JANE DAVIES CONSERVATION

Architectural Paint Research

PETERBOROUGH CATHEDRAL, NAVE CEILING

PHASE 3 INVESTIGATION OF PAINTING MATERIALS AND TECHNIQUES

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SUMMARY

The nave ceiling at Peterborough is a rare survival of a thirteenth century timber ceiling *in situ* in England. It retains original thirteenth century paint although heavily restored in the 1740s and again in 1836. The ceiling is currently being conserved and its condition recorded. As part of the conservation programme a thorough technical examination of the painting materials and techniques has been undertaken. This research was undertaken by the Conservation of Wall Paintings Department, Courtauld Institute of Art in 1997. They have documented their findings in three reports dated September 1997, September 1998 and December 1999. [1] Due to other commitments the Courtauld was unable to carry out research during autumn 2000 and Jane Davies was commissioned by Julian Limentani (of Marshall Sisson), the Cathedral Architect to examine twenty two paint samples which had been gathered during the third phase of conservation. These samples had been taken by Helen Howard, Courtauld Institute, and the first twelve samples had been mounted and analysis begun. The remaining ten samples required mounting and full analysis.

[1]Howard, H. 'Peterborough Cathedral, Nave ceiling: Scientific examination of the original decoration', unpublished report, Conservation of Wall Painting Department, Courtauld Institute of Art, September 1997. Howard, H. 'Peterborough Cathedral, Nave ceiling: Scientific examination of the original decoration of bays 36-39', unpublished report, Conservation of Wall Painting Department, Courtauld Institute of Art, September 1998. Kakoulli, J. 'Peterborough Cathedral, Nave Ceiling Paintings: Scientific Examination Phase 2', unpublished report, Conservation of Wall Painting Department, Courtauld Institute of Art, December 1999.

SUMMARY

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1 BACKGROUND AND BRIEF

1.1 INTRODUCTION

The nave ceiling at Peterborough is a rare survival of a thirteenth century timber ceiling *in situ* in England. It retains original thirteenth century paint although heavily restored in the 1740s and again in 1836. The ceiling is currently being conserved and its condition recorded. As part of the conservation programme a thorough technical examination of the painting materials and techniques has been undertaken. This research was undertaken by the Conservation of Wall Paintings Department, Courtauld Institute of Art in 1997. They have documented their findings in three reports dated September 1997, September 1998 and December 1999. [2] Due to other commitments the Courtauld was unable to carry out research during autumn 2000 and Jane Davies was commissioned by Julian Limentani (of Marshall Sisson), the Cathedral Architect to examine twenty two paint samples which had been gathered during the third phase of conservation. These samples had been taken by Helen Howard, Courtauld Institute, and the first twelve samples had been mounted and analysis begun. The remaining ten samples required mounting and full analysis.

[2]Howard, H. 'Peterborough Cathedral, Nave ceiling: Scientific examination of the original decoration', unpublished report, Conservation of Wall Painting Department, Courtauld Institute of Art, September 1997. Howard, H. 'Peterborough Cathedral, Nave ceiling: Scientific examination of the original decoration of bays 36-39', unpublished report, Conservation of Wall Painting Department, Courtauld Institute of Art, September 1998. Kakoulli, J. 'Peterborough Cathedral, Nave Ceiling Paintings: Scientific Examination Phase 2', unpublished report, Conservation of Wall Painting Department, Courtauld Institute of Art, December 1999.

1.2 BRIEF HISTORY OF THE CEILING[3]

The history of the ceiling has been researched and reported in Howard's reports of 1997 and 1998 as well as in Kakoulli's work of 1999. Therefore it is not the intention of the author of this paper to reproduce the historical information here except in the briefest form:

***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).

***c.* 1220** painting of the nave ceiling.

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.

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. Structural repairs were necessitated by infestation of death watch beetle.[5] The upper surface of the boards was covered with hessian and glue at this time.

[3] The author is indebted to Helen Howard for this information and would draw the readers attention to her reports for a more detailed discussion.
[4] Cave & Borenius 1937:304-9.
[5] A report on the condition of the roof at this time is provided by the architect, see Moore 1925.

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 Conservation treatment and documentation of present condition by the Perry Lithgow Partnership commences in the zones around St. Peter, St. Paul and the Psaltery Player.

1.3 SUMMARY OF PREVIOUS RESEARCH FINDINGS

The Courtauld reports contain a great deal of valuable information. In addition to setting out the project brief, a selected history of the ceiling, research methodology and documentary evidence, they present a considerable body of evidence about the materials and techniques of both the original and later interventions. The findings of the previous reports are briefly summarised in the text below. The cumulative results of investigations of the original paint technique from all research phases including the present one are shown below as Table 1.

ORIGINAL MATERIALS AND TECHNIQUES:

- Original paint layers exist in a number of areas, usually beneath layers of rather crude overpaint, as in the flesh tones of St. Peter.
- Some original layers remain exposed — although juxtaposed with cursorily applied overpaint, as in the Psaltery Player
- **Original palette**: **natural azurite** ($2CuCO_3.Cu[OH]_2$), **red lead** (Pb_3O_4), **lead white** ($2PbCO_3.Pb[OH]_2$), **basic verdigris** ($Cu(C_2H_3O_2)_2.2Cu(OH)_2$), **yellow iron oxide** ($Fe_2O_3.H_2O$) and **red iron oxide** (Fe_2O_3), **carbon black** (C) and **vermilion** (HgS)
- **Original:** Drying oil medium in lead white and verdigris paint
- **Original:** Underpaint to flesh tones used azurite combined with lead white and yellow iron oxide
- **Original:** Flesh tones used lead white and vermilion with a little yellow iron oxide and carbon black. ***Repainting:*** *flesh tones lead white combined with red lead or carbon black.*
- Calcium sulphate present at timber/paint interface and at varying concentrations throughout the paint layers
- Pigment alteration: natural azurite to copper oxalate (caused by an episode of high humidity in past?)
- **Preparatory drawing:** dark brown line almost directly on wood, contained carbon black combined with a few brown and yellow iron oxide particles. In addition, traces of underdrawing in carbon black are evident.

LATER INTERVENTIONS:

- No ground layer generally applied — overpaint directly on original below. EXCEPT: to prepare replacement boards and where extensive repainting was undertaken, e.g., geometric border patterns, St Paul's hair.

- **Repainting:** flesh tones lead white combined with red lead or carbon black.
- **Overpaint palette**: 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 ($2PbCO_3.Pb[OH]_2$), red iron oxide (Fe_2O_3), brown and yellow iron oxides ($Fe_2O_3.H_2O$) and barytes ($BaSO_4$).

TABLE 1 Cumulative summary of analysis results of investigation of the original painting scheme (research phases 1 to 3 inclusive)[6]

Italics indicate that it is not clear if the material is original, or an alteration product or a contaminant

Author/Date	Preparatory techniques	Ground/preparation	Pigments	Combinations	Alterations/contaminants	Medium
Howard 1997	• Carbon black drawing (under & over lead white ground) • *Dark brown preparatory drawing line*	• Lead white • Lead white + black + red • Lead white + *calcium sulphate* • Lead white + *calcium sulphate* + carbon black • lead white with clay-rich material • *calcium sulphate + protein* • *(animal glue?)*	• Lead white • Red iron oxide • Red lead • Vermilion • Yellow iron oxide • *Massicot* • Basic verdigris • Natural azurite • Carbon black	• Red iron oxide in lead white matrix • Red lead + calcium carbonate • Red lead + lead white + carbon black • Red lead + carbon black • Vermilion in lead white matrix • Vermilion + yellow iron oxide +carbon black in lead white matrix • Vermilion + carbon black in lead white matrix • Yellow iron oxide + siliceous inclusions in lead white matrix • Azurite + yellow iron oxide • Azurite + yellow iron oxide in lead white matrix • Copper oxalate + lead white + *calcium sulphate* • Black + orange/red iron oxide in lead white matrix • Carbon black in matrix of *calcium sulphate* • Carbon black + brown & yellow iron oxide + *massicot* • Carbon black + red & yellow iron oxides + lead white	• Azurite to copper oxalate • Calcium carbonate to *calcium sulphate*	• Drying oil • *Animal glue*
Howard 1998	• *Relief carving of trefoil*		• Charcoal black	• Lead white + charcoal black • Lead white + vermilion		

[6] This table is based on Kakoulli, 1999, Table 11, p.25 and has been modified to show cumulative results, i.e. only new findings have been listed. Findings reproduced in each phase are not repeated. The table has also been revised to include results of phase 3 research.

	decoration			• Red iron oxide + charcoal black		
Kakoulli 1999			• Red ferric oxide	• Red lead + lead white		
Davies 2000		• Lead white + natural chalk	• *Arsenic containing pigment?*	• Red iron oxide + calcium sulphate + quartz inclusions • Red iron oxide + calcium sulphate + quartz inclusions + charcoal • Lead white + iron oxide pigments • Lead white + vermilion + iron oxide • Natural azurite + yellow ochre + chalk	• Azurite to copper chloride • *Arsenic*	

2 PAINT ANALYSIS

2.1 METHODOLOGY

Paint samples were examined under low power magnification (2.5x-10x) and representative fragments mounted in acrylic modified polyester resin and polished in cross-section using a Metaserve 2000 grinding/polishing machine and a range of graded abrasives. Prepared cross-sections were examined under dark-field reflected light at magnifications 50x-500x using a Leica DMLM research grade microscope. Microchemical tests were carried out to identify some metallic ions and functional groups. Histochemical tests were undertaken to indicate the presence of proteins (glue) and oils.[7] Samples were also mounted as dispersions (in Meltmount, which has a refractive index of 1.662) and polarised light microscopy (PLM) carried out. Representative samples were photographed for reproduction within this report.

Scanning electron microscopy with energy dispersive X-ray (SEM.EDX) analysis has been undertaken by Dr Andrew Beard at the Department of Geology, University College London. Additional PLM and further SEM.EDX work was undertaken by Catherine Hassall.

[7] The microchemical tests included: hydrochloric acid and potassium chromate, which produce a yellow stain for lead and hydrochloric acid, which results in the evolution of carbon dioxide to identify carbonates. Preliminary staining for oils used Sudan Black B which stains oils a blue black colour. Preliminary staining for proteins used Coomassie blue (R250) which stains proteins (glue) a mid-blue colour.

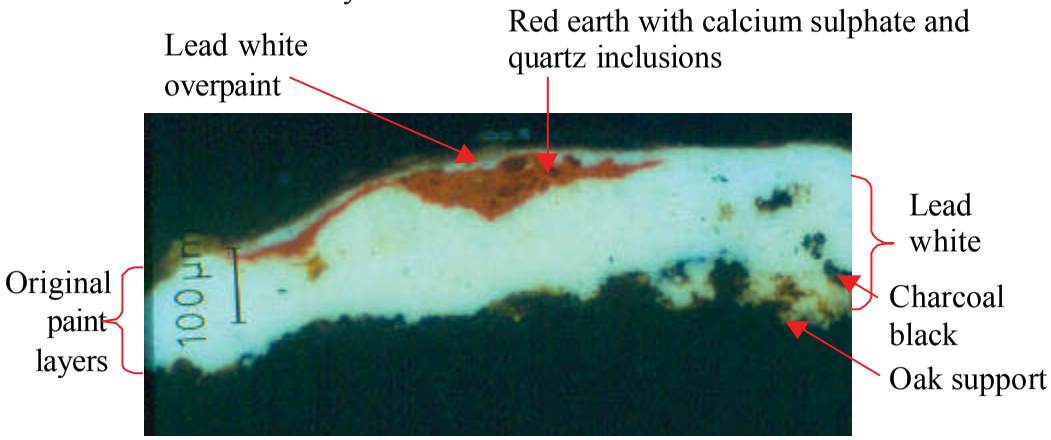
2.2 ILLUSTRATED DISCUSSION OF FINDINGS

Sample 1 (2989)

Sample 1 was taken from the original frieze decoration on an oak replacement board (22 III o), where it was suspected that original ashlar decoration was present, as a design was visible in relief on two repositioned oak ceiling boards. A sample of paint was taken from trefoil design in order to identify the original paint if present.

Sample location photograph (*below*):

The sample appears to show the original paint layers and a thin lead white overpaint. The original layers comprise the surface bright red trefoil design (red earth with calcium sulphate and quartz inclusions) on a lead white ground and charcoal black underpaint on the oak substrate. The overpaint is lead white, surface dirt is present on the upper surface of the overpaint. No barytes was identified using SEM.EDX analysis.



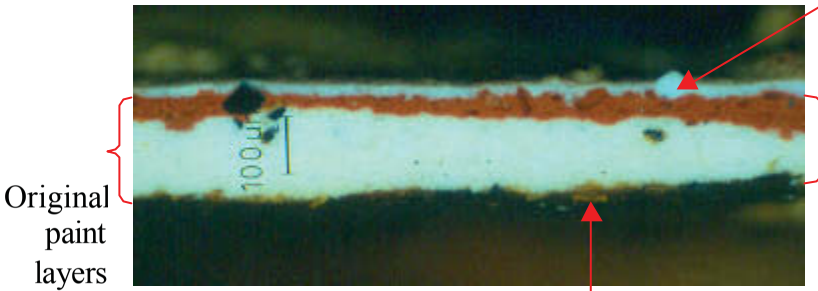
Sample 1 photographed in cross-section under reflected light at 220x magnification (on slide). (Printed magnification not calculated).

Sample 2 (2990)

Sample 2 was taken from the original frieze decoration on oak replacement board (22 III o), where it was suspected that original ashlar decoration was present, as a design was visible in relief on two repositioned oak ceiling boards. A sample of paint was taken from the tendril design in order to identify the original paint if present.

Sample location photograph (*below*):

The sample shows the original paint layers and a thin lead white overpaint. The original layers comprise the surface bright red trefoil design (red earth with calcium sulphate, charcoal black and quartz inclusions) on a lead white ground and charcoal black underpaint on the oak substrate. The overpaint is lead white, surface dirt is present on the upper surface of the overpaint. No barytes was identified using SEM.EDX analysis.



Sample 2 photographed in cross-section under reflected light at x 148 magnification. (Printed magnification not calculated).

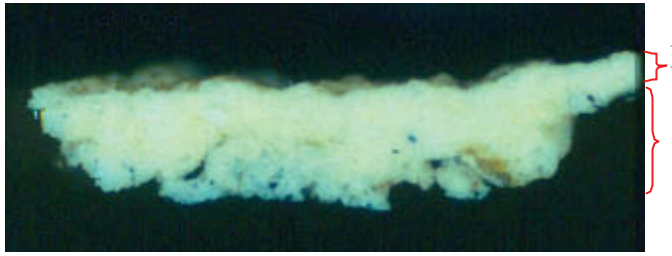
Sample 3 (2991)

Sample location:

The sample was taken from an area of apparently original linear white dogstooth pattern (22 IV e), which had been revealed by previous restoration but not overpainted. It was hoped that the sample could be confirmed as original paint and that it might further knowledge of the original preparatory technique.

Sample location photograph (*below*):

The sample shows only two paint layers: a surface lead white (the upper boundary of which is marked with surface dirt), and a lower paint consisting of lead white combined with a little charcoal black. The timber substrate (and possibly lower paint layers) are absent.



Sample 3 photographed in cross-section under reflected light at x 185 magnification. (Printed magnification not calculated).

Sample 4 (2992)

Sample location:

Sample 4 was taken from the linear wave pattern where red paint was visible under edge of black wave pattern (22 I r). The sample was taken to confirm Kakoulli's findings in 1999 (sample 18) and to identify the original scheme if it was present.

Sample location photograph (*below*):

Kakoulli (1999) identified a lead white and barytes paint overlying lead white and red lead paints on sample 18. She interpreted these layers as later overpaint (2 layers lead white and barytes) on a red lead layer belonging to an earlier phase.[8]

This sample shows a finely divided black pigment combined with lead white. This is interpreted as later overpaint. Below this is a layer of red lead, combined with lead white and some inclusions, directly on the timber substrate.

Sample 4 photographed in cross-section under reflected light at 210x magnification. (Printed magnification not calculated).

[8] Kakoulli, J. 'Peterborough Cathedral Nave Ceiling Paintings: Scientific Examination Phase 2', unpublished report, Conservation of Wall Painting Department, Courtauld Institute of Art, p.16, plates 45-47 and appendix 2.

Sample 5 (2993)

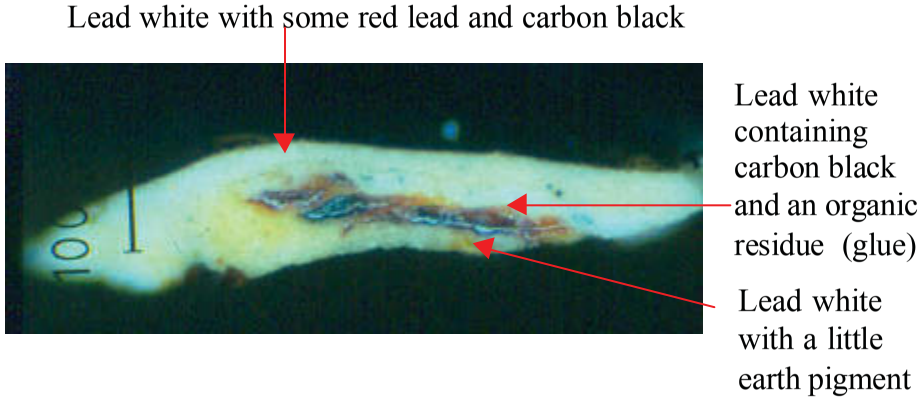
Sample location:

Sample 5 represents paint on original nail heads and the sample was taken from original non-corroded nail head (overpainted in 1740s and 1830s with white background paint.) from the extended chevron (24 IV r). The aim of sampling was to identify the original scheme if present and to suggest whether the nails were painted to match the unpainted background.

Sample location photograph (*below*):

The sample shows an early lead white paint with a little earth pigment. Over this is a lead white layer containing a little carbon black, apparently contaminated with an organic 'glue'.

Later overpaint comprised of lead white with a little red lead (?) and carbon black pigments. The surface of the sample is marked by dirt accumulation.



Sample 5 photographed in cross-section under reflected light at 250x magnification. (Printed magnification not calculated).

Sample 6 (2994)

Sample location:

Sample was taken from paint under an original nail head — now missing (21 I o Coloured bands). The sample was of a thin layer of white paint or preparation layer from within a groove. The intention of sampling was to identify the original paint, if present, and to compare the sample with Kakoulli, 1999 (sample 57).

Sample location photograph (*below*):

Kakoulli (1999) identified a black consisting of charcoal black particles mixed with lead white and dispersed ferric hydroxide particles, which is understood to date to the 1740s repainting.[9]

The sample shows only a very thin layer of lead white paint, directly on the timber substrate.

Sample 6 photographed in cross-section under reflected light at 90x magnification. (Printed magnification not calculated).

[9] Kakoulli, J. 'Peterborough Cathedral Nave Ceiling Paintings: Scientific Examination Phase 2', unpublished report, Conservation of Wall Painting Department, Courtauld Institute of Art, p.15, plates 149-150 and appendix 2.

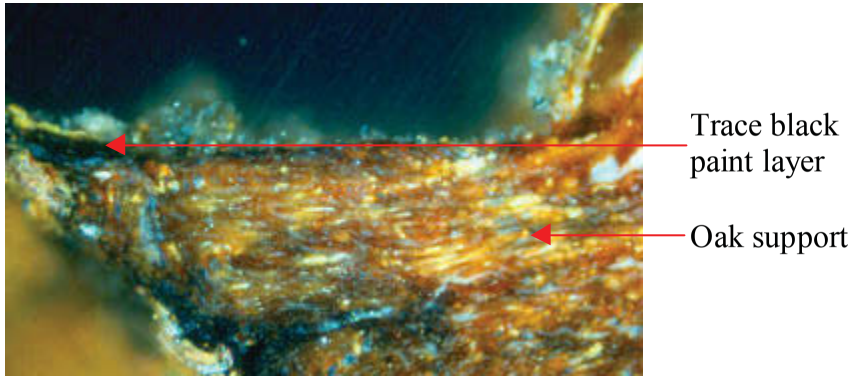
Sample 7 (2995)

Sample location:

Sample was taken from paint under an original nail head — now missing (21 I o Coloured bands). The sample was of a thin layer of black paint on a raised area between grooves. The intention of sampling was to identify the original paint, if present.

Sample location photograph (*below*):

The sample shows only a very thin layer of black paint, directly on the timber substrate.



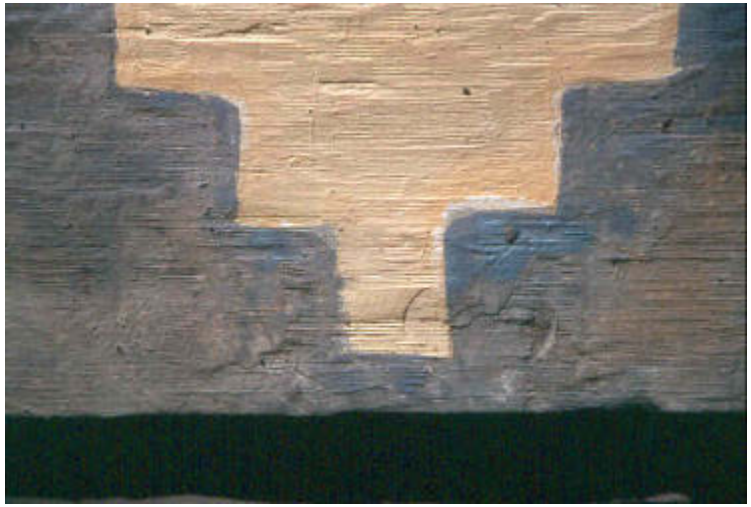
Sample 7 photographed in cross-section under reflected light at 180x magnification. (Printed magnification not calculated).

Sample 8 (2996)

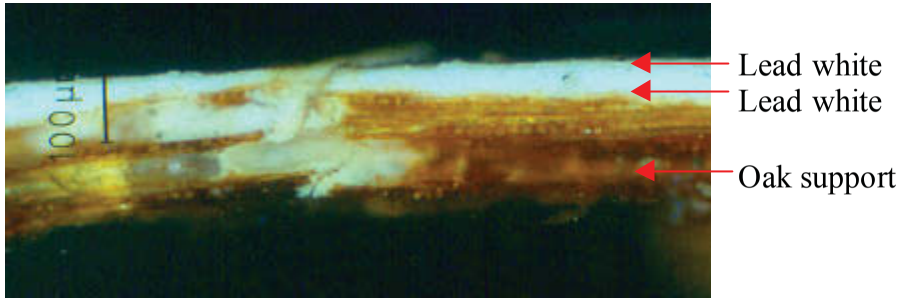
Sample location:

The sample was taken to establish the presence of original paint on the raised linear design which is visible in raking light (20 II f).

Sample location photograph (*below*):



The sample shows a layer of lead white paint, directly on the timber substrate. Over this is a very thin lead white paint layer, the surface of which is marked with dirt accumulation.



Sample 8 photographed in cross-section under reflected light at 169x magnification. (Printed magnification not calculated).

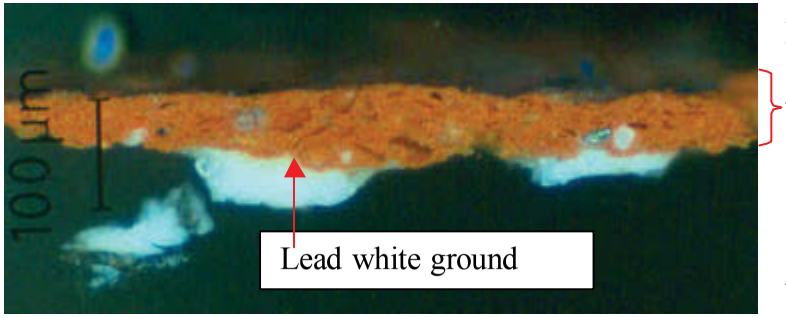
Sample 9 (2997)

Sample location:

Red paint from frieze decoration underpaint on replacement softwood boards (27 II s Grey chevron). It was hoped that identification of the paint layers might assist in dating of the boards.

Sample location photograph (*below*):

The sample shows a layer of red paint, comprised of red earth combined with silica, calcium sulphate and charcoal black. This was applied over a lead white ground.



Sample 9 photographed in cross-section under reflected light at 250x magnification. (Printed magnification not calculated).

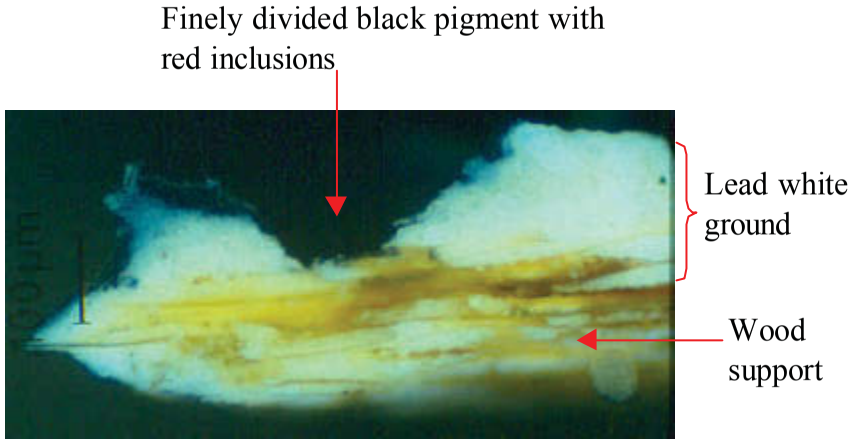
Sample 10 (2998)

Sample location:

Black paint from frieze decoration underpaint on replacement softwood boards (27 II s Grey chevron). It was hoped that identification of the paint layers might assist in dating of the boards.

Sample location photograph (*below*):

The sample shows a finely divided black pigment together with some red inclusions, which was applied over a lead white ground, to the timber support.



Sample 10 photographed in cross-section under reflected light at 248x magnification. (Printed magnification not calculated).

Sample 11 (2999)

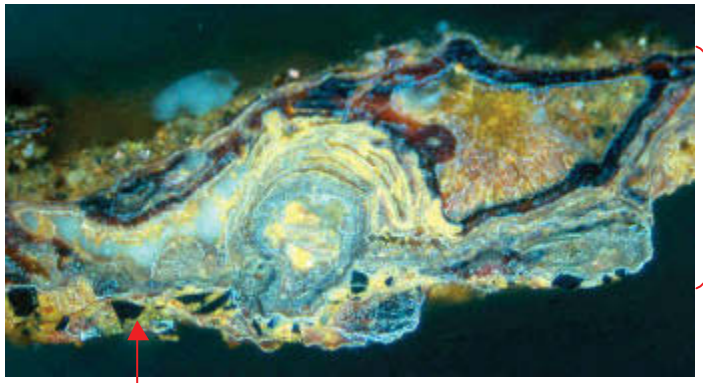
Sample location:

The sample was taken from paint on a nail head — as an aid to identification of 1740s nails (22 III j Grey chevron).

Sample location photograph (*below*):

The sample shows a thick build up of paint, distorted during application and also, it is likely, by the formation of corrosion products from the metal substrate.

The surface paint comprises a dark paint layer with black, yellow, red and brown inclusions. Under dark-field reflected light this appears similar to the dark paint attributed to the 1740s by Kakoulli (1999) (sample 57). Corrosion products and possibly also an organic 'glue' are present. The lower paint layer contains charcoal black in a yellow earth matrix. The appearance of the charcoal is consistent with charcoal identified on other areas believed to date to the 1740s.



Sample 11 photographed in cross-section under reflected light at 180x magnification. (Printed magnification not calculated).

Sample 12 (3000)

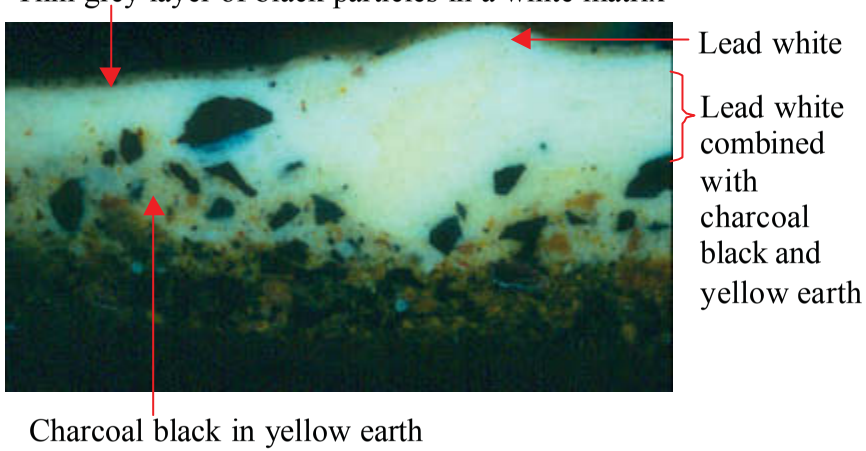
Sample location:

Paint on suspected 1740s softwood replacement board — sampled to confirm presence of 1740s paint below 1830s paint (23 I r Grey chevron).

Sample location photograph (*below*):

The sample shows a build up of four paint layers: the surface paint comprises a thin grey layer of black particles in a white matrix. This lies over a fairly pure lead white layer, which in turn covers a layer of lead white combined with charcoal black and yellow earth. The lowest paint layer consists of charcoal black in yellow earth matrix.

The charcoal present in the lower two layers appears to be of the type identified within 1740s paint layers. For example, Kakoulli (1999) samples 13, 34, 47 and 52, which show similar large charcoal particles.[10]



Sample 12 photographed in cross-section under reflected light at 182x magnification. (Printed magnification not calculated).

[10] Kakoulli, J. 'Peterborough Cathedral Nave Ceiling Paintings: Scientific Examination Phase 2', unpublished report, Conservation of Wall Painting Department, Courtauld Institute of Art, p.27, plates 32, 87, 116 and 130, and appendix 2.

Sample 13 (3060)

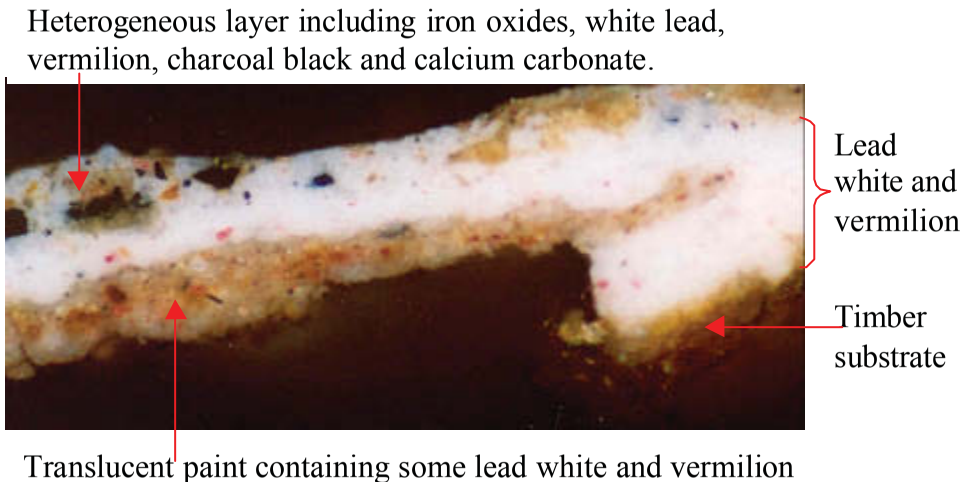
Sample location:

Sample 13 was taken from the *flesh tone on neck* of an angel with trumpet (22 II z Lozenge). It was hoped original paint would be identifiable.

Sample location photograph (*below*):

The sample has a heterogeneous surface paint layer containing lead white, iron oxides, vermilion and charcoal black. The upper surface of the layer is marked by accumulations of dirt. The layer has a slightly transparent appearance under reflected light and this may be due to the inclusion of calcium carbonate. Calcium was detected by SEM.EDX, together with carbon and oxygen, but not sulphur.

Underlying this layer is a dense pink paint of vermilion in a lead white matrix. This is applied directly to the timber substrate. Intermingled with the pink paint is a more transparent paint, again containing lead white and vermilion.
At the boundary of the pink paint and the timber substrate there appears to be a clear substance. Further analysis may confirm the nature of this layer.



Sample 13 photographed in cross-section under reflected light at 200x magnification. (Printed magnification not calculated).

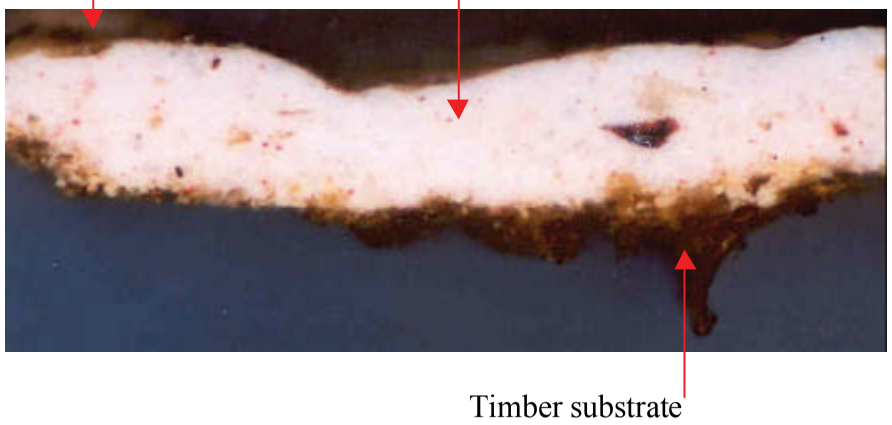
Sample 14 (3061)

Sample location:

Sample 14 was taken from the flesh tone on bridge of nose of the angel with trumpet (21 II a Lozenge). It was hoped that sampling would identify original paint.

Sample location photograph (*below*):

The sample shows a single thickly applied pink paint layer directly on the timber substrate. The pink paint is comprised mainly of lead white coloured with both iron red and vermilion. SEM.EDX indicates the presence of Sn (tin) with the iron red pigment, however the reason for this is not yet clear. No barytes is present. The layer may be original.



Sample 14 photographed in cross-section under reflected light at 100x magnification. (Printed magnification not calculated).

Sample 15 (3062)

Sample location:

See cross-section photomicrograph on following page.

Sample 15 was taken from the flesh tone of the Bishop's left temple (19 III aa Lozenge) to identify any original paint that may be present.

Sample location photograph (*below*):

The sample shows a surface pink paint comprised mainly of lead white coloured with iron oxide red and vermilion pigments. Below this is a semi-translucent layer of copper green pigments mixed with barium sulphate and silicates. At the base of the sample is the timber substrate. The presence of barium sulphate at low level in the sample suggests the paint is of nineteenth century date.

Sample 15 cross-section photomicrograph (*below*):

Sample 15 photographed in cross-section under reflected light at 100x magnification. (Printed magnification not calculated).

Detail of sample 15 cross-section photomicrograph (*below*):

Sample photographed in cross-section under reflected light at 200x magnification. (Printed magnification not calculated).

- Pink paint comprised mainly of lead white coloured with iron oxide red and vermilion pigments
- Semi-translucent layer of copper green pigments mixed with barium sulphate and silicates
- Timber substrate

SEM.EDX identified Ba and S in this area, strongly suggesting the presence of barytes. It occurs at low level in the sample and therefore suggests the paint in this area probably dates from the nineteenth century.

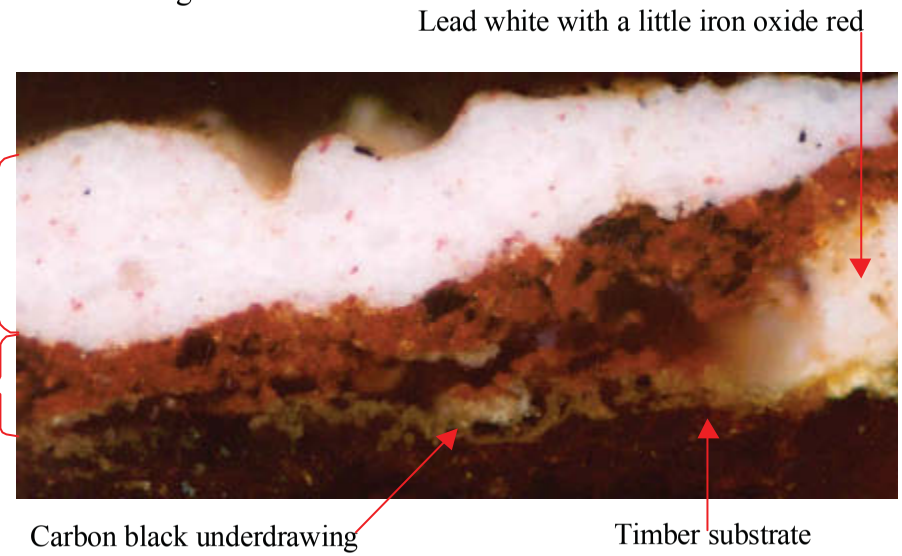
Sample 16 (3063)

Sample location:

Sample 15 was taken from the flesh tone below the nostril of the Bishop's face (19 III aa Lozenge) to identify any original paint that may be present.

Sample location photograph (*below*):

The sample shows at the surface a pink paint of lead white, iron oxide red and vermilion, and which probably dates from later restoration. Below this is a dark red paint comprised of red iron oxide and carbon black, with just a little lead white. This was applied over a lead white ground, only slightly pigmented with iron oxide. Below this layer, directly on the timber substrate is a thin carbon black layer — this appears to be evidence of original black underdrawing.[11]



Sample 16 photographed in cross-section under reflected light at 200x magnification. (Printed magnification not calculated).

[11] Kakoulli, J. 'Peterborough Cathedral Nave Ceiling Paintings: Scientific Examination Phase 2', unpublished report, Conservation of Wall Painting Department, Courtauld Institute of Art, p.25, Table 11: Summary table of analysis of original painting scheme.

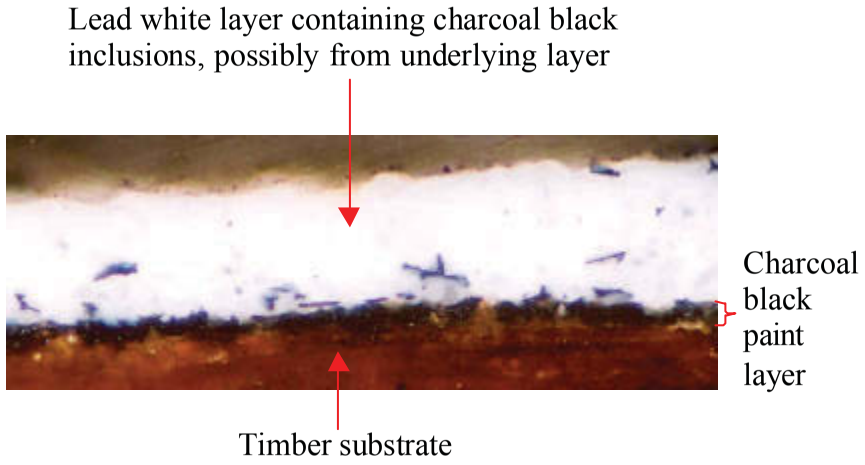
Sample 17 (3064)

Sample location:

Sample17 was taken from an area where a raised trefoil design is just visible showing as black through the 1830s white background paint (18 II r Extended chevron). Sampling was undertaken in order to identify original paint if present.

Sample location photograph (*below*):

The sample shows white lead paint overlying a charcoal black paint, which lies directly on the timber substrate. The lead white paint contains some charcoal black particles, these appear to be of the same type as comprise the underlying black layer. However it may be that loose particles were mixed into the wet paint as it was applied rather than suggesting the two paint layers are co-eval.



Sample 17 photographed in cross-section under reflected light at 220x magnification. (Printed magnification not calculated).

Sample 18 (3065)

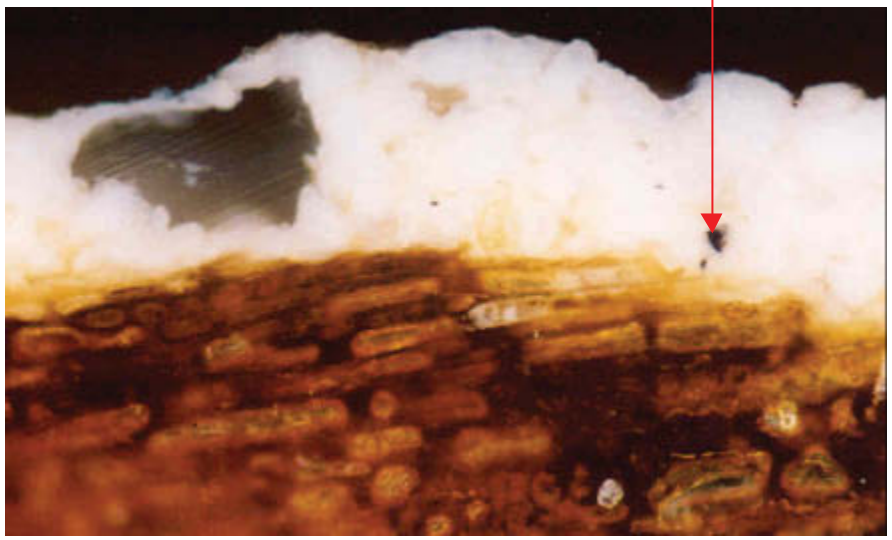
Sample location:

Sample of white paint from the inner of three grooves, possibly original paint, under lost nail head (19 III t Grey chevron). Sampled to establish the presence of original paint or later introductions.

Sample location photograph (*below*):

The sample shows a single thin layer of lead white with a tiny amount of carbon black. SEM.EDX also detected some calcium, towards the boundary of the paint and timber substrate. This may possibly be suggestive of the presence of a very thin calcium-based ground as identified in previous studies. No sulphate was detected and previous studies have identified calcium sulphate within ground layers, although possibly as an alteration product. This suggests the sample is probably original paint.

Single layer of lead white, containing a tiny amount of carbon black.



Sample 18 photographed in cross-section under reflected light at 200x magnification. (Printed magnification not calculated).

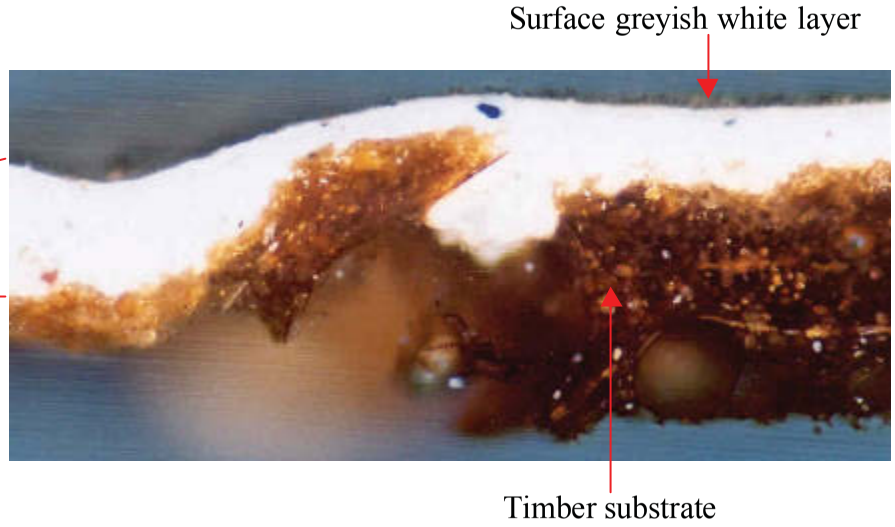
Sample 19 (3066)

Sample location:

Sample 19 was taken from the raised linear design visible in raking light through the white background paint of the stepped chevron (20 II f). The aim of sampling was to identify the colour of the original raised design.

Sample location photograph (*below*):

The sample appears to show two layers of white paint. The upper white lead paint has a greyish, slightly transparent appearance. SEM.EDX of this layer identified lead and calcium, possibly the presence of a calcium rich extender explains the translucency of the layer. The lower white layer consists mainly of lead white, but contains a few sparse particles of carbon black and a very few iron oxide yellow particles are apparently visible under reflected light. At the boundary of the lower lead white layer and the timber substrate is a thin translucent material. SEM.EDX of two separate sites within this material both produce similar spectra: the layer contains sulphur (sulphates?) and potassium. At the base of the sample the timber substrate is present.



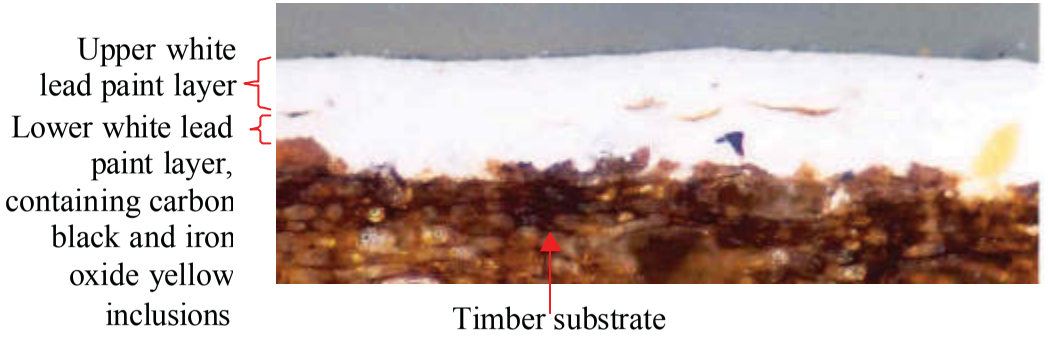
Sample 19 photographed in cross-section under reflected light at 100x magnification. (Printed magnification not calculated).

Sample 20 (3067)

Sample location:

Sample20 was taken from raised scroll design visible underneath 1830s white paint (19 III m Base board). The aim of sampling was to identify original paint if present below later layers.

Sample location photograph (*below*):



Sample 20 photographed in cross-section under reflected light at 100x magnification. (Printed magnification not calculated).

The sample shows two layers of white lead paint. The upper layer is clearly separated from the lower by an intermittent medium rich layer. Backscattered SEM images also show a marked difference in the particle sizes of the upper and lower layers. The lower layer is composed mainly of lead white but also contains a few carbon black and iron oxide yellow pigment particles.

Sample 21 (3068)

Sample location:

Sample 21 was taken from the collar of the archbishop (22 III a Lozenge) — from a fragment of green paint within area of paint loss on collar. The aim of sampling was to identify original paint if present.

Sample location photograph (*below*):

In dispersion particles of yellow ochre, calcium carbonate and a blue copper pigment can be seen. In section, the blue copper pigment looks like azurite, and the red-brown particles of cuprite confirm this identification. In dispersion some particles do resemble azurite, but the majority has undergone change to other copper salts.[12]

SEM.EDX of a pigment particle near the upper surface of the green paint gives peaks for copper and chlorine: suggestive of the alteration to a copper chloride identified by previous studies.[13]

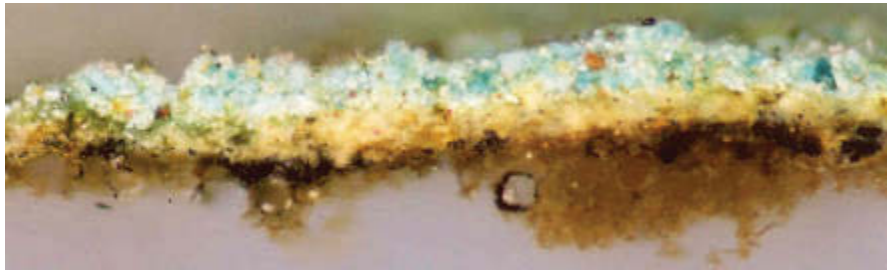
Barytes was detected by SEM.EDX in one area of the sample and this might suggest a nineteenth century date for the layer. However, it is not generally present in the sample – it may be contamination from a later paint.

SEM.EDX also detects arsenic within the mixed green layer, although in dispersion neither orpiment, realgar or Emerald Green were visible. The origin of the arsenic (confirmed by two separate SEM.EDX analyses) remains elusive.

See following page for cross-section photomicrograph.

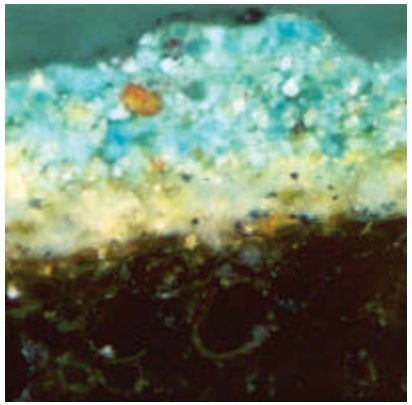
[12] I am grateful to Catherine Hassall for undertaking PLM.
[13] Howard, H., 'Peterborough Cathedral, nave ceiling: Scientific examination of the original decoration', unpublished report, Conservation of Wall Painting Department, Courtauld Institute of Art, 1997, pp.4-5.

Sample 21 cross-section photomicrograph (*below*):



Sample 21 photographed in cross-section under reflected light at 100x magnification. (Printed magnification not calculated.)

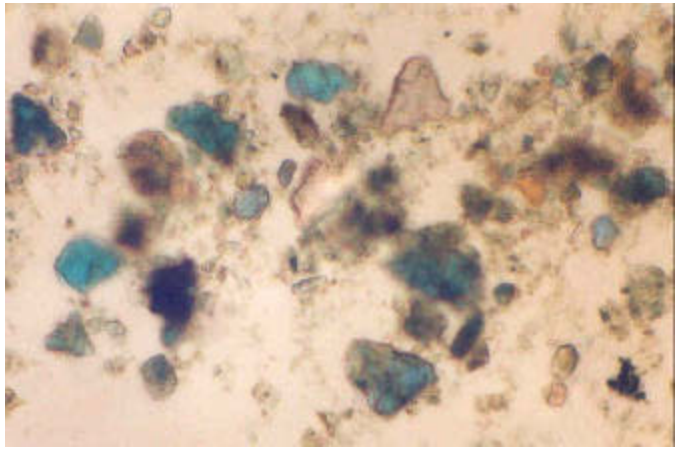
Detail of sample 21 cross-section photomicrograph (*below*):



Sample photographed in cross-section under reflected light at 200x magnification. (Printed magnification not calculated).

- Green layer is azurite with calcium carbonate and yellow ochre.
- Has similar appearance to 2108 and 2115 where Howard (1997) identified natural azurite is mixed with yellow ochre over a lead white ground.
- Arsenic detected by two separate SEM.EDX analyses although origin is elusive – no arsenic containing pigments were visible in dispersions.
- Ground contains natural chalk and lead white.
- Dark underdrawing? Carbon black
- Barytes identified by SEM.EDX in one area, which is suggestive of a nineteenth century date or contamination with overpaint.

Paint dispersion from the green layer in sample 21 photographed in transmitted light at 200x magnification. (Printed magnification not calculated.)



Sample 22 (3069)

Sample location:

Sample 22 was taken from the central lozenge board (21 III a Lozenge) which appears to be without 1830s overpaint — it was assumed that the sample was through 1740s blue/green paint.

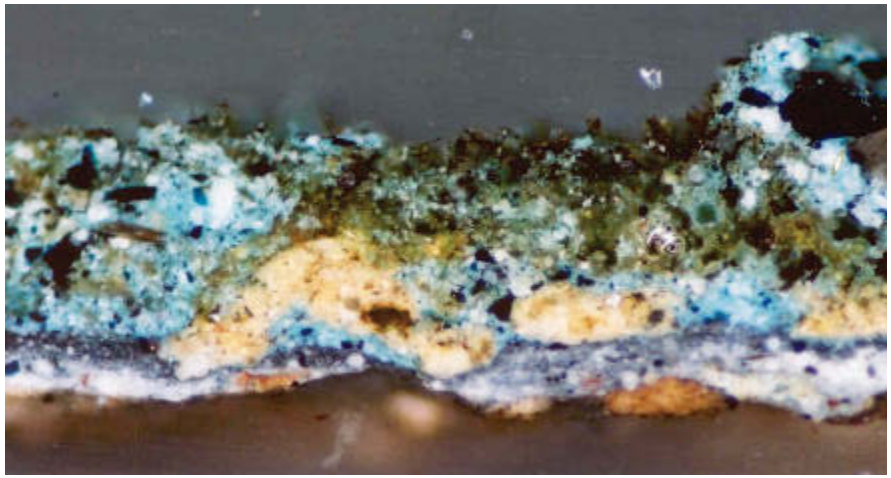
Sample location photograph (*below*):

The sample shows a complex build up of paint layers. The surface layer contains large blue particles which have been identified as Prussian blue. The presence of aluminium, potassium and sulphur (detected by SEM.EDX) together with iron is strongly suggestive of the use of alum (potassium aluminium sulphate) in the production of the pigment. This historic production method has been associated with relatively large particle size and may be considered typical of early eighteenth century Prussian blue.[14] The blue paint contains Prussian blue, lead white and carbon black.
A translucent greenish brown layer, which is partially intermingled with the blue paint, contains copper, probably from basic verdigris. However a small amount of barium and sulphate have been detected together by SEM.EDX, suggesting the presence of barytes within this layer. On first examination the green layer appears to be associated with the Prussian blue paint, however the Prussian blue layer is itself quite disrupted and it is possible that a later paint application has seeped into the voids.
A yellow coloured paint, intermingled with the blue, contains lead white and iron oxides.
Below these layers is a separate dark grey layer, which contains Prussian blue, lead white and some carbon black. Underlining this is a light grey layer is lead white and carbon black. The fragmentary layer of light brown paint at the base of the sample appears to comprise iron oxides and lead white.
SEM.EDX also detected calcium and sulphur together in several locations throughout the sample. This confirms findings of previous studies that have identified calcium sulphate at different concentrations throughout the paint layer.

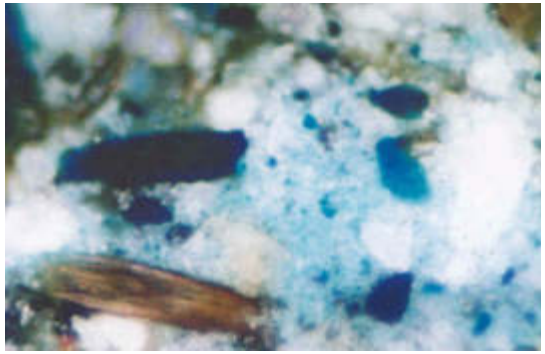
See following page for cross-section photomicrograph.

[14] Welsh, F., 'Particle characteristics of Prussian Blue in an historical oil paint', JAIC 27 (1988): 55- 63.

Sample 22 cross-section photomicrograph (*below*):



Sample 22 photographed in cross-section under reflected light at 100x magnification. (Printed magnification not calculated.)



Area shown as detail is visible to the upper left of 100x image.

Detail of sample 22 photographed in cross-section under reflected light at 500x magnification. (Printed magnification not calculated.)

- SEM.EDX spectra from large blue particles confirm the presence of iron which is indicative of Prussian blue. Interestingly aluminium, potassium and sulphur was also detected. This is strongly suggestive of the use of alum (potassium aluminium sulphate) in the production of the pigment. This historic production method has been associated with relatively large particle size and may be considered typical of early eighteenth century Prussian blue. The blue paint contains Prussian blue, lead white and carbon black.
- Translucent greenish brown layer contains copper, probably from basic verdigris. However a small amount of barium and sulphate have been detected together by SEM.EDX, suggesting the presence of barytes within this layer. On first examination the green layer appears to be associated with the Prussian blue paint, however the Prussian blue layer is itself quite disrupted and it is possible that a later paint application has seeped into the voids.
- SEM.EDX detected calcium and sulphur together in several locations throughout the sample
- The yellow coloured paint contains lead white and iron oxides
- Dark grey layer is Prussian blue, lead white and some carbon black
- Light grey layer is lead white and carbon black
- Fragmentary brown appears to contain iron oxides and lead white