996 G. Lewis and J. Limentani inspect the ceiling from a hoist. G. Lewis samples the ceiling painting at this time.

1997 Preliminary phase of examination and analysis undertaken by H. Howard in April 1997.

1997 Phase of emergency conservation treatment and documentation of present condition by the Perry Lithgow Partnership in the zones around *St. Peter, St. Paul* and the *Psaltery Player.*

1998 Further scientific examination of the ceiling undertaken by H. Howard in conjunction with a phase of conservation treatment and documentation of bays 36-39 by the Perry Lithgow Partnership.

4 *Methodology of the investigation*

The area examined in detail and sampled was limited to that accessible from a bridge scaffold spanning the nave from bays 36-39, and focused particularly on the *Green Man* (*ref.: 37/38 III & IV*) and *Janus* (*ref.: 36/37 II & III*). Following a detailed inspection of this part of the ceiling in normal and UV light, and at magnification with the aid of a video microscope, a small number of samples was taken to identify the original and added materials and to answer particular queries arising from the preliminary phase of sampling. This examination and sampling was undertaken in February 1998.

The paint samples were mounted as polished cross-sections (in polyester embedding resin), and as dispersions (in *Meltmount,* which has a refractive index of 1.662), and were examined with an optical microscope at 170-2500x magnification in incident, transmitted and UV light; photomicrographs were taken at between 500 and 2500x. Microchemical tests were undertaken to identify some metallic ions (Pb^{2+}) and functional groups (SO_4^{2-}), and

5 Spons Workshop Receipts 1885.

6 A report on the condition of the roof at this time is provided by the architect, see Moore 1925.

histochemical tests were carried out to indicate the presence of oils and proteins.[7] A scanning electron microscope (SEM), used with energy-dispersive X-ray (EDX) analysis which provides elemental analysis, was employed to confirm the identifications made with polarised light microscopy (PLM). Identification of organic materials and additional confirmation of inorganic components were undertaken using Fourier Transform Infra-red (FTIR) microspectroscopy.[8] X-ray diffraction (XRD) analysis was also employed to determine the identity of the salts which are evident in a few discrete areas across the ceiling.[9]

5 Previous analytical investigations

Hirst Conservation undertook some pigment analysis which indicated the presence of red iron oxide, vermilion, lead white, and verdigris. It was also suggested that no white ground layer was present in the earlier decoration, though a chalk and size ground was identified in Samples 3 & 15.[10]

Further paint samples were taken by G. Lewis in 1996, and were examined and photographed at English Heritage. Some of the samples were also subjected to analysis by SEM/EDX which confirmed the presence of: a copper green with some sign of alteration to a copper chloride; yellow iron oxide; red iron oxide; red lead; and some calcium sulphate at the wood/paint interface.[11]

A preliminary phase of sampling and analysis was undertaken by H. Howard in April of 1997. This investigation was undertaken in conjunction with a phase of emergency conservation treatment and documentation by the Perry Lithgow Partnership, focusing on the zones around St. Peter, St. Paul and the Psaltery Player.[12]

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7 The microchemical tests included: hydrochloric acid and potassium iodide, which produce a yellow stain for lead; lead nitrate and sodium rhodizonate, which produce a purple colour in the presence of sulphate ions; and hydrochloric acid, which results in the evolution of carbon dioxide, in order to identify carbonates. Preliminary staining for oil was undertaken using Sudan Black B which produces a blue colour when indicating a positive result. In UV light, proteins give a yellow fluorescence when stained with fluorescein isothiocyanate (FITC). Acid fuchsin was also used for the identification of protein.

8 All FTIR microspectroscopy was carried out by the author at Imperial College, London.

9 I am grateful to Malcolm Ward of the Ancient Monuments Laboratory at English Heritage for undertaking this analysis for me.

10 See Hirst Conservation 1995: Appendix B, and additional notes.

11 SEM/EDX analysis was undertaken by H. Howard and G. Satterthwaite (English Heritage) at the Ancient Monuments Laboratory.

12 For the results of the analytical investigation, see Howard 1997; and for the conservation and documentation, see Lithgow 1997.

6 Results: The original decorative scheme (Table 1)

6.1 Support

Preliminary results of dendrochronological analysis undertaken at Sheffield University suggested that the ceiling joists were felled in *c.* 1150-70, and that the ceiling was constructed in a single phase during the latter part of the 12th century. However, in bay 10, two timbers appear to be slightly later, though there was no evidence of a difference in tool marks or working of the wood. The wood employed for the ceiling joists was identified as long-lived, straight-grained oak from English woodlands, and though it is thought that the boards themselves are made from similar wood, the results of this part of the investigation are not yet available.[13]

6.2 Preparatory techniques

The results which are perhaps of greatest interest in this phase of investigation concern the raised motifs which are visible in raking light beneath the present paint surface. In some places the slightly raised areas appear to be the result of shallow carving into the original oak boards, and may have been employed to assist in setting out the design. This is evident for example in the foliate motifs on boards 37 IV b and 36 IV dd (Plate 14, lower right, and Plate 5, right side) where a distinct raised edge is clearly visible. In each case the shallow carving of the scroll motif is followed—though not absolutely—by the crude line of the repaint. Elsewhere, as in the chevron motif on board 38 IV t (Plate 12), the crude later repainting is completely offset from the earlier raised pattern. Similar shallow relief carving employed to produce lozenge and contiguous circle patterns has been identified on the contemporary reredos now at Adisham, Kent.[14]

Examination of the extended chevron border surrounding St. Peter in the preliminary phase of investigation in 1997 revealed traces of a trefoil pattern which extends beneath the chevron pattern in some places. Initially it was thought that the trefoil pattern was painted in impasto, but in the light of other observations described above, this may also have been carved in shallow relief.

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13 The dendrochronologial analysis was undertaken by Cathy Groves and colleagues at Sheffield University.

14 Howard 1993.

6.3 The original scheme of decoration: pigments and their application

The pigments identified in paint layers which appear to be original include: natural azurite ($2CuCO_3.Cu[OH]_2$); vermilion (HgS); charcoal black (C); lead white ($2PbCO_3 \cdot Pb[OH]_2$); red iron oxide (Fe_2O_3); and yellow iron oxide ($Fe_2O_3 \cdot H_2O$).

The original flesh tones were produced from varying combinations of vermilion and lead white (Sample 12/2358 from *Janus*, Plates 23-24), or with lead white and charcoal black (Sample 8/2354 from the *Green Man*, Plates 17-18). The comprehensive later repainting of the flesh, undertaken in lead white combined with red lead or carbon black—and with harsh outlines in black reinforcing linear details—effectively conceals any subtle effects of modelling which may have been intended by the medieval artist.

6.4 Original binding media

Although analysis of the original binding medium has been severely compromised by the later phases of repainting and invasive conservation treatment, FTIR analysis of the original flesh tone in Sample 12/2358—taken from the flesh tone just above Janus' left eye—confirmed the presence of lead white in a drying oil.

Linseed oil has been identified as the original binding medium of other early medieval English panels as for example the Westminster paterae of *c.* 1263-6 and the Westminster Retable of *c.*1270-90 .[15]

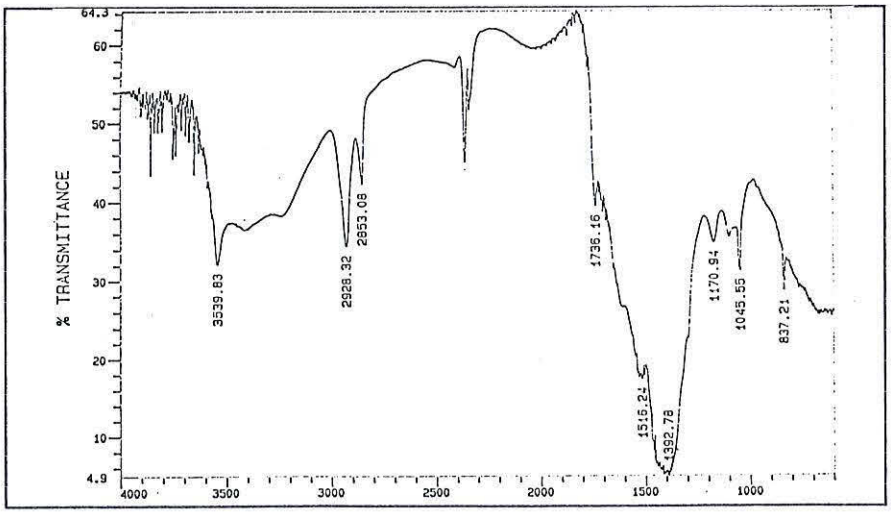

Figure 1: *The presence of lead white is indicated by the broad band around 1400* cm^{-1} *(CO_3) and peaks at 3539* cm^{-1}, *837* cm^{-1} *& 679* cm^{-1}, *oil is suggested by the carbonyl band at 1736* cm^{-1} *and CH_3 stretches at 2928* cm^{-1} *and 2853* cm^{-1}. *The effect of lead white on the drying of oil results in the characteristic features around 1537* cm^{-1} *and 1622* cm^{-1}.

15 Liversidge & Binski 1995:499; Lynn 1997; and Binski & Freestone 1995:60.

7 Results: Later phases of decoration

7.1 Preparatory techniques

It appears that no fresh ground layer was generally applied to the surface in preparation for the 18th- and 19th-century interventions, but that layers of repainting were applied directly over existing paint. For example, in Sample 1/2347 (Plates 1-2), Prussian blue combined with lead white has been applied directly over verdigris and yellow iron oxide.

However, in some cases a later lead white ground is evident, as for example in Sample 10/235 taken from the vertical boarding below the ceiling. Here a distinct layer of dirt and subsequently applied lead white ground and red paint layer confirm that extensive repainting of this zone was undertaken (Plates 20-21).

7.2 Pigments and their application

Pigments identified over the original paint layers are as follows: Prussian blue ($Fe_4[Fe(CN)_6]_3$); vermilion (HgS); red lead (Pb_3O_4); basic verdigris ($Cu(C_2H_3O_2)_2.2Cu(OH)_2$; carbon black (C); lead white ($2PbCO_3 \cdot Pb[OH]_2$); red iron oxide (Fe_2O_3); yellow iron oxide ($Fe_2O_3 \cdot H_2O$); and charcoal black (C). All of these pigments were also identified in the preliminary phase of examination and analysis.

8 Queries arising from the previous investigation

Initial examination of paint samples taken from the areas carved in shallow relief indicated the presence of a single paint layer of lead white with no distinct stratigraphy— i.e. no early paint layer with a dirt layer on top followed by layers of repaint. However, further examination of the paint cross-sections in bright field illumination indicated the presence of two distinct paint layers, both consisting principally of lead white (Plates 7 & 16).

The lack of a distinct dirt layer between the two layers of lead white may be explained by the vigorous cleaning of the paint surfaces before repainting—thus removing any dirt and making it difficult to see the interface between two layers of white pigment. It seems increasingly likely that while the faces of figures such as St. Paul and St. Peter were only lightly cleaned before repainting—and therefore that original paint layers are consistently present in these zones—the remainder of the surface must have been comprehensively scrubbed.

In a few areas a distinct line of white salts was evident adjacent to designs in black paint, as is clearly visible along the edge of the chevron pattern on board 37 I d (Plate 19). Preliminary analysis of these salts by optical microscopy suggested the presence of two species. Both displayed pleochroism and birefringence in transmitted light, but though the refractive indices of one were greater than 1.58, the refractive indices of the other appeared to be less than 1.58. Subsequently instrumental analysis was undertaken by SEM/EDX and by XRD and this confirmed with presence of ammonium lead sulphate $\{(NH_4)_2.PbSO_4)_2\}$ and sodium sulphate {thenardite, Na_2SO_4}. Although a high degree of sulphation was noted in the ground and paint layers in the preliminary phase of analysis, the mechanism for the production of these salts in such distinct zones requires further investigation. However, it is evident that the presence of these salts is associated only with the later paint layers.

Extensive areas and drips of a dark brown material were also noted in some areas of the ceiling, particularly on board 37 III r (Plate 22). Analysis of this dark-brown material by FTIR microspectroscopy confirmed the presence of shellac.

9 Discussion

The results of this phase of examination and analysis support the evidence found in the initial phase of investigation, namely that original paint layers (dating to *c.*1220) are present on the ceiling, and moreover, confirm that oil was employed as a binding medium in these layers. In addition, it now seems likely that some shallow relief carving may have been employed in the initial setting out of the design.

With respect to added and altered materials, the presence of shellac has been confirmed in heavily stained areas of the ceiling, and in addition, analysis of the salt efflorescence evident in a few discrete zone has confirmed the presence of ammonium lead sulphate and sodium sulphate. In addition, it is now evident that extensive repainting of the vertical boarding below the ceiling was undertaken.

10 Acknowledgements

I am particularly grateful for the active collaboration of Adrian Heritage (English Heritage), who was fully involved with the *in situ* investigations, including undertaking the examination of the painted surface with a video microscope. Julian Limentani and Gillian Lewis have facilitated the investigations throughout, and thanks are also due to Mark Perry and Richard Lithgow for valuable practical help of numerous kinds. I am indebted to the Photogrammetric Unit of the Professional Services Survey of English Heritage for providing drawings based on its photogrammetric survey of the ceiling, which have been used here in the graphic documentation.

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Sample No. Accession No.	Location & Description	Original & Later Polychromy	Additional materials & Comments
1/2347	Nave ceiling (35 IV), green background to foliate motif: *later blue/green over green.*	• Prussian blue in lead white matrix 15 µm • verdigris combined with a brilliant yellow earth pigment in an oil medium 80 µm • *wood (oak) support*	• thick dark surface accretion • re sample 3/2095
2/2348	Nave ceiling (36 IV ee), centre of foliate motif: *crude black and red overpaint on creamy-white ground.*	• dark paint layer including black and vermilion particles 20 µm • lead white with a few red lead inclusions applied in thick impasto 580 µm • red iron oxide with a few charcoal black and red lead particles 25 µm • lead white with a little red lead 50 µm • *red iron oxide with some charcoal black particles 7 µm* • *trace white ground*	• stain at surface of lead white layer re sample 29/2121 • it is possible that the lowest red layer is a trace of original preparatory drawing
3/2349	Nave ceiling (36 IV dd) foliate motif: *foliate scroll beneath creamy-white repaint.*	• lead white 40 µm • *lead white with single vermilion particle 150 µm* • *wood (oak) support*	• re sample 27/2119 • differentiation between the two lead white layers is only possible in bright field illumination
4/2350	Nave ceiling (35 IV): *new board with crude painting in red and black.*	• red lead with red iron oxide and carbon black 100 µm • lead white 50 µm • wood support	• thick dark surface accretion
5/2351	Nave ceiling (36 III w): *black with bloom and extensive craquelure.*	• large charcoal black particles combined with yellow iron oxide and lead white 300 µm • wood support	
6/2352	Nave ceiling (38 IV t), chevron pattern: *raised detail of earlier decoration beneath grey chevron.*	• grey layer of carbon black combined with lead white and some red, yellow and brown iron oxide particles 280µm • lead white 40 µm • lead white 120 µm • *wood support*	• re sample 28/2120 • differentiation between the two lead white layers is only possible in bright field illumination
7/2353	Nave ceiling (37 IV b), 'Green Man', mouth, foliate motif: *raised curvilinear detail beneath creamy-white overpaint.*	• lead white 50 µm • *lead white 100 µm* • *wood support*	• surface accretion and dirt • differentiation between the two lead white layers is only possible in bright field illumination

8/2354	Nave ceiling (37 III a), 'Green Man': *purple flesh tone below right eye as viewed.*	• small zone of red lead combined with red iron oxide and carbon black 10 µm • pale pink layer of lead white combined with red iron oxide and carbon black 45µm • *lead white with some charcoal black 90 µm* • *azurite combined with yellow earth in a lead white matrix 70 µm* • *wood support*	• surface accretion and dirt • SEM/EDX analysis suggested the possible presence of lead-tin yellow as well as an iron oxide in the green layer.
9/2355	Nave ceiling (37 I d) chevron pattern in black on cream ground: *salts along edge of black chevron.*		• Preliminary results of optical mineralogy indicated that at least two different salts are present - both principal species are pleochroic and birefringent. The refractive indices of one are greater than 1.58, while the refractive indices of the other are less than 1.58. • SEM/EDX indicated the presence of sodium sulphate(Na, S & O), a little Pb was also present in one of the spectra. • XRD provided a clear and strong pattern for ammonium lead sulphate $(NH_4)_2$ Pb $(SO_4)_2$ and a little sodium sulphate
10/2356	Nave ceiling, E. end, N. side, vertical boarding below ceiling: *red flower with greyish bloom on surface.*	• vermilion combined with a little lead white and red lead. The vermilion particles are larger in the upper portion of the layer 110 µm • lead white 125 µm • pale pink layer of lead white combined with red iron oxide, carbon black and red lead 45µm • lead white applied in two layers (total thickness 70 µm)	• sample re 8/2354 • Hg & S (vermilion) confirmed by SEM/EDX in the uppermost red layer
11/2357	Nave ceiling (37 III r): *extensive drips and staining of dark brown material on creamy-white ground.*		• FTIR analysis indicated the presence of shellac
12/2358	Nave ceiling (36 III a) flesh tone of Janus: *pink/cream flesh tone above his left eye.*	• *lead white combined with a few particles of vermilion 65 µm* • *azurite combined with yellow earth in a lead white matrix 80 µm* • *wood support*	• surface accretion and dirt • FTIR analysis indicated the presence of lead white in an oil medium

The tables above give the location where each sample was taken, the sample number, its Courtauld archive accession number, and the stratigraphy of the various layers from the top layer down, with the thickness of each layer in microns (µm). Layers in italics are those which are likely to have formed part of the original scheme.

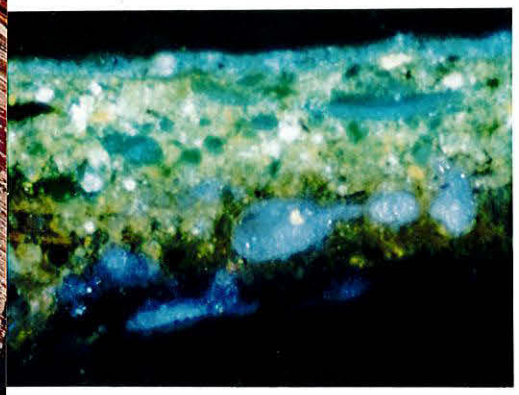
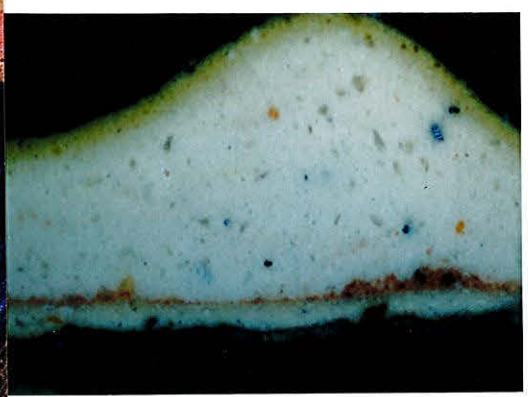


Plate 1 (*above*): green background of foliate motif on ceiling board 35 IV with blue/green overpaint. **Plate 2** (*left*): Cross-section of Sample 1/2347 taken from the blue/green overpaint shown in Plate 1, shown here at 1536x magnification. Prussian blue in a lead white matrix was applied over a layer of verdigris combined with yellow earth in an oil medium. **Plate 3** (*below*): crude black and red overpaint on the creamy white ground of ceiling board 36 IV ee. **Plate 4** (*lower left*): Cross-section of Sample 2/2348 taken from the crude overpaint shown in Plate 3, shown at 592x magnification. A very thin layer of black and vermilion is present at the top of the sample. Below this is a thick layer of lead white—which is stained at the upper surface—over a layer of red earth in a lead white matrix. Another layer of lead white is evident beneath this red layer. This lower layer of lead white was applied over a trace of red earth and charcoal black on a trace of a white preparatory layer. The lowest red and black layer may represent traces of an original underdrawing. (*Macrophotographs, Heritage & Howard 1998; photomicrographs, Howard 1998*).



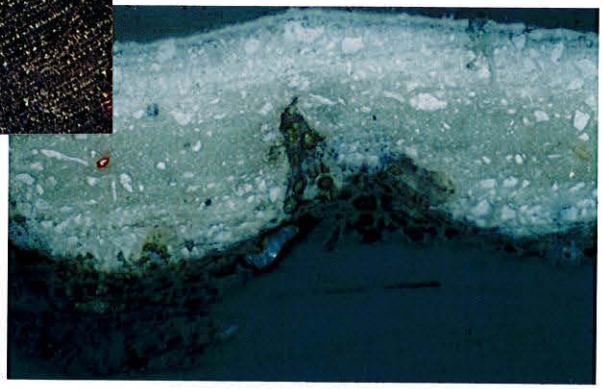


Plate 5 (*above*): Detail of foliate scroll on ceiling board 36 IV dd. Close examination of the raised foliate motif in this area indicated that it may have been carved in shallow relief into the oak board. **Plate 6** (*above right*): Cross-section of Sample 3/2349 taken from the foliate scroll shown in Plate 5, shown at 1240x. In normal incident light only a single layer of lead white is apparent over the wood support. However, when the sample is viewed in bright-field illumination (**Plate 7**, *right*), it is clear that two distinct layers of lead white are present, the lower containing a single particle of vermilion. **Plate 8** (*below*): Detail of modern board and crude repainting in red and black. **Plate 9** (*below right*): Cross-section of Sample 4/2350 taken from the crude red repainting shown in Plate 8, shown at 2000x magnification. A thick layer of red earth combined with carbon black was applied over a lead white ground on the new support. (*Macrophotographs, Heritage & Howard 1998; photomicrographs, Howard 1998*).

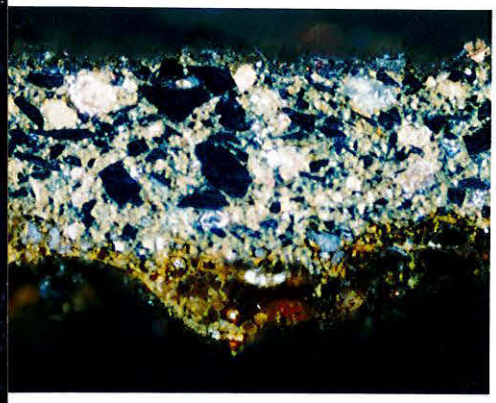
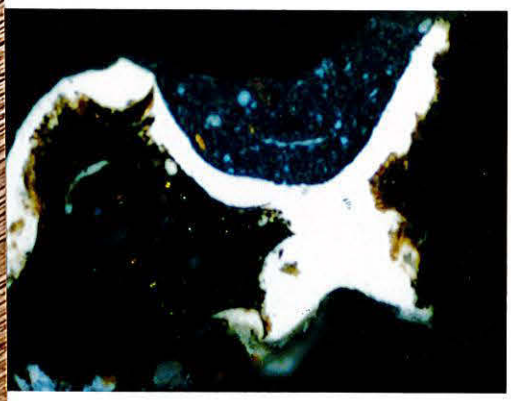
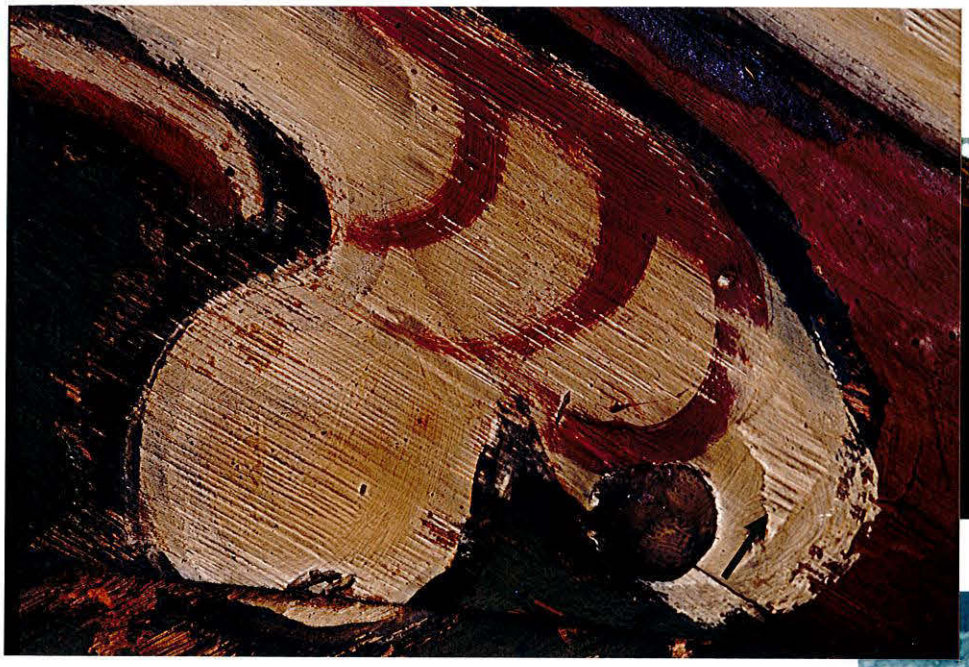
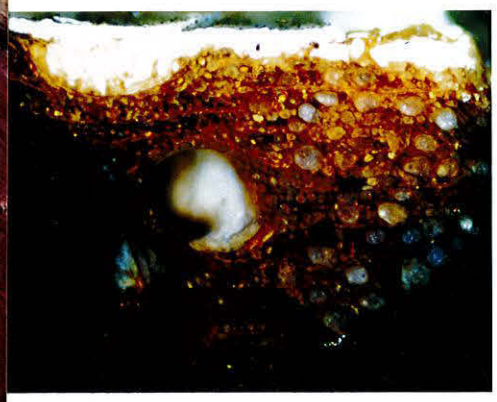


Plate 10 (*above*): Detail showing black paint with blooming and extensive craquelure on board 36 III w. **Plate 11** (*above right*): Cross-section taken from the black paint shown in Plate 10, shown at 800x magnification. A thick layer of charcoal black combined with yellow earth and lead white was applied directly to the wood support. **Plate 12** (*below*): Detail of the chevron pattern painted in grey on ceiling board 38 IV t. Beneath the grey chevron pattern there are traces of a similar motif which appears to have been carved in shallow relief into the ceiling board. **Plate 13** (*below right*): Cross-section of a sample taken from the grey chevron pattern, shown at 472x magnification. Here a layer of carbon black combined with lead white and red, yellow and brown earth particles was applied over a lead white ground. (*Macrophotographs, Heritage & Howard 1998; photomicrographs, Howard 1998*).







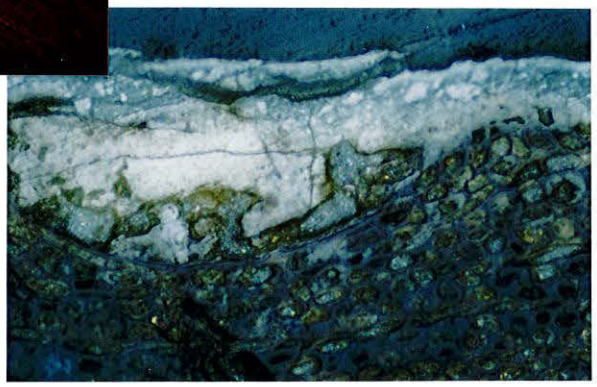
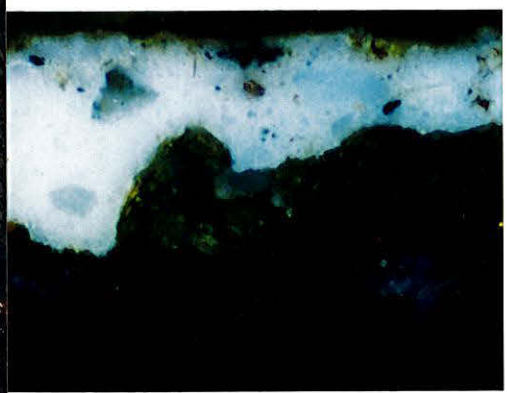


Plate 14 (*above*): Detail of foliate motif near the mouth of the *Green Man* on ceiling board 37 IV b. In raking light it is apparent that the curvilinear detail was carved in shallow relief in the oak board. **Plate 15** (*top right*): Cross-section of Sample 7/2353 taken from the creamy-white paint over the raised line, shown at 584x magnification. In normal incident light a single layer of lead white is visible on the wood support, however, when viewed in bright-field illumination at 1760x mag. (**Plate 16**, *right*) two distinct layers of lead white are visible. **Plate 17** (*below*): Detail of the *Green Man*. **Plate 18** (*below right*): Cross-section of Sample 8/2354 taken from the flesh tone below the *Green Man's* left eye, shown at 2000x magnification. At the base of the sample the original green shading of the flesh tone—in azurite, yellow earth and lead white—is evident, over which lead white with some charcoal black was applied. (*Macrophotographs, Heritage & Howard 1998; photomicrographs, Howard 1998*).



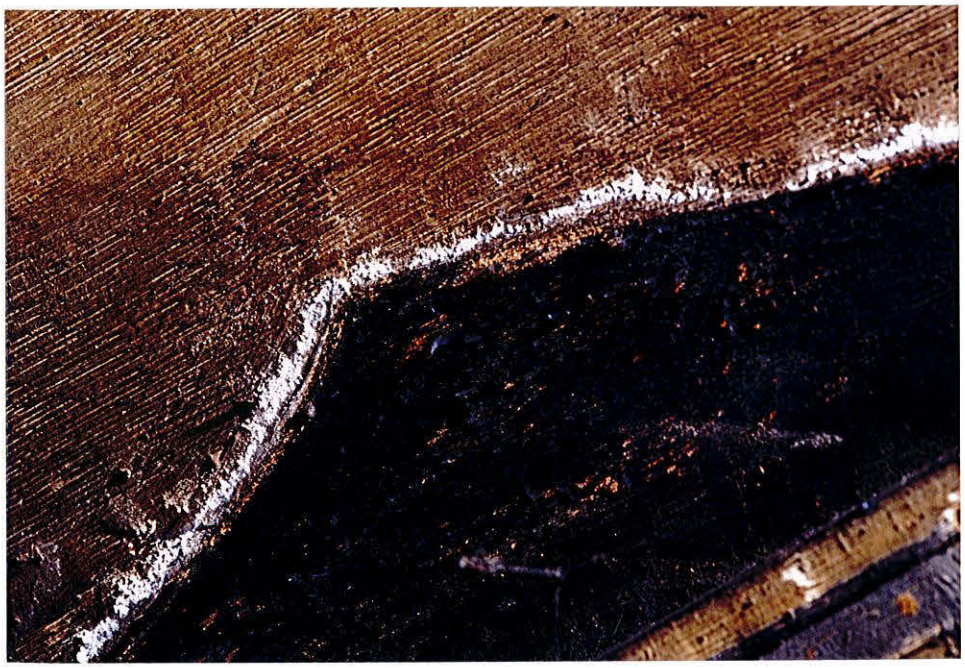


Plate 19 (*above*): Detail of the salt efflorescence which follows the edge of the black chevron pattern on ceiling board 37 I d. Instrumental analysis of the salts in a sample taken from this area confirmed the presence of ammonium lead sulphate and sodium sulphate. **Plate 20** (*below*): Detail of the vertical board below the ceiling on the north side of bays 38-39. **Plate 21** (*below right*): Cross-section of Sample 10/2356 taken from the flower bud shown in Plate 20, shown at 1720x magnification. The secondary lead white ground and thick uppermost red layer of vermilion combined with red lead and lead white clearly indicates that this zone has undergone comprehensive repainting. (*Macrophotographs, Heritage & Howard 1998; photomicrograph, Howard 1998*).

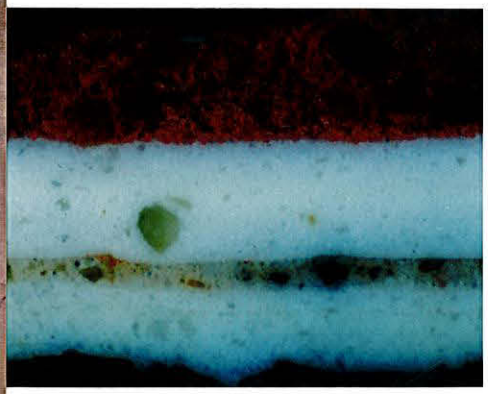


Plate 22 (*above*): Detail of the extensive drips and brown staining which is evident on ceiling board 37 III r. Instrumental analysis of the brown material indicated the presence of shellac. **Plate 23** (*below*). Detail of Janus showing the flesh tone above his left eye. **Plate 24** (*below right*). Cross-section of Sample 12/2358 taken from Janus' flesh tone, shown at 1984x magnification. Here the original paint layers are evident, with the shadow of the flesh applied in azurite combined with yellow earth and lead white, over which lead white with a few particles of vermilion was applied. (*Macrophotographs, Heritage & Howard 1998; photomicrograph, Howard 1998*).