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PETERBOROUGH CATHEDRAL: THE NAVE CEILING

PHASE 5: ROWS 0 - 7

MAY - OCTOBER 2003

CONDITION SURVEY AND CONSERVATION TREATMENT

VOLUME I TEXT AND GRAPHICS

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ABSTRACT

This report is a record of treatment carried out from May/October 2003 to Bays 9 and 10 of the Nave Ceiling: *Panels 0/7 I/II/III/IV,* associated Ashlar and West End Vertical Boards. Included in this report is a detailed written, graphic and photographic condition survey and treatment record of both the Ceiling structure and painted decoration; references to previous recorded treatment and investigations; a record of tests conducted as a preliminary to this treatment phase; and observations and findings made during the condition survey and treatment.

ACKNOWLEDGEMENTS

The Perry Lithgow Partnership and Hugh Harrison wish to thank the Dean and Chapter of Peterborough Cathedral and English Heritage for their enthusiasm and commitment throughout the Nave Ceiling Conservation Project.

As for previous Phases we are grateful to the Project Team whose members have directed and advised on all aspects of the works; in particular, to Julian Limentani, Cathedral Architect to the Dean and Chapter. Gillian Lewis, Consultant Conservator to the Cathedral has given invaluable guidance and practical support throughout. The research carried out by Donald Mackreth, Cathedral Archaeologist, and Paul Binski, Art Historian, has contributed significantly to our understanding of the Ceiling structure and the painted scheme.

The paint sample analysis and dendrochronological investigations have been central to this project. We would like to thank both Jane Davies, of Jane Davies Conservation and Cathy Groves of the Sheffield Dendrochronology Laboratory, University of Sheffield and Dr Brian Gilmour of the Archaeo-Metallurgy Group, Dept. of Materials, University of Oxford for their continuing collaboration.

The graphic documentation for the technical survey is based on photogrammetric drawings of the underside of the Ceiling plotted by Photarc Ltd, images provided by the English Heritage Survey Team and a plan of the ceiling structure, upper side created by Bill Blake of English Heritage Survey Team using a Reflectorless EDM (Electromagnetic Distance Meter). The work carried out by Bill Blake and the ready support provided by Paul Bryan and the rest of his Survey Team has been crucial. We are immensely grateful for their co-operation.

List of Project Team members for Phase 5:

Julian Limentani, Don Mackreth, Gillian Lewis, David Goode, Robert Gowing, Ian Harper, Helen Howard, Paul Binski, Tobit Curteis, Paul Bryan, Sharon Cather, Catherine Groves, John Ward, Linda Monckton, the Perry Lithgow Partnership, Hugh Harrison.

WEST

0/I	0/II	0/III	0/IV
1/I	1/II	1/III	1/IV
2/I	2/II	2/III	2/IV
3/I	3/II	3/III	3/IV
4/I	4/II	4/III	4/IV
5/I	5 /II	5/III	5/IV
6/I	6/II	6/III	6/IV
7/I	7/II	7/III	7/IV
8/I	8/II	8/III	8/IV
9/I	9/II	9/III	9/IV
10/I	10/II	10/III	10/IV
11/I	11/II	11/III	11/IV
12/I	12/II	12/III	12/IV
13/I	13/II	13/III	13/IV
14/I	14/II	14/III	14/IV
15/I	15 /II	15/III	15/IV
16/I	16/II	16/III	16/IV
17/I	17/II	17/III	17/IV
18/I	18/II	18/III	18/IV
19/I	19/II	19/III	19/IV
20/I	20/II	20/III	20/IV
21/I	21/II	21/III	21/IV
22/I	22/II	22/III	22/IV
23/I	23/II	23/III	23/IV
24/I	24/II	24/III	24/IV
25/I	25 /II	25/III	25/IV
26/I	26/II	26/III	26/IV
27/I	27/II	27/III	27/IV
28/I	28/II	28/III	28/IV
29/I	29/II	29/III	29/IV
30/I	30/II	30/III	30/IV
31/I	31/II	31/III	31/IV
32/I	32/II	32/III	32/IV
33/I	33/II	33/III	33/IV
34/I	34/II	34/III	34/IV
35/I	35 /II	35/III	35/IV
36/I	36/II	36/III	36/IV
37/I	37/II	37/III	37/IV
38/I	38/II	38/III	38/IV
39/I	39/II	39/III	39/IV

NORTH

SOUTH

EAST

Figure 1. *Plan of the Nave Ceiling indicating Bays 9 and 10 and illustration of Bays 9 and 10 after the Phase 5 works*

PART 1: INTRODUCTION

1.1. THE NAVE CEILING PROJECT

The Phase 5 works described in this report, involving the westernmost two bays (20% of the ceiling), were originally scheduled for 2002 but had to be postponed for a year following a fire in the Cathedral on 22 November 2001. The Nave Ceiling conservation project was initiated in 1997 with treatment tests and holding repair works carried out in two sections of the Ceiling. From 1998 onwards the works proceeded in annual phases starting at the east end (Bay 1).

The fire occurred two weeks after completion of Phase 4. The blaze was confined to the east end of the North Aisle which was used as a storage area for stacks of polypropylene chairs. A verger fortuitously spotted the blaze, some 15 minutes before smoke detectors activated, allowing a speedy response by the Fire Brigade. The fabric and objects within Bay 1 of the North Aisle sustained considerable physical damage. Everything else in the Cathedral was coated with a veil of soot.

The restoration of fire damage to Bays 1-8 of the Nave Ceiling – the areas previously conserved during Phases 1-4 – was carried out between May and September 2002. The one benefit resulting from the need to re-clean the Ceiling was that it allowed us to revisit the eastern bays and to carry out additional investigations, recording and treatment in the light of knowledge gained during latter phases. These works are the subject of a separate report.[1] The removal of soot from Bays 9 and 10 of the Ceiling was incorporated into the Phase 5 works.

1.2. SCOPE OF PHASE 5

To continue on from and complete the recording and treatment works carried out in 1998 (Phase 1 – Bay 1[2]), 1999 (Phase 2 – Bays 2 and 3[3]), 2000 (Phase 3 – Bays 4, 5 and 6a[4]) and 2001 (Phase 4 – Bays 6b, 7 and 8[5]). Phase 5 works were confined to the two western Ceiling Bays (9 and 10) including Ceiling panels *(0-7 I/II/III/IV)*[6] north and south vertical Ashlar boards (*0-7),* the West End Vertical Boards and associated Ceiling structure.

1.3. OBJECTIVES

Documentation

- Carry out full documentation of the conditions of the ceiling and its support structure.
- Record all details of the work carried out.

Monitoring and maintenance

- Monitor the condition while the work is being carried out
- Monitor the environmental condition and light levels
- Provide on-going maintenance recommendations.

Investigations

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[1] *Peterborough Cathedral, The Nave Ceiling: Fire Damage Restoration & Additional Investigations and Treatment, May – September 2002* The Perry Lithgow Partnership and Hugh Harrison

[2] *Peterborough Cathedral: The Nave Ceiling, Phase 1: rows 36 – 40. Condition Survey and Conservation Treatment, January – June 1998, Vols. I, II & 3.* The Perry Lithgow Partnership and Hugh Harrison.

[3] *Peterborough Cathedral: The Nave Ceiling, Phase 2: rows 28 – 35. Condition Survey and Conservation Treatment, May – July 1999, Vols. I, II & 3.* The Perry Lithgow Partnership and Hugh Harrison.

[4] *Peterborough Cathedral: The Nave Ceiling, Phase 3: rows 18 – 27. Condition Survey and Conservation Treatment, May – October 2000, Vols. I, II & 3.* The Perry Lithgow Partnership and Hugh Harrison.

[5] *Peterborough Cathedral: The Nave Ceiling, Phase 4: rows 8 – 17. Condition Survey and Conservation Treatment, May – October 2001, Vols. I, II & 3.* The Perry Lithgow Partnership and Hugh Harrison.

[6] These reference numbers refer to Nave Ceiling panels identified in **Figure 1.** Plan of the Nave Ceiling.

- Investigate the underpaint to the original boards.
- Investigate the underpaints of the grooved boards and the wave pattern boards.
- Examine and check the support structure.
- Investigate the wear back/carving to the original boards.
- Investigate the dating of the softwoods. Complete the investigation on the nails.
- Investigate the residues in the open grain of the oak boards and the cause of the open grains.
- Investigate any coatings to the paint and boards, if found. To facilitate research by other Team Members including: Dendrochronology; Video Production; Paint Sampling; Environmental Monitoring; Micro-movement Monitoring.
- **Interventions**
- Resecure the paint.
- Remove the glue from the painted surfaces
- Refix the boards that require support
- Treat the bolts
- Remove unnecessary screws and treat the remainder
- Consolidate the damaged timber
- Remove soot from the painted surfaces and from the ceiling structure above
- Remove the grime from the painted surfaces
- insert areas of board to maintain continuity of the overall design.

Outreach

- Assist with film recording
- Assist with compiling the update on works carried out in Phase 4 for general circulation

1.4. CONSERVATORS

Treatment of the Ceiling boards and Ceiling structure was carried out by Hugh Harrison - Ringcombe Farm, West Anstey, South Molton, Devon EX36 3NZ - and his team: Bob Chappell, Cameron Stewart, Peter Ferguson RIBA,

Richard Lithgow and Mark Perry of the Perry Lithgow Partnership, 1 Langston Lane, Station Road, Kingham, OXON OX7 6UW carried out treatment of the painted decoration. Assistant conservator - Peter Martindale, Louise Bradshaw, Cristina Beretta, Bianca Madden, Greg Howarth, Natalia Seggerman, Sasa Kosinova, Sarah Livermore.

1.5 DOCUMENTATION

Richard Lithgow and Hugh Harrison have collaborated in compiling this document. All sections relating to the Ceiling structure have been written by Hugh Harrison; sections relating to the painted decoration by Richard Lithgow.

From the start the Project Team were aware of the need for continuity throughout the phased programme of works. The intention was to devise recording formats and treatment methods that would be consistent across the Ceiling and in the early stages every effort was made to achieve this. Nevertheless, as the phases progressed and we learned more about the original techniques and subsequent interventions, there was a need to modify the categories of information recorded as part of the condition survey and make some minor changes in our approach to treatment. The fire in 2001 provided an unexpected opportunity to revisit the eastern part of the ceiling, allowing us to bring into line the technical survey documentation and treatment of that area with the later phases and as presented for Bays 9 and 10 in this document.

The principle objective throughout the project has been to gather and record as much information as possible about the Ceiling structure and painted decoration. The emphasis has been on the collection rather than the display of information. An enormous amount of data is now available in written and graphic formats, not all of which is presented in this report. All such additional data has been submitted to the documentation co-ordinator for this project on hard copy or CD-ROM and shall be entered into the project database.

1.5.1 Graphic Record

A detailed graphic record has been made of the Ceiling structure upper side. The location of all elements of the structure and interventions made during this phase of treatment have been plotted onto photogrammetric plans of the Bays 9 and 10. Similar graphic records have been generated of the Ceiling structure lower side: these locate all visible fixings and previous alterations. For the condition survey of both the structure and the painted decoration categories of damage and deterioration have been plotted onto the photogrammetric plans: the individual panels and vertical Ashlar boards at either 10:1 or 15:1 scale). For the treatment record all interventions made during this phase have been similarly plotted and identified. All this information has been transferred onto overall plans of Bays 9 and 10 and has been reproduced at either 50:1 or 35:1 scale in Part 13 of this report.

As an aid to reference, the graphics for the lower side of the Ceiling have been plotted over photographic images of Bays 9 and 10, individual panels, Ashlar and West End Vertical boards[7].

The graphic record has been digitised so that any combination of categories may be generated in any format on overall plans of Bays 9 and 10 or on plans of the individual panels. Parts 1 to 12 of this report - as well as the graphics containing some 30 categories of damage and treatment - have been put onto CD-ROM. A copy of the disk, along with all source material associated with Phase 5, has been submitted to the documentation co-ordinator for this project.

1.5.2 Written Record

To compliment the graphic records many aspects of the construction and condition of the Ceiling boards have been recorded for each Ceiling panel. (see example in **Appendix 6**). Information relating to the structure includes: wood type, measurements and shape, joints, displacement, interventions, forms of insect damage and decay. Similarly a board by board condition survey of the paint has been drawn up (see examples in **Appendix 7**). This records the decoration on each board, visible underpaint, surface accretions and alterations to the paint surface as well as descriptions of damage and deterioration. These board by board surveys of the Ceiling structure and painted decoration have been recorded as tabulated data using the Microsoft Excel spreadsheet programme. They are to be transferred to the Microsoft Access project database set up by Tobit Curteis.

To ensure the documentation has remained consistent throughout the project we developed a glossary of categories, terms and definitions relating to all elements of the structure and condition of the Ceiling. This glossary is reproduced in **Appendix 8** of this report. Copies of the glossary and other statements defining the recording process were given to all members of the Perry Lithgow Partnership/Hugh Harrison Team. The team members communicate and collaborate throughout the recording process to ensure consistency.

1.5.3 Photographic Record

The photographic record includes identical sets of colour transparencies and prints. In an effort to keep the number of record photographs for this phase within manageable proportions the following strategy was adopted:

[7] Images taken from photographs used by English Heritage Survey Team as part of the photogrammetric survey.

All areas were photographed from the scaffolding, both before and after treatment using moderately angled flashlight. The larger, horizontal panels *(II/III)* are covered by three photographs each, the canted panels *(I/II)* by two. The 10 full and 4 half-figurative lozenges included in Phase 5 were photographed as individual objects. Each figurative lozenge crosses over 4 panels.

Examples of deterioration and phenomena categorised in the graphic and written records have been photographed repeatedly in different lighting conditions before, during and after treatment. The area covered by each photograph and the lighting conditions employed are recorded on reference sheets (see example in **Appendix 2**). In addition, the Plate Reference Sheets in Volume II locate the area of the Ceiling covered by each photograph.

1.6. PARALLEL INVESTIGATIONS AND WORKS

The condition survey and treatment completed over Phases 1 - 5 and recorded in this document is only a part of a comprehensive, ongoing investigation of the Nave Ceiling undertaken by the Project Team and others.

- Photogrammetric survey - English Heritage Survey Team and Photarc Ltd.
- Dendrocronology – Cathy Groves, Sheffield Dendrochronology Laboratory, University of Sheffield.
- Paint sample analysis - Helen Howard and Dr Ioanna Kakoulli, Conservation of Wall Paintings Department, Courtauld Institute of Art. Jane Davies, Jane Davies Conservation.
- Analysis of nails – Dr Brian Gilmour The Archaeo-Metallurgy Group, Dept. of Materials, University of Oxford
- Analysis of microbiological growth – Dr Brian Ridout, Brian Ridout Associate
- Environmental monitoring – Tobit Curteis, Tobit Curteis Associates
- Archaeological survey - Donald Mackreth, Cathedral Archaeologist
- Art historical research – Professor Paul Binski, Art Historian, Cambridge University
- Timber Analysis - Dr Al Brewer, Royal Paintings Collection, Windsor Castle

Aspects of these investigations and research are referred to in this document; although, the findings are presented as separate reports by the specialists concerned.

PART 2: DESCRIPTION OF THE NAVE CEILING

2.1. GENERAL

The wooden Nave Ceiling at Peterborough is an extremely important survival. There are three Ceilings of comparable age in Europe but all are smaller: St Martin's, Zillis in Switzerland (c. 1150); St Michael's, Hildesheim in Germany (c. 1200); Dädesjö, Småland in Sweden (c. 1275). Binski[8] suggests: '*The painted wooden ceiling of Peterborough Abbey is the largest surviving example of its type from the Middle Ages, easily surpassing in scale those in Switzerland, Germany and Scandinavia to which it is sometimes compared. ..... It stands with a very few other 13th-century English instances of painted vault or ceiling decoration: the paintings of c. 1220 formerly on the vaults of the Trinity Chapel at Canterbury Cathedral; the overpainted mid 13th-century choir and presbytery vaults at Salisbury Cathedral; the late 13th-century wooden painted vaults of the presbytery at St Albans Abbey; the Chapterhouse vault at York Minster; and in the secular domain, the ceiling of the Painted Chamber in the Palace of Westminster* .'

[8] Paul Binski, Cambridge, 1999.

The church at Dädesjö was visited in the course of the Compotec visit to Sweden in May 2000 and the construction of the ceiling and roof examined and recorded, see **Appendix 17**.

Whilst visiting our Compotec colleagues in Oslo, we took the opportunity to examine the Viking Ship Museum. The fixing of the boards to the frames is with wide headed nails as at Peterborough, and there is a grooved detail at the edge of the boards which is loosely reflected at Peterborough. This edge groove was also noticed on many occasions on joinery in stave churches, especially Torpu. (Here the groove is often picked out in black).

There are two basic aspects of the woodwork at Peterborough which seem stand out from any other work of this type at this date. The first is the use of the clinker technique to fix the boards, and the second is the even more basic question, which is the use of the lozenge design. The clinker technique produces a sculptural treatment which is extraordinary. It may, of course, be no more than expediency, as this technique is the easiest way to use tapered boards. The clinker technique is also cheap, as the boards only need one straight edge, and they do not need to be flat or true. This technique may also have been used because the carpenters were otherwise, or had experience of boat building. Don Mackreth refers to Abbot Godfrey de Croyland (Abbott at Peterborough 1299) presenting a "great ship" to the king[9]. It is likely that there was a substantial ship building trade in the area; shipwrights are skilled men at laying planks, so this ceiling at the Abbey would be a natural extension to their normal work.

So if the use of the clinker technique was chosen merely for practical reasons, then the edge details of the boards and the special shaping of the central lozenge boards shows a noteworthy concern for appearance, and a new technique for the shipwrights.

The lozenge design although looking very simple to construct does actually require extraordinary intensive attention to detail. Every board has to be mitred at both ends, not with one repetitive mitre, but with two different length mitres, a long and a short mitre. The mitres are further complicated by being cut in boards that meet each other at an angle from the horizontal as they are clinker built and not lying flat in the same plane as the ceiling. At the change of angle of the ceiling the mitres are even more complicated being angled both ways. In addition with every variation in length and particularly width of a panel constituting a quarter of a lozenge (Row 13 is 1544mm wide but Row 9 is 103mm wider), the lengths of all the boards are different, and so therefore would be the angle of the mitre.

All the boards have been chamfered and shaped to produce a tight joint with the adjoining board in addition to the general taper. This means that in practice, every board has to be offered up, marked, cut on a bench, fitted to its neighbour, mitres cut and fitted and then offered up into the ceiling.

It is certainly recommended that the use of the lozenge design and the clinker technique should be reviewed as part of the Final Report.

The dendrochronological analysis by Cathy Groves[10] for this Phase indicates that the oak boards are clearly of northern German origin and were felled in the late AD 1230s or 40s. The date of use of the boards is likely to be within the same period as the felling date range or possibly a few years after the latest felling year. This phase of analysis has not carried on the trend of pushing the earliest possible date for construction of the painted ceiling slightly further forward in time as has happened previously.

The overall chronology has now been extended back to AD 944 indicating that the boards were being derived from trees over 300 years old when felled. These boards are the earliest group of deliberately imported timbers analysed in Britain. They pre-date the period of extensive export of timber through the German Hanse, in the form of oak planking, from the eastern Baltic region,

[9] Unpublished letter to Julian Limentani 14 July 2000, and extract from *Excavations in Peterborough 1972-1982* D F Mackreth Unpublished

[10] Letter from Cathy Groves, University of Sheffield, 19 September 2001 to Julian Limentani

during the early-fourteenth century to around AD 1650. They are thus a valuable addition to the growing body of information concerning the evolution of the timber trade in Europe.

2.2. MEASUREMENTS

- Nave Ceiling: 204 ft (62.2 m) x 35 ft (10.7 m)
- Horizontal panels within rows (II/III): 11-ft (3.35 m) x 5 ft 3 ins (1.61 m).
- 45° canted panels in the outer rows (I/IV): 8 ft 5 ins (2.56 m) x 5 ft 3 ins (1.61 m).
- Central lozenges (boards within the key -pattern): 7 ft 7 ins (2.31 m) x 3 ft 9 ins (1.15 m).
- Outer canted lozenges: 5 ft 9 ins (1.76 m) x 3 ft 5 ins (1.05 m).
- The vertical Ashlar boards running the length of the Nave immediately beneath the Ceiling on the north and south walls: 19 ins (0.48 m) high .

2.3. ROOF STRUCTURE

2.3.1 Original Structure Drawing 1[11]

The chronology of the early roof structures has never been discussed in any previous report. Don Mackreth[12] has now presented his paper on the construction of the cathedral at this time, from which we have produced a resumé on the roof structure alone.

- William be Waterville(1155-1175) covered Bay 1 of the nave with a flat ceiling probably under a queen post truss roof as he had done in the transepts.

- Benedict (1177-1193) completed the nave up to bay 9 presumably finishing it with de Waterville's flat ceiling[13]. Very shortly afterwards, Benedict decided to discard this old fashioned design for a stone vault which necessitated removing the old flat ceiling and roof above and erecting a new roof scissor brace roof which would accommodate the peaks of the vault masonry. He completed this to bay 9.

- Robert de Lindsey (sacristan and master of works?-1214, abbot 1214-1222) must have completed bay 10 and the vault early in his time at Peterborough.

- The vault fails and is taken out in the 1230s at which time the boarded ceiling is inserted.

Something curious seems to have occurred in the roof of Bay 10 as the two centre panels II and III progressively become wider from row 4 to row 0 by 13" (330mm). This is happening as the span between the walls decreases by approx 5" (125mm). The latter is accountable by the end of the bulge; however, the widening of the centre panels is unaccountable. There is no perceptible lowering of the flat ceiling panels, nor steepening of the sloping joists both criteria that would explain the wider panels. It should also be noted that the sloping ceiling panels are significantly shorter in row 0 than row 7 (16" [410mm] on the north side and 8" [200mm] on the south side).

The only further thoughts on the history and design of this roof hypothesise on the unusual design of the Peterborough scissor brace roof. All illustrations known to the writer show scissor brace roofs to be more like that over the N.W.Portico with a substantial length between the joint of the scissor brace with the common rafter and the foot of the rafter. The very low junction of scissor brace with the common rafter allied with a very low collar suggests a positive effort by the roof designer to minimise the thrust effect of the roof. There must have been a concern at inserting a stone vault in the unbuttressed upper nave walls, and this roof design may have been a deliberate response.

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[11] All drawings can be found at the end of Section 3

[12] *The Building of the Nave and the West Ends*. D Mackreth October 2004

[13] **Appendix 18** *Longitudinal section of the Cathedral* by J. Bridges 1791 highlights the disruption at the beginning of bay 9.

From Phase 3 onwards, considerable attention has been paid to the appearance of the boards on the sloping ceilings ending short of the ashlar panels, see **Plate 1**. This was previously attributed to accommodating the extra width of the ceiling where it spans the bulge in the clerestory walls. The span of the walls has been measured and recorded and for the sake of continuity the complete set of measurements are shown below.

Row 40	35' 1"	10.694m
Row 31	35' 11"	10.952m
Row 17	35' 10"	10.922m
Row 8	35' 5"	10.803m
Row 0	34' 8"	10.580m

Measurements of complete sets of original joists were taken to see if they expanded in line with the measurements for the bulge but the figures were not sufficiently accurate and could not be completed because no original sets of joists are found at the west end of the ceiling in this Phase. The reason so much attention was paid to this phenomenon is that in the absence of any other concrete evidence, potentially this information might have told us when this ceiling was made in relation to the date of the bulge in the nave walls. It might also have helped inform us as to whether the design of the present ceiling was coincidental on the shape of an existing roof structure, or whether a new roof was built to provide the particular shape of the present ceiling. The haphazard completion line to the bottom of the sloping sides (shown in **Figure 5**) must therefore remain open to speculation.

Two drawings of the roof from the early 19th C. survive, one by Charles Ware in 1805 (see **Figure 2**), the other by H. Ansted which was published in Britten's *History and Antiquities of Peterborough Cathedral* in 1828 (see **Figure 3**). This latter was made from site drawings by R. Cattermole. It has been said that Ansted's drawings formed part of the survey drawings made for the Cathedral architect at the time, Edward Blore. Both drawings show what is basically a scissor brace roof, but Ansted shows the painted ceiling attached to separate lower sloping joists which are quite distinct from the scissor braces. Perhaps more interestingly, neither drawing shows the Ashlar boarding or any space for it. Of the two drawings, that by Ansted has the most inaccuracies compared

None of the original roof survives other than as individual components reused in later reconstructions. The discovery in this phase of stones in the east wall of the north west tower showing the angle of (presumably) the original roof is interesting, (see **Plates 26, 27**), and these have been recorded in **Figure 4**.

Throughout the roof a substantial number of reused timbers are found, presumably from the original roof[14], some with carpenters' numbers. The re-used timbers were measured and those with sufficient constructional details have been recorded on **Drawing 2.** These timbers were also carefully projected onto the reconstruction study (**Drawing 1**) for the original roof, allowing also for the adjusted pitch measured from the surviving sloping string course discovered embedded in the S.E. corner of the N.W. Transept Tower wall. Results obtained were inconclusive for replacement sloping joist 73 south and ceiling joist 81, but an excellent match was obtained for sloping joist 71 south, and this is shown on **Drawing 1**. However, this must remain tentative.

[14] Dean and Chapter Audit Accounts NRO Box 5053, Bundle 2, 1834-1837; bundle (4) Audit Accounts 1836, Item "Stripping off old Boarding with Rafters and Principals of Roof…..Sawing old Timber into common Rafters, Bearers etc."

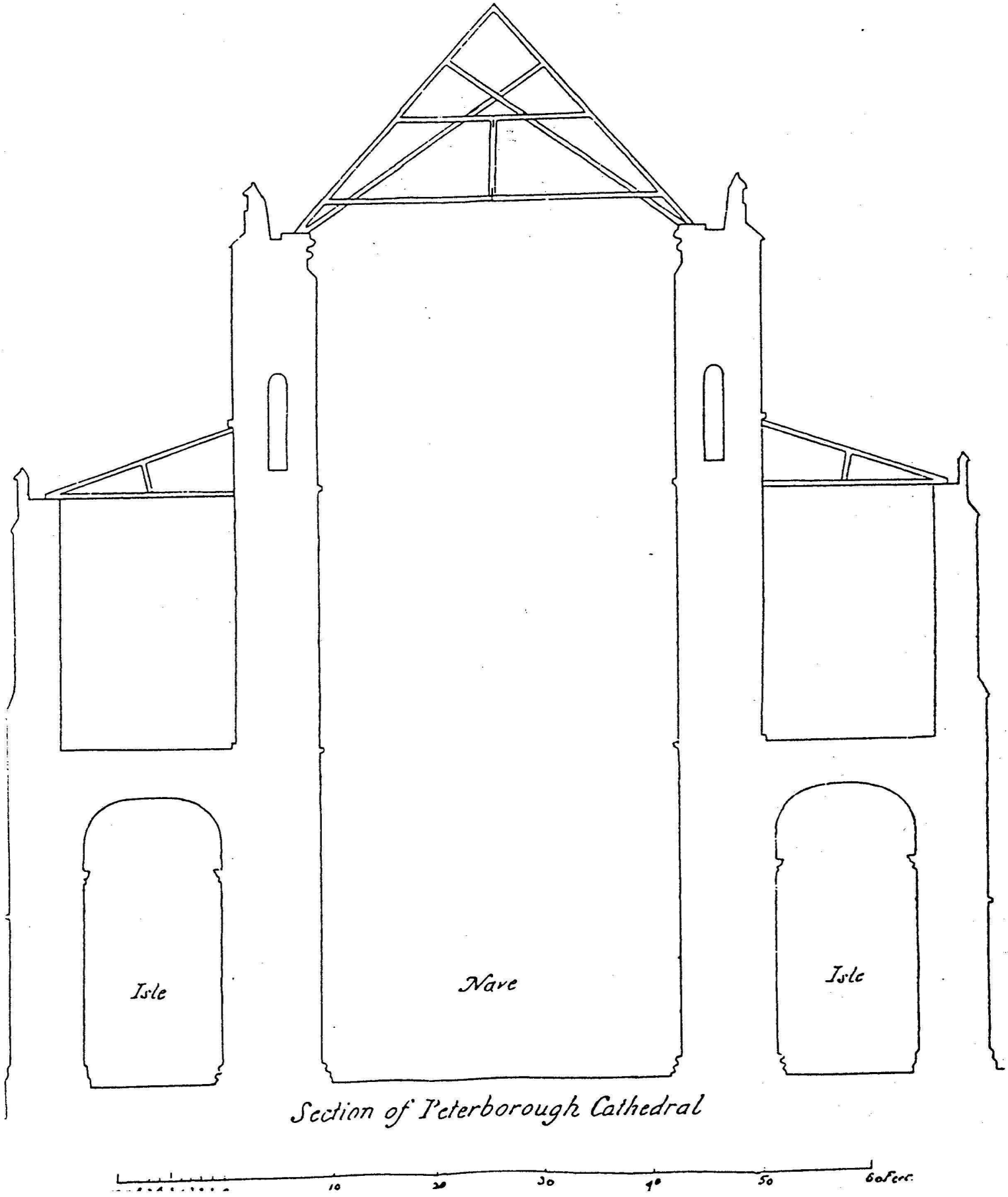

Figure 2. *Section of Peterborough Cathedral - Drawing by Samuel Ware, ca. 1805*

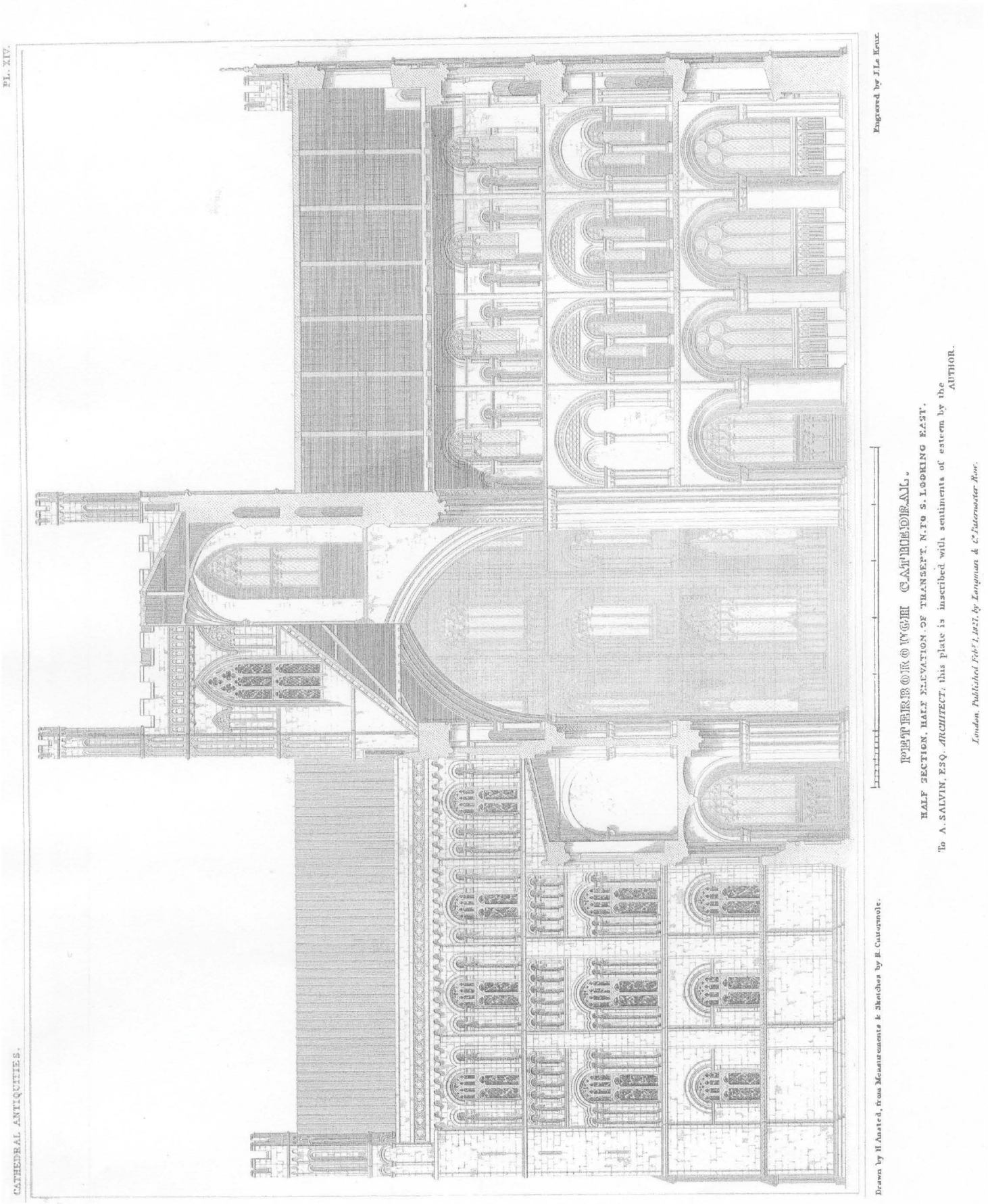

Figure 3. *Half section , half elevation of Transept, N to S looking East - Drawing by H. Ansted, ca. 1828*

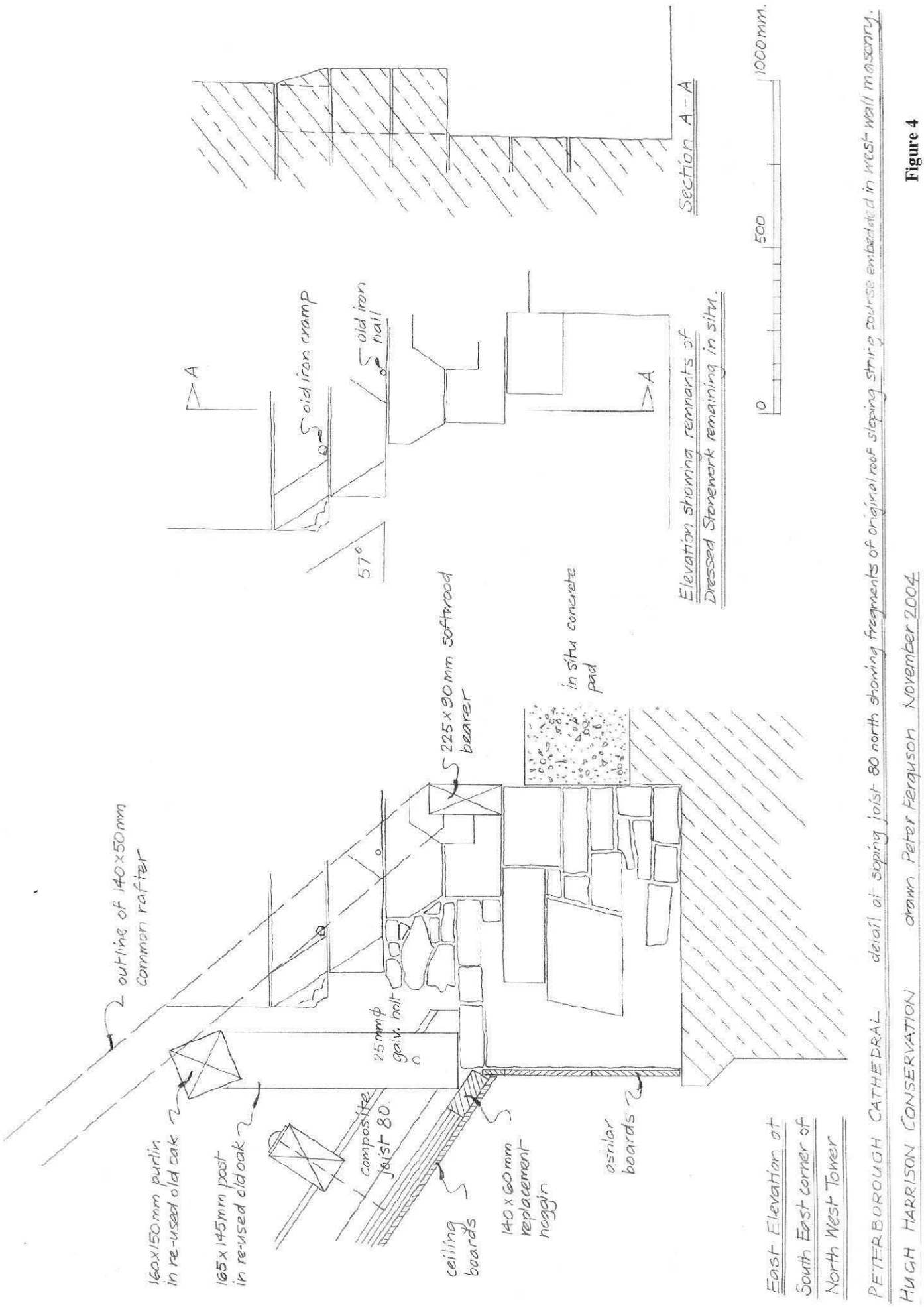
outline of 140x50mm common rafter
160x150mm purlin in re-used old oak
165x145mm post in re-used old oak
25mm ϕ gal. bolt
composite joist 80.
ceiling boards
140x60mm replacement noggin
ashlar boards
225x90mm softwood bearer
in situ concrete pad
old iron cramp
old iron nail
57°
A
A
Elevation showing remnants of Dressed Stonework remaining in situ.
Section A-A
0
500
1000mm.
East Elevation at South East corner of North West Tower
PETERBOROUGH CATHEDRAL detail of sloping joist 80 north showing fragments of original roof sloping string course embedded in west wall masonry.
HUGH HARRISON CONSERVATION drawn Peter Ferguson November 2004

Figure 4

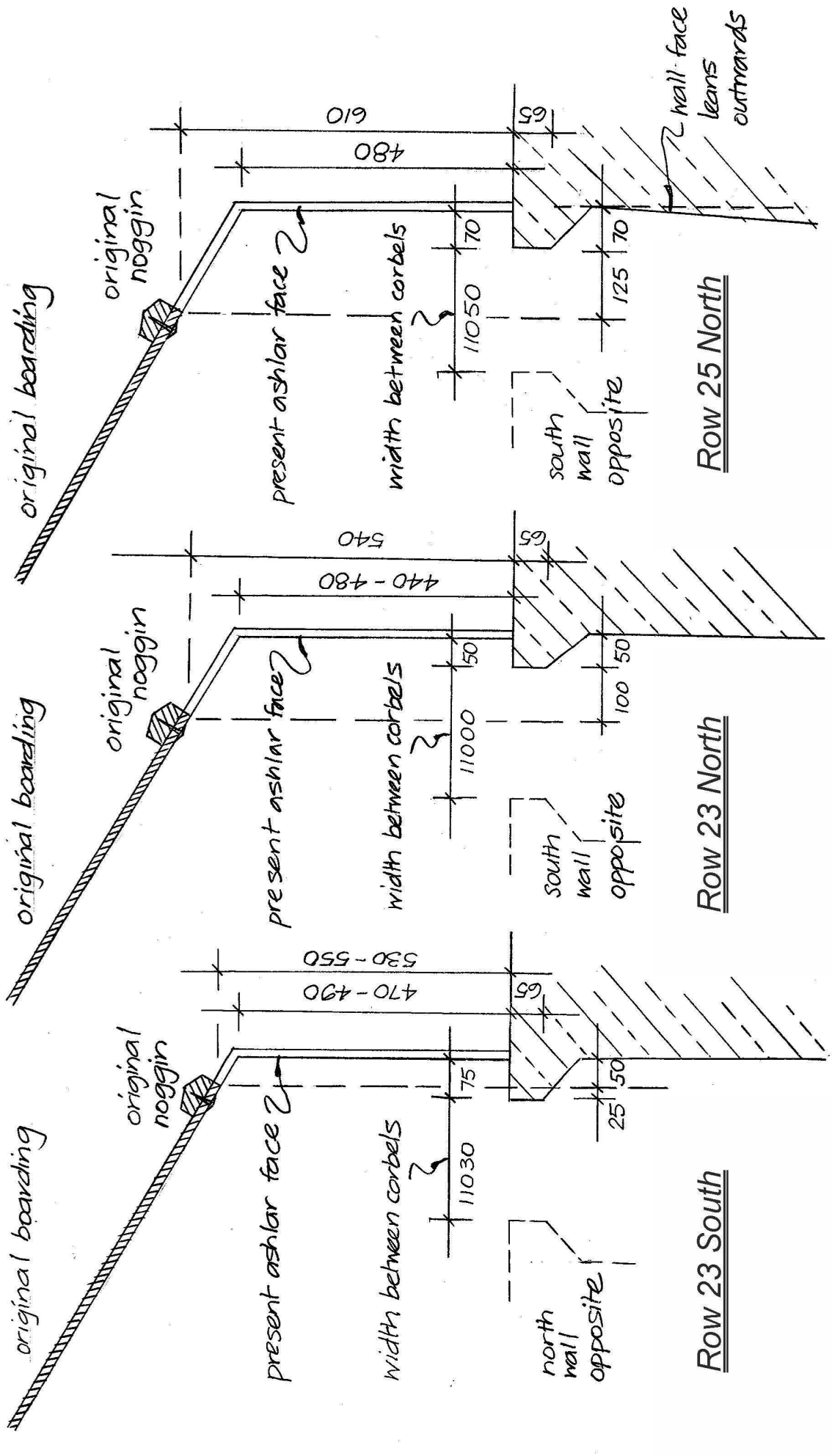
original boarding
original noggin
present ashlar face
width between corbels
south wall opposite
north wall opposite
wall face leans outwards
Row 25 North
Row 23 North
Row 23 South
610
480
540
440 - 480
530 - 550
470 - 490
65
70
125
50
100
75
25
11050
11000
11030
PETERBOROUGH CATHEDRAL Details at Junction of Sloping Joists and Ashlar Posts
HUGH HARRISON CONSERVATION drawn Peter Ferguson April 2001

Figure 5.

English Heritage has submitted two speculative reconstruction drawings based on the existing geometry of the surviving ceiling timbers and the geometry of the scissor brace roof in the north west portico[15].

2.3.2 Tower Rebuild in the 1370s

Any evidence of work carried out at this time was destroyed when the roof was renewed in the early 19th C. by Edward Blore.

2.3.3 1830s Roof Drawing 3

The entire roof was rebuilt by the Cathedral Architect, Edward Blore, in 1834-36, using Francis Ruddle, (now carrying out the work in place of Daniel his father), with Robert Bell doing the slating and torching inside, and Thompson doing some minor work[16]. It seems from the drawings by Ware and Ansted, referred to above, that Blore's roof is similar in size to the original roof (possibly shallower and wider, see **Drawing 1**), but with the fundamental difference that Blore's is a truss and common rafter roof .

The roof from the central tower to the western vaulted Bay consists of 26 main trusses which are spaced at 2600mm-2900mm centres. There are five common rafters between each truss. These trusses are bolted together using cast iron couplings and stiffeners. The feet of the trusses are contained in cast iron shoes which are bolted down to stone plinths built on top of the wall head. The entire structure is made in fir and the tie beam is a coupled beam, with a beam placed on either side of the principal rafter and bolted together.

2.3.4 1920s Restoration

Starting in 1924, the Cathedral Architect, Leslie Moore, carried out a major restoration of the roof using the local building firm J. Thompson and Sons. This restoration is recorded by the cast iron plate dated 1924 on the lowest collar of the east truss. The work mostly involved re-slating the roof, and inserting the low level roof lights etc.[17]. The extent of Moore's work within the roof has not been investigated to date, as this investigation has not been seen to be part of this project.

2.4. CEILING STRUCTURE

2.4.1 Original Structure

Upper Side – The original oak ceiling structure consists of 80 cambered horizontal joists jointed at each end with a halving joint to a sloping joist (originally a scissor brace). Those in Bay 10 vary in detail sufficiently from the rest, being consistently wider in cross section, to reflect the later decision to extend the nave by an additional Bay at the west end. Joist 73 is a different section, has no camber, nor has a halving joint at the south end. This suggests that the timber might originally have been temporarily placed there as part of an end truss for the roof pending a decision on the final configuration of the west end and transepts, and when Bay 10 was added it was found unnecessary to remove it. The timber may even have been originally cut for some other purpose altogether. The sloping joists have mortices at their lower ends which are considered to be the joint for the ashlar post. Unfortunately no ashlar posts survive to confirm the design of the original roof or ceiling structure at wall plate level.

Fixed between the joists are oak noggins, these are much smaller timbers, say on average 3" x 2" (75mm x 50mm) which are jointed with birds beak joints to the underside of the joists and fixed

[15] The Perry Lithgow Partnership and Hugh Harrison 2001, Vol. I: Figure 4
[16] D Mackreth Unpublished letter to Julian Limentani 13 July 2002 and Dean and Chapter Audit Accounts for the years 1835-1836
[17] The Perry Lithgow Partnership and Hugh Harrison 1998, Vol. I: Appendix 2

with nails. South sloping joist 81 has been reused and has a noggin cut off flush with the face of the joist still nailed into the birds beak in the top surface of the joist.

Lower Side – The ceiling is formed of riven boards placed clinker-fashion and nailed directly to the underside of the joists and noggins, with additional nails spaced along the edges of adjoining boards. The visible edge of each board is moulded with one of three different moulds and the sequence for these moulds remains constant with every lozenge. The centre boards in each lozenge, on which the figurative painting has been applied, have a different flatter profile than the patterned boards.

2.4.2 Interventions

2.4.2.1 14th C Tower Reconstruction – No positive evidence exists of any intervention at this time, which is extraordinary considering that the ceiling abuts the tower masonry.

2.4.2.2 15th/16th C

Brian Gilmour has identified a nail in the dovetail at the south end of joist 22 as likely to be of this date[18].

2.4.2.3 1740s

There is no record of the extent of repairs carried out during the 1740s restoration, but a number of boards have been identified by paint analysis to be from this period. There is also no record of what 1740s repairs were discarded in the 1830s. An insight into the detail of the junction of the original sloping ceiling with an ashlar line is perpetuated in the surviving 1740s boards whose bottom edges on the sloping ceilings all line up with the original board ends which are frequently short of the present ashlar panels. All or part of the ashlar was renewed. Unfortunately no evidence of the form of the 1740s ashlar has been obtained from the surviving ashlar boards.

2.4.2.4 1830s

Because Blore stripped out the whole of the ancient roof, he had to find some way of supporting the painted ceiling. He supported the flat part of the ceiling from three longitudinal binders placed on top of the coupled ties, from which each joist is hung with a wrought iron bolt. Blore appears to have designed a similar system for supporting the sloping sides of the ceiling, though evidence of this system survives only in the east Bay on both the north and south sides. There is no evidence of any other support for the sloping ceilings at this time, when Blore cut back joists at least one foot (300mm) each side short of their joints. Often several joists in a row. These parts of the flat ceiling can only have been held up by the propping action of the boards on the sloping ceilings.

The 1830s campaign was far more intrusive than that in the 1740s, with the removal of many original boards and their replacement with softwood boards. It also included the repositioning of original and 1740s boards. Many of the original boards were also additionally nailed, both at their ends into noggins and joists above, and along their edges, from board to board. All or nearly all the ashlar boards were also renewed.

Above the ceiling, many joists were cut back at the scissor joint, sloping joists (20, 27 and 81 north, and 67-71, 73 and 81 south, and flat joist 81) were replaced with old roof timbers, and it is thought that extensive patches (probably in oak) were nailed to the top of the ceiling boards from above. Many other weakened joists were strengthened with doublers etc. It was during this restoration that the ceiling was suspended from the new roof structure which was built at the same time. With the construction of the new roof, all evidence of the base of the original roof was lost, including all Ashlar posts and boarding.[19]

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[18] *Nails from the wood panelled nave ceiling at Peterborough Cathedral: Technological investigation of Nails from Bays 5 and 6* B Gilmour 2001

[19] Except boards *(m)* and *(o), Panel 22 III* which are thought to be reused original Ashlar boards.

However the position of the mortices in the sloping joists suggests that the original Ashlar posts were in much the same position as the modern ones are now.

The extent of the 1830s work is somewhat clarified by the Dean and Chapter Audit Accounts, but sadly the descriptions of the work are so abbreviated that they are often more tantalising than informative.

2.4.2.5 1880's Tower Reconstruction – A very small number of alterations/repairs have been found at the east end of the ceiling.

2.4.2.6 1920s Restoration – Moore's work, carried out in 1926-27 by the local building firm J. Thompson and Sons, is characterised by concern (with today's scientific knowledge it would be considered as over-concern) with damage from deathwatch beetle infestation. Almost all the 1830s strengthening and patches were stripped out and replaced with composite joists, noggins and patches all laminated from 6" x ½" treated softwood and fixed with screws many of which protrude beneath the ceiling.. This method was adopted so that new wood required for the restoration was small enough in section to be creosoted under pressure and would be simple to order. This system was also infinitely flexible, making it easy to accommodate undulations in the ceiling using repetitive techniques varying only in the number and disposition of the laminates. It is very likely that Thompson's quarter-size drawings confirm the design of these works. Additionally, in the archive are preliminary sketches showing techniques that were never used[20]. The whole top surface of the ceiling was bonded together with hessian, glued to the ceiling with animal glue. All the work was carried out without the use of a scaffold below.

2.5. PAINTED DESIGN

2.5.1 Date

Binski suggests a likely date for the original painted decoration of not before about 1220 and not much later than about 1240. This is corroborated by the findings of paint sample analysis (Howard, Kakoulli and Davies) and tree-ring analysis (Groves).

There is documentary evidence that the painted scheme was restored between 1740 and 1750 and again in 1830s. There are no detailed records of these restorations; although, it clear that repainting on both occasions was extensive and inept. Investigations conducted throughout this project have established that the 1740s and 1830s restorers in the main followed closely the original foliate and figurative designs on the central boards of the lozenges, although the original lozenge border designs differ significantly from the present scheme. These differences and the results of all investigations and observations made during the Phase 5 technical survey of the painted decoration are detailed in Part 8 of this report.

2.5.2 Subject Matter

The painted design follows the arrangement of the Ceiling boards. It consists of three interlocking rows of diamond-shaped compartments, with a further row of half diamond-shaped compartments on the north and south sides. The inner boards of each compartment are decorated with a figurative subject. **Figure 6** is a table of all subjects on the Nave Ceiling. The subjects included in Bays 9 and 10 are shown in **Figure 7**.

The following extracts from Professor Binski's paper explain the iconography in this section of the Ceiling:

> '….the "backbone" of the Ceiling., the row of kings, bishops and archbishops along the central spine of the western and central portion of the Ceiling. None of these eleven figures, six kings, three bishops and two archbishops, carries an identifiable attribute, and no evidence has come to

[20] The Perry Lithgow Partnership and Hugh Harrison 2000, Vol.1: Item 3.3.5 fn38

light for the presence of inscriptions on the Ceiling. Two are perhaps striking: one king who holds a long banderole - a speech-scroll or, more likely, a rotulus - and the easternmost king on an ornate ground, who holds a flaming torch and sceptre. The kings and prelates are paired in apparently peacable dialogue, like figurines on a metalwork shrine.' ……. 'A gallery of paired kings and high churchmen is much more likely to have been historical in nature, and a "church and state" display would in turn be vastly more typical of the 13th than the 12th century' ……. 'Peterborough's selection of figures seems quite particular, and might accord better with the "local' history of the abbey, rather than a "national" iconography. The co-ordination in pairs of kings and bishops in fact smacks strongly of founder-iconography. And for that we need again to consult the Peterborough chroniclers, as for example Hugh Candidus' account of the early history of Medeshamstede. Candidus relates the role in the foundation of the abbey, the establishment of its rights and privileges and their protection of mighty King Oswald, Kings Oswy, Peada, Wulfere and Ethelred, their subject kings Sebbi and Sighere, and eventually King Edgar, from which a cast of a half-dozen figures is much more easy to establish. The two archbishops by this reading would be Deusdedit and Theodore of Canterbury, and the bishops might be those cited in Candidus: Ithamar of Rochester, Wini of London, Jaruman of Mercia, Tuda of Lindisfarne and so on. Hypothetical as this contention is, it is worth adding that the Great Hall of the abbot's house at Peterborough had at the upper end three thrones "wherein were placed sitting, the three Royal Founders (i.e. Peada, Wulfere and Ethelred) carved curiously of wood, painted and gilt". Peterborough evidently celebrated its founders with care.

If so, the Ceiling would amount to the earliest assertion in monumental painting of a form of local historical consciousness which was not preoccupied solely with sainthood. Peterborough's kings and bishops are by this reading the figures involved in the early foundation and enrichment of the house, and in the defence of its privileges.' ….

'If the kings and bishops at Peterborough show every sign of being local in inspiration, the representations of the Liberal Arts are in one sense apparently universal. Yet the ceiling's images appear to be the only important English monumental instance of the topic. This greatly adds to their interest and importance. As a theme, or complex of themes, the seven arts in the form of the *trivium* and *quadrivium* were commoner in northern France (e.g. Chartres, Deols, Sens, Laon, Auxerre), the Holy Roman Empire (e.g. the *Hortus Deliclarum')* and Italy (e.g. the Trivulzio candelabrum, though this is probably again of northern French manufacture than in England. That we are dealing with the arts and not with some other subject seems to me clear. The personifications accompany the kings and bishops in the western half of the ceiling, and fall into two triangular formations on the northern and southern perimeters of the ceiling. To the west, the *quadrivium is* disposed in a triangle with its base along the north side, with the *trivium* to the east. As an odd-numbered figure, the arts are thus perforce laid out lopsidedly. In identifying them we should recall Michael Evan's important observation that there was no single standard set of attributes for the arts at this time, and that even this well-known theme occurred less frequently and in a less orderly fashion than might at first be thought. Bearing this in mind, Peterborough's set is not in fact over-problematical. Thus, amongst the *quadrivium,* Geometry and Music are immediately recognisable with their attributes, a pair of compasses and a set square, and an organistrum. Astronomy to the west is extensively repainted but appears to have held up an object, perhaps originally, a sphere; Arithmetic has both arms raised, holding in her hands two attributes, of which one is probably an abacus. To the east, in the *trivium*, Rhetoric with her tablets is conventional, as is Grammar with her disciplinary palmer and pupil; and Logic sits making a gesture of instruction to a tonsured clerk on a pedestal, who holds up to her a curious, object which, unless it betokens a piece of architecture, defies identification at present, but which doubtless has some propaedeutic significance.'

The same genealogy may be traced for the sun and moon to the west of the arts, the sun on the south side falling opposite Astronomy. Though heavily repainted, both sun and moon are in chariots which now lack their full complement of four horses and two oxen respectively. They are not to be confused with the chariot of *Prudentia* provided by the Liberal Arts, in Alan de Insulis' well-known *Anti-claudianus***.** The fact that they are in chariots separates them from their most common manifestation in the art of the period, either as companions to the Crucifixion or as attributes of the Laudate Psalms,: as in the Angel Choir in Lincoln. That they are separate in this sense, is merely demonstrated by their occurrence at the west end of the nave, free of association with the nave rood altar 44 . They are in fact decidedly festive pseudo-antique personifications which hint at a more distinguished ancestry. In this guise their origin is Carolingian, since they compare well with charioteer personifications of' the sun and moon in the 9th-century so- called Liuthard group of ivories**.** Though the sun and moon continue in Anglo-Saxon art as bust-length figures in the tradition of the Aratus manuscripts, most especially in the Stuttgart and 'Utrecht Psalters 46, they occur seldom thereafter, as for 'example in 12th-century Canterbury 47. I know of

> only one East Anglian occurrence of the charioteers, namely the 11th-century metal frontal of the high altar at Ely specified in the *Liber Ellensis* as having "11 *curruum solis et lunell,* accompanying a Majesty**.** But I suspect the existence of a similar filiation for the Peterborough charioteers as for its arts, namely from within a consciously humanistic, neo-antique Benedictine visual culture in which repositories of Anglo-Saxon and Carolinglan material at major monastic centres in the south of England played an important role.
>
> This makes us more curious about the *"caelum egregia pictura decoratim"* which Gervase tells us adorned Conrad's choir at Canterbury itself in 1107-26**.** This painted ceiling had of course disappeared in the 1174 fire. But it, or its like, may have remained a memory at Peterborough via the agency of Canterbury's former prior (1175-7), Benedict, Abbot of Peterborough 1177-94. The arts, sun and moon, could in fact all have an ultimately Canterbury provenance and from a context of this type. And that in turn reminds us of the most celebrated link of all, that between Canterbury's typological stained glass and the choir-stall paintings at Peterborough. The Canterbury-Peterborough nexus is in this respect at least certain. Is it possible that these subjects on the ceiling are traces of the contents of a Benedictine encyclopaedic compendium also including an extensive typological repertory, which appeared at Peterborough from a site in south-east England around 1200?

Throughout Bays 1-8 it was evident that the 1740s and 1830s restorers followed closely the original foliate and figurative designs on the central boards of the lozenges except in one instance. That exception being the Dragon lozenge in Bay 2 (*33/34/III/IV*) which has been found to be a 1740s invention. Underpaint visible in raking light indicates the original scheme had a Renard occupying only one quarter of the lozenge. Not enough low relief underpaint survives within the other three-quarters of this lozenge to suggest the original subject: although, after comparison with a margin illumination in Peterborough psalter, Binski suggests the fox may have been carrying a cockerel. In turn this may be connected with the allegories of Aesop's Fables.

In September 2001 there was a meeting between some members of the Project Team to review and interpret new information about subject matter recorded since the start of the main project. Working with the colour photographs taken during the project, the hand plotted 1: 10 scale visible underpaint graphics that recording all traces of original detail showing in relief through the later overpaint prepared during the condition survey, and referring to the large scale orthophotographs made by Paul Bryan's team at English Heritage, the painted subjects and patterned boundaries were examined, west to east (omitting Bays 9 and 10 which were scheduled for Phase 5 so had not been documented at the time of the meeting). A record of the findings of this very productive meeting was later circulated by Julian Limentani, the Cathedral Architect. A copy of that record is appended to this report (**Appendix 19**).

Bays 9 and 10 have a significantly higher proportion of softwood replacement boards. In some of the figurative and foliate lozenges only 1-3 original boards remain and none survive within the westernmost two foliate half-lozenges. As a result there is less evidence of visible underpaint and incision lines to confirm the original scheme. Nevertheless, it must still be assumed that the 1740s and 1830s restorers studied the surviving paint prior to the replacement of deteriorated boards and that they made every effort to replace the original scheme. Only where there is low relief ‘underpaint’ or incision lines to indicate otherwise is it appropriate to suggest the repaint does not follow the original. Within Bays 9 and 10 the Eagle lozenge (*2/3/II/III*) alone falls into this category (**Plate 305**). Significant traces of a cusped mandorla is visible in low relief on two of the original boards in that lozenge. There is nothing to indicate whether the mandorla originally framed a smaller eagle or another subject. A sixth bishop, continuing the series of alternating kings and bishops, would seem more likely. **Plate 368** – showing the 1740s paint layer exposed from under temporarily removed 1830s Ceiling bolts and washers - suggests that even the 1740s scheme within the Eagle lozenge may have been very different from the 1830s.

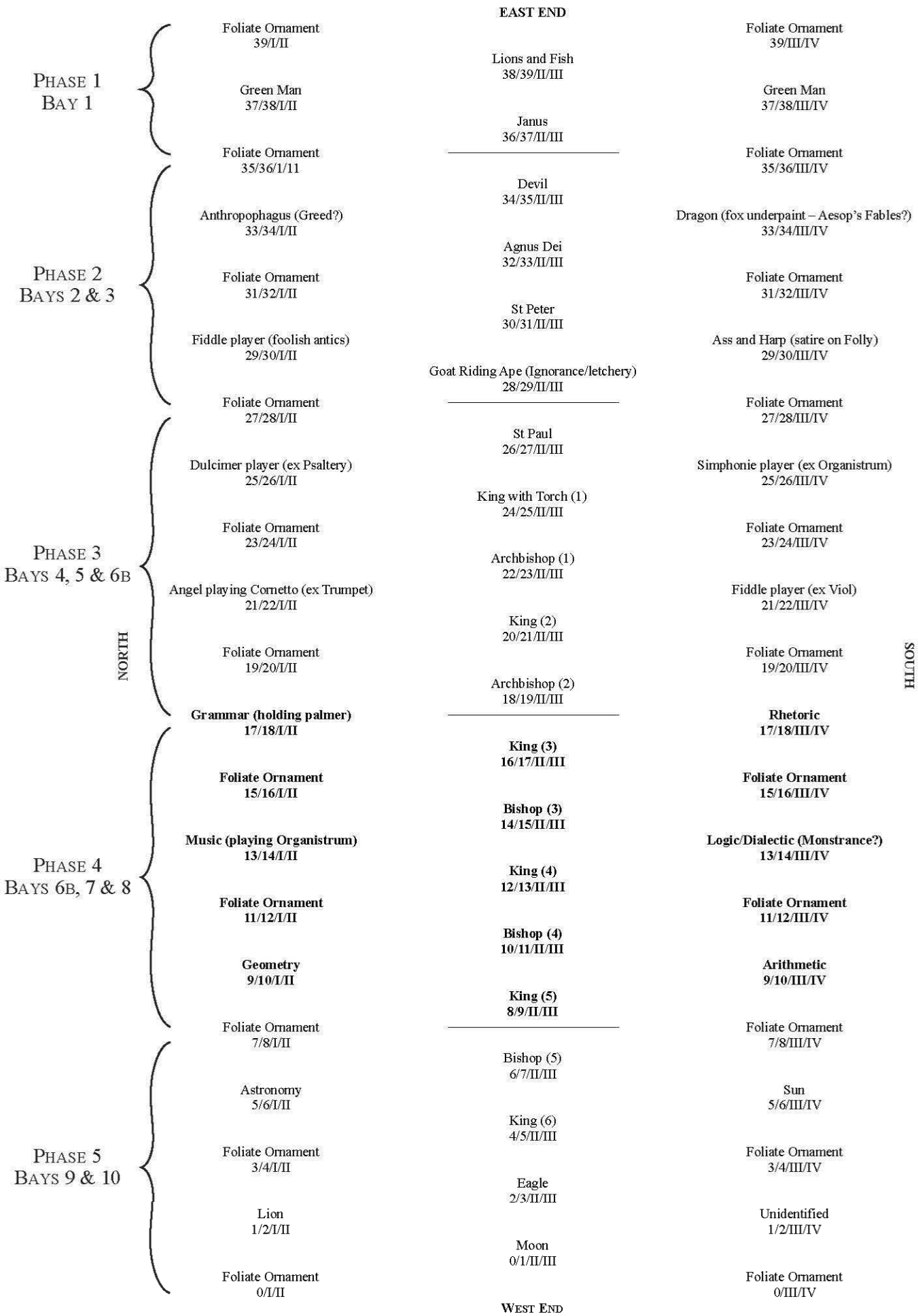


Figure 6. *Table of all subjects on the Nave Ceiling*

EAST

Figure 7. *Illustration detailing the figurative subjects within the lozenges of Bays 9 and 10.*

2.5.3 Decorative Designs

The figurative elements are small in scale relative to the surrounding decorative borders. The border ornamentation is similar for each diamond; although with occasional minor variations. The inner band a black key pattern on an off-white background. A black chevron or wave pattern with fleur-de-lis at the corners, also on an off-white ground. A crenellated or stepped chevron pattern, black on off-white. A grey, extended chevron pattern separated from the black background by a white line; the chevrons have white embellishments. An extended, black chevron or wave pattern with fleur-de-lis at the corners, all on an off-white ground. The outer design is of coloured bands, brown and off-white; the off-white band forming the background to a red and a black line. The base boards filling the spaces between the diamond-shaped compartments have a white scroll design with trefoil ornament on a black background. **Figure 9** illustrates the sequence and arrangement the lozenge border decoration and board sections.

The white embellishments on the grey chevron border design vary considerable within Bay 1 and the east half of Bay 2 (*Rows 39-33)*. To this point in the Ceiling the embellishments date from the 1740s restoration: they were not overpainted in the 1830s . From *Row 32* westwards the 1740s embellishment becomes more formalised as a small V shaped 'leaf' motif. It is also from this point on that the 1830s restorers overpainted the grey chevrons and replaced the V shaped 'leaf' motif with a graduated series of white brush strokes along each grey chevron. However, even this 1830s white detailing varies considerably in size and design throughout Bays 6 to 10 .

The lozenge border decoration varies for the smaller, half-lozenges immediately over the Ashlar boards. These boards have keyhole and dog-tooth patterns - both in black on off-white - in place of the stepped chevron and wave patterns. The width and spacing of boards within the lower part of the canted panels varies considerably. As a result the adjacent key, keyhole and dog-tooth patterns sometimes cover two rather than three boards.

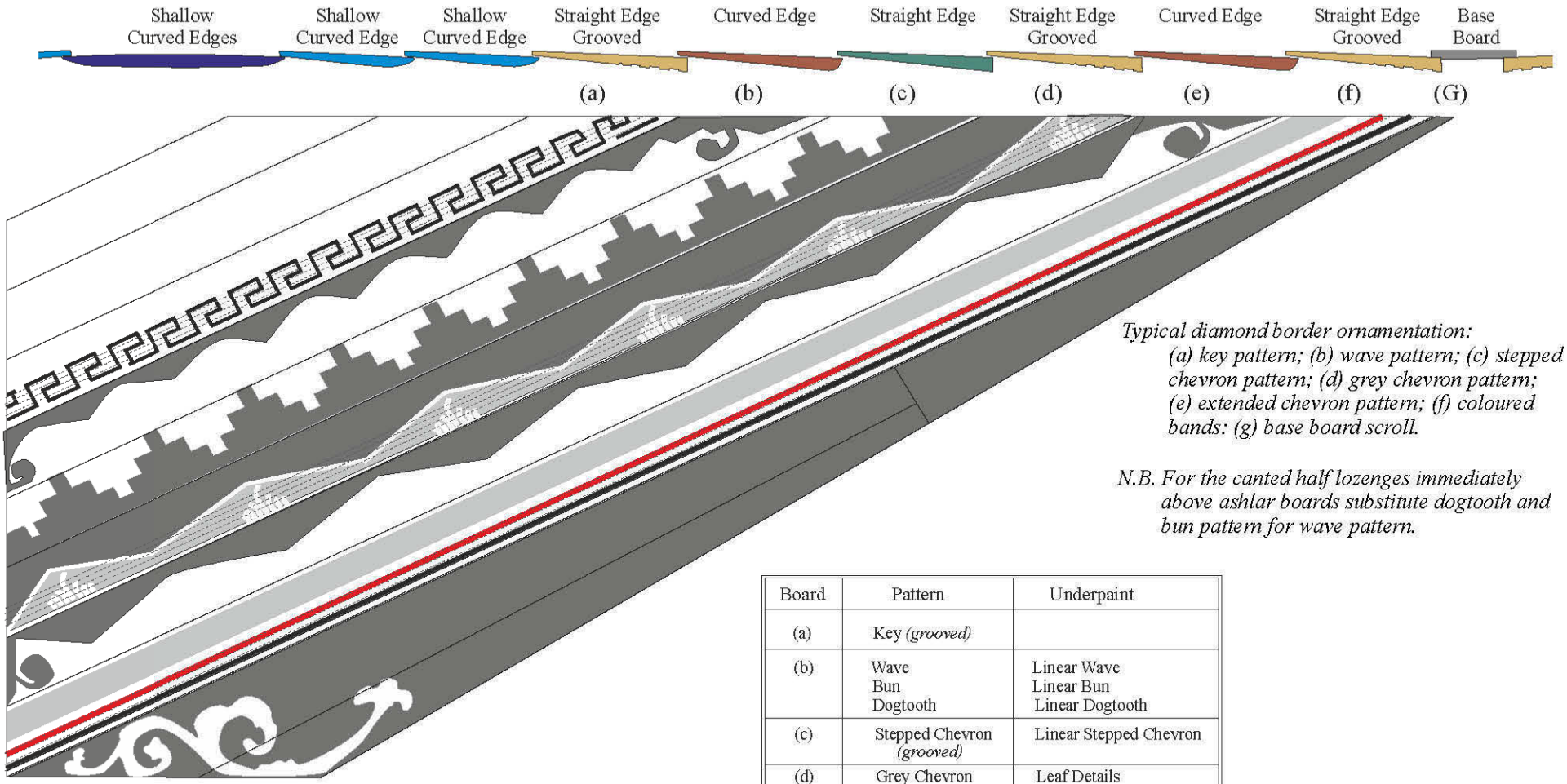
2.5.4 Ashlar Boards

Running the length of the Nave over the top of the north and south walls is a decorative frieze pattern: a scrolling design of stylised tendrils - in black, red, green and off-white - with recognisable flowers depicted in every downward loop alternating with stylised 4 petal flowers. Apart from the rose, the flowers are difficult to identify, but look similar to common garden plants, such as the mallow, and cranesbill. Detailed examination of the Ashlar boards during the Phase 2 survey and paint sample analysis has confirmed that the boards and painted decoration date from the 1830s restoration.

2.5.5 West End Vertical Boards

Filling the space between the west end of the ceiling and the stonework over the west arch are 1830s tongue and groove softwood boards aligned vertically. They are decorated with a heraldic scheme: the arms of Peterborough Abbey (Gu. two keys endorsed in saltire betw. Four crosses formée fitchée or) filling the central space. The shield of arms is flanked by billowing red and white mantling and black shadowing on a dark, brown/grey background. To the north and south, on the boards abutting the canted Ceiling panels is an ornate harp adorned with a man's helmeted head facing inwards towards the shield.

Figure 8. *The 1830s heraldic decoration on the West End Vertical boards.*



Typical diamond border ornamentation: (a) key pattern; (b) wave pattern; (c) stepped chevron pattern; (d) grey chevron pattern; (e) extended chevron pattern; (f) coloured bands: (g) base board scroll.

N.B. For the canted half lozenges immediately above ashlar boards substitute dogtooth and bun pattern for wave pattern.

Board	Pattern	Underpaint
(a)	Key *(grooved)*	
(b)	Wave Bun Dogtooth	Linear Wave Linear Bun Linear Dogtooth
(c)	Stepped Chevron *(grooved)*	Linear Stepped Chevron
(d)	Grey Chevron	Leaf Details
(e)	Extended Chevron	Trefoil
(f)	Coloured Bands *(grooved)*	
(g)	Scroll	Scroll

Figure 9. *Diagram of a typical lozenge showing the sequence and arrangement of the different board sections.*

PART 3: TECHNICAL SURVEY: THE CEILING STRUCTURE

All the drawings referred to below can be found at the end of Part 3 (page 45).

3.1 PREAMBLE

With the experience of four Phases of work, it is obvious that particularly with the later interventions, the thinking behind the repairs was to fix reinforcing material above the ceiling to secure the boards below. To split the Report into the two categories of "above the ceiling" and "below the ceiling" as originally specified is therefore both false and confusing. The Report now splits the Technical Survey into periods of work, and, within each period, the structure above the ceiling and below are discussed together

3.2 ORIGINAL CEILING STRUCTURE Graphic I

The original oak ceiling structure consists of 80 cambered[21] horizontal joists jointed at each end with a halving joint to a sloping joist. These joists measure 9" x 5" (225mm x 125mm) in the centre and 7" x 5" (175mm x 125mm) at each end. In the centre of the west face of each joist is a dovetail presumably into which was jointed a vertical timber linking this collar with the upper collar, see **Drawing 1**. **Plate 19** shows the dovetail in joist 73.
The sloping joists (ex-scissor brace) have been shaped to meet the common rafters and have mortice joints cut in the underside of their lower ends (see **Drawing 4**) into which it is assumed were jointed the Ashlar posts. **Plate 18** shows part of the ashlar mortice at the north end of the sloping joist 70. Note part of wood pin still in position. This Phase has produced three further examples (sloping joists 68, 72 and 78 all on the north side) of the side lap joint with which the sloping joists were fitted to the common rafters, see **Drawing 1**, **Plate 61**, and **Drawing 2** of the NW Portico where similar joints are found.

Running between each joist are oak noggins, (**Plates 20, 23, 28, 29**) all as shown in the positions on **Drawing 1**. These noggins are quite small timbers, say on average 3" x 2" (75mm x 50mm) which are jointed with birds beak joints and fixed with nails to the underside of the joists. Two fixing nails were tested by Dr Brian Gilmour, The Archaeo-Metallurgy Group, Dept. of Materials, University of Oxford[22]. His findings were that the nails had consistent characteristics of ironwork of the early 13th C.

Positions of original noggins and birdsbeak joints have been recorded on **Graphic 1**. The remains of three ashlar post mortices were found on the undersides of sloping joists 70, 71 and 72, all on the north side. All aligned with each other and were more or less on correct alignment with the boards and wall face.

A possible carpenter's mark was recorded on the side of sloping joist 75 north near the cut off end. This discovery was potentially interesting as it occurs on the added Bay 10, but neither of the numbers suggested by the mark (either an X or a V) seems to tell us anything about the likely construction sequences for the set of timbers.

3.2.1 Dendrochronology - Structure

Dendrochronology samples were taken from the joists throughout the length of the roof by the University of Sheffield, Dendrochronology Department[23].

[21] Joist 73 is a different section, has no camber, nor has a halving joint at the south end.
[22] Nails from the wood panelled nave ceiling of Peterborough Cathedral. Dr B. Gilmour 1999
[23] I Tyers 1999

The broad conclusion is that the ceiling joists indicate a construction date for the roof of AD 1180 – 1188, with some statistical evidence that Bays 1, 5, and 7 are slightly earlier. The report indicates that the trees are likely to have come from a single area of woodland in the eastern part of the country, likely to be somewhere in the vicinity of Peterborough. The trees were unusually slow in growing and exceptionally long lived, the earliest recorded ring dating to AD 887. A very few joists are likely to be from the same tree.

3.2.2 Boards – General

The underside of the ceiling consists of boards laid clinker fashion on both the flat part of the ceiling and the two sloping sides. In addition there is the Ashlar boarding which is laid flush, and fills the space between the lower edge of the sloping sides and the stone wall head.

The ceiling boarding comprises the original oak boards and those replaced in softwood at various times. The Ashlar boarding is softwood tongue and groove boarding, probably 18th or 19th century in date[24].

3.2.2.1 Original Ceiling Boards – The original boards are "riven" or "cleft oak" and mostly appear to have a tapered section. All the original boards were measured for sight width in Phases I and 2 but only by averaging the results was it found that a pattern of board widths did actually exist. In this phase there are two roughly equal groups of board widths, one measuring approx. 7" (175mm) in width and the other 8½" (220mm). The sample was quite small consisting of 19 boards, the widest being 11½" (290mm) *Panel 3II (b)*. The overlap averages at 1¼" (33mm).

All boards vary in thickness but average at ¾" (19mm) and they do vary in thickness along their length.

Some boards were measured for length to see if a standard length emerged. The only situation where choice of length of board occurs is where two boards are scarfed together and one assumes that a long board is selected and made up in length with a short board taken from the offcuts. Even here one has to be careful, as it does seem that the majority of scarves in the flat panels are made to coincide either beneath or close to a joist or noggin above. However in the sloping panels no attempt was made to place scarves beneath the intermediate joist if one take the situation in Phase 4 as typical where there are 67 scarves with none between an intermediate joist.

It does seem that there was a standard length board as can be seen from the table below. It is also worth noting that the maximum length of a diagonal across each panel is nearly 13' 0" (3950mm) so the fact that the average length board used is about half this length and the maximum circa 8'0" (2450mm) shows that no boards anywhere near this length were available.

Table showing average length of Original Boards

Phase No.	Total boards measured	Average length	No. of boards within 2" (50mm) of average length	% of Total	No. of boards within 4" (100mm) of average length	% of Total	Maximum length board In this phase	
							Imperial	Metric
3	185	6' 9½ "	88	48%	144	78%	8' 8½"	2650mm
4	166	6' 10¼"	85	51%	156	94%	7' 6"	2288mm
5	58	6' 9½"	37	64%	50	86%	7'10"	2385mm

[24] Dean and Chapter Audit Accounts include the supply of 1002 sq ft of ¾" deal "to enclose the end of Nave and border to roof. Planed O.S. (one side?) plough[d] and tory[d] (tongue and grooved?)"

All previous Reports have described the border boards as tapered and the centre lozenge boards as being aerofoil in section, and it is now well accepted that the border boards have various moulded edges. Good examples of end sections presented themselves in this phase and they are illustrated in **Plate 30**. Some border boards are in fact rectangular in section. The front and back faces are chamfered where they overlap so that adjacent boards fit exactly and, because the boards are laid clinker fashion, there are no gaps. **Figures 10** and **11** illustrate this feature.

This new understanding of the section of the border boards accords with Cathy Groves' suggestion that some of the trees might have been large enough to produce two boards from the width of the radius. This would automatically create boards with very little taper[25]. Examples of the economic use of materials continue to be found, such as the grooved board in the upper left hand corner of **Plate 34** which is say ½" (12.5mm) short.

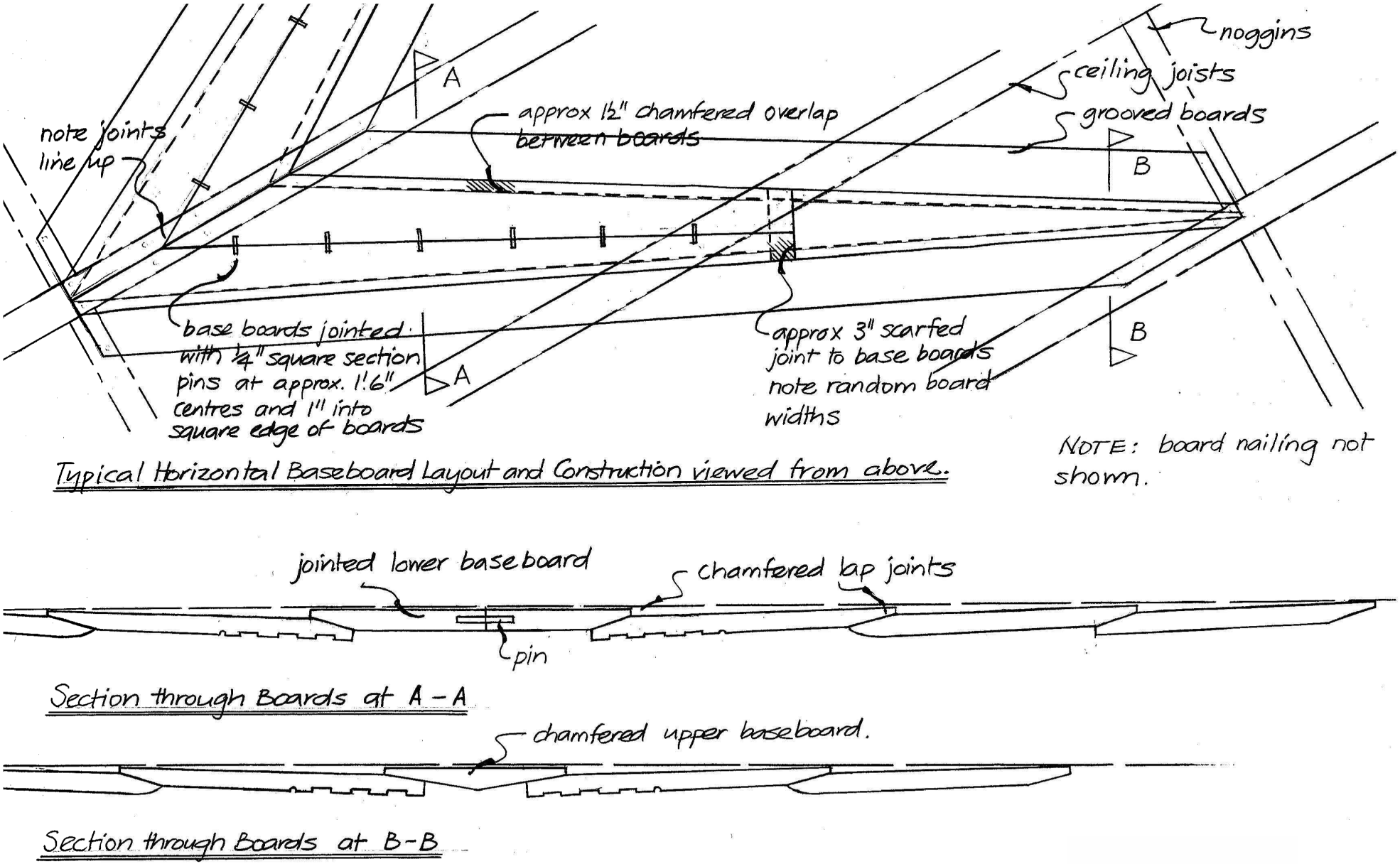
Further examples were also found in this Phase of torn grain (**Plate 37**). More examples of careless adzing were noted as seen in **Plates 36**, **38**.

No further examples of felling shakes were found. These occur when a long log hits the ground on felling and it bounces back up. These shakes are normally hardly visible when the boards are first cut.

The same moulds on the edges of the boards were found as in previous Phases, but the narrow groove, consistently the same size, on the grooved boards from the east end of the ceiling is no longer found west of Row 24, other than on one board in Row 21 and one board in this Phase in Row 14. A wider groove first appeared in *Panel 27 IV* and is now found on all grooved boards.

Plates 33, 39 show judders in the groove formed by uneven grain where the blade has cut the normal fibres easily but has jammed in the much harder medullary ray. The scratch stock was set too coarsely and the blade has dug into the wood rather than cut through it. The **Plates** show that each groove was cut individually as the judder marks are not found on the adjoining grooves.

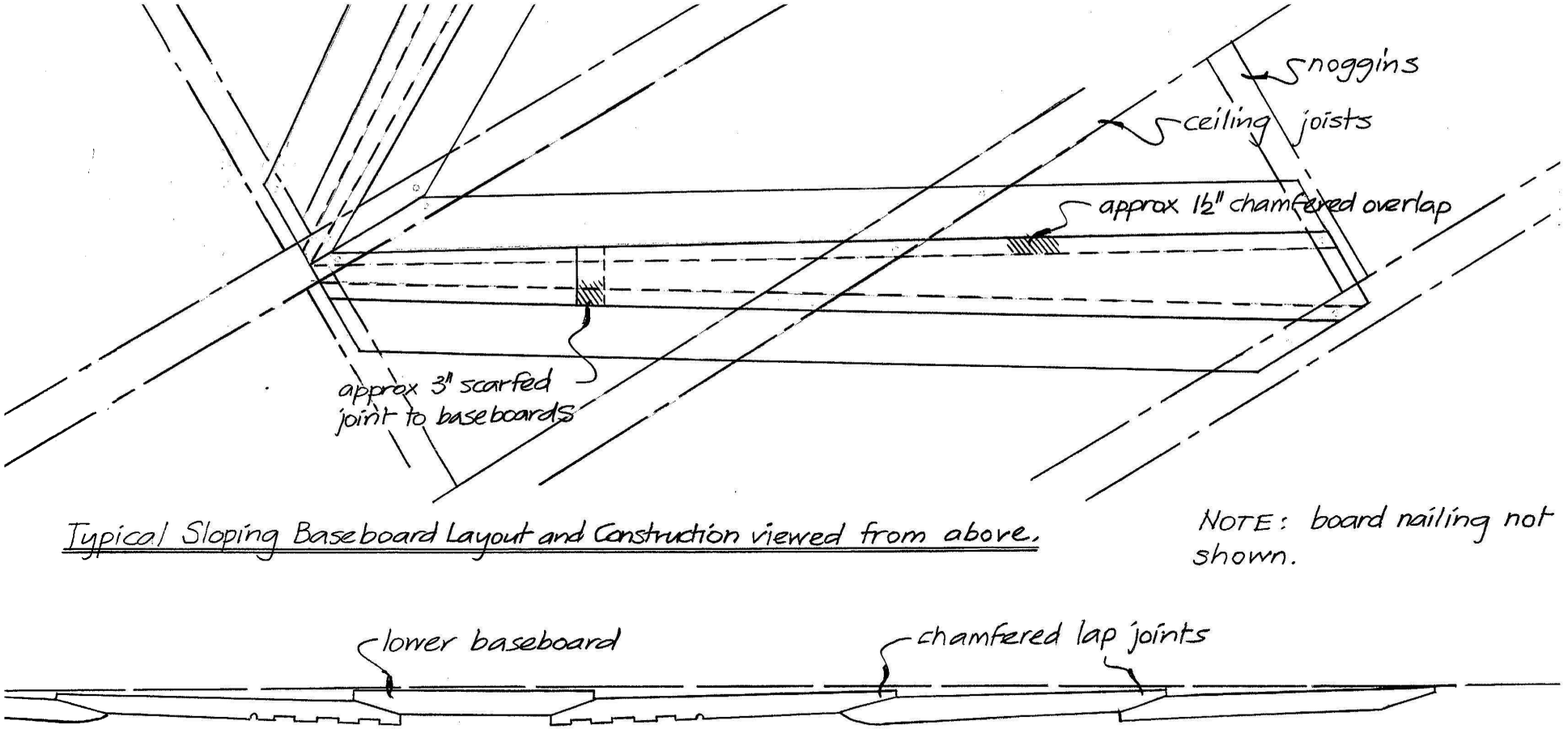
[25] The Perry Lithgow Partnership and Hugh Harrison 1999, Vol.1: Item 3.2.2.1



Peterborough Cathedral, Details of Baseboards in flat section of Nave Ceiling

HUGH HARRISON CONSERVATION drawn Peter Ferguson July 2002

Figure 10.



Peterborough Cathedral, Details of Baseboards in sloping sides of Nave Ceiling

HUGH HARRISON CONSERVATION drawn Peter Ferguson July 2002.

Figure 11

3.2.2.2 Base Boards – The base boards in the flat part of the ceiling (**Plate 32**) are made up of three separate boards. A single board at the narrow end is scarfed to twin boards at the wide end. The twin boards are dowelled at approx. 1'6" (450mm) centres using oak dowels, some of which are marked with scratches on the surface. In Phase 3 it was noted that the dowel holes were made with a spoon bit, which has a rounded end, and which preceded the screw end found on today's traditional bits. The base boards in the sloping sides are one board wide, but scarfed in length with one short board at the narrow end and a long board from there to the bottom end, see **Figure 11**.

Because the base boards taper to a narrow point below the ceiling, and the whole upper surface of the ceiling is covered with hessian, little known about the actual shape of these boards. Considerable effort was made in Phase 4 to find out whether the base boards tapered following the overlap of the border boards or not. It was revealed that the base boards are quite wide at their narrow ends and are nailed with a single nail. As regards the situation above the ceiling, a base board in *Panel 10 II* was uncovered and this revealed the actual width of the board when below the ceiling its width diminishes to nothing, The board investigated measured approx. 5" (125mm) at its narrowest point and had very little taper in its length. It is more common for the base board to taper more than this, which is why **Figure 10** has shown it this way. What is noteworthy is the extent of the overlap, which requires the base board front outer edges to be chamfered down to allow the first border board each side to lie flat. The section at "B-B" shows the chamfer to continue across the front of the board producing a ridge down the centre.

One recurring aspect with the base boards is that although the twin boards are often unequal in width where they scarf with the single narrow end board, they are cut in their width so that the joint between them comes in the middle of the mitre with the other twin boards coming from the other side of the lozenge. Thus the centre joint always meets exactly with the centre joint between the other twin boards. As it would never be noticed from the floor if the two centre joints did not intersect, one wonders why so much effort was made to achieve this result. Good examples in this phase can be seen in *Panels3 III* and *2 II.*

In this phase three further base boards were found (one below the ceiling, **Plate 31**) with curved cut-outs from an edge and are marked on **Graphic 1** as "Notched base boards". They are often difficult to detect because of the hessian covering.

One of these cut-outs, *Panel 4 III* is illustrated in **Plates 20**. There still seems no explanation for the cut-outs, with their sharply defined edges. This cannot be accidental damage from a side axe and there is no splitting out of the grain where the curve enters and leaves the wood. All cut-outs are found above the ceiling with the exception of two, *Panel 11 II (b),* and *Panel 2 II (z)* (**Plate 31**). Cut outs were recorded and none in this phase were in base boards.

3.2.2.3 Scarf Joints – Many of the boards are jointed in length and where this occurs scarf joints have been used.

In Phase 1 it was deduced that a noggin had actually been inserted in *Panel 39 II* purely to support a scarf joint (there seems no other reason for it). In Phase 2, note was made that in most instances the boards were cut so that the scarf joint came beneath an intermediate joist or panel noggin. This continues to be true with only 23 scarves out of 125 in Phase 4 having no relation to an intermediate joist or noggin. The picture is quite different in the sloping parts of the ceiling where none of the 67 scarves recorded come anywhere near an intermediate joist. In phase 5 there are so few original boards it is useless to try to extrapolate data that means anything. It is commented on in the nail section that the panel noggins are used less than one would anticipate to nail boards up to, it is notable however how often scarf joints occur within the vicinity of one of these noggins. All baseboard scarf joints seem to be positioned beneath or very close to an intermediate joist.

In this Phase, as in Phases 3 and 4, nearly 50% of the scarf joints were nailed with one nail (see **Plate 39,42**), about 30% contained no nails at all, about 15% were nailed with two nails (see **Plate**

42), and one or two scarf joints contained three nails (see **Plate 40**). This is a distinct departure in technique from Phase 1 where virtually every scarf was nailed with two nails.

The same variety of techniques used to form the scarfs have been found in this Phase as in previous Phases. Thus beautifully fitting joints are seen in **Plates 39, 40, 42**, with the top board coming to a feather edge.

3.2.2.4 Ashlar Boards – Two original Ashlar boards were found in Phase 3 now fixed in the ceiling in *Panel 22 III (m & o).* No further similar boards were found in this Phase.

3.2.2.5 Upper Surface of Boards – In the course of investigating the cut-out in a baseboard (see 3.2.2.2 above), it was noticed that the upper surface of this baseboard is in very good condition. It can now be confirmed that the upper surfaces of the boards were finished, though to a lower standard than the lower front surface.

3.2.2.6 Location Marks – In this Phase there are numerous examples of scratched marks, but none deeply incised as in Phase 2. **Graphic 1** illustrates these marks. It is thought that they are from the original construction as many appear on original boards which have original nails and do not appear to have been moved. The marks appear to be of three different types. One identifies certain boards and consists of a roughly scratched cross. A second type of mark seems to be a setting out mark for the mandorlas which frame so many of the central figures. The third type are position marks which show the relative position of adjoining boards. One variation of this third type, records the relative position of adjoining boards in their length with one/two/ three scratch marks across the joint; a second variation marks the overlap between two boards (**Plate 35**), and a third variation shows the position of dowels in the base boards.

Richard Lithgow has now established that all the boards were painted before they were finally fixed. As all the patterned border boards are different lengths yet require the patterns to intersect where they mitre, they either have to be painted in situ or set up temporarily, marked, and reset up accurately on the bench. The centre lozenge boards require even greater accuracy of refitting. This then explains why the position marks are required, but if this degree of accuracy is required, why are the marks not more frequent?

Why are some boards marked with the identification marks? As some identification crosses are substantially hidden behind the overlap of the adjoining board, many/all being undisturbed, they must be original.

As with so many comments on this ceiling, conclusions have to be drawn from the numerical frequency of phenomena. For example, approx.16 identification marks have been noted, in itself quite a number but when related to 900 original boards, is this number a reliable guide to a stated practice?

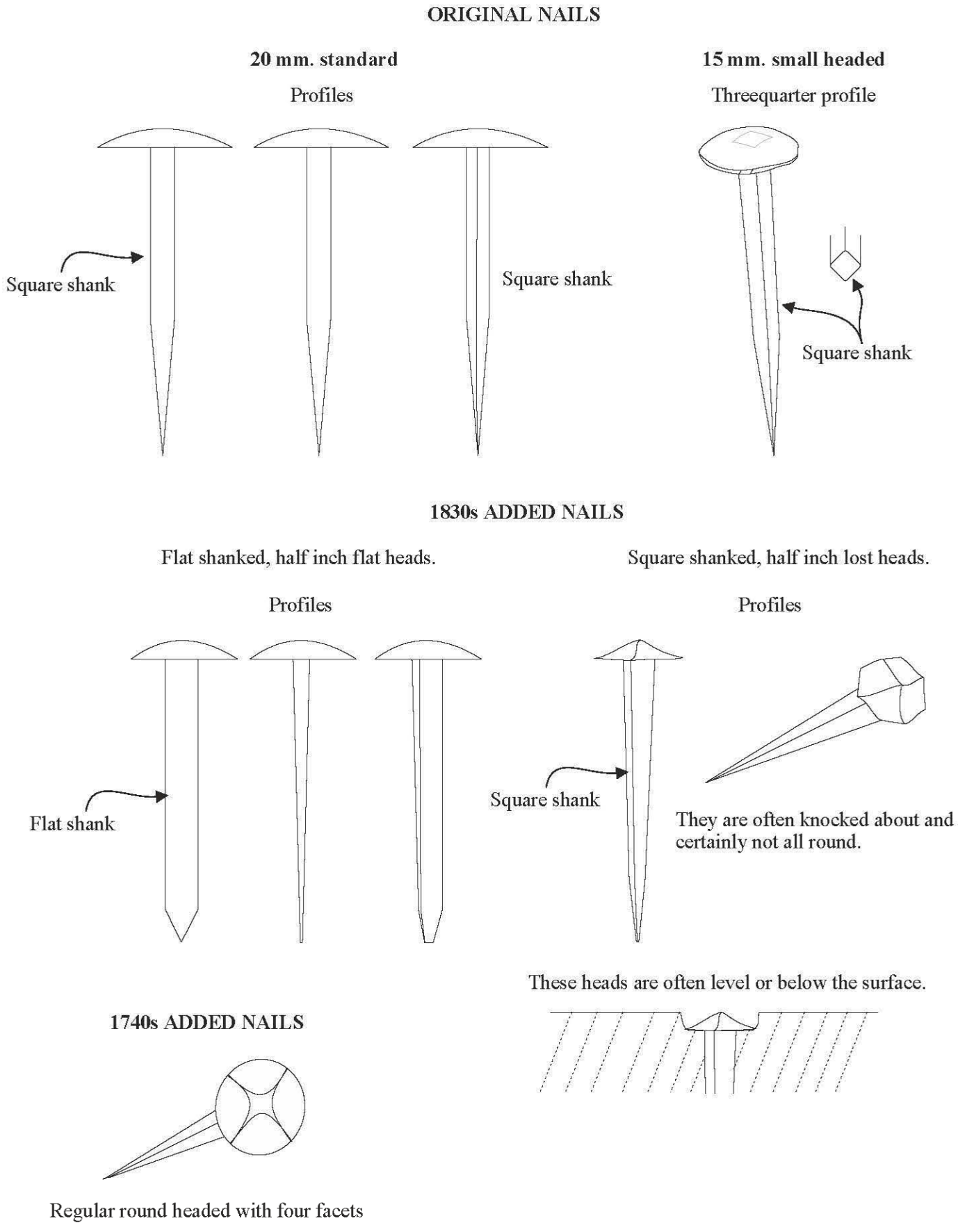


Figure 12. *Categories of nails identified in Bays 2 to 8.*

3.2.3 Fixings Figure 12

3.2.3.1 Nails – The boards are nailed to a noggin with two nails at each end, and if the boards pass beneath an intermediate joist, they are nailed to that as well, with one or two nails. The use of the panel noggin to nail to, to support the boards mid span, seems more consistent in this phase with most noggins having 3 or 4 nails in them.

In Phases 1 and 2 one style of original nail was identified which has a large round head approx. 20-23 mm across, (now to be called "standard", see **Plates 41, 42, 67**), and in Phase 3 another type of original nail was found with a smaller and often a more irregular shaped head, as confirmed by Gilmour (see **Plate 42**). The standard original nails now often show the shank protruding through the round nail head Occasionally two nails side by side are found as in **Plate 44**. One assumes that the second was driven as there was uncertainty about how well the first nail was holding. If it is worth drawing attention, the first nail presumably in a pre-drilled nail hole has no split associated with it, the second presumably not in a pre-drilled nail hole does have a split running through it.

Working on numbers of nails, the pattern of use remains fairly similar to that noted in Phases 3 ands 4. In this Phase there are so few baseboards surviving that counting nails to confirm a pattern of use would not provide reliable data. However, there do seem to be a majority of small headed nails fixing the base boards as in previous phases.

Due to the lack of original boards data could only be obtained from *Panel 4 I.* There are no complete or nearly complete panels with original boards further west than this. The evidence of the one panel does seem to confirm the previous pattern of use, and this consistency is remarkable. Why are approx. 10 small headed nails used in each panel around the edge, why are small headed nails used so consistently to fix the base boards, why are more small headed nails used in preference to the standard nails to fix the board edges together?

Distribution of Small Headed Nails

Row No.	Nails Around Edge of Panels		Nails Securing Board Edges	
	Standard	Small Headed	Standard	Small Headed
Phase 3				
27	64	9	Nil	5
23	105	15	32	41
18	217	5	76	47
Phase 4				
17	115	11	49	61
12	154	10	50	51
8	97	10	37	16
Phase 5				
4	66	9	8	11

3.2.3.2 Pre-Drilled Nail Holes – Throughout all Phases of work on the ceiling to date, it has looked as though the original nails were driven into pre-drilled holes. Many times it has been noticed (and mentioned in previous reports) that when an original nail head has snapped off, the hole that is revealed appears to be round.

Distribution of Unused pre-drilled nail holes

Phase	Square edge	Round edge	Lozenge	Total	No. Original boards	1 per No. boards excl.lozenges
2	17	19	8	44	382	10
3	45	33	24	102	774	7
4	65	28	30	132	839	8
5	20	15	10	45	403	10

In the Phase 4 report it was commented that in an earlier phase it appeared that the pre-drilled nail holes were predominantly in the square edge boards. This aspect has been re-examined and as there are twice as many square edged boards as round, then there are generally significantly more holes per the round edged than square, but hardly enough to make a technical point. Equally there are quite a number per lozenge, but conclusions should not really be drawn as it seems that some lozenges have a perhaps 4/5 holes and many none. What is extraordinary for what must be a coincidence is the consistency of number of boards per hole. As in Phase 2 where there is a board with 4 holes in the edge, in this phase board *(m) Panel 3 III* has 4 holes. The regularity of spacing of the holes in these two boards provides a strong case confirming that each board edge was pre-drilled. An example can be seen in **Plate 43.**

3.2.3.3 Quality of Workmanship – Bob Chappell and Cameron Stewart who have been working on the ceiling from Phase 1 gained the impression that the "quality" of the original work was not as good in Phase 3 as in previous Phases. In Phase 4 there were large areas of superb quality work so if there had been a drop in quality in phase 3 this was reversed in Phase 4. In Phase 5 there are comparatively few areas of original work on which to base comments, but there is no evidence of the work being any different in quality to previous phases.

3.2.4 Dendrochronology - Boards

Groves' preliminary findings[26] confirm the origin of the boards as North German with the earliest measured ring now extended back to 944. Groves reported weathering on the outermost edges which could mark the heartwood/sapwood boundary. Combining this information with the measured ring sequences, she speculates that the felling dates were late AD 1230s or 40s and that the boards are likely to have been converted in much the same period. There is no indication that the felling dates are getting later the further west on the ceiling the boards are found.[27]

3.3 PREVIOUS INTERVENTIONS

This section investigates evidence for previous interventions.

3.3.1 14th Century

There are empty birds beak joints on the east side of joist 1 indicating that there may have been additional noggins in this area. This might constitute evidence that the eastern infill panels were different before the tower was rebuilt.

The evidence of the paint (not thought to be original) found on the east side of joist 1 indicates that after the tower was rebuilt the space between the west tower wall and joist 80 was open, or was boarded over above the joist. This may indicate that only the boards between Joist 1 and the tower were taken down to enable the tower to be rebuilt, but they were not reinstated after the work was complete. The inclusion of a reused oak board and a 1740s board in *Panel III* indicate that either the infill panels were inserted at that time, or that old boarding was already in place and that some boards were considered to require renewing at that time.

It is possible that the extra large dome-headed nails found in this part of the ceiling only, may have been used in the 14th century, and re-used in the 1740s restoration. However, there are no original oak boards with these nails still in them, nor are there marks of these nails on any original boards.

3.3.2 15th/16th C

In earlier phases dovetails have been found cut in the sides towards the south end of flat ceiling joists. In the dovetail in joist 22 a large nail survived. This was sent to Gilmour for analysis, and

[26] Letter to J Limentani 19 September 2001
[27] C. Groves' letter to J Limentani 19 August 2003

his findings are that it is "late mediaeval/early post-mediaeval"[28]. This would seem to imply that there was a scheme of repairs at this time.

3.3.3 1740s Graphic 2

It is recorded that the ceiling was re-painted in the early 18th C[29], and visual recognition backed by an analysis now enables Richard Lithgow and his Team to identify all the boards painted at that time. This identification has enabled Hugh Harrison's Team to look for 1740s noggins where all the boards between two joists are of this date. One was found at the bottom of *Panel 0 I* (see **Plates 24, 25**).

Because this noggin is covered in hessian it was not possible to examine it closely enough to accurately determine whether it is 1740s or 1830s. It is similar to many other 1830s inserted noggins so our suggestion is that in fact this noggin is 1830s not 1740s.

The one important feature of the 1740s work that is now understood is that the boards replaced at the bottom of the sloping ceilings were fixed level with the original boards.

3.3.3.1 Saw cuts in Bays 1 and 10- We now consider that the cuts through the boards alongside the intermediate joists in Bays 37, 38 and 39 were made in the 1740s, because in every instance 1740s boards are found on one or both sides of a cut. The fact that in some places there are 1830s boards on one side of a saw-cut and 1740s boards on the other, is likely to show that one end of an original board was replaced in 1740 and the surviving piece was taken out and replaced in 1830. Where saw-cuts cross 1740s boards it is suggested that this either indicates that one long board was not available, or that scraps of short boards were used wherever possible. **Plates 67** and **78** show location marks dating from the 1740s intervention. There is one similar saw cut in Bay 10 *Panel 0 IV* which has reused original boards on one side of the cut. The prevalent period for the use of these boards was also in the 1740s. The appearance of these saw cuts in Bays 1 and 10 begs the question as to whether work in the 1740s started at both ends of the ceiling?

3.3.3.2 Repositioned original ceiling boards.
17 in Bay 1 *9 in Bay 2* *12 in Bay 3* *15 in Phase 4* *7 in Phase 5*

In Phase 4 we found conclusive proof that the 1740s restorers did indeed re-use original Ceiling boards as replacements.[30] However it is likely that the policy of salvaging for re-use stable sections of deteriorated boards was adopted for both interventions.

3.3.3.3 Repositioned oak Ashlar boards -In Phase 3 we considered it likely the policy of salvaging for re-use stable sections of deteriorated boards was adopted for both the 1740s and 1830s interventions. This because it conformed with our theory that the two oak boards with a foliate design unlike anything found to date on the Ceiling were sections of original Ashlar boards.[31] If so they must have been inserted as replacement Ceiling boards in the 1740s because we are certain the Ashlar boards were entirely replaced at that time (see Item 3.3.3.5 below).

3.3.3.4 1740s replacement boards
78 in Phase 1 *42 in Phase 2* *28 in Phase 3* *46 in Phase 4* *44 in Phase 5*

There are very few reliable features visible from the scaffold to distinguish 1740s softwood replacement boards from 1830s replacements. In the absence of conclusive evidence, such as obvious underpaint, identification of 1740s replacement boards involves an assessment of numerous physical and contextual factors including: dimensions and manufacture of the board in question, properties of adjacent boards, nails, nail holes, shot holes, thickness of the paint etc.

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[25] Gilmour June 2001 Item 6 (HM105) p 8
[29] *Observations on Ancient Paintings in England* Governor Pownall to Revd Mich Lort, D.D. V.P.A.S. published Society of Antiquaries Vol IX Archaeologia. See Glennie June 2001
[30] The Perry Lithgow Partnership and Hugh Harrison 2001, Vol. II: Plates 553 and 554
[31] The Perry Lithgow Partnership and Hugh Harrison 2001, Vol. I: Item 8.2.5

Softwood boards with other impasto painted detail visible in raking light beneath the 1830s overpaint have been categorised as 1740s softwood replacement boards on the accompanying condition survey graphics (**Graphics 9**). Also included in this category are a number of boards with a noticeably thick paint covering. In Phase 3 a confirmatory paint sample was taken from two of these boards and the findings indicate our identification in these instances was correct.[32] In Bays 4, 5 and 6a only twelve softwood boards were recorded as 1740s replacements: this should be considered a minimum figure given the uncertainties discussed above. On a number of replacement boards in Bays 6b, 7 and 8 offset 1740s decoration was visible through the 1830s white paint.

3.3.3.5 Repositioned 1740s softwood Ashlar boards
9 in Phase 1 *8 in Phase 2* *15 in Phase3* *0 in Phases 4 and 5*

Throughout Bays 1-5 of the Nave Ceiling we have identified a number of softwood replacement boards with a scheme very similar to the existing 1830s frieze decoration visible in raking light beneath 1830s overpaint. These we consider to be 1740s Ashlar boards salvaged in the 1830s, and re-used as Ceiling boards.

In Phase 2 we noted that the frieze decoration on one such replacement Ceiling board appeared to be overpainted with the 1740s composite black paint. However, the identification of a visually identical 1830s brown/black paint suggests that attribution was in error.[33] In Phase 3 two paint samples (red and black) were obtained from an area of frieze design protected from subsequent repaint by an overlapping board.[34] The purpose was to validate our belief that the frieze decoration on these replacement boards could indeed be 1740s. The findings of analysis on these two samples indicated they did indeed conform to a possible 1740s date.

Evidence provided by the softwood replacement Ceiling boards with frieze decoration as underpaint suggests the original Ashlar boards (probably referred to by the 1740s restorer as the *'wainscot'*) were replaced entirely during this intervention and the new boards painted with a scheme very similar to the existing 1830s frieze decoration. In turn, the 1740s Ashlar boards were entirely replaced in the 1830s when a number of the boards were salvaged for re use as replacement Ceiling boards. The discovery in Bay 5 of two possibly original Ashlar boards (Item 3.3.3.3 above) would suggest the same policy of salvaging Ashlar boards for re-use had been adopted by the 1740s restorers.

3.3.3.6 Now that whole panels of undisturbed 1740s boards have been identified, it is axiomatic that the nails are coeval. **Plate 68** shows that the nails have faceted heads rising to a point in the middle and that they are irregular in size and shape.

3.3.3.7 **Plates 77 and 78** show examples of 1740s repairs. The twice scarfed insert shown in **Plate 77** is important as very few similar repairs have been recorded. It has also been very sympathetically carried out.

3.3.4 1830s Graphic 2

Transcribed below is an extract from the Dean and Chapter Audit Accounts for 1836 in which all the materials and labour for Blore's work to the ceiling is listed.

[32] Davies 2000: Samples 11 and 12
[33] The Perry Lithgow Partnership and Hugh Harrison 2000: Plate 461
[34] Davies 2000: Samples 9 and 10

EXTRACT
Dean and Chapter Audit Accounts
NRO Box X5053
Bundle 2, 1834-1837
Bundle (4) Audit Accounts 1836

			Old Ceiling							
			Repairing old Ceiling putting in new Binders, preparing and fixing new Platform over Dº with proper Handrail and Step ladders to the same							
9	0	Cube	Labor to old Mat[ls] in framing uprights and Bearers etc.	1/-		9	0			
175	9	..	Fir framed in Binders etc.	3/11	34	8	4¼			
1002	0	Sup	¾ In deal boarding to enclose end of Nave and border to roof							
			Planed O.S. Plough[d] & tory[d]	7[d]	29	4	6			
402	7	..	1 ½ In deal rough in platforms to							
			the top of the Ceiling	6 ½	10	18	0¾			
111	9	..	2 ½ In Deal rough	10¾	5	0	1¼			
96	6	..	2 ½ In Deal rough and framed	1/0½	5	0	6¼			
14	6	..	3 In Deal rough	1/0¼		14	10½			
117	6	Run	2 In Deal rough 3 In wide	3d	1	9	4½			
131	0	..	Rounded Edge 3 In Girth	1½d		16	4½			
		Nº	38 Housings to 2½ In deal Steps	4d		12	8			
			4 Bevel cuttings in 2½ In deal	3d		1	0			
			1 Pr 16 In & Garnet hinges	2/-		2	0			
			Inside Work							
			cwt qu lbs							
			14 3 4 Wrot Iron in Bolts and plates from Binders to old Ceiling							
			including labor fixing etc	4¾	32	15	6			
								121	12	4
			Day Work							
			To Shoring up and repairing ceiling							
			Taking down part of old Boarding							
			repairing and halving sloping							
			Bearers and uprights to side							
			Boarding							
			Carpenters 360 Days	3/6	63	0	0			
			Laborers 120 Days	2/6	15	0	0			
			2712 0 sup ¾ In deal no labor	2¾	31	1	6			
			300 0 .. 1¾ In Dº	4¼	5	6	3			
			420 lbs 8[d], 10[d], & 12[d] nails	3¼	5	13	9			
			3½ M Flat head[d] nails	5/-	..	17	6			
								120	19	0

Blore's work to the ceiling structure (**Drawing 3)** is as follows:

- Install softwood binders and hanging bolts to carry the ceiling.
- Install reused oak binders and hanging bolts in Row 39 only, to carry sloping ceilings.
- Take out all old ashlar posts and ashlar boarding and install oak (reused) and softwood (possibly reused) ashlar posts and new softwood ashlar boarding.

- Take out and renew sloping joists 20, 27 and 81 north, and 67-71, 73 and 81 south, and flat joist 81.
- Take out most original noggins at the bottom of the sloping ceilings and renew with (probably reused) oak.
- Add sprocket pieces to the sides of some joists to lengthen them.
- Take out noggins in rows 31-29 at scissor joint level south side, and renew in rough oak.
- Cut out many of the scissor joints.

Blore's work to the ceiling itself is as follows:

- Take out original boards and some 1740s boards and replace with reused original boards, reusable 1740s boards and new softwood boards.
- Patch over fragile areas above the ceiling with oak boards.
- Additionally nail any loose areas of boarding.
- Carry out minor repairs to some boards.

In addition the Audit Accounts show that he installed a central walkway and some doors (presumably to the parapets) and the west wall panelling.

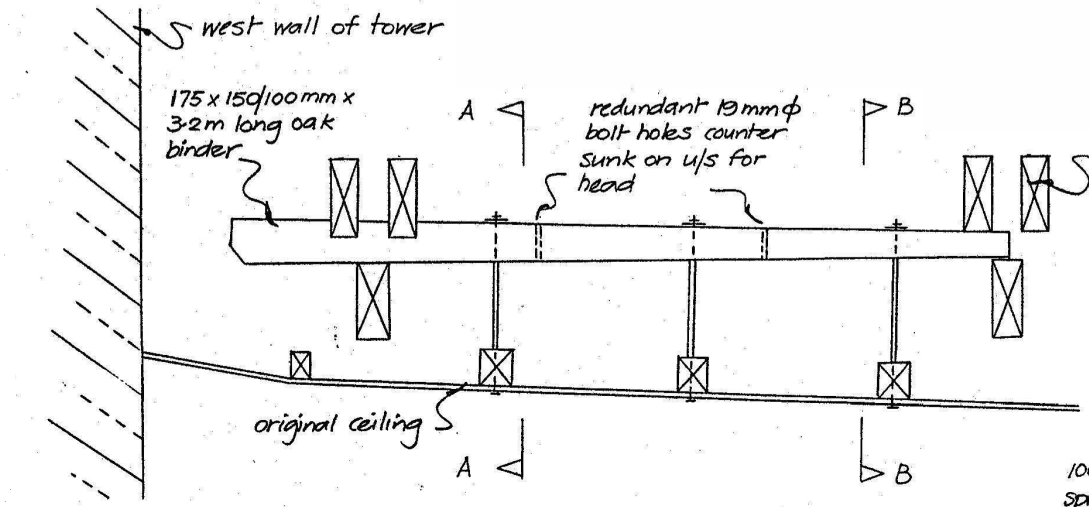
Most of Blore's work in this phase continues previously encountered patterns of repair, and there are no surprises, with perhaps the one notable exception of the lower south side of the roof (*Panels 4,5,6, IV*) where from the evidence now presented he was faced with massive failure of the sloping joists and boards. Since there is no evidence of fire damage or adjacent upper masonry collapse, one must assume that poor conditions and maintenance of the roof above were the probable cause of decay. All the sloping joists and boards were replaced, the joists with re-used original timbers from the old roof (confirmed by dendrochronological dating of sloping joist 68 south)[35], some retaining evidence of earlier halved joints which have been recorded on **Drawing 2.**

In addition Moore reports on all the doublers and stiffeners Blore inserted, which Moore then cleared out, so that there is little evidence of them now.

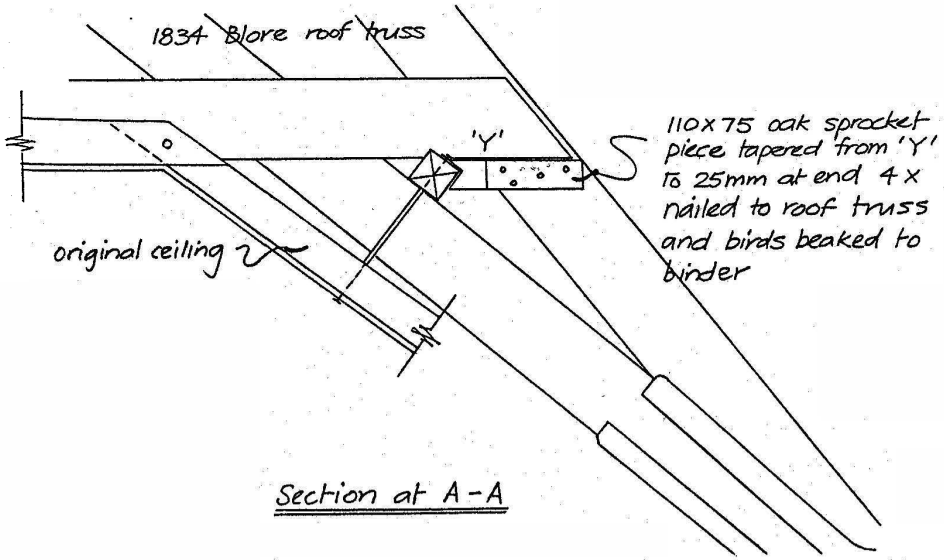
Leslie Moore[36] reported in his initial survey of the Nave roof that the original sloping ceiling joists were merely hung from the 1830s roof with assorted timbers of smaller dimension than the joists themselves:

> *"This method of hanging the ceiling was adopted on the re-construction of the roof and at the same time some of the oak ceiling joists were repaired, but, owing to the difficulty of removing the decayed joists and attaching the ceiling to new[37], the original diseased timber is merely secured to inserted strengthening timbers and in about six cases the added timber is now infected with decay from the older. In these instances both should be removed and replaced with new creosoted joists. ……..The oak joists (6" x 4¾") of the sloping sides of the ceiling are themselves in a fairly sound condition generally speaking……but at the present time they are merely hung from the roof and supported by short lengths of odd timber of a smaller section themselves.. this is most unsatisfactory especially as in by far the majority of cases the small timbers are in varying states of decay and are only nailed. This particular work is "rough and ready" workmanship (probably executed under difficulty with only light from lanterns) and the stability of the sloping ceiling joists cannot now be regarded as secure."*

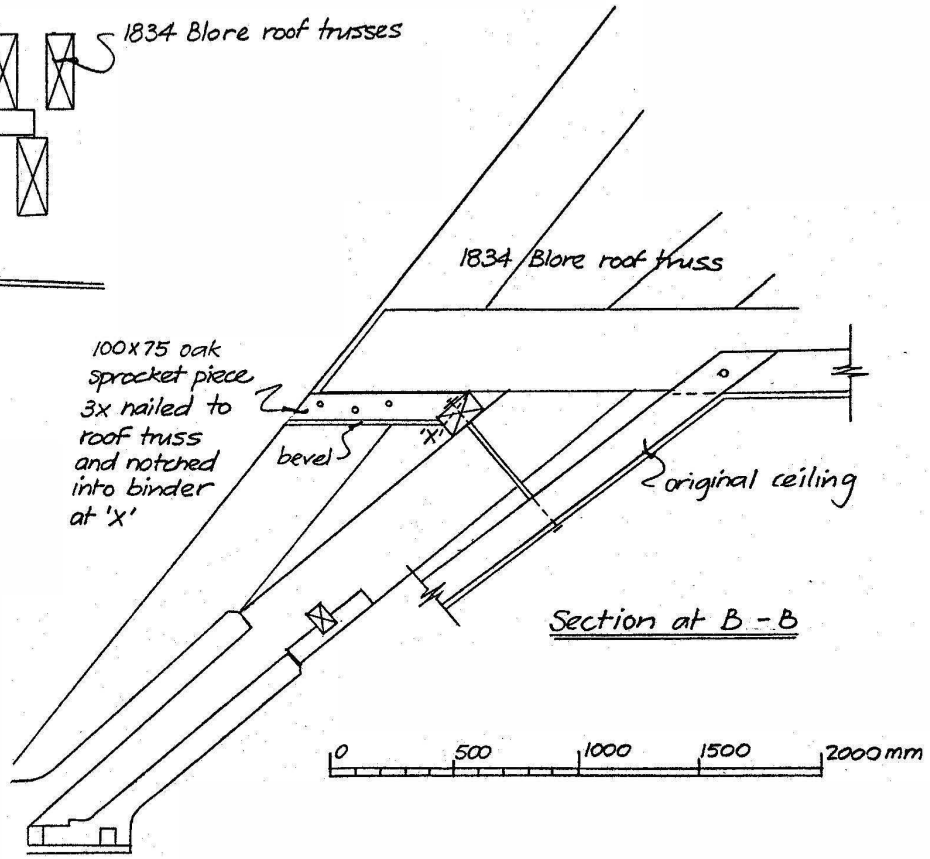
[35] I Tyers, 1999
[36] *Peterborough Cathedral – Report on the Structural Condition of the Nave Roof and Ceiling*. L.T. Moore, ca. 1920. See The Perry Lithgow Partnership and Hugh Harrison 1998, Vol. I: Appendix 2
[37] Underlining by H Harrison



Binder supporting sloping ceiling joists Bay 39 IV south



Section at A-A



Section at B-B

PETERBOROUGH CATHEDRAL Top binder details Bay 39 IV south side

HUGH HARRISON CONSERVATION drawn Peter Ferguson June 2002

Note: there is no corresponding top binder on the north side, sloping joists 1 and 4 have no vertical holes where bolts should have been. sloping joist 2 has an empty hole and 3 is filled with two old nails and wood fragments. there is no evidence on other roof timbers of any binders having once been fitted however on u/s of painted ceiling, positions are occupied by bolts/washers.

Figure 13

No evidence of nail holes for these hangers has been found on the sides of the rafters to date. However marks on the top side of the lowest purlins are consistently found along the length of the roof, and might indicate the position for some system used to support the sloping ceilings.

3.3.4.1 Blore's system for hanging the sloping ceiling sides from his new roof structure used an oak binder (reused timber in the only example that survives) that was inserted above the scissor brace. Hanging bolts similar to those used to suspend the flat part of the ceiling, were suspended from this binder and through the ceiling below, see **Figure 13.** Only the binder on the south side now exists, but the bolt holes on the north side show that the same system once existed there as well. There is no evidence that this system was continued beyond the second truss.

3.3.4.2 Hanging Bolts – The hanging bolts are specifically mentioned in the Audit Accounts (Item 3.3.4 above) and were supplied and fixed at fourpence three farthings each.

Some bolts are loose where the ceiling has undulated upwards and there is insufficient thread to tighten the nut, and packers have not been inserted to make up the space. Other loose bolts were recorded at the south end of joists 47 and 45 and the north end of joist 56. A change of mind was noted where alongside the south bolt in joist 54 an additional ¾" hole has been drilled.

The deflection noted around various bolts was measured and recorded. See **Plates 102, 103** and **137**). In the previous phase, when a straight edge was placed parallel with the longitudinal axis of the ceiling at joist 62, it appeared that the ceiling had been lifted by the bolt by some 2" (50mm). However, when the straight edge was turned to run across the width of the ceiling the apparent deflection was reduced to between ½" and ¾". All that this in fact shows is that the joist is out of line with its neighbouring joists and that the ceiling has had to follow the subsequent deflection.

3.3.4.3 Structural Repairs – The structural repairs in this phase are recorded on **Graphic 2** and examples of reused sloping and flat joists, ashlar posts, sprocket pieces and noggins can be seen in **Plates 19, 22, 23, 62-66, 18, 61, 24** and **25** respectively**.**

3.3.4.4 Ashlar Panelling and West wall panelling – Perhaps the most complete surviving aspect of Blore's intervention to the ceiling structure was the rebuilding of the Ashlar and west wall panelling (**Plates 79 - 81**).

Fairly extensive research in Phase 2 did not appear to reveal any particular system of spacing of the Ashlar posts in connection with the stone plinths for the truss shoes, nor a regular length for the Ashlar boards. The ashlar posts are nailed to the bottom ends of the sloping joists and have no fixing into the stone wall head. Some of the posts are oak, some are softwood.

The Ashlar and west wall panelling consists of ¾" thick tongue and grooved boards ("Planed O.S. Plough^{d} & tory^{d}" Extract from the Audit Accounts) nailed to the posts with the 1830s flat head nails. Each panel is three boards high and random width, and in this phase they generally span 4 rows (approx 21'0" or 6.400m). A central door, now blocked by a fire screen behind the west wall panelling, formerly gave access to a broad stone ledge across the west end return of the nave.

3.3.4.5 Patches – No patches were found in this phase but from the disposition of 1830s nails, examples of probable 1830s patches have been defined on **Graphic 2**. The regularity of the patches in the centre of the sloping sides of the ceiling is particularly noteworthy as are the easily defined patches on the flat section of the ceiling. The extent of patches as shown is certainly not definitive. Evidence that the patches existed can be found in Moore's initial survey where he states *"Many stiffeners to the boarding have been added from time to time in a haphazard manner and repairs executed in places"*. There are many examples of nails projecting below the ceiling that are clenched over, and which once fixed the patches above the ceiling.

3.3.4.6 Replacement Boards – Extent of Replacement Boards

AVERAGE NUMBER OF BOARDS REPLACED PER BAY								
	1740	Reused oak	1830	Total replaced boards	North side	South side	% of total boards per Bay	Total all boards
Phase 1	79	17	106	**202**			43%	470
Phase 2	23	5	70	**99**			23%	430
Phase 3	11	5	119	**135**	29%	20%	31%	430
Phase 4	22	6	84	**112**	13%	32%	25%	442
Phase 5	22	3	170	**195**	32%	50%	49%	400

The table above clearly shows the significantly larger number of 1740 boards in Bay 1than other Bays, and if the Reused oak boards are included, this number is almost equal to the 1830s replacement boards. It is also interesting to see that almost double the average number of boards have been replaced in the two end Bays.

As regards disposition on which side of the ceiling, in Phases 3, 4 and 5, 356 boards were renewed on the north side and 485 on the south. This is quite a normal finding as the south side has much greater variations in temperature, and is probably wetter. It is notable that in Phase 5 no original boards survive at the bottom of the south sloping panels. Indeed the first original board at the bottom of a sloping panel is not found for a further 2 rows east when there is one board.

Generally the replacement softwood boards have a uniform finish, but **Plate 69** shows a board which has had little preparation, thus leaving exposed the sawn surface. Note the regular indentations indicating that the board was cut mechanically.

3.3.4.6.1 Timber Species – In Phase 2 Groves identified 4 boards of the *Picea/ Larix* group east of joist 14, and 15 boards of *Pinus sylvestris* to the west. In Phase 3, 19 boards identified as 1740 by the paint stratification were all tested and found to be *Pinus sylvestris.* 22 boards identified as 1830 by their paint stratification were also tested, and in Bay 4, 6 were *Pinus sylvestris* and 5 *Picea/Larix.* In Bays 5 and 6a all the other 11 samples were *Picea/Larix,* none were *Pinus sylvestris.* There does seem to be a coherence with the 1740s boards which are all *Pinus sylvestris;* the 1830s boards seem to be a mix of both species[38].

3.3.4.7 Nails – Two styles of added nail (square headed and dome or flat headed) have been identified, and are illustrated in **Figure 12.** The dome headed nails have been further analysed by Gilmour[39] and confirmed as early 19th C. The square headed nails are no longer positively identifiable from their heads alone, hence only 13 are marked for the whole phase. They do also seem to be only rarely used now with only one end recorded. Gilmour grouped 4 nails as of uncertain date (HM107, HM110, HM112, HM123), and these unidentifiable nails are all marked simply as "Added nail heads".

3.3.4.7.1 Numbers of Nails

AVERAGE NUMBER OF ADDED NAILS PER BAY				
	Square Headed	Dome Headed	Added	Total
Phase 2	497	791	Nil	1288
Phase 3	104	1055	Nil	1057
Phase 4	5	511	524	1040
Phase 5	1	41	863	905

[38] Letter from C Groves to J Limentani 12 June 2001
[39] B Gilmour 2001 Item 11 (HM125), p11

3.3.4.7.2 Nails Beneath Collars – It should be remembered that in the 1830s not only was the new roof erected, but many ancient boards were taken out of the ceiling and exchanged for softwood. In addition patches were fixed over the boards and nailed down through the ceiling. In the flat section of the ceiling this work would have been seriously hampered by the collars of the new roof which are positioned only 2" (50mm) above the ceiling boards. On **Graphic 2** for this Phase of work speculative patches are shown running between the collars. The Graphic also shows many nails directly beneath the collars which would either require them to have been driven before the collars were fixed, or it shows that the Graphic is slightly inaccurate in correlating the position of the collars with the ceiling boards. If the ceiling was considered to be as fragile as it seems it was thought, it would have been quite logical to have repaired and strengthened it before exposing it to the potential dangers of major roof works which would have followed. On-site research in Phase 3 actually revealed that some of the nails which were examined which the Graphic showed to be beneath the collars were actually just outside the line of the collars[40]. More intriguingly quite a large number of nails (approx. 40) were found to have been driven down between the collars.

3.3.4.7.3 Investigated Nail Ends – In previous phases the heads of a number of nail ends below the ceiling have been investigated above the ceiling, these included square and flat headed nails (previously referred to as dome headed), some with clenched ends against the ceiling boards, some with clenched over ends that hung down below the ceiling. All those nails with clenched ends tight against the ceiling boards were found to have no sign of their heads above the ceiling boards. All those which hung down below the ceiling were found to have their heads resting on the top of the board.

3.3.4.7.5 Patterns of Use for Added Nails – The Table in Item 3.3.4.7.1 shows the square headed nails to be hardly used at this end of the ceiling. However there is now a large category of unidentifiable nails, so it may be that the square headed type is still being used, but as the head is slightly different in appearance the nail is no longer positively identifiable.

3.3.4.8 Screws – No screws were found in this Phase of work. In past Phases where screws had been found it was assumed they were from this period of work. In another part of the Dean and Chapter Audit Accounts referred to in Item 3.3.4 above there is an entry for 3 Doz^{n} 3 1n screws, so they were obviously in common use at this time.

3.3.4.9 General Repairs – Phase 4 commented and illustrated at great length the continuing mix of shoddy and careful workmanship from this period. This phase is no different, but two examples of sympathetic repairs stand out, illustrated in **Plates 75, 76**, and one of apparent improvisation where, in *Panel 1 IV* the setting out of boards a-d and j-m are standard but boards e-i do not conform as they do not create the lozenge design. The only apparent explanation being that boards of the correct length were not available.

3.3.5 1880s

The Tower was completely dismantled and rebuilt by Pearson. A screen was built in Row 33 at the west end of the scaffold erected for the rebuilding of the tower. In this area, some boards were found to have been screwed up from below. Some boards were taken out to provide working access and they are characterised by being much dirtier than the surrounding boards and required considerably more effort to clean to the same level as the adjoining boards. No further evidence of work to the ceiling has been found, or is likely to be found, as the current work moves further away from the tower. All the east end infill panels were taken down at this time and *Panel 40 IV* is composed entirely of 1880s boards.

[40] More conclusive evidence could be obtained by stripping back hessian where nails appear to be beneath collars. To be conclusive this evidence would have to be quite widespread and it may well be considered that the information gained does not add substantially to the history of the ceiling.

3.3.6 1926 Graphic 3

Moore made substantial alterations to the ceiling structure[41], but very few to the ceiling boards or ashlar boards as he had no direct access to them, as all the 1920s work was carried out without a scaffold beneath the ceiling. Two strong philosophies characterised Moore's work. One was a paranoia for eradicating beetle infestation and the other was his own attitude to conservation/restoration. An extract from a book on Gothic Architecture by Moore[42] is produced below, which neatly encapsulates both philosophies.

Moore held a pragmatic view of restoration, retaining old work where possible but being unafraid to replace existing structures wholesale where more long term eradication of defects demanded it. He showed scant regard for the work of Edward Blore, architect to the cathedral in the 1830s, who had previously repaired the roofs in a less thorough going manner.

"Unfortunately," Moore noted *"the conservative spirit of the restorers at that time in retaining some of the old oak timber of a former roof has left the necessary food for the beetle, and there is evidence of active attack in some of the main beams".*

It is only because of our current knowledge of beetle infestation that we see Moore's attitude as paranoid, and it must be acknowledged that the cathedral was well served by Moore's industrious outlook on this problem. There is no indication now of any infestation throughout the roofs, except possibly some common furniture beetle at the west end of the nave roof. It is interesting to note that only 30 years before Moore's work, J. T. Irvine, Pearson's Clerk of Works and an antiquarian[43], in a period of general wholesale restoration, saved the $12^{th}/13^{th}$ C beams in the South Transept, only for them to be lost just a few years later in a period of supposedly greater antiquarian enlightenment.

The extract above surely describes Moore's approach concerning work to the nave ceiling: eradication of anything that might be infested, and if that involved the loss of original material, that was a price worth paying. Thus when it came to deciding on the ceiling joists, it is likely that it only needed the vaguest suggestion of current beetle infestation for the decision to have been made that that piece had to go.

It also explains Moore's ingenious repairs which were all carried out in creosote impregnated timber[44], and being produced from thin laminates ensured that even the biggest members were treated right through to the core. These repairs are recorded in J. Thompson and Sons drawings of work carried out for Moore and are now stored in Peterborough Museum, see **Drawing 5**.

The main items of work carried out by Moore are as follows:

- Many original flat and sloping ceiling joists were taken out and renewed with composite joists made from laminated softwood.
- The binders for the sloping ceiling joists were installed.
- The hanging bolts to the sloping joists in *Panel 39 I* were taken out (though this could have been done by Pearson in the 1880s).
- Rigid connections between the sloping joists and the flat ceiling joists where these had been cut away in the 1830s were mostly reinstated using softwood laminates.

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[41] *Peterborough Cathedral – Report on the Structural Condition of the Nave Roof and Ceiling*. L.T. Moore, ca. 1920. See The Perry Lithgow Partnership and Hugh Harrison 1998, Vol. I: Appendix 2

[42] D Glennie June 2001 Appendix 3

[43] Personal comment by D Mackreth

[44] "Under pressure" comment from Thompson's drawings

- All, or nearly all the 1830s patches nailed to the top of the ceiling boards were taken out and exchanged for a variety of noggins built up in laminated softwood.
- Original noggins were reinforced with laminated softwood.
- All of Blore's wooden hangers at the top end of the sloping joists were stripped out, if there were any, as well as (nearly) all his inserted doublers and stiffeners added to the edges of joists etc.
- A considerable number of patches were screwed down to the tops of the original boards.
- The whole roof was treated with Silvertown Solution, an insecticide containing sulphur chloride and carbon bisulphide[45], and mercuric chloride[46].
- Lastly, the whole ceiling, except the 1920s noggins and the original and composite replacement joists, was covered with a layer of hessian adhered with a water soluble animal glue.

Much speculation has been aired in previous reports on how the 1920s work was carried out without a scaffold beneath. It may be worth remembering that the ceiling boards are fixed at each end (and in the middle of the flat ceiling to panel noggins) and along their edges or an intermediate joist. If the 1830 patching was as extensive as the number of flat nail ends seem to suggest, temporary studding could have been screwed to these patches and the ceiling boards would have been quite secure even if separated along one side. Alternatively, if the patches were stripped off and if the strips of hessian were applied at the outset of the work, the boards would have generally been quite secure when separated from a joist.

3.3.6.1.1 Composite Ceiling Joists – 24 joists were replaced by Moore with composite joists in this phase, representing 24% of the total. One should remember that 9joists had already been renewed by Blore. Now that figures are available for the whole ceiling it is interesting to compare the very consistent percentage number of replacement joists, whereas the percentage of boarding replaced is quite different. How can there be no relationship of decayed joists to decayed boards?

	% Joists replaced	**% Boards replaced**
Phase 1	15%	43%
Phase 2	22%	23%
Phase 3	25%	31%
Phase 4	38%	25%
Phase 5	24%	49%

3.3.6.2 Sloping Ceiling Binders – Softwood binders were inserted near the top and bottom ends of the sloping joists. The top binders were carried either on steel hangers, or on wooden cleats fixed to the side of the principal rafters. In this Phase all the top binders were held by steel hangers. The lower binder was supported on wooden cleats fixed immediately above the projecting flange of the cast iron shoe made for the feet of the scissor braces. Galvanised coach screws (265mm x 18mm) were inserted where each binder passed over the joist beneath. This system is perfectly satisfactory so long as the sloping joists remain in good condition, but should they ever decay, the system would fail because the coach screws will no longer hold.

3.3.6.3 Joist Connections – In this Phase all connections severed by Blore between the flat ceiling joists and the sloping joists are reinstated by laminated repairs see **Plates 82 - 84.** They are all neatly carried out and follow the techniques commented on in earlier Phases. The scissor join at the south

[45] Spons Workshop Receipts, 5th Series, 1885.
[46] Site meeting Minutes 30 May 2001, this material was suggested by Dennis Robertson of Bedford Timber Preservation Co. as it was used to treat imported timber in the 1920s and was produced by a firm in the Docklands, London

end of joist 57 survived more or less intact so was merely bolted by Moore as were all other intact halving joints.

3.3.6.4 Patches – In addition to reinforcing original noggins, patches using the 150mm (6") by 12mm (1/2") creosote impregnated softwood are fixed one board thick on top of the ceiling boards ranging from just 1 or 2 boards wide to 15 boards wide. The boards are laid at right angles to the joists (unlike Phase 1 where the only extensive patch in *Panel 37 I* was laid at approx. 45° to the joists) and fixed with large numbers of screws. In Phase 4 there is only one patch in *Panel 11 II*, and in this phase there are only 2/3 individual boards.

This reduction in the number and size of patches would seem to indicate a major policy change in the use of patches, as can be seen by comparing the small number found in this Phase compared with the large number of patches found in Phase 2. When the large patch in *Panel 11 II* was compared with adjacent areas and it is hard to see any huge difference in condition that requires a patch above. It must be speculated that this patch may be the result of change of personnel carrying out the work as much as change of condition.

3.3.6.5 Noggins – Moore took out Blore's patches and inserted a whole series of noggins and original noggin reinforcements in half inch impregnated softwood boards which are screwed and nailed together and down into the ceiling. Assuming the 1830s patches ran from joist to joist, the problems of taking them out would have been considerable. As so many of the nails holding these patches survive it is suggested that each board was split out leaving the nails intact. If these patches extended beneath the collars the difficulties would have been considerably increased.

17 different designs of noggin have been found throughout the ceiling, of which 2 are new in this Phase, shown as types 16,17 on **Drawing 6** (see **Plate 85**). In addition 4 new variants of original noggin reinforcement were found in this Phase (**Drawing 7**), including a one-off steel noggin support strap (**Plate 86**), which is thought to be by Moore, but could belong to the 1830s period of repair by Blore. The positions of these varying noggins and reinforcements are found on **Graphic 3** where the type numbers are printed adjacent to each noggin/reinforcement. Again it is interesting to see that there is a broad correlation between noggin disposition and type of noggin.

A few further examples of fitted gusset plates were found that are scribed to the shape of the ceiling boards (**Plate 22**). As far as we know these pieces were only inserted as a means of providing a ledge on the side of the joist to carry the noggin that spanned the space between the joists.

3.3.6.6.1 Screws – Screws were used to fix all of Moore's laminated noggins and composite joists to the ceiling boards and also in the build up of the laminates themselves. The screws found in this phase are the same type and size as in previous Phases. Wire nails have also been used (as in previous Phases) to fix laminates together to form noggins.

Number of Screws per Bay			
	Iron Screws	Galvanised Screws	Total
Phase 1	600	120	720
Phase 2	396	90	486
Phase 3	552	111	663
Phase 4	643	47	690
Phase 5	165	18	183

The table above needs little explanation, except to say that phase 1, 3 and 5 are remarkably consistent in the number of screws inserted per Bay per phase, and the proportion of iron to galvanised screws remains consistent. Phase 5 is notable fore the reduction in screws used, which might relate to the reduction of original boards. For the consistency of the proportion of iron to galvanised screws, it seems likely that there has to have been a strategy of using iron screws in one situation and the galvanised in another. The pattern of use looks totally haphazard.

3.3.6.7 Repairs – Further evidence of "running repairs" can be found in a small number of reinforcing strips of wood of varying sizes fixed above the ceiling, some of which can clearly be seen below the hessian. These are indicated on **Graphic 3**.

3.3.6.8 Timber Treatment – Moore recorded that he had already used Silvertown Solution to treat the North Transept Roof, and in his report he specifies its use on the Nave roof.

3.3.6.9 Hessian – On completion of all the patching and reinforcing work, Moore had the whole upper surface of the ceiling covered in hessian adhered with animal glue. A sample of the hessian was sent to Dr DM Catling, Department of Biological Sciences, University of Durham[47] who analysed the fibres and confirmed that they are jute which is a species of *corchorus* (see **Appendix 13**). Significant additional patching to the hessian was noticed and recorded using another layer of hessian or strips of canvas. A piece of the canvas was also analysed by Dr DM Catling and confirmed as cotton, a species of *gossipium*. Strips of additional hessian have frequently been applied where the hessian runs up the sides of joists, and in earlier phases beneath composite joists. In phase 4 only a very few strips were found beneath composite joists, and in this phase there are none. The canvas strips are often concentrated in certain panels where almost every joint is reinforced with additional strips (see the one group in this phase, *Panel 2 IV*), and the patches of hessian are in groups of patches (see the one small group in this phase *Panel 6 III*).

The hessian has been applied in two layers. The first layer is comprised of strips approximately 50mm wide which are applied roughly perpendicular to the direction of the boards at approximately 200mm centres. A second overall layer has then been laid over the whole surface and is taken approximately 25mm up the sides of the joists.

A canvas strip was investigated at one end (*Panel 9 I*)) and as usual no apparent fault could be seen beneath to explain the patch. Similarly, there are no obvious reasons for the hessian patches as found in this phase.

An unusual feature is that there are no hessian patches between rows 19 and 12 except for two in the eaves in row 14, and then suddenly in row 11 there are a number of hessian patches (and the extra screws and the softwood patch etc.) As the distribution of canvas patches does not seem to follow the pattern of hessian patches, it might be surmised that they are from a different era of work.

In earlier Phases the hessian has clearly split above joins between the boards, presumably due to shrinkage of the hessian after application. No splits were found in this Phase.

There are two other anomalies with the hessian, one is that in previous Phases up to four layers have been found and the other is that in some parts of the ceiling whole areas of hessian look a different colour.
Where the slight differences in colour were found, no perceptible differences in the hessian were detected.

Three samples of the glue were analysed by Ioanna Kakoulli, of the Courtauld Institute of Art, Conservation of Wall Paintings Department, using FTIR, and have been confirmed as proteinaceous glue[48]. Further tests are being carried out at present by Dr B. Singer, University of Northumbria, Department of Chemical Life Sciences.

3.3.7 Graphic 4

This Graphic is included in order to illustrate the ceiling as it is to-day. It also helps to demonstrate the historical layering of additional support to the ceiling, and to make sense of the lumps and bumps covered by the sea of hessian. It also emphasises the extent of the original ceiling structure

[47] Dr D M Catling. Unpublished letter to H Harrison, 16 October 1999
[48] *Peterborough Cathedral Nave Ceiling Paintings: Scientific Examination Phase 2* Dr Ioanna Kakoulli, December 1999

that still survives, which is something one gets very little idea of when one is actually there in the roof looking at the ceiling.

3.3.8 Graphic 5

This Graphic highlights the total number of screws and nails in the ceiling.

	NAILS PER BAY									
TYPE AND DATE	**Bay 1**	**Bay 2**	**Bay 3**	**Bay 4**	**Bay 5**	**Bay 6**	**Bay 7**	**Bay 8**	**Bay 9**	**Bay 10**
ORIGINAL										
Standard Original	771	786	515	595	640	903	817	678	384	281
Small Headed Original	119	52	54	98	135	267	386	178	110	196
Pos. small headed orig.	150	215	215	128	31	29	11	28	22	53
Total	**1040**	**1053**	**784**	**821**	**806**	**1199**	**1214**	**884**	**516**	**530**
ADDED 18th-19th century										
Added Square heads	553	297	321	75	100	61	4	8	3	3
Added Flat heads	378	314	459	591	370	248	56	91	46	36
Added nail heads uncat.	20	-	-	-	-	213	457	640	905	869
Total	**951**	**611**	**780**	**666**	**470**	**522**	**517**	**739**	**954**	**908**
Added Flat ends	-	33	465	452	566	349	363	566	317	287
Added Square ends	23	101	138	9	10	1	1	1	-	-
Total	**23**	**134**	**603**	**461**	**576**	**350**	**364**	**567**	**317**	**287**
ADDED 20th century	**SCREWS PER BAY**									
Iron screws	600	419	357	513	620	847	614	395	198	129
Galvanised screws	120	57	123	160	55	88	32	60	27	8
Total	**720**	**476**	**480**	**673**	**675**	**935**	**646**	**455**	**225**	**137**
Total all metal fixings	**2734**	**2274**	**2647**	**2621**	**2527**	**3006**	**2741**	**2645**	**2012**	**1862**

Total all metal fixings **25,069**

This Table like **Graphic 5** helps to separate out into their various categories the myriad fastenings which pepper the underside of the ceiling but which are quite incomprehensible when seen close to.

Notes on the Table above

- The number of original nails must of course be related to the number of surviving original boards. It is for this reason that there are so few in Bays 9 and 10.

- As the number of categories of added nails increased, so it became less possible to categorise them definitely and especially into the original two groups, of square headed nails and flat headed nails. Thus a new category was born, and when this is included it will be seen that the total numbers do not vary that greatly.

- Even before the categorisation became difficult, note how the square headed nails decreased from Bay 1 to Bay 4.
- Note how the flat nails have been used consistently from above.
- Note how the number of screws decreased so substantially from Bay 6 to Bay 10.

3.3.9 Further Documentary Research

The Moore papers at the Northampton Record Office have not yet been examined in relation to these reports and this is recommended.

Revision 'B' November 2004

roof redrawn to "new" pitch
original sloping string course indicated
possible location of re-used timber shown.

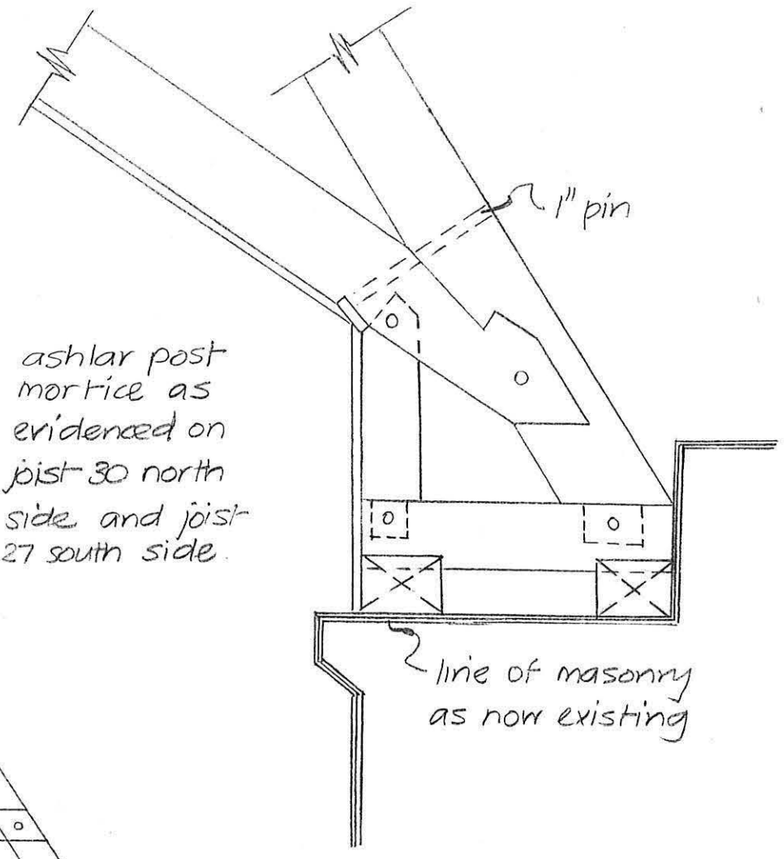
outline of present 1834 roof by Blore at pitch of approx. 52°. Blore's roof is approx. 600mm. wider and 1000mm. lower than reconstruction shown here.

possible original location of replacement Sloping Joist 71 S.

0 1 2 3 metres.

re-used timbers found in ceiling projected on to amended conjectural reconstruction of roof

wooden pin



Enlarged Reconstruction Detail 'A'

fragments of original roof sloping string course shown in situ at pitch of 57°

NOTE : general configuration of roof as for Ware's 1805 drawing.

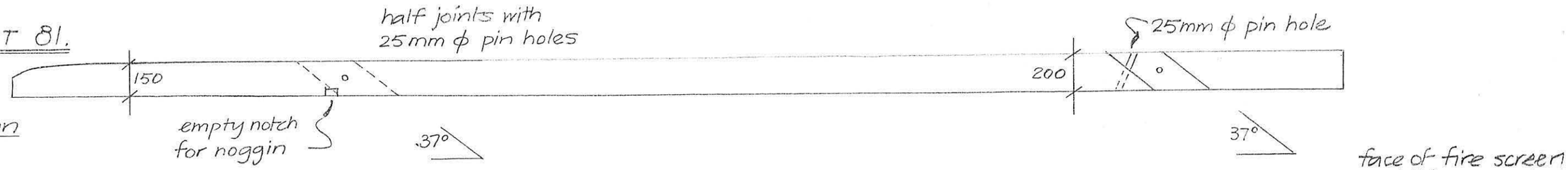
'A'

PETERBOROUGH CATHEDRAL conjectural reconstruction of 13th C. nave scissor roof truss suggesting placement of some re-used timbers found in roof.

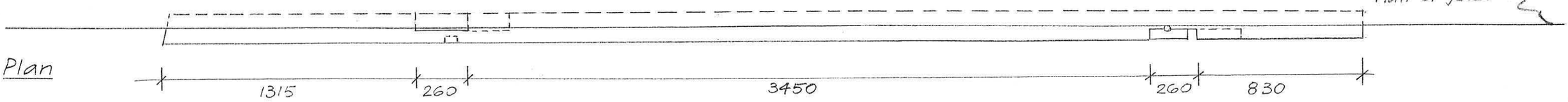
HUGH HARRISON CONSERVATION drawn Peter Ferguson November 2004

DRAWING 1

CEILING JOIST 81.

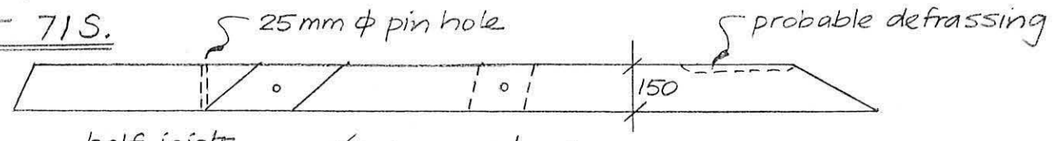


East Elevation



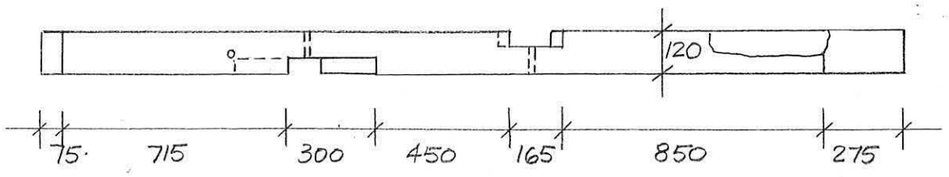
Plan

SLOPING JOIST 71S.



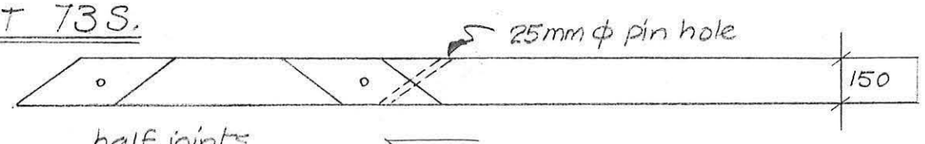
East Elevation

half joints with 25mm ϕ pin holes



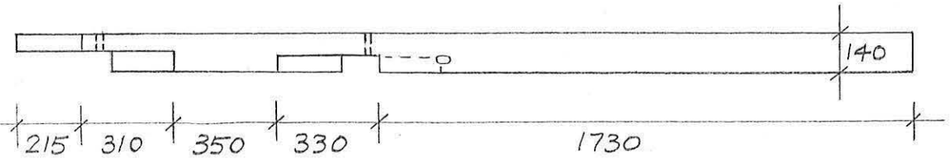
Plan

SLOPING JOIST 73S.



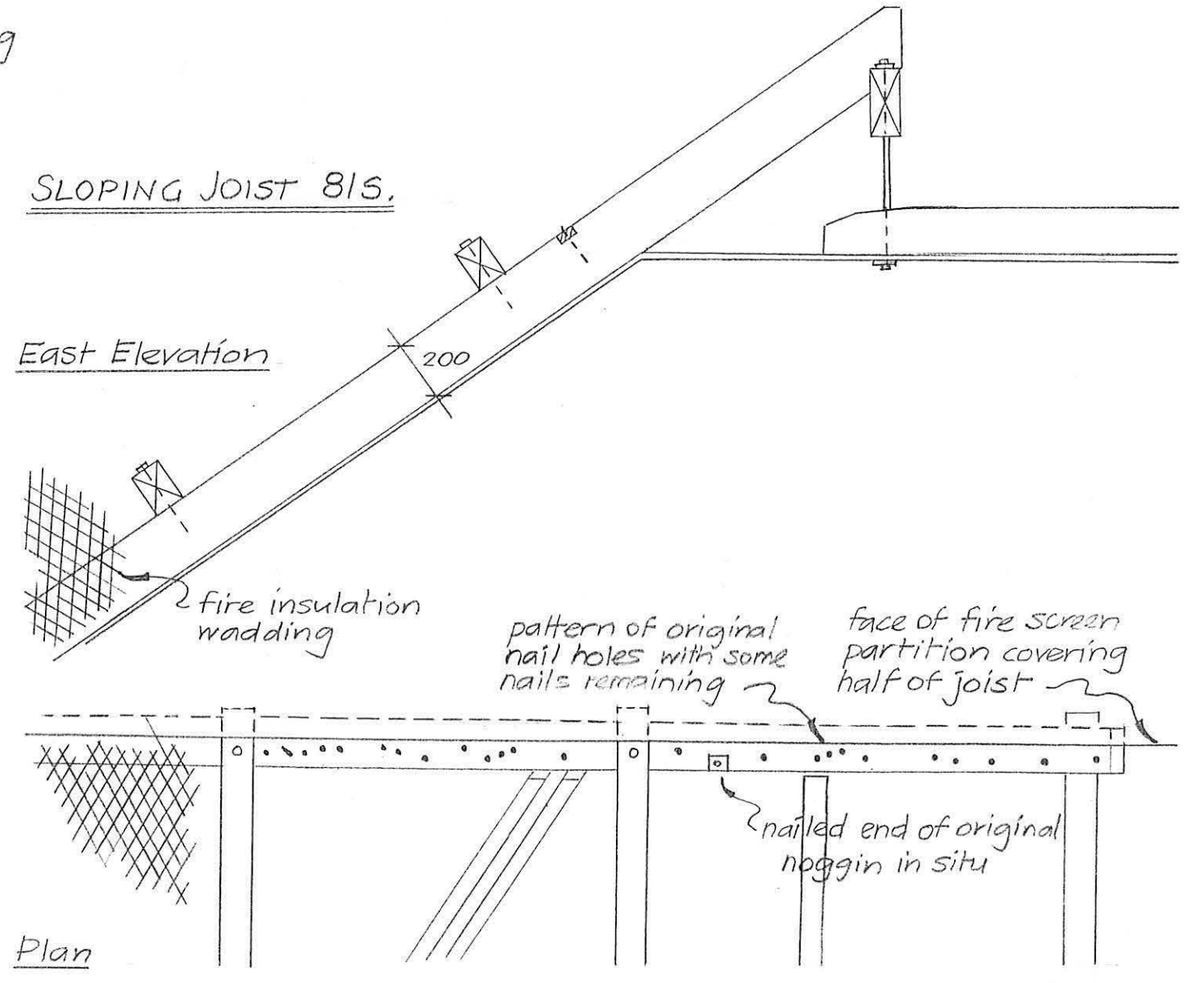
West Elevation

half joints with 25mm ϕ pin holes



Plan

SLOPING JOIST 81S.



East Elevation

Plan

PETERBOROUGH CATHEDRAL 1830s replacement ceiling timbers using re-used material from original roof.

HUGH HARRISON CONSERVATION drawn Peter Ferguson November 2004

0 200 400 600 800 1000mm.

DRAWING 2

Revision 'A' July 2002
1834 and 1926 binders indicated
for roof truss No. 2.

0 1 2 3 metres

drawn from Limentani survey 1996
with some amendments and additions

Roof truss No 2.

Blore's 1834
binders to horizontal
ceiling joists

Blore's 1834 binder to sloping joist
only found between Roof trusses 1 and 2.

Moore's 1926
binders to
sloping ceiling joists

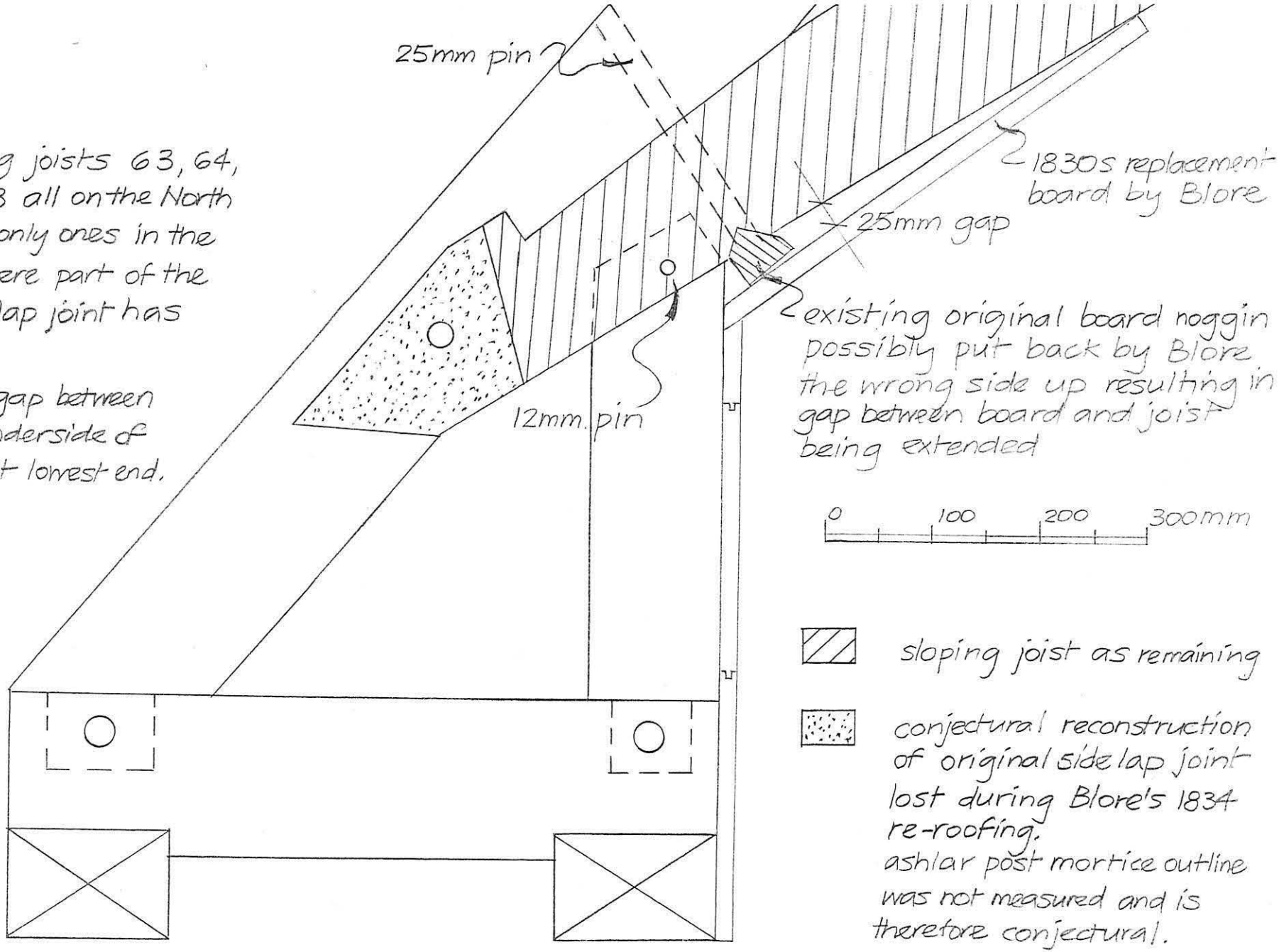
South Wall

North Wall

PETERBOROUGH CATHEDRAL roof as existing showing original ceiling suspended from 1834 roof

HUGH HARRISON CONSERVATION drawn Peter Ferguson April 2001

DRAWING 3



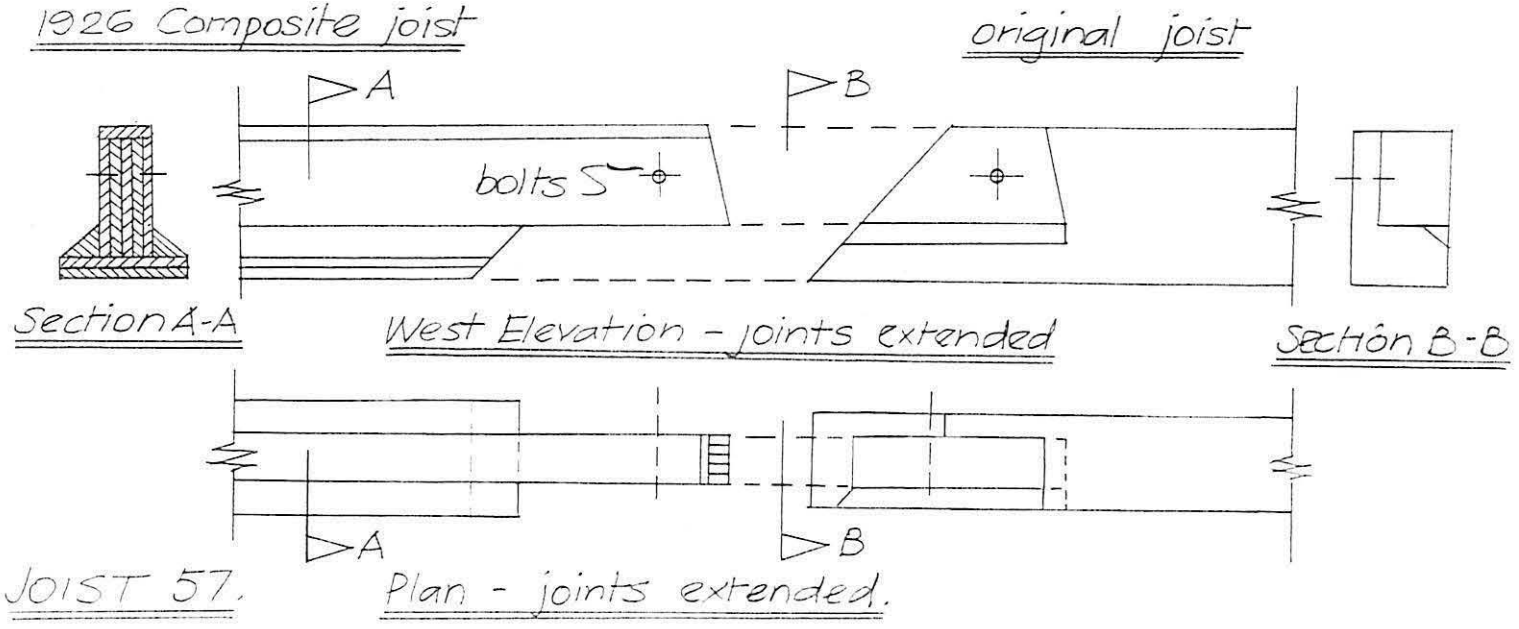
note sloping joists 63, 64, 68, 72 and 78 all on the North side are the only ones in the whole roof where part of the original side lap joint has survived.

note 25mm gap between boards and underside of sloping joist at lowest end.

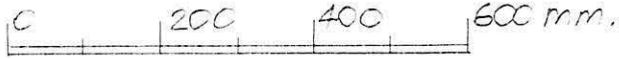
PETERBOROUGH CATHEDRAL Sloping Joist 72 north side projected onto conjectural eaves detail

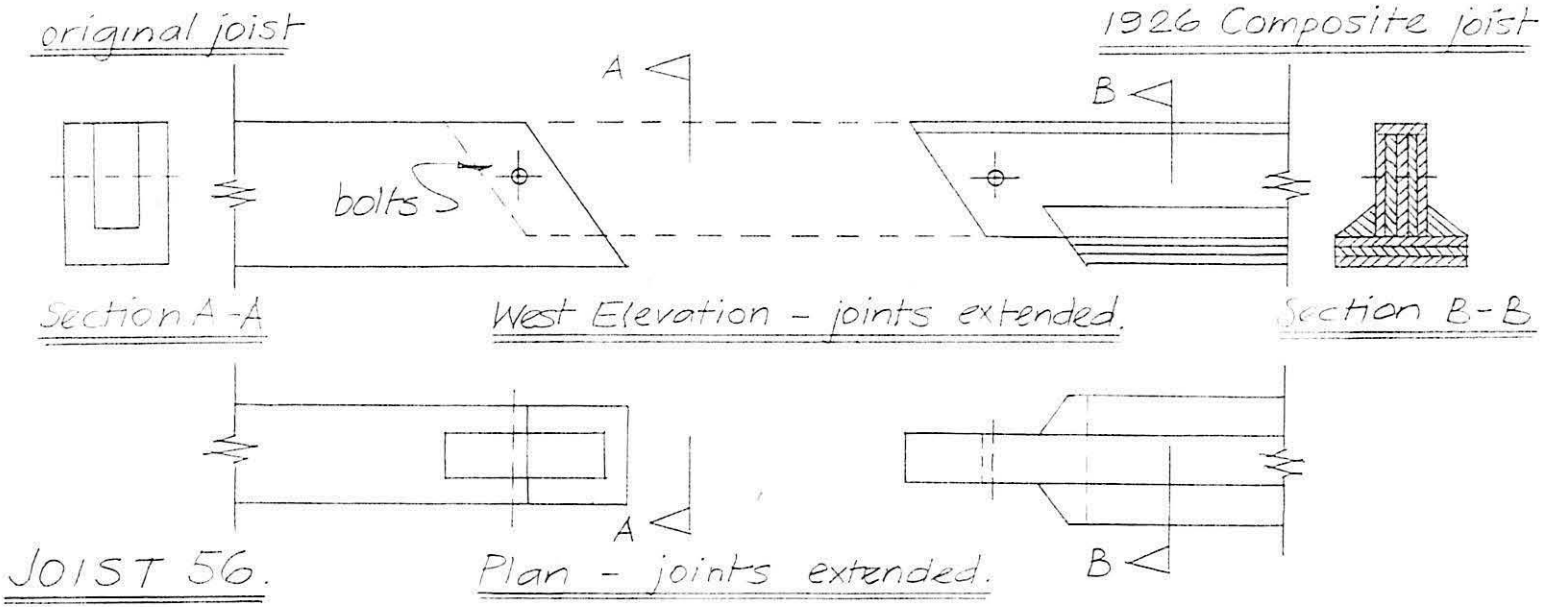
HUGH HARRISON CONSERVATION drawn Peter Ferguson October 2004

DRAWING 4



to joint the 1926 composite to original the scarph has been formed to the north side of the dovetail and the dovetail widened out to it to form the halving into which the 1926 vertical 12mm boards forming the web of the inverted tee section are extended the joint is similar in form to joist 26 measured and drawn in phase 3.



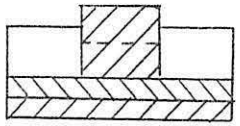


composite scarphed to south side of empty central post dovetail with web of composite joist fitted into an open slot mortice formed in the original joist and through bolted using a 10mm diameter galvanised coach bolt the joint is similar in form to joists 37 and 41 measured and drawn in phase 3.

PETERBOROUGH CATHEDRAL, details where 1926 composites are jointed to original ceiling joists

HUGH HARRISON CONSERVATION drawn Peter Ferguson May 2002

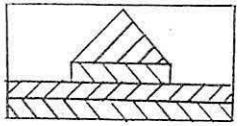
DRAWING 5



50x50mm notched over bearer each end

150x12mm boards

TYPE 1.

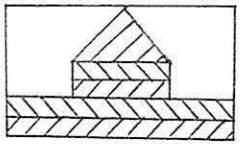


ex 50x50mm

65x12mm

150x12mm boards

TYPE 3.

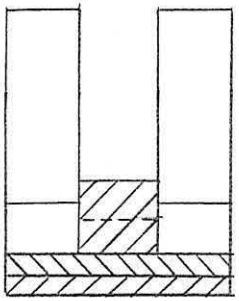


ex 50x50mm

65x12mm

150x12mm boards

TYPE 16.

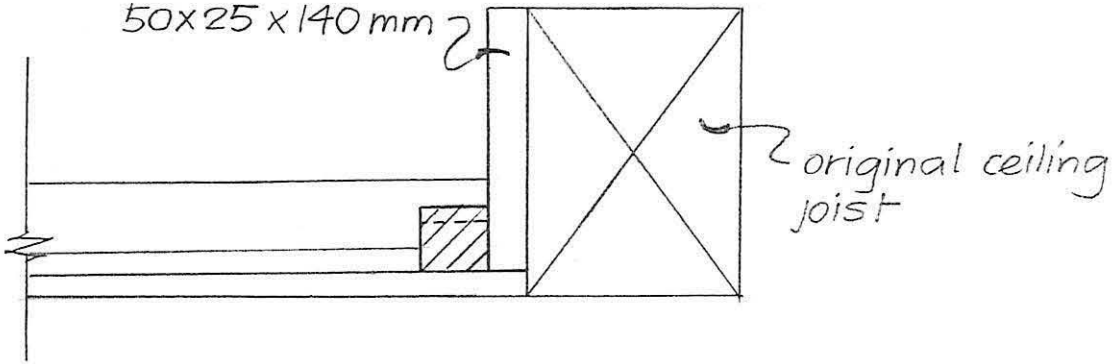


50x50mm notched over bearer each end

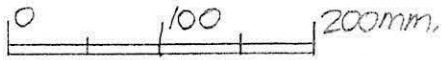
150x12mm boards

TYPE 17.

NOTE: noggin variations continue to occur again with Types 16 and 17 new in this phase, overall there is less variation in Phase 5 than for Phase 4 with Types 1 and 3 being the most commonly used, no particular pattern of use is suggested and where sagging of the board panel probably accounts for variation 16, no satisfactory explanation is apparent for variation 17.



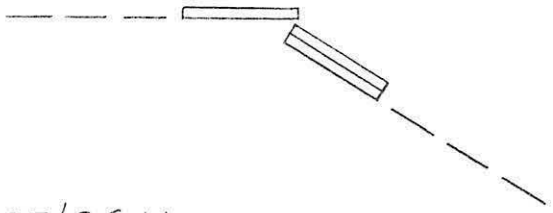
PETERBOROUGH CATHEDRAL 1926 Ceiling Noggin Details



HUGH HARRISON CONSERVATION drawn Peter Ferguson November 2004.

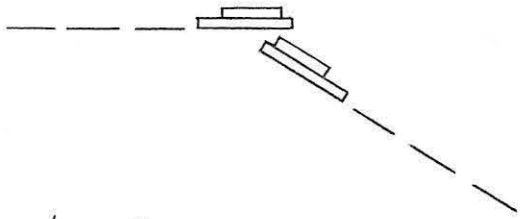
DRAWING 6

1.



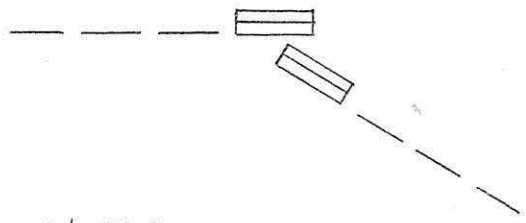
65/66 N.

2.



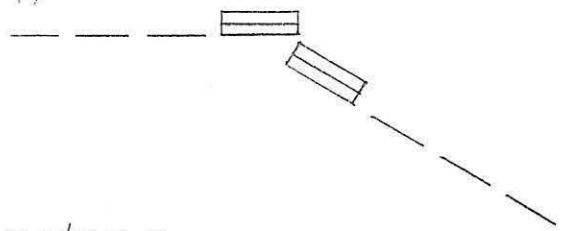
71/72 S.
72/73 S.

3.

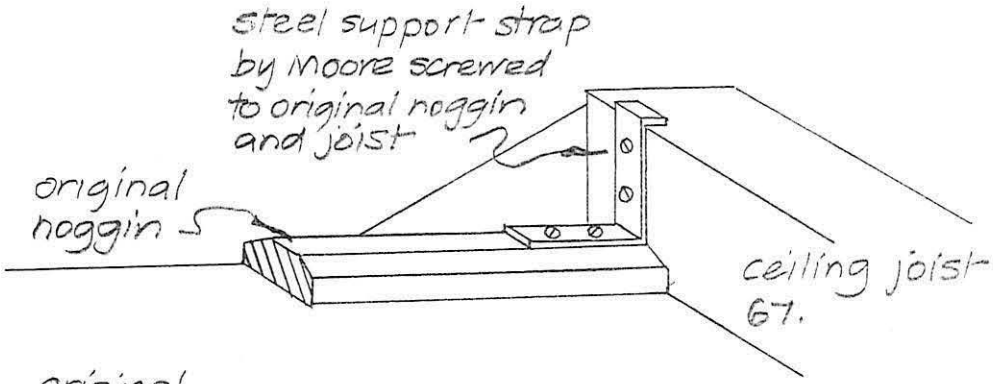


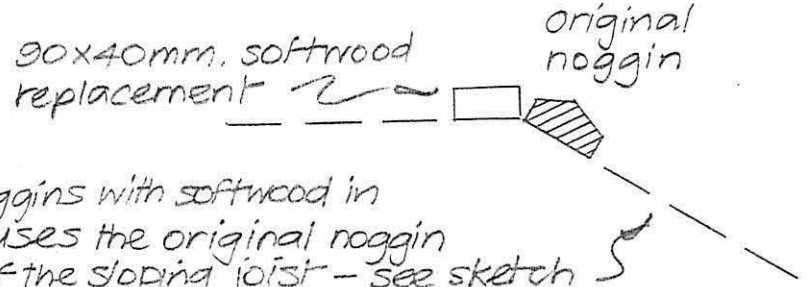
74/75 S.

4.



76/77 S.





Blore replaces three original noggins with softwood in the 1830s but at 66/67N. re-uses the original noggin as a strengthener over the top of the sloping joist – see sketch

1926 strengthening at the scissor brace intersections only occurs five times in Phase V. using combinations of 12mm softwood boarding with four variations recorded not found on previous phases bringing the total no. of variations found in the roof to 27. Moore also uses a steel strap to support the original noggin at 67/68N (see sketch above)

PETERBOROUGH CATHEDRAL, 1926 Strengthening Detail at Scissor Brace Intersection

HUGH HARRISON CONSERVATION drawn Peter Ferguson October 2004

DRAWING 7

PART 4: CONDITION: THE CEILING STRUCTURE, UPPER SIDE

4.1 ROOF TIMBERS

Evidence of old infestation by Common Furniture Beetle (CFB) has been found in the softwood roof timbers extensively but not intensively. Following the collection of live common furniture beetles in April 2001 by Julian Limentani, a particularly careful examination was made of the lower roof timbers and "fresh" exit holes from CFB were found on the south side of the truss over joist 60 by the central walkway. Similar evidence was noticed elsewhere, but no frass was found anywhere. As frass is a reliable indication of fresh activity, its absence would indicate that the "fresh" exit holes referred to above may not be evidence of current activity. Vertical Technology noticed signs of current infestation throughout the roof structure and treated the outbreaks with Microtech Dual Purpose AQ insecticide/fungicide.

4.2 CEILING TIMBERS

The flat and sloping original joists show little sign of any past infestation from either Death Watch Beetle (DWB) or CFB.

Precisely because of the present minimal evidence of past infestation, it was recommended in Phase 3 that a detailed survey be made of the condition of the original joists to see if evidence was being missed that might help explain the extent of Blore's stiffening and Moore's subsequent replacement of so many original joists. A further aspect of the survey was to ascertain if there is a correlation with the board survey. Joists 45-65 were examined during Phase 4 and joists 1-9 during the fire damage works.

From these surveys it has been found that there is little correlation between decayed boards and decayed joists. Neither is there any increased infection or decay in proximity with areas of replaced boards, which is surprising and makes Moore's replacing strategy even less comprehensible.

The records reveal exactly what might be expected, which is areas of death watch beetle infestation along sap edges and at the bottom ends of the sloping joists where higher levels of damp might be expected. There are isolated but extensive areas of common furniture beetle infestation but there seems to be no apparent significance to these instances. As proof of the generally excellent condition of the original joists, it is worth noting that the heavy trafficking of the top surface of the joists during conservation work has so far not caused any damage. Had extensive tunnelling been present under the surface, even allowing for the care taken by operatives, there is no doubt that surface breakdown would have resulted.

From Moore's survey report on the fabric carried out in 1920 we know that Blore in 1834 placed stiffening timbers and doublers alongside/either side of badly affected joists rather than cut them out and disturb the boards. By the 1920s, Moore describes these repairs as being "severely worm-eaten" as were some of the original timbers to which they had been attached. Virtually all these repairs were removed and replaced with Moore's ingeniously fabricated composites (except for the odd survival as in **Plates 24, 25**). Interestingly it appears that the boards replaced in the 1830s were not nailed up into Blore's doublers, as no redundant 1834 nailing patterns remain as evidence. Thus little/none of Blore's joist repair now exists to show us precise damage locations, except on the south side of this phase where he replaced most of the sloping joists with reclaimed original roof timbers and also renewed the boarding (see Bay 9, **Graphic 2**).

Evidence suggests that the lower ends of the sloping joists (where damp problems might safely be assumed to have existed) had become affected by the time Blore re-roofed the nave, which would explain why most of this woodwork was cut out (**Plates 18, 21, 92**). No comprehensive evidence

can now be found on the surviving ends of joists to explain why Blore cut out so many of the connecting joints between the sloping and the flat ceiling joists.

It would be reasonable to connect replaced joists with replaced boards. On the grounds that joists had become so weakened by infestation that they had to be strengthened by Blore, it should follow that adjacent boards were similarly infested, both by infestation from the joist and from the same agents that led to the infestation in the joist.

From study of the Graphics (**Graphic 1** is the best) it will be seen that large areas of panels have been renewed with replacement boards (*Panels O II and III, 5 II and III)*) though the original joist survives, and large areas of original boards survive, yet the joist has been replaced (*Panels 7 I, 6 II*).

The precise nature of the damage which led to the complete removal of so many joists must remain conjectural in the absence of more detailed records of the earlier restoration and repairs.

One feature of any timber that could explain the necessity of rigorous replacement due to structural weakening would be if large knots existed. These knots could easily be locally heavily infested, and the combination of the infestation and the knot could reduce the strength of the joist sufficiently to require reinforcement/renewal. However, examination of surviving timbers shows a remarkable absence of branching and only at the east end of the nave were a couple of heavily knotted joists recorded, yet these have survived. It was not considered necessary to further survey joists in Phase 5. No conclusions can be drawn from the records of infestation regarding Blore's work, and Moore was only doing his job thoroughly within the limits of what was known at the time about DWB infestation.

No evidence of infestation was found in any of the 1924 softwood noggins, joists, binders, or patches where they were revealed.

4.3 BOARDS

Where the upper sides of ceiling boards were exposed, most showed signs of previous infestation by both CFB and DWB. None was seen to be active, nor had been active for many years. Surface decay was found, noticeable as a general softening of the surface and by miniature cross checking, however some boards remain in excellent condition.

Moore was the last person to see the entire upper surface of the boards and reported that it was "very dirty – as far as can be seen it is apparently free from decay." However one must add a note of caution in that he also says that the surface was covered with detached torching, so how detailed was his view of the surface is difficult to surmise.

4.4 FIXINGS

4.4.1 Pre 1830s

The only fixings that come in this category are the surviving pins holding the small number of complete halving joints at the intersection of the flat and sloping ceiling joists. Although no pins were extracted, the visible ends are in good condition and one would assume that they are sound throughout their length.

4.4.2 1830s

Light surface corrosion was found on the hanging bolts and nuts inserted in the 1830s.

The cast iron shoes are well painted, as was recommended to be carried out by Moore in his programme of works in 1924.

4.4.3 1924

The steel hangers used for the binders over the sloping ceiling were painted by Moore with a red oxide type paint along with the 1830s iron work. Although steel was presumably used by Moore rather than the cast iron used in the 1830s, the painted surface is still in good condition.

The visible heads of coach screws through the binders into the sloping ceiling joists and those used in the construction of the laminated joists seem to have a zinc or galvanised coating and are in satisfactory condition. Similarly, screws used to fasten the laminations forming the noggins are in a satisfactory condition. Nails used in the laminations and the triangular side pieces on the joists were not withdrawn specially for inspection, but where they were extracted to investigate a 1920s noggin in Phase 1, they were seen to be in excellent condition.

4.5 HESSIAN

Analysis by Dr Christina Young at the Tate Gallery, proved that the hessian now retains only 10%-15% of its original strength. Her analysis was discussed in detail In the Phase 2 Report and can be found as **Appendices 15** and **16** in this Report.

The condition of the hessian in this Phase is satisfactory, and appears to be very similar to the condition found in previous Phases.

Dr Al Brewer[49] commented briefly on the animal glue adhering the hessian. His experience is that the tannins in oak if exposed to air will rapidly degrade animal glue, possibly within 50 years, definitely within 100 years. On the basis that the glue/hessian cover may slow moisture exchange to a minor degree, and as it forms "*a pretty good dust cover*" he recommended that it should not be removed or replaced yet.

Very little patching in canvas or hessian either above the boards or between boards and the underside of the joists was found in this Phase (see **Graphic 3**).

[49] *Observations on Wood Effects for the Nave Ceiling of Peterborough Cathedral* Dr J. A. Brewer, B.Sc., M.A.C. Ph.D, November 2000. Reproduced as **Appendix 4** of this report.

PART 5: CONDITION: THE CEILING STRUCTURE, LOWER SIDE

5.1 BOARDS

The condition of each board is described in the 'Board by Board Survey' and is shown on **Graphics 6A-6B.**

The boards are suffering from the following categories of damage

- Splits
- Wood losses
- Intended wood losses
- Infestation by CFB and DWB
- Wet rot
- Lead shot
- Surface degradation
- Impact damage/scratch marks
- Subsequent restorations (including repositioning and splinters from screws).

The boards are discussed in the two categories – Original and Replacement – for each type of damage.

5.1.1 Splits

5.1.1.1 Original Boards – It is suggested that the majority of the splitting has occurred relatively recently since the building has been extensively heated in the winter (**Plate 70**). Pre-drilling the nail holes would substantially reduce the incidence of splitting at the time of first fixing, which explains the comparative lack of splits between the nails and the ends of the boards. **Plate 100** shows an original board held along both edges, so that when it dried and contracted it could only split between the two sets of fixings. The point of greatest weakness would be where the nail was driven near the edge of the board, and this is where the split would have started and then extended as the board contracted. **Plate 71** shows similar splits to that described above. Proof of when a split occurred can better be seen on **Plate 97** where the paint line created by the last repaint has become exposed as the board shrank away from the nail.

Plates 72, 96 show simple splits created when the nail was driven from above and clenched over. These boards will have become comparatively brittle by the 1830s, so they would split easily if the nail is driven through a spot where the timber was vulnerable. **Plate 74** shows where an 1830s nail has been knocked back down through the ceiling in the 1920s.

5.1.1.2 Replacement Boards – it is more difficult to be specific about the cause of splitting in these boards, but evidence exists for splitting both from initial fixing and subsequent shrinkage, (**Plates 68, 99, 101**).

5.1.2 Wood losses

5.1.2.1 Original Boards – Most wood losses can be attributed to acute infestation that has so weakened the timber that it has freckled away, or detached by contact or rough handling during previous restorations, (**Plates 95, 97, 105, 115, 125, 130)**. However the most common loss is that seen along board edges, see **Plate 93**. Other losses have occurred when boards were cut back and moved around when the replacement boards were inserted. All wood losses are shown on **Graphics 6A-6B**.

5.1.2.2 Replacement Boards – There are few wood losses in the replacement boards. No losses are attributable to beetle infestation or decay, and the boards have not been touched since they were first fitted.

5.1.3 Intended wood losses

The pattern of holes in original oak boards revealed in Phases 2, 3 and 4, were also found in this Phase (**Plate 87**). These consist of three holes in line across the centre of the ceiling, the two outside holes being 2'0" (600mm) in from the joint of the flat ceiling with the sloping ceilings, and the third hole roughly in the centre. These sets of three holes are spaced approx. two panels apart down the length of the ceiling. No complete set was found in this Phase but three were found in Phase 3 and one in Phase 4. In the first four Phases far more holes are found in the centre and north sides than south, though for this Phase the numbers are more even. Two further holes were found regularly spaced near the north edge of the north sloping ceiling, and none in a similar position on the south side, which is almost entirely made up of replacement boards, so any holes would have been lost. By the same token, the lack of regular sets of holes in the flat part of the ceiling could be ascribed as much to loss of original boards as to the possibility that the holes never existed.

It seems likely that these holes indicated the position of a lighting system, but the extra holes in the centre of the ceiling may reveal another earlier (or later) system that had lights only down the centre of the ceiling. It should be noted that with the three light system, none of the holes are particularly close to a joist, so the lights must have been suspended from noggins placed across the joists. Not a single hole in the flat part of the ceiling has been found through a softwood board in any Phase. No holes were noted in this Phase with worn edges.

Other holes appear for no accountable reason, of which **Plate 98** is an example.

5.1.4 Infestation by CFB and DWB

The system for recording the intensity of infestation was formalised in Phase 2. This system was continued in Phases 3 and 4. The area of maximum intensity of exit holes for both DWB and CFB is assessed on each board. A 25mm x 25mm frame is placed over this area and the number of exit holes counted and recorded on the Board by Board Survey sheet. The maximum density is recorded for both species. The position of the recorded area or areas is recorded on the source documents. Other comments on density of infestation are recorded on the Comments sheet on the back of the Board by Board Survey sheets.

5.1.4.1 Original Boards – Infestation by CFB and DWB is widespread (see **Graphics 6A-6B**) and occurs both as a general outbreak throughout the whole of a board (DWB - **Plate 88,** CFB - **Plate 94**, and a mixture of both-**Plate 95**), or is confined in a certain area (**Plate 125**). Where the infestation has been intense, so much of the wood has been consumed that the remainder has crumbled away completely, and the adjacent areas that have survived are very fragile and vulnerable to damage see **Plate 93.**

No signs of current activity of either DWB or CFB were observed.

It is presumed that the upper surface of the boards was treated with Silvertown Solution in 1924, as specified by Moore.

There is more infestation by DWB than by CFB, as one would expect in oak. As the upper surface of the boards is covered by the hessian, it is impossible to compare the incidence of exit holes through the upper unpainted surface with that through the lower painted surface.

There are many incidences of infestation along the outer (thick) edges of boards, see **Plate 93**. Groves considers that these may mark the heartwood/sapwood boundary[50].

5.1.4.2 Replacement Boards – There is consistent mainly light (occasionally heavy, see **Plate 99**) infestation by CFB and negligible by DWB.

5.1.5 Wet rot

5.1.5.1 Original Boards – Surprisingly little sign of wet rot is found. The small areas that do occur are shown on **Graphics 6A-B,** and appear as surface cross checking. It is interesting to see that this rot is entirely confined to board edges, and that they are also areas of infestation. It is suggested that this phenomenon may be associated with the fact that the edge of the board is exposed to the air on two adjoining sides and is therefore likely to have a higher moisture content than other parts of the board.

5.1.5.2 Replacement Boards - There is no evidence of wet rot in any of these boards.

5.1.6 Lead shot

Samples of shot were sent to OIC The Weapons Collection, HQ Small Arms School Corps, to see if the shot could be identified for date. Unfortunately Lt. Col A Wilson MBE was unable to help as the shot size varies between makers of guns, size of load and size of gun[51] (see **Appendix 14**). A comparison with modern shot used for game bird shooting puts the shot in this ceiling as nearly buck shot size!

The Abstracts of the Dean and Chapter Accounts[52] show three entries for "Powder and Shot" in 1824, 1825, and 1826.[53]

Analysis of the type of board containing shot, and whether the shot holes are overpainted, seems to reveal the periods when the pursuit of pigeon shooting was most popular. Perhaps it should be remarked that the presence of paint in individual boards is sometimes difficult to tell, so this aspect of the analysis should be taken as firm evidence but not absolute proof. Now that the 1740s boards have been positively identified, it is much easier to date the shot.

In this Phase there is less evidence of shot than in Phase 4 and the patterns recorded in **Graphic 2** do not show any which can be positively identified as pre 1740. By far the most shots appear to have occurred post 1740 but pre 1830s , there being very few shots recorded in the 1830s replacement boards. Once again evidence on **Graphic 2** points to most shots being fired at birds roosting or perching on the stone projecting wall head mould directly in front of the ashlar boards.

5.1.7 Surface Degradation

This phenomenon had been identified in Phase 1 as shallow carving. In Phase 2 Dr B Ridout somewhat undecidedly identified it as either some form of soft rot, or differential collapse of wood cells, or surface deterioration from the old coke stoves. It was also, from Phase 1, speculated that the phenomenon could have been caused by different methods of protection of the surface (painted/unpainted, oil painted/thin limewash, or size), in which case it should also be found where original nail heads had detached. This phenomenon was indeed confirmed in the Phase 2 Report. It was also reported that Richard Lithgow had found the same phenomenon on the St.Albans Cathedral Choir ceiling.

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[50] Groves letter to J Limentani 19 September 2001
[51] Unpublished letter to H Harrison, 29 June 1999
[52] Unpublished *Preliminary Exercise* by D F Mackreth sent to J Limentani 2000
[53] 1824 Mesrs Farside and White 1- 3- 8 ½d, 1825 (no named supplier) 11-4d, 1826 Thomas White jr (taken over from his father's partnership with Mr Farside?) 1- 3- 8d

Examples of the phenomenon found in the section of the ceiling covered by this Phase are illustrated in the following Plates.

The grooves on the grey chevron boards are consistently less weathered than those on the coloured bands boards; the stepped chevron often is noticeably less weathered on the white areas than the black; and the curved edge wave pattern board is hardly weathered at all. The weathering on **Plates 38, 88** shows the pronounced undulations produced where the medullary rays are prominent on the surface. **Plates 88, 89** show the common feature of the narrow base board often having a smooth surface which progressively gets more weathered the wider the space is between the adjacent boards.

Dr Al Brewer of the Picture Conservation Studio for the Royal Collection at Frogmore Gardens, Windsor was kindly "loaned" by Christopher Lloyd to investigate the weathering effect from the perspective of paintings on wood panel. Dr Al Brewer's explanation is paraphrased as follows:

Description of Effect
Prominence of medullary rays and deep relief between the annual rings.

Cause
Time and past environmental conditions.

Agent
Rots and decay were ruled out as they cause "*generalised damage which is not simply confined to the softer cell walls*", also they require a moisture content of 20% or greater, spread over the whole ceiling for extended periods.

Chemical deterioration from the coke stoves was also considered unlikely due to the fact that our own environmental monitoring concluded that there would be insufficient deposition of anything other than smoke, also that if the deposition was that bad, it would have been noticed in the paint layer analysis.

It was recognised that if these areas had been limewashed, the initial period of alkalinity of lime could have degraded the hemicellulose molecules until it had completely reacted with atmospheric carbon dioxide, but this was considered unlikely to have caused such a deep effect.

Shallow carving was ruled out for the reasons already given in the Phase 2 report.

Conclusion
The masking effect of oil paint protected these areas from any one or all of the possible agents mentioned above. The weathered surfaces may well have been painted but with a medium which has since disappeared.

Environmental effects on timber were discussed in detail, and generally seasonal variations were considered unlikely to be damaging due to the response time of 50 to 100 days for boards of this thickness to equilibrate to seasonal changes in RH relative humidity. With considerable changes in RH above the ceiling on a diurnal basis, this was considered sufficient to cause the surface cells to swell and contract with sufficient restraint from the cells deep within the wood to cause "set".

With long term set and long term contraction, the boards have now become "*well seasoned*" and as stable as they have ever been given the current environmental conditions.

Richard Lithgow describes the survey of weathering on original ceiling boards (8.2.4). In this Phase **Plates 90, 91** illustrate the phenomenon. Note that there are three levels of weathering. The linear design representing the original surface with the first reduced layer being the white coloured areas and the second the black.

5.1.8 Impact Damage/Scratch marks

Considerable surface damage has been recorded on the Board by Board Survey sheets. The most frequently found marks are hammer marks from misplaced blows to drive nails from below or clench over nail ends coming down from above **(Plates 72, 73)**.

5.1.9 Subsequent Restorations

Many of the boards, both original and replacement have been damaged by later interventions. These can be put into three categories, as follows.

5.1.9.1 Displaced Boards, Lateral – These are boards that were removed, and then replaced out of alignment, in either 1740 or 1830, and are recorded on the Board by Board Survey sheets with the distance of the displacement (in millimetres) and its direction (N, S, E, W).

5.1.9.2 Displaced Boards, Vertical – These are boards which were displaced vertically by screws inserted in the 1924/6 restoration and are also recorded on the Board by Board Survey sheets, with the distance (in millimetres) that the board has been displaced. The cardinal point recorded in the next column identifies the edge of the board where the displacement has been recorded.

5.1.9.3 Splinters – Screws were inserted from above in the 1924/6 restoration, and when they emerged through the underside of the ceiling boards, many splintered the surface. In this Phase there are very few screws which project beneath the surface so there is much less damaged than in previous Phases. All splinters are recorded on **Graphics 6A-6B.**

5.1.10 Fixings

There is slight surface corrosion on the nail and hanging bolt heads wherever the paint has detached. Some original nails have come loose and were taken out by Julian Limentani during his initial inspection. A small number of other nails were loose but could not be extracted as they were clenched over above the ceiling boards.

Nearly all the screw ends from the 1924 restoration showed signs of corrosion, whether they are steel or zinc-plated. There was no sign of the shanks within the timber having corroded to the extent that they were putting sufficient pressure on the wood to split it, indeed all shanks were remarkably bright showing very little sign of any corrosion.

PART 6: TREATMENT TESTS: THE CEILING STRUCTURE

6.1 PHASE 4 TREATMENT TESTING

No further tests were required as no new treatment materials or techniques were used during Phase 5.

PART 7: TREATMENT: THE CEILING STRUCTURE

7.1 GENERAL

The broad categories of repair include:-

- cleaning all upper ceiling surfaces,
- work to the hanging bolts,
- replacement of screws to which there is access above the ceiling, and re-fixing splinters,
- supporting detached or partially detached fragments of ceiling board,
- replacing windows cut in the hessian with sailcloth,
- consolidation of fragile areas of decay,
- gluing splits,
- fillings,
- re-integration with timber inserts.

All strategies for repair as agreed in Phase 1 were continued in Phase 5.

7.2. CLEANING ABOVE CEILING

Before work commences the boundaries of the scaffold below the ceiling are marked with danger tape. The cleaning is carried out using "Henry" vacuum cleaners using only the brush attachments. The cleaners are first suspended from a suitable purlin from which the suction tubes extend down to the bottom of the pits between the stone pads for the truss shoes, and also over the majority of each half of the ceiling. This prevents banging as the machine is lifted around to each new area, and also prevents the machine tipping over inadvertently. Ear defenders, masks and protective clothing is worn at all times. All debris that has been bagged up from previous phases has been sorted and all nails retrieved and kept.

7.3 HANGING BOLTS

The hanging bolts were taken out in the agreed manner using the bolt pusher described in the Phase 3 Report. Before each bolt is extracted a telltale is fixed to the adjoining binder to measure any change in relative distance between the binder and the joist.

As each bolt is extracted, a temporary stainless steel bolt is installed . After extraction, the hanging bolts are rubbed down lightly and painted, firstly with the Trimite SAP3 2 Pack Self Etching Primer[54] then, within 16 hours, the Trimite 2 Pack Acrylic finish AE262[55]. This is left to harden for 24 hours before the bolts are replaced. The thread is not painted, nor the head of the bolt which is treated with Paraloid B72 by the Perry Lithgow Partnership.

The top washer is painted on both sides, but the bottom washer is only painted on the top surface. The sides and bottom of the bottom washer are treated with Paraloid B72 by the Perry Lithgow Partnership.

Before the bolts are replaced in the binders, the empty holes in the joists and binders are carefully but thoroughly cleared through with the 22mm threaded stud used for the temporary bolts.

The hanging bolts are assembled as per David Goode's Specification using 40mm x 20.4mm x 2mm spring steel washers, supplied by Skegness Springs Ltd. Plastazote LD45[56] packers (6mm)

[54] A 2 pack Primer consisting of a zinc tetroxychromate pigmented base and an acid solution, supplied by Trimite Ltd.
[55] A 2 pack acrylic Finish free of isocyanates, supplied by Trimite Ltd.
[56] Plastazote foam is a closed cell, low density, cross-linked polyethylene foam, supplied by Polyformes Ltd.

are cut to the size of the washers and positioned between the washer and the ceiling. Before the nuts are fitted, the threads of the bolts are coated with Castrol LMX Heavy Duty Grease[57]. Where the ceiling has dropped, the hanging bolt may not be sufficiently long to include the spring washers. The agreed solution is to cut a notch in the top of the binder to enable the nut to be fully threaded with the spring washers.

After setting up each bolt, a simple telltale system, using one piece of batten screwed to the binder and another to the joist, is fitted so that the corners of the two battens just touch. It will be easy to measure any deflection in the future by measuring either the gap between the pieces, or the overlap.

7.4 SCREWS AND SPLINTERS

In Phase 5 Bay 9, 80 screws were replaced, but in Bay 10 only 7. The number of screws removed but not replaced totalled 9 for Bay 9 and 3 for Bay 10. This indicates a dramatic reduction at the extreme west end of the roof compared with previous phases as indicated in the table showing the averages per Bay obtained for phases 1, 2, 3, 4 and 5.

Phase	Average no. of screws replaced per Bay	Average no. of screws removed but not replaced per Bay
1	0	28
2	135	12
3	117	26
4	127	37
5	44 (Bay 9 80)	6
	(Bay 10 9)	

From row 9 westwards we see an apparent change of policy since the number of screws dramatically drop yet the condition of the boards remain much the same as before. This policy seems to have continued even more rigorously as the work progressed westwards till in Bay 10 only 9 screws were replaced.

All screws which projected below the ceiling to which there was access from above (without dismantling any woodwork) were taken out and replaced with shorter stainless steel screws. All the replaced screws were found beneath 1924/6 laminates and along the edges of boards, see **Graphics 7A-7B**. A simple battery powered electrician's circuit probe was used in Phase 2 to locate the screws beneath the hessian. In Phase 3, as the Graphics showing the position of the screws projecting beneath the ceiling were available at the time the work was carried out, these were used in preference to electric probe. In addition, the probes involved additional work connecting a wire from the probe above the ceiling to the grips to fix to the screw beneath the ceiling. It was also frequently found to be difficult to make a proper electrical connection, which may have had something to do with the galvanising or the corrosion products on the screws.

In the new system, screws were identified in a particular area on the Graphic as likely candidates for removal. A cocktail stick would be introduced through a nail hole or gap nearby, and the position of the screw to be removed would be measured from the marker cocktail stick by the joiner below the ceiling and the information relayed by walkie-talkie to the joiner above the ceiling. The joiner above the ceiling tapped with a sharp probe through the hessian till he found the screw. Once one screw was located this and the cocktail stick could be used as reference points to locate other screws etc. This was found to be as quick as using the probe and avoided the extra wire trailing through the ceiling.

After locating the screw the hessian could be cut just across the screw head, and the screw withdrawn without cutting a larger hole in the hessian.

[57] A high performance lithium complex Grease, supplied by Castrol Lubricants.

Where a screw was located right on the edge of a board, or maybe was missing the edge of the board beneath, or because it was so close to the edge it was splitting the timber, it was not replaced.

The only other screws to be replaced were the central screws in the noggins which fix the top stiffening bars or triangles to the noggin laminates. In many places, it was found that the original screws were too short to even enter the top laminate, let alone the bottom laminate. In other places the screws were so long they penetrated through to the front of the ceiling. The point of the noggin is to support the boards in the centre of the span between the joists. This is done by screwing a stiff batten across the width of the span and supporting it each side on a joist. Therefore to not connect the stiffener to the boards is merely adding weight without increasing the support. Each screw was tested, and all those too short or too long were exchanged for the correct length stainless steel screws.

Where splinters of wood have been created by protruding screw ends, these are repositioned and adhered with a solution of Plextol B500[58] (diluted 1:1).

7.5 STAINLESS STEEL FIXINGS

The basis for the specification for repair was an assessment of how secure each board or fragment was. The repairs consisted of securing loose pieces of timber with 3mm threaded stainless steel studding bent over to form an angle with an average length across of 12mm, fixed above the ceiling with nuts and washers. In some instances the studding was bent a second time to form a hoop. The second leg was either cut off say 3mm above the angle, or returned above the ceiling and secured with a second nut and washer. The third type of fastener used was a stainless steel screw with washer, the average size of which was 25mm No 8's, though some were a little longer and some a little shorter (**Plate 104**).

Wherever possible old screw holes were used, or the fixings were placed between boards, or in splits. If no suitable hole or split was available, the type of fixing may have been changed from a screw to an angle if that enabled the fixing to be inserted without drilling through an original board. Tiny pieces of Melinex[59] were inserted between the angle bolts and the painted surface. All stainless steel fixings below the Ceiling were touched in with acrylic colour to prevent any chance of reflecting the light and being seen from the floor (see **Graphics 7A-7B** and **Plate 99**).

Each board was examined and the specification for each repair was listed (see Table below).

Specification of Phase 5 repairs to ceiling boards.

Panel	Board No.	SPECIFICATION
7 I	g	East edge, north end of board, two stainless steel screws and washers to secure a fragment of board end detached by fracture through a nail.
7 II	s	Stainless steel screw through existing nail hole of replaced slip inserted to extend board s.
4 I	c	North end of board, three stainless steel screws and washers inserted to secure large fragment of detached original board.
4 II	b	East edge, stainless steel screw and washer inserted to secure detached fragment.
	a	East edge, stainless steel screw and washer inserted to secure this board.
4 III	q	Angled rod inserted in gap between panels 4 and 3 to secure fragment of end of board that was added and become loose.
3 I	a	Stainless steel screw and washer inserted in the joint between panels 3 and 4 to hold corner of board detached by split from a nail.
	p	Stainless steel screw and washer inserted in existing nail hole to secure substantial section of this board now bereft of nails.

[58] Plextol B500 is an aqueous dispersion of a thermoplastic acrylic resin. A product of Röhm.
[59] Archival polyester (ICI Melinex®) 75mc

Panel	Board No.	SPECIFICATION
	u	Two stainless steel screws and washers inserted in joints to secure this board.
2 IV	v	Stainless steel screw and washer in existing nail hole to secure this board.
1 I	c	Angle inserted though joint between 1 I and 1 II to secure detached edge of this board.
1 IV	c	Stainless steel screw and washer inserted to secure fragment split off this board.
O II	m	Stainless steel screw and washer inserted in old nail hole to secure this board.
	c	Stainless steel screw and washer inserted in joint between boards d and c to secure detached fragment of board c.
0 IV	e	Stainless steel screw and washer inserted in split to secure detached fragment.
	r	Stainless steel screw and washer inserted to secure this board.

7.6 HESSIAN

Windows cut in the hessian either for samples sent for testing, or to find screws beneath were made good with sailcloth (code no. 00169/23A manufactured by Richard Hayward & Co.) and attached with Beva 371[60]. Four coats of Beva 371 were first applied to the sailcloth and allowed to dry, then the coated sailcloth was cut into patches to fix over the windows in the hessian and adhered using a heated spatula or domestic iron on a low setting. Prior to fixing, the area to be covered was given a coat of Beva 371 and allowed to dry (see **Plate 107**). The position of all new sailcloth patches is recorded on **Graphic 8**.

To obscure shafts of light penetrating through holes in the boards and hessian behind (probably caused by insertion of marker sticks to aid location of screws above and below the ceiling) pads of Plastazote LD45 were glued with Plextol B500 to the upper side of the hessian (see **Plate 108**).

7.7 CONSOLIDATION OF FRAGILE AREAS OF DECAY

7.7.1 Paraloid B72

To prevent further wood loss from small areas of boarding that were unstable due to decay or infestation, exposed wood was consolidated with infusions of Paraloid B72 (10% in xylene) (see **Graphics 7A-7B**).

7.7.2 Bencon 19 Epoxy Resin

No consolidation with this epoxy was required in this Phase.

7.8 FILLINGS

As an added precaution against loss of both wood and overlying paint, following consolidation treatment, a filler was inserted to secure vulnerable edges. The filler consisted of 1 part Polyfilla, 1.5 parts fine oak dust, 1 part Plextol B500 (10% solution). (see **Graphics 7A-7B**).

7.9 SPLITS

No splits needed to be glued in this Phase.

[60] Beva 371 is a heat seal adhesive developed by GA Berger in 1970.

7.10 RE-INTEGRATION WITH TIMBER INSERTS

It was felt that some lacunae would be sufficiently visible and distracting from the floor, and that they should be made good either with a new timber insert or by inpainting. No attempt would be made to disguise the timber inserts, but equally the re-integration would not be made artificially visible. The criteria for having a timber insert is set out in **Appendix 12**. The ceiling was inspected by J Limentani, G Lewis, R Lithgow and H Harrison, and a list of inserts and inpainting of backgrounds was agreed, see **Appendix 13.**

The inserts are described below:

Plates 109 – 111	Lozenge *6/5 I/II*	Before and after fitting and inpainting timber insert.
Plates 112 – 114	*Panel 6 II*	Before and after fitting and inpainting timber insert.
Plates 115 – 116	*Panel 4 I*	Before and after fitting and inpainting timber insert.
Plates 117 – 119	*Panel 3 II*	Before and after fitting and inpainting timber insert.
Plates 120-121	*Panel 3 II*	Before and after fitting timber insert (**Plates 120-121**) and inpainting (**Plate 119**).
Plates 122 – 124	*Panel 3 III*	Before and after fitting and inpainting timber insert.
Plates 125 – 126	*Panel 3 IV*	Before and after fitting and inpainting timber insert.
Plates 127 – 129	*Panel 2 IV*	Before and after fitting and inpainting timber insert.
Plates 130 – 132	*Panel 1 III*	Before and after fitting and inpainting timber insert.
Plates 133-134	*Panel 1 III*	Before and after fitting and inpainting timber insert.

PART 8: TECHNICAL SURVEY: THE PAINTED DECORATION

8.1 PAINT SAMPLE ANALYSIS

Throughout this project it has been necessary to rely heavily on the analysis of paint samples for answers to queries arising from on-site examinations and treatment tests. There is no record of the original painted scheme and little detail of subsequent restorations.

In 1995 paint samples were taken from the Eastern Bay and examined as part of the survey conducted by Hirst Conservation[61]. In 1996, Gillian Lewis obtained a number of paint samples during the inspection of the entire Nave Ceiling from a mechanical hoist: these were examined and analysed by Lewis and Howard. In 1997, as part of the emergency treatment phase, Helen Howard and Adrian Heritage conducted a technical study of the paint layer including 29 paint samples.[62] Howard obtained an additional 12 paint samples from Bay 1 at the start of Phase 1 in 1998.[63]

For Phase 2 in 1999 Ioanna Kakoulli carried out the paint sample analysis. Her extensive report details analysis results from the 57 paint samples obtained during her two visits to the Ceiling.[64]

Jane Davies carried out the paint sample analysis for Phases 3, 4 and 5. Twenty-two paint samples were obtained from Bays 4, 5 and 6a of the Ceiling for analysis as part of the Phase 3 works in 2000.[65] For Phase 4, in 1991, thirty one samples from Bays 6b, 7 and 8 were analysed. [66]

In 2002, during the fire damage restoration work, three paint samples were obtained from an area of paint found on the upper side of the ceiling structure on the east side of the easternmost joist of Bay 1. The samples were analysed by Jane Davies and presented as an addendum to her Phase 4 work.[67] The findings discussed further in our fire damage restoration report.

Analysis for Phases 1-4 provided a good knowledge of the original technique and materials as well as of the 1740s and 1830s interventions. During the Phase 5 works nothing was found on the boards in Bays 9 and 10 that warranted further paint sample analysis. However, while removing smoke damage from the Phase 3 area in September 2002 we obtained 11 samples of paint from under original nail heads that are now missing. These were overlooked during Phase 3 but all appeared to be of original paint and it was thought they might add to our knowledge of the original figurative and foliate decoration. Consequently they were analysed as part of the Phase 5 investigations. A list of these 11 paint samples is included as **Appendix 21**.

The sampling strategies prepared for each phase of work formed an important record of our developing understanding of the Ceiling as the work progressed. The strategy for each phase has been appended to the respective condition survey/treatment record. The sample strategy prepared for Phase 5 has been annotated with observations made during site meetings and is appended to this report (**Appendix 20**).

A total of 172 paint samples have been analysed during this conservation project: 134 are from original Ceiling boards of which 64 are from central lozenge boards. To facilitate the

[61] *Nave Ceiling Peterborough Cathedral* Hirst Conservation, October 1995.
[62] *Peterborough Cathedral, Nave Ceiling: Scientific examination of the original decoration*. Helen Howard, Sept.1997.
[63] *Peterborough Cathedral: Nave Ceiling. Scientific examination of the original decoration of bays .36-39.* Helen Howard, 1998.
[64] *Peterborough Cathedral Nave Ceiling Paintings: Scientific Examination Phase 2* Dr Ioanna Kakoulli, December 1999
[65] *Peterborough Cathedral Nave Ceiling: Phase 3 Investigation of Painting Materials and Technique* Jane Davies, October 2001
[66] *Peterborough Cathedral Scientific Examination Nave Ceiling Phase 4, 2001/2* Jane Davies, April 2002
[67] *Peterborough Cathedral Nave Ceiling Roofspace: Investigation of Painting Materials and Techniques* Jane Davies, May 2003

interpretation of findings from all 7 paint sample analysis reports we have created a tabulated inventory of the samples including basic stratigraphy, pigment identification and the analyst's comments. The samples have been grouped according to the boards from which they were obtained: the eight different border patterns, central lozenge boards and replacement boards; with the 3 samples from the joist above the ceiling listed finally. The inventory is included in this report as **Appendix 23**.

8.2 THE ORIGINAL SCHEME

A report compiled by D S Glennie on Edward Blore's Work on the Nave Ceiling in the 1830's[68] contains a description of the Nave Ceiling written by Govenor Pownall in a letter to the Rev. Mich Lort in the late 1780s. It is not stated whether Pownall is describing the painted decoration as it appeared before the 1740s restoration or after that work was complete; however, going by the findings of investigations and analysis carried out for the current project, the description is more likely of the original scheme:

> 'The ceiling of the Cathedral of Peterborough is said to have been done at the time that the nave of the church was built, that is, at a period between 1177 and 1199. It is of wainscot, formed into three compartments, running the whole length of the nave, a principal one along the middle, and two lesser ones- on each side. Each compartment is framed into panes, or panels, in the form of lozenges or half-lozenges; the fillets, mouldings and rosettes are gilt. A fret antique runs round the panels as a bordure, and on the naked wood within this are the figures painted.'

The reference to the gilded elements and the 'naked' wood are of particular interest. No evidence has been found to indicate the use of gold leaf in the original scheme but are positive it was not used in the 1740s restoration. Moreover, there is considerable evidence to suggest that in the original scheme the background to the border patterns was unpainted (see Item 8.2.3), which fits the allusion to 'naked' wood; and we are now certain that the ceiling boards were entirely overpainted in the 1740s (see Item 8.3.1).

Sample analysis has shown that most of the original paint was applied directly over the wooden support. Traces of an interface layer between the wood and the paint of calcium sulphate mixed with animal glue and in some cases with white lead have been found on 17 of the 134 paint samples obtained from original ceiling boards to date. However, in her 1997 (Emergency Phase) report Howard notes '...the degree of sulphation which occurs throughout the paint layers at Peterborough makes certainty impossible as to whether calcium sulphate or calcium carbonate was originally applied to bulk out the sealant'[69]. Calcium sulphate mixed with animal glue has been identified in samples from only 5 original boards in the subsequent phases of treatment: not enough to alter that opinion.

The palette of the surviving medieval polychromy includes lead white, red lead, red iron oxide, vermilion, yellow iron oxide, massicot(?), basic verdigris, natural azurite, carbon black, charcoal black, orpiment and realgar. The paint medium is oil. The orpiment and realgar pigments were identified for the first time by the Phase 4 analysis.

A detailed graphic record of all underpaint visible in low–relief below the present scheme was drawn up during the Phases 2-5 condition surveys. In Phase 1 underpaint on the Ceiling boards was categorised in the written board by board survey and denoted with a symbol on the graphic record where it exists on the lozenge border pattern boards. Only the underpaint on the Ashlar boards was drawn up accurately in Phase 1. However this recording inconsistency was rectified during the fire damage restoration phase in 2002. Amended graphic records for Bays 1-3 and the

[68] *Peterborough Cathedral Research Project: Edward Blore's Work on the Nave Ceiling* D S Glennie, June 2001. Appendix 4

[69] Howard, 1997.

findings of all additional investigations in that area are discussed in our restoration of fire damage report.[70]

8.2.1 Central Lozenge Boards

Throughout Bays 1-8 it was evident that the 1740s and 1830s restorers followed closely the original foliate and figurative designs on the central boards of the lozenges except in one instance. That exception being the Dragon lozenge in Bay 2 (*33/34/III/IV*) which has been found to be a 1740s invention. Underpaint visible in raking light indicates the original scheme had a Renard occupying only one quarter of the lozenge. Not enough low relief underpaint survives within the other three-quarters of this lozenge to suggest the original subject.

Bays 9 and 10 have a significantly higher proportion of softwood replacement boards. In some of the figurative and foliate lozenges only 1-3 original boards remain and none survive within the westernmost two foliate half-lozenges. As a result there is less evidence of visible underpaint and incision lines to confirm the original scheme (see **Graphics 9a/b**). Nevertheless, it must still be assumed that the 1740s and 1830s restorers studied the surviving paint prior to the replacement of deteriorated boards and that they made every effort to replace the original scheme. Only where there is low relief 'underpaint' or incision lines to indicate otherwise is it appropriate to suggest the repaint does not follow the original. Within Bays 9 and 10 the Eagle lozenge (*2/3/II/III*) alone falls into this category (**Plate 305**). Significant traces of a cusped mandorla is visible in low relief on two of the original boards in that lozenge. There is nothing to indicate whether the mandorla originally framed a smaller eagle or another subject. A sixth bishop, continuing the series of alternating kings and bishops, would seem more likely.

The fact that the original designs are now visible in relief on so many boards throughout the ceiling would indicate that the timber surface adjacent to the relief must have been either unpainted or perhaps painted with a water-based medium, such as a distemper. This aspect is discussed further in Item 8.2.3 below. It is difficult to believe that only part of the figurative lozenge boards would have been painted in the original scheme so the accumulated evidence suggests the original painting was of mixed media. It had seemed logical to suggest oil-based paints were used for flesh tones and other detailed features of the composition and distemper for the remainder. However the identification of original oil-based paint forming the plain red background to the Rhetoric figure,[71] together with the unpredictable pattern of weathering on central lozenge boards, and the general use of oil-based paints for the linear border decoration do little to corroborate this observation. Paint sample analysis carried out for this project has found no definitive evidence for the use of distemper paint on the ceiling.

The 11 paint samples analysed as part of the Phase 5 works were obtained from within the Phase 3 section of the Ceiling during the fire damage restoration in 2002. All were from under original nail heads now absent and therefore were thought to be original paint. The purpose of analysis being to compare them with other original paint samples to identify any changes in original painting technique across the ceiling. In fact, analysis found the original paint in each of these samples was consistent with previous samples, suggesting a uniformity of painting technique across the breadth of the ceiling. As the samples appeared so similar to those from earlier phases, they were studied in cross-section only: expensive instrumental analysis was deemed unnecessary.

Eight of the final group of samples came from the Archbishop(1) lozenge (*22/23/II/III*) and one each from the Angel playing a Cornetto (*21/22/I/II*), Grammar (*17/18/I/II*) and King (2) (*20/21/II/III*). The flesh tones from the Archbishop comprised mainly of lead white with some vermilion and carbon black.[72] Red from the Archbishop's robe drapery and from the background of Angel playing a Cornetto is red lead with a little carbon black and some white particles which

[70] *Peterborough Cathedral, The Nave Ceiling: Fire Damage Restoration & Additional Investigations and Treatment, May – September 2002* The Perry Lithgow Partnership and Hugh Harrison
[71] The Perry Lithgow Partnership and Hugh Harrison 2000, Vol II: Plate 561
[72] Davies 2003: Sample 1

are either calcium carbonate or possibly cerussite arising from the conversion of red lead.[73] The green paint from the Archbishop and Grammar contains a mixture of natural azurite with lead white and a red pigment, either vermilion or iron oxide.[74] One sample of off white paint overlaid a translucent substance, possibly calcium sulphate combined with animal glue.[75] This is only the seventeenth probable instance of such an preparatory layer found on the Ceiling from a total of 134 samples from original boards. For the most part the original paint was applied directly onto the boards.

8.2.2 Lozenge Border Patterns

The original lozenge border designs differed significantly from their present appearance. During Phase 1 it was noted that a trefoil pattern terminating in an elaborate scroll design existed under the extended chevron pattern on many original oak boards. Other examples of underpaint showing the outlines of border designs in relief on boards with otherwise 'weathered' surfaces were also noted. In Phase 2, as a consequence of the detailed examination required to accurately record the visible underpaint and with the results or extensive paint sample analysis we developed greater understanding of how the essentially linear border designs evolved through at least two restorations. The results of paint sample analysis carried out in Phases 3 and 4 significantly altered our interpretation of the original border patterns and this is set out below.

Nothing was found in Phase 5 to alter this interpretation. Only one instance was noted of original paint exposed on border pattern boards from under original, missing nail heads. This has been included in the grey chevron tabulated list (below) and conforms with earlier examples. A paint sample from an anomaly found during the fire damage restoration works to the Phase 3 area was analysed as part of the Phase 5 works.[76] This being an apparent black line on the outer curved edge of a wave pattern board (see **Plate ??**). This feature has not been found on any other wave pattern board; therefore the analysis finding of very limited traces of carbon black paint mixed with corrosion products is insufficient evidence on with to base an alternative border design.

Figure 16 (see page 73) is the same reconstruction of what is now consider to be the 13th century lozenge border decoration that was presented in the Phase 4 report. Starting from the outside the original decorative pattern sequence was as follows:

- The base boards filling the space between the diamond-shaped compartments had a white scroll design with trefoil ornament. A sample obtained in Phase 3[77] shows two layers of white lead paint. There is a marked difference in the particle sizes of the upper and lower layers. The lower layer is similar to other paint identified as original being composed mainly of lead white but also contains a few carbon black and iron oxide yellow pigment particles. Prior to this finding it had been assumed this scroll would be in black: this because, assuming the background was unpainted, a white design would be difficult to see against the light colour of new oak boards. However, as there is now evidence that white was used for the stepped chevron and dogtooth linear designs and on the coloured bands clearly this was not a factor.

- A grooved board with the alternating red (red and white lead)[78] and white (white lead)[79] bands intersected at the corners by an elaborate black scroll with trefoil ornament. Previously we had it in our minds the inner band was black but in Phase 4 we recorded fourteen examples of apparent original paint in the grooves (of what we now refer to as coloured bands boards) exposed as a result of missing original nail heads. In addition, a single example was found in both Phases 2 and 3. Thirteen of the sixteen examples are within the outer of the three grooves: all show red paint. Two from the middle grove show white paint and the single example from

[73] Davies 2003: Samples 4, 5, 6 and 10
[74] Davies 2003: Samples 2 and 11
[75] Davies 2003: Sample 7
[76] Davies 2003: Sample 9
[77] Davies 2000: Sample 20
[78] Kakoulli 1999: Sample 26. Davies 2001: Sample 9.
[79] Davies 2000: Sample 6.

the inner groove is of red paint. Black paint has been identified in one sample from a raised area between the grooves[80] but this should be considered an aberration as generally, the raised areas between grooves on these boards are considerably weathered: indicating the oak surfaces were not protected by overlying paint until the 1740s restoration.

Paint under original nail heads (now missing) found on grooved boards

Grooved Board Pattern	Board Ref	Groove	Colour
Phase 2			
Coloured bands	32 II l	Outer	Red
Phase 3			
Coloured bands	21 I o	Middle	White
Phase 4			
Coloured bands	16 II r	Middle	White
Coloured bands	11 II j	Outer	Red
Coloured bands	17 I j	Outer	Red
Coloured bands	17 I p	Outer	Red
Coloured bands	10 I h	Outer	Red
Coloured bands	15 I k	Outer	Red
Coloured bands	15 I o?	Outer	Red
Coloured bands	16 I o	Outer	Red
Coloured bands	14 I j	Outer	Red
Coloured bands	10 III k	Outer	Red
Coloured bands	11 III p	Outer	Red
Coloured bands	17 II l	Outer	Red
Coloured bands	14 II j	Outer	Red
Coloured bands	14 III l	Inner	Red

- A series of regularly spaced black (carbon black)[81] trefoil motifs springing from a black band along the inner edge of the board. At each corner a black elaborate scroll extends onto the outer coloured bands board. This pattern is mirrored in the opposite quarter of the lozenge so that the trefoil motifs spring out towards the extended corners forming an impression of crocketed gables. The trefoil motifs vary considerably in shape - in some cases even along one board. Examples of the different shapes found have been traced and are reproduced at smaller scale in **Figure 14**.

[80] Davies 2000: Sample 7.
[81] Howard 1997:Sample 27. Kakoulli 1999: Samples 16 and 39. Davies 2000: Sample 17. Davies 2001: Samples 13 and 14.

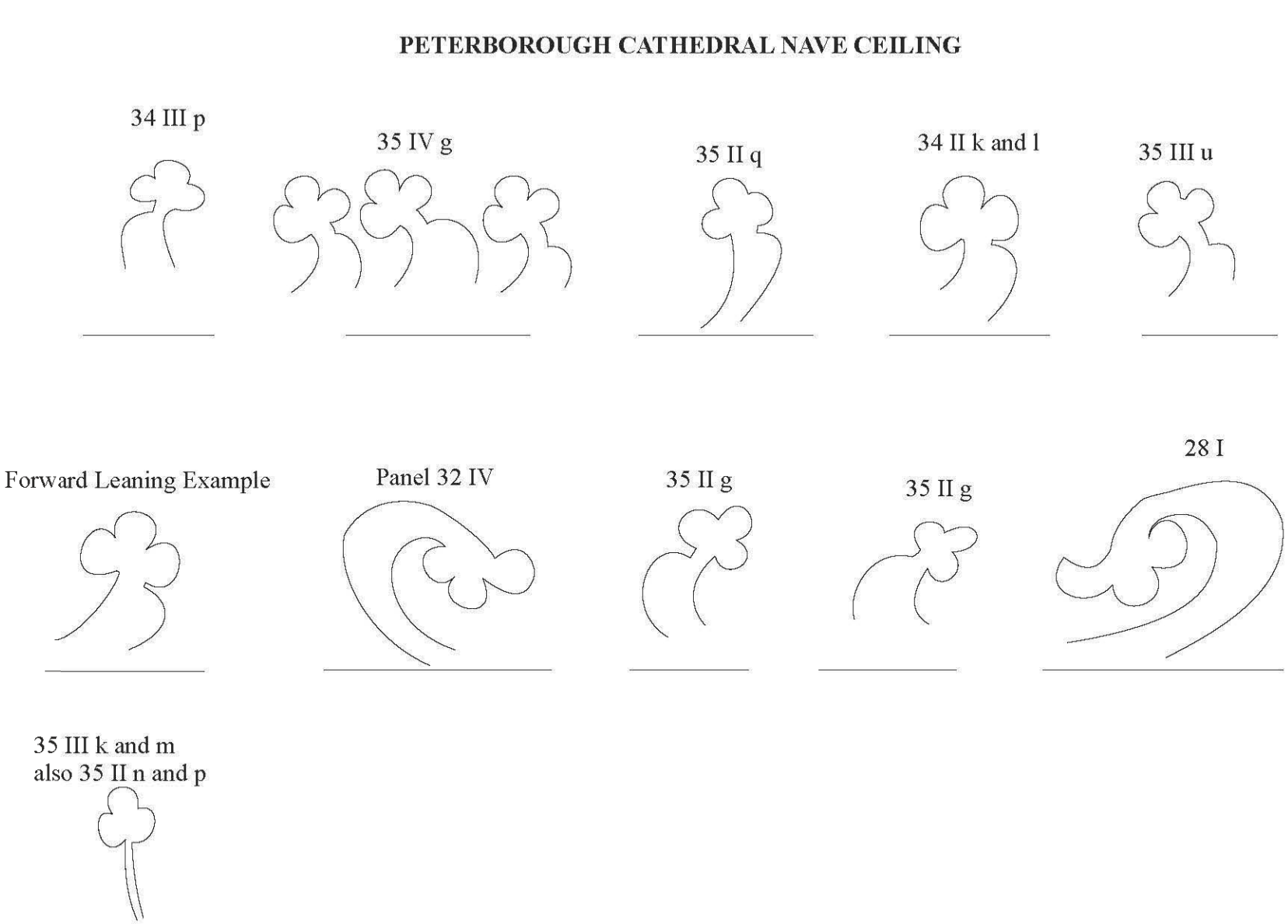

Figure 14. *Tracings of typical trefoil shape (Scale 1:5).*

- A grooved board with the alternating white and red bands[82]. Previously we had assumed that the series of three grooved boards within each lozenge quarter had the same decoration but in Phase 4 we recorded thirteen examples of apparent original paint in the grooves (of what we now refer to as grey chevron boards) exposed as a result of missing original nail heads. In addition, two were found in Phase 2 and one in Phase 5 (**Plate 365**). Four of the five outer groove examples are white; the fifth, inconsistently, being red. All five from the middle groove are red and five out of six examples from the inner groove are white. The two inconsistent finding in the series are on the same board (12 I v). A notable finding in our survey of weathering on original ceiling boards (see Item 8.2.4) is that the raised areas either side of the grooves on grey chevron boards are consistently less weathered than equivalent areas on the coloured bands and key pattern boards.[83] This finding would indicate that in the original scheme the raised areas on this board were painted; however there is no other visual evidence to corroborate this and it has not been substantiated by paint sample analysis.

Paint under original nail heads (now missing) found on grooved boards

Grooved Board Pattern	Board Ref	Groove	Colour
Phase 2			
Grey Chevron	28 IV o	Outer	White
Grey Chevron	Plate 391	Outer	White
Phase 4			
Grey Chevron	12 I v	Outer	Red
Grey Chevron	17 IV e	Outer	White
Grey Chevron	11 I f	Middle	Red
Grey Chevron	11 I s	Middle	Red
Grey Chevron	17 III g	Middle	Red
Grey Chevron	16 IV r	Middle	Red
Grey Chevron	17 III g	Middle	Red
Grey Chevron	12 I v	Inner	Red
Grey Chevron	14 I s	Inner	White
Grey Chevron	17 I g	Inner	White
Grey Chevron	9 IV f	Inner	White
Grey Chevron	15 IV	Inner	White
Grey Chevron	11 III t	Inner	White
Phase 5			
Grey Chevron	7 III i	Outer	White

- A linear stepped chevron design in white. Prior to the Phase 4 works we had been unable to establish to the original paint colour for this design and had assumed it would be black. The six paint samples obtained from stepped chevron boards previously showed two layers of white lead paint but it was impossible to determine whether the earliest layer was original or belonged to the 1730s repaint. Only in Phase 4 where we found three examples of apparently original white paint outlining the stepped chevron design exposed from under missing original nail heads could we be reasonably certain of the original scheme.[84] Both samples of exposed white paint[85] shows a very thinly applied white lead layer directly on the timber substrate. Its microscopic appearance is consistent with it being of thirteenth century date. Two samples of apparent black paint adjacent to the white under the missing original nail heads in fact contained dirt and iron corrosion products, probably from the absent nail heads. Before finding the exposed original paint eight samples from the linear decoration visible in relief through the later repaints. Most of these show two layers of lead white, no different from previous samples. Interestingly three of the eight samples included a beige layer at the base of the sample that appears to be calcium sulphate in an animal glue binder.

[82] Kakoulli 1999: Samples 37, 57. Davies 2001: Samples 10 and 11.
[83] The Perry Lithgow Partnership and Hugh Harrison 2001: Plate 54
[84] The Perry Lithgow Partnership and Hugh Harrison 2001: Plates 562-564
[85] Davies 2001: Samples 23 and 25

- A linear wave pattern in red with scrolled ends.[86] In Phase 3 a further sample[87] confirmed the previous finding. On the smaller, half-lozenges immediately over the Ashlar boards the wave pattern is substituted with linear keyhole and dog-tooth patterns: the linear keyhole in black (charcoal black)[88]; no original paint was identified in the sample taken from a board with relief linear dogstooth in Bay 1.[89] In Phase 3 an exposed area of seemingly original linear dogstooth pattern in white was discovered on *22 IV e.*[90] The white tips of the original chevron/dog tooth design is partially obscured by the displaced adjoining keyhole/bun pattern board.[91] The original linear pattern extends onto bare wood that had been protected from subsequent repaint by the overlapping board. This visual corroborates our theory that the background to the linear border decoration must have been unpainted: The original white paint follows the raised linear 'visible underpaint' of the dog tooth pattern on this board. Similar linear original white paint can be seen in the adjacent missing nail head, which adds to the now overwhelming evidence that most of the scheme was painted before the boards were nailed in place.

- A grooved board with the alternating red and white(?) bands. As already stated we had assumed that the series of three grooved boards within each lozenge quarter had the same decoration; but having established the outer two are different we cannot be certain of this one. To date we have found seven examples of apparent original red paint in the grooves of the key pattern boards: all within the outer groove (see the two examples in **Plate 364**). That photograph also shows apparent black paint on the raised sections either side of the groove; however a sample taken from this area detected accretions of dust and debris, rather than a deliberately applied paint finish.[92]

Paint under original nail heads (now missing) found on grooved boards

Grooved Board Pattern	Board Ref	Groove	Colour
Phase 2			
Key	32 I e	Outer	Red
Key	Plate 390	Outer	Red
Phase 4			
Key	11 I c	Outer	Red
Key	12 I x	Outer	Red
Key	13 I d	Outer	Red
Key	8 I s	Outer	Red
Key	8II z	Outer	Red

All these findings help to explain the curious ship-lapped sequence of grooved, straight edged and curved edged boards. Each of the three grooved boards in the sequence were painted with alternating colours. The existence of the shallow grooves, which are certainly not visible from any distance, may be explained as a guide for the painting of these coloured bands. The straight edges on the grooved and stepped chevron boards mark the division between tiers of decoration and help to create an illusion of depth. The shallow curved edges of the central boards minimises the impact of the ship-lap construction on the figurative decoration. Similarly, the slightly steeper curved edges of the linear, stepped chevron and trefoil pattern boards act to reduce the appearance of a division between patterns on the same 'tier'.

8.2.3 Low Relief Original 'Underpaint'

Throughout the current conservation programme considerable efforts have been made to explain the presence in shallow relief of elements of the original scheme beneath 1740s and 1830s paint

[86] Kakoulli 1999: Sample 18
[87] Davies 2000: Sample 4
[88] Kakoulli 1999: Sample 19
[89] Howard 1998: Sample 6. In the light of subsequent findings this sample should be re-examined.
[90] Davies 2000: Sample 3
[91] The Perry Lithgow Partnership and Hugh Harrison 2000: Plate 444
[92] Davies 2000: Sample 7

(see **Plates 90, 91, 95**). Visual examination suggests that the relief effect, first thought simply to be the result of impasto underpaint, is in most instances too pronounced for the thickness of surviving original paint to be wholly responsible. This is born out by analysis results from numerous samples obtained from such shallow relief during this project. In many cases no original paint exists in the cross sections and where it is present the layer/s are thin.

The shallow relief appears and fades along the boards with no trace of the jagged, stepped edges that would signify flaking and loss of a paint layer. The fact that this relief decoration is so intermittent suggests it was not created by shallow carving. In addition, there are numerous instances where the shallow relief intersects and is level with a prominent medullary ray. This suggests the softer wood between the rays has receded through decay where it was not protected by a paint layer. It is inconceivable that a carver would have only carved the lower ground between the medullary rays. **Plate 91** illustrates the way in which the wood surface around the original linear border patterns appears to have has receded through decay: the softer part of the growth rings being more affected and resulting in a close-ridged surface.

Dr Al Brewer[93] suggests in his paper written following his site visit and inspection of the Ceiling during the Phase 3 works: '*I would attribute the relief of the trefoil designs to a masking effect of a painted surface. That is, the trefoils were painted, thus protecting them from a degrading factor such as weathering, while the surrounding was less protected; though not necessarily unpainted. The trefoils may simply have been painted with a more protective medium such as oil, as your research indicates, while the surrounding may have been a water-based medium, such as a distemper. The latter may have entirely disappeared.*'

The same close-ridged, receded surface occurs widely - but also somewhat unpredictably - around foliate and figurative detail on central lozenge boards.[94] As discussed in Item 8.2.1 sample analysis has established the original oil-bound paint in varying colours was applied directly over the timber surface or occasionally on what may be a preparatory drawing layer of carbon black; also, that oil paint was used on the background of at least some central lozenge boards. As it is now generally agreed that the receding is the result of 'weathering' of the wood surfaces not protected by oil paint we must conclude that the oil paint did not extend overall the central lozenge boards. However, weathering has often occurred randomly not only within the backgrounds on central lozenge boards but also within the figures. This and suggests the original painting may have been of mixed media. Unfortunately, paint sample analysis has found no conclusive evidence to corroborate this observation.

Analysis has not established whether the background to the Nave Ceiling border designs were painted or the wood surface left exposed. Nevertheless, paint sample analysis has established that the lozenge border decoration was painted directly onto the oak boards without an intervening preparatory layer. By implication this finding suggests the background to this linear scheme must have been unpainted: otherwise the finely painted border designs would overlay the previously applied background paint. Nevertheless, the following observations concerning variations in weathering across the lozenge border sequence suggest it would be wrong to dismiss the possibility that the backgrounds were painted with non-oil based paints.

Investigation of oil binding medium residue in the wood. Brewer raised the possibility of differentiating between original oil on raised linear design and later oil from 1740s work on receded background. To that end Gillian Lewis, Consultant Conservator for this project, contacted Raymond White at the National Gallery in September 2001. He has more knowledge and experience of the procedures necessary for such sensitive identification of organic media in early paint layers as would be required for this project than has anyone else in UK. His opinion is set out below:

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[93] *Observations on Wood Effects for the Nave Ceiling of Peterborough Cathedral* Dr J. A. Brewer, B.Sc., M.A.C. Ph.D, November 2000. Reproduced as **Appendix 5** of this report.

[94] The Perry Lithgow Partnership and Hugh Harrison 1999: Plates 396, 397

Raymond White has occasionally met this problem of vestigial early layers thoroughly coated in later material which is all-pervasive. Consequently he thought this problem did not sound to be at all an easy one. It would be particularly difficult if the original paint is very thin and fragmentary (as at Peterborough). If already fragmented it will have acted like a sponge to the later upper layers and is likely to be heavily contaminated by them (as found by Helen Howard). In such a situation it is almost impossible to sort out the contents of the sample. The only hope might be to pick out original fragments using a micro-manipulator under binocular microscopy; a combined cross-section infrared examination (perhaps embedded in silver chloride) might be carried out. If the differences were- sufficiently marked one might assemble a corpus of partial fragments, but then another group of corroborative samples would still needed to confirm any findings.

Such procedures would be very labour-intensive, quite complex and the end results probably would not justify the time and expense involved. One could spend an inordinate amount of effort and any results would be very tenuous; more likely would be to find nothing useful whatsoever, or something thoroughly misleading, because of fractionation problems.

There are beam techniques - matrix absorption spectral techniques - which are very expensive and which the National Gallery does not have. Even if we pursued this option a sub-set of results could occur. As a result Raymond White sees this as unwarranted.

Previously Helen Howard had expressed similar reservations so Gillian Lewis' opinion, agreed by the Project Team, is that as there is no need to identify the early medium for conservation reasons it is best to leave this analysis for future scientists.

8.2.4 Survey of Weathering on Original Ceiling boards

In previous phases we had noted that curved edged Ceiling boards with lozenge border decoration tend to have a smoother surface that the straight edged and grooved boards. In many cases the original linear wave and trefoil patterns on these curved edged boards is in relief yet the recessed background appears generally to have less prominent medullary rays than is the case on the other boards. Another observation was that the black areas of stepped chevron boards often appear more heavily weathered than those painted white (see **Plate 91, 360**). In addition, the base boards are generally more weathered than other boards with the base-board scroll decoration often in exaggerated relief. The additional focus on the weathered surface of the original boards resulting from Al Brewer's visit during Phase 3 provoked us to conduct a structured investigation of this aspect.

As in Phases 3 and 4 Hugh Harrison and Richard Lithgow carried out a survey of the original oak Ceiling boards within Bays 9 and 10. Each board was examined and graded for extent of weathering - Rough, Medium, Smooth. The white areas and black areas on the wave pattern, stepped chevron and extended chevron boards were graded separately. The Phases 3 and 4 survey findings were consistent, suggesting the weathering patterns are similar along the length of the ceiling. In some respects, the findings for Phase 5 were less consistent; partly because a smaller percentage of original boards remain in Bays 9 and 10. Nevertheless, 70% of the ceiling has been surveyed and the combined results provide a more than adequate sample area for meaningful interpretation. The survey data for Bays 9 and 10 is displayed separately and in combination with the data from Bays 4-8 as **Appendix 5** of this report.

Generally the results are more consistent for the horizontal Ceiling boards (*Rows II and III*).

Central lozenge – These are difficult to grade because weathering occurs - as for as we can ascertain - only where the boards were unprotected by oil-based paint. The extent of original oil paint varies widely on these boards so the results are bound to be misleading so have not been included in the survey.

Wave pattern and extended chevron (curved edged boards) – Both black and white areas predominantly smooth: only 2 black and 2 white areas from 240 of these boards are classified as rough and 19% as medium. In *Row IV* all the extended chevron and wave boards are classified as

smooth. The linear wave pattern is rarely visible, and then only in very low relief. The original trefoil decoration of the extended chevron boards is much more often visible but in relatively low relief. The surface of these boards appears recognisably different from the other boards, as if they were from a different batch of timber. It may be that they are simply less affected by the weathering process as an original, non oil-based paint partially protected the timber surface.

Stepped chevron (straight edged boards) – The original linear design is generally visible in prominent relief. 45% of the boards are smooth on the white areas, 41% medium and 14% rough. The black areas are consistently more weathered than the white: 58% rough, 39% medium. This finding is significant as it suggests that the white areas on these boards may have been partially protected by a non oil-based paint while the black areas were unpainted.

Key Pattern, coloured bands (grooved boards) – The key pattern and coloured bands boards display consistent weathering patterns with the inner half being predominantly smooth and the area with the raised bands being excessively weathered: to the extent that the raised bands are often level or lower than the grooves. This disparate weathering of the inner and outer halves made it difficult to grade the boards meaningfully into the smooth, medium, rough categories; consequently, the overwhelming majority were classed as medium. These observations suggest that the inner half of the grooved boards were protected by a non oil-based paint while the raise bands between the grooves were unpainted. Paint sample analysis has established that oil paint was used in the grooves themselves.

Grey chevron (grooved boards) – Surprisingly, the raised bands of the grey chevron boards were consistently less weathered than those on the other two grooved boards: 26% of grey chevron boards were graded as smooth and 65% medium. This finding raises the possibility that the raised bands on this board were painted, probably with a non oil-based paint.

Base boards – In Phase 3 70% of the base boards in *Rows II and III* are rough, 22% as medium and only 6% as smooth. Surprisingly the Phase 4 results are very different with 11% rough, 50% medium and 39% smooth. In Phase 5 the results were 50% rough and 50% medium. There is no ready explanation for the difference between the Phase 3, 4 and 5 results. Generally, we found that the narrow areas of base boards were significantly less affected by weathering than the wider areas: this was the case on both the horizontal and canted panels.

Results were less consistent for the canted Ceiling boards (*Rows I and IV*).There are many more softwood replacements within the canted rows suggesting more severe deterioration previously in these areas. The extent of weathering varied considerably along the length of canted boards, so the three grade system is misleading. In the Phase 5 area there are a small number of boards in Row 1 on which there is a particularly exaggerated difference in weathering of the black and white areas (see **Plates 90 and 91**). Again there is no ready explanation for this.

The weathering survey has proved a valuable exercise, allowing us to quantify what were previously vague observations and crystallise our theory on the use of mixed media in the original paint scheme.

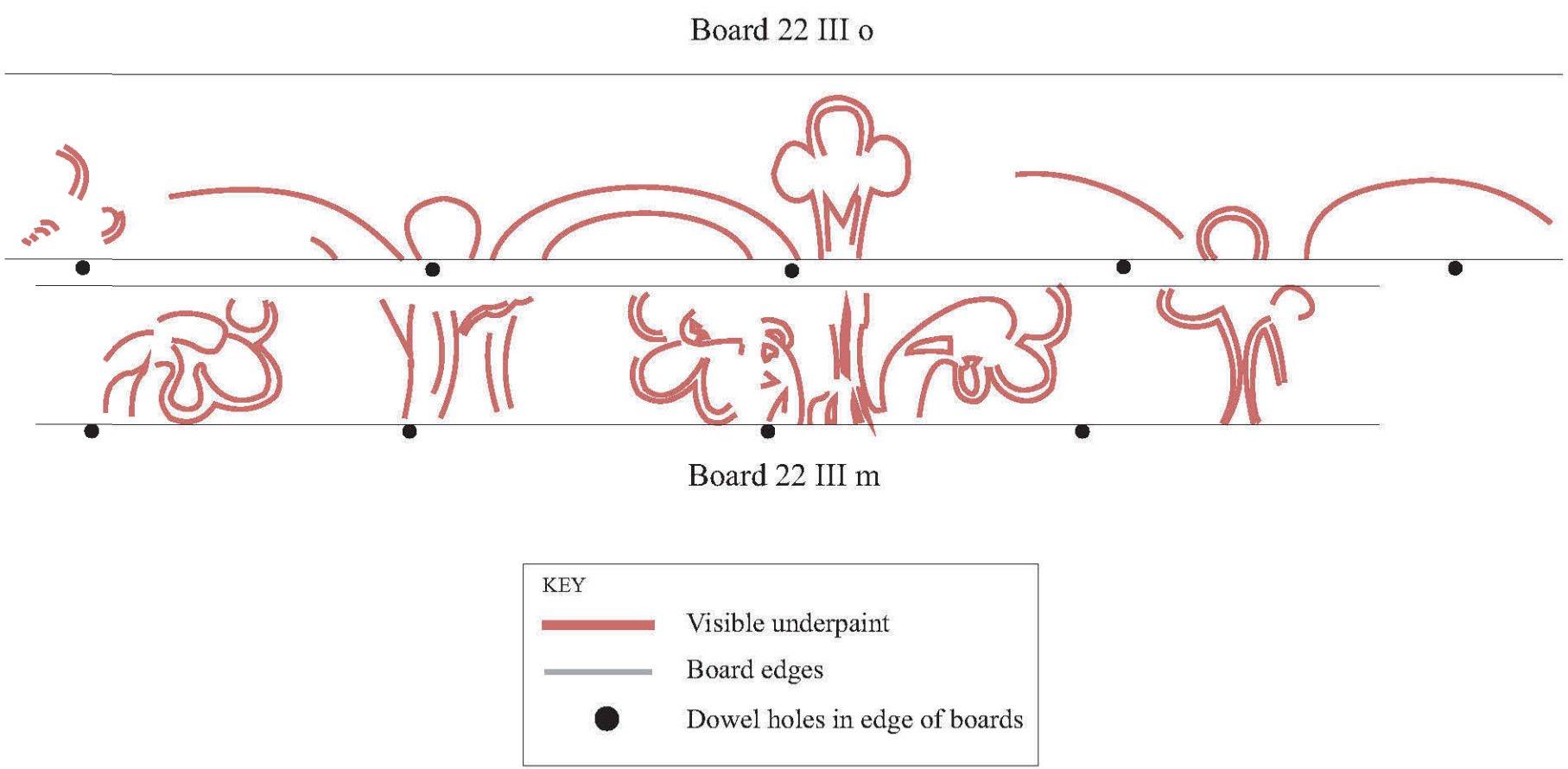

Figure 15. *Tracing of linear visible underpaint on repositioned oak boards found in Bay 7 considered to be original Ashlar boards (Scale*

8.2.5 Original Ashlar Boards

In Bay 5 there are two early oak boards (*22 111 m, o*) that have a very different linear pattern visible in relief beneath the 1740s and 1830s repaint[95]. The underpaint is a foliate design unlike anything found to date on the Ceiling. Both boards have a series of dowel holes with broken pegs along their exposed edge. The pegs alone indicate these boards did not originally form part of a Ceiling panel. Only the original base boards are pegged in this manner, but they have a different pattern visible as underpaint. Our current thinking is that they may be original Ashlar boards salvaged, and re-used as replacement Ceiling boards, when the entire frieze was replaced in the 1740s. The 'weathering' to the board surfaces is identical to that on many original Ceiling boards. Alignment of tracings of the relief underpaint on these boards indicate the foliate design would fit the space now filled by the 1830s Ashlar boards (see **Figure 15**). Sample analysis results indicate the leaves were a bright red and the linking tendrils a dark red or purple[96]. Interestingly these colours were painted over a white lead ground rather than directly onto the timber surface: as was the case for the original lozenge border decoration, and indeed some of the original paint on the central lozenge boards.

8.2.6 Original Setting Out Lines

In addition to the carpenter's or alignment marks (discussed in Item 3.2) there are a number of incised lines following the paint scheme. For instance, some of the mandorla framing the figures on central lozenge boards are partially outlined in this manner (see **Graphic 1**). It is impossible to be certain these are preliminary setting out lines for the original design; if so one would expect them to be more prevalent. However, in Bay 3 - on the St Peter lozenge – a section of cusped mandorla has been incised where none has been painted: indeed there is no room for a mandorla around the St Peter figure. If the C18th restorer copied exactly the St Peter figure he would not have thought to include a mandorla and it would follow that these incision lines must be original.

Most of the incised alignment marks (**Plates 361 and 362**) are considered to be original because in many instances the boards have C13th nails in place and therefore have not been repositioned. Prior to the Phase 4 survey their purpose was unclear since the lozenge design and ship-lap construction dictates the position of each board: the alignment marks would seem superfluous. There was evidence of original paint under missing original nail heads to prove the border designs were painted before the boards were attached. However, we considered it unlikely the figurative and floral elements on central lozenge boards also had been painted before the boards were nailed in position: mainly due to the perceived difficulties in laying the overlapping central lozenge boards accurately on the ground in order to paint the detail; also because, if the incised lines served as reference marks to align the painted decoration, one would expect to find examples on many more boards. Nevertheless, the numerous examples of original paint under missing original hail heads in Bays 6b, 7 and 8 (Phase 4) provide conclusive proof that the central lozenge boards were painted beforehand (**Plates 364 and 365**). We must assume that nail heads interrupting painted detail were overpainted and any necessary adjustments to align the painted decoration made once the boards were finally attached to the ceiling.

Having established as fact that all the boards were painted before being fixed in place it has become easier to explain why many of the incised lines that extend across two boards are slightly offset. The lines were incised when the boards were first offered up to the ceiling and cut to fit. They were then used to re-align boards when they were laid out on the ground for painting. As soon as the paint was applied the incised lines became irrelevant and the painted decoration became the primary alignment indicator.

During Phase 4 the significance of incision lines running serving to delineating the edge of the overlapping boards - particularly central lozenge boards - became clear.[97] With the extent of

[95] The Perry Lithgow Partnership and Hugh Harrison 2000: Plates 445-448
[96] Davies 2000: Samples 1 and 2.
[97] The Perry Lithgow Partnership and Hugh Harrison 2001: Plate 78

overlap marked and the individual boards cut to length it was possible to accurately recreate the lozenge shape on the ground for painting without the need for cross-board reference marks.

8.3 PREVIOUS INTERVENTIONS

There is documentary evidence that the painted scheme was restored between 1740 and 1750 and again in 1830s. There are no details of the 1740s restoration but there is a record of materials and other costs for the 1830s work. The repainting on both occasions was extensive and inept. It is not known if there were significant interventions to the painted decoration prior to 1740; however, it would be remarkable had nothing at all been done to the scheme during the intervening 500 years. Some structural alterations would have been made to the east end of the Ceiling when he tower arch was remodelled in the 14th-century; subsequent structural intervention when the tower wall was rebuilt in the 1880s has confused indications of previous works. In the absence of evidence to the contrary this survey assumes the earliest repaint to date from the 1740s.

8.3.1 The 1740s Restoration

Cave[98] states that in 1789 Govenor Pownall wrote of a meeting in 1773 between the then Bishop of Peterborough and the restorer (still living some 30 years later). The Bishop recalled he '*learnt from him that the whole was repainted in oil. He told his lordship that several of the figures were entirely encrusted with dirt, but that upon applying a sponge they became clear and bright, but whence he concludes that the last coat was oil. He was altogether of the same opinion with what 1 had suggested, that the body of the painting (under what he supposed to be the coat of oil) was in distemper: parts came clear off from the wainscot. He assured his Lordship that he only retraced the figures, except in one instance the third or fourth compartment from the West door, where the whole figure peeled off: in this single instance he followed his own fancy…*'

Evidence from paint sample analysis and observations from the scaffold indicate the extent of the 1740s intervention to be as follows:

- The original oak Ashlar boards were replaced with softwood boards. These were decorated with a scheme including elements similar to the existing 1830s frieze pattern.
- At least two of the original oak Ashlar boards were salvaged and re-used as replacement Ceiling boards.
- A number of original oak Ceiling boards were replaced with softwood boards.
- The figurative and foliate central lozenge boards were entirely repainted in oil-based paints. A study of original detail visible in relief as a result of the weathering process (Item 8.2.3) does not quite corroborate the restorers statement that he 'retraced the figures, except in one instance'. There is evidence to suggest the designs of two figurative lozenges are different from the original (Item 2.5.2).
- The lozenge border pattern decoration was entirely repainted in oil-based paints. The restorer making significant changes to the original scheme (Item 8.3.1.1).

[98] *Archaeologia LXXXVII* 'The Painted Ceiling in the Nave of Peterborough Cathedral' Cave and Borenius 1938.

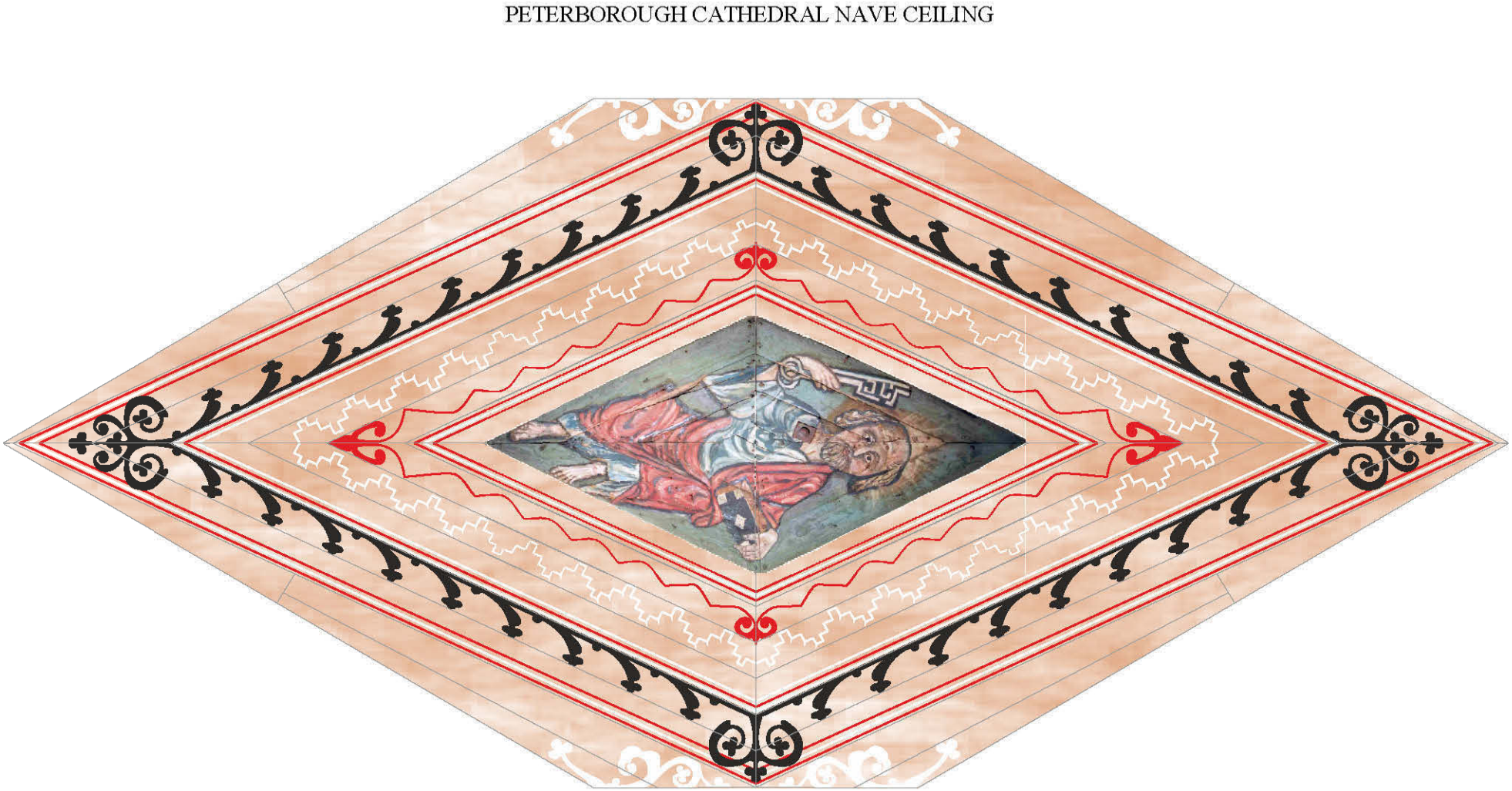

Figure 16. *Reconstruction of probable original medieval lozenge border decorations (background assumed to be bare oak boarding).*

Figure 17. *Lozenge border decorations as painted in the 1740s and 1830s.*

8.3.1.1 1740s lozenge border patterns – Observations from the scaffold during Phase 4 changed our view of the 1740s lozenge border decoration as reconstructed in our Phases 2 and 3 reports[99]. We were mistaken in thinking that the trefoil and wave pattern boards were not overpainted during this intervention and are now certain that the lozenge border scheme as it now appears - reproduced in **Figure 17** of this report - was painted in the 1740s. The 1830s restorers did not alter the design but simply repainted many elements. Starting from the outside the 1740s decorative pattern sequence was as follows:

- The base boards filling the space between the diamond-shaped compartments were coated with very characteristic brown/black paint over a white lead ground[100]. The scroll design with trefoil ornament painted white[101].

- Two coloured bands, black and red over a lead white ground, occupy the outer half, a grey/brown thinly applied wash[102] the inner. The removal, during Phase 4, of two 1830s softwood patches partially covering coloured bands boards revealed the underlying 1740s scheme.[103] These allied with a similar observation in Phase 3[104] - and numerous incidents of offset underlying red and black lines visible through the 1830s white paint - prove conclusively this design was painted in the 1740s.

- Generally, within the eastern half of the Ceiling there appeared to be only one layer of overpaint covering the original trefoil pattern. In Phase 3 it was noted that a larger percentage of these boards had two layers of overpaint and during Phase 4 it became obvious that the original design had, in fact, been replaced in the 1740s with the extended chevron pattern in charcoal black and lead white. The main factor that lead us to the mistaken belief the original trefoil and wave pattern boards were not overpainted in the 1730s was that, early in the project, we had formed the view that the only black paint used in the 1740s was the brown/black composite (large carbon black particles, yellow iron oxides and lead white).[105] This persuaded us the single layer of deep matt black paint (carbon black mixed with lead white), often associated with microflaking on the wave pattern boards, must belong to the 1830s intervention.[106]

- This grooved board was painted with the grey chevron pattern over a brown/black ground[107]. The white embellishments on the grey chevron design varied considerable within Bay 1 and the east half of Bay 2 (*Rows 39-33)*. From *Row 32* westwards the embellishment becomes more formalised as a small V shaped 'leaf' motif (white lead with a little carbon black)[108].

- The original linear stepped chevron design was completely overpainted with a brown/black stepped chevron design over a lead white ground.[109]

- The linear, red wave pattern with scrolled ends was overpainted with a deep matt black layer(carbon black mixed with lead white). In the Phases 1-3 reports we suggested this layer was not overpainted in the 1740s but in Phase 4 a section of 1740s wave pattern was exposed from under temporarily removed 1830s Ceiling bolts and washers.[110] In Phase 5 a section of a 1740s scrolled end was similarly exposed (**Plate 369**)

[99] The Perry Lithgow Partnership and Hugh Harrison (1999, Fig. 17, p. 62) and (2000, Fig. 13, p. 73).
[100] Kakoulli 1999: Sample 17
[101] Davies 2000: Sample 20
[102] To date there has been no analysis of this paint. For inclusion in list of samples for Phase 5?.
[103] The Perry Lithgow Partnership and Hugh Harrison 2001: Plates 265 and 570
[104] The Perry Lithgow Partnership and Hugh Harrison 2000: Plate 458
[105] Howard 1997: Sample 17. Kakoulli 1999: Sample 30
[106] Kakoulli 1999: Sample 45
[107] Howard 1997: Sample 28. Howard 1998: Sample 5. Kakoulli 1999: Sample 47
[108] Howard 1997: Sample 28
[109] Howard 1997: Sample 17. Kakoulli 1999: Sample 30
[110] The Perry Lithgow Partnership and Hugh Harrison 2001: Plate 589

- This inner grooved board was repainted with a Greek key pattern in brown/black over a lead white ground.[111] A section of the 1740s key pattern was exposed from under temporarily removed 1830s Ceiling bolts and washers in Phase 4.[112]

8.3.1.2 1740s central lozenge boards –It is apparent, from the areas of 1740s paint on the central lozenge boards temporarily revealed during this conservation project, that the 1830s restorers - with few exceptions - followed very closely the 1740s scheme.[113] Such examples also indicate the condition of the painted decoration immediately prior to the 1830s intervention and provide visible confirmation of the analysis findings and our interpretation of the conservation history. That being said, analysis found that a sample of seemingly 1740s blue-green paint - taken in Phase 3 from behind a temporarily removed 1830s softwood patch – had a very complex stratigraphy and may, in fact, be 1830s paint applied before the covering softwood patch was attached.[114]

Analysis has established that the 1740s restorer did not apply a preparatory ground overall the figurative and foliate panels prior to repainting. Much of the 1740s decoration is directly over the original paint layer. Where a plain white lead layer underlies the 1740s paint it is not always clear whether it is original or a 1740s ground. In addition to the brown/black composite paint, a red paint (red ferric oxide with red lead inclusions)[115] and an olive green copper-bearing pigment mixed with ferric oxide particles[116] were identified as belonging to this restoration. In Phase 3 two samples of flesh tones from the head of the angel with cornetto included apparent 1740s paint: vermilion in a lead white matrix and lead white coloured with both iron red and vermilion.[117] In Phases 4 and 5 analysis of paint from central lozenge boards concentrated on paint under missing original nail heads so did not include 1740s paint.

8.3.1.3 1740s replacement boards – There are very few reliable features visible from the scaffold to distinguish 1740s softwood replacement boards from 1830s replacements. In the absence of conclusive evidence, such as obvious underpaint, identification of 1740s replacement boards involves an assessment of numerous physical and contextual factors including: dimensions and manufacture of the board in question, properties of adjacent boards, nails, nail holes, shot holes, thickness of the paint etc.

Softwood boards with other impasto painted detail visible in raking light beneath the 1830s overpaint have been categorised as 1740s softwood replacement boards on the condition survey graphics (**Graphic Nos: 9a/b)**. Also included in this category are a number of boards with a noticeably thick paint covering. In Phase 3 a confirmatory paint sample was taken from two of these boards and the findings indicate our identification in these instances was correct.[118] In Bays 9 and 10 forty four softwood boards were recorded as 1740s replacements: this being nearly 6% of the total number of boards in these two bays.

In Phase 2 we thought that the brown/black 1740s paint - a composite of large charcoal black particles, ferric hydroxide and lead white - was sufficiently different from the 1830s black paints to be easily distinguished with the naked eye.[119] However, observations made during Phase 3 suggest this may not be correct in every instance.[120] We identified an 1830s composite brown/black paint that is indistinguishable in appearance from the 1740s composite brown/black. Were it not that the overpaint covers losses within the underlying 1740s paint as well as overlapping the white 1830s background paint, we would have taken it to be from the earlier intervention.

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[111] Howard 1997: Samples 13, 25. Kakoulli 1999: Sample 13
[112] The Perry Lithgow Partnership and Hugh Harrison 2001: Plate 591
[113] The Perry Lithgow Partnership and Hugh Harrison 2000: Figure 15 and Plates 161, 171, 455 and 456
[114] Davies 2000: Sample 22
[115] Kakoulli 1999: Sample 55
[116] Kakoulli 1999: Samples 15 and 29
[117] Davies 2000: Samples 13 and 14
[118] Davies 2000: Samples 11 and 12
[119] The Perry Lithgow Partnership and Hugh Harrison 2001: Plate 616
[120] The Perry Lithgow Partnership and Hugh Harrison 2000: Plate 461

Throughout Bays 1-5 of the Nave Ceiling we have identified a number of softwood replacement boards with a scheme very similar to the existing 1830s frieze decoration visible in raking light beneath 1830s overpaint. These we consider to be 1740s Ashlar boards salvaged in the 1830s, and re-used as Ceiling boards. Eight of these boards were identified in Bay 1; seven in Bays 2 and 3; eleven in Bay 4 (seven within one panel alone); only four boards in Bay 5; none in Bays 6-9 and one only in Bay 10 (**Plate 370**).

In Phase 2 we noted that the frieze decoration on one such replacement Ceiling board appeared to be overpainted with the 1740s composite black paint. However, the identification of a visually identical 1830s brown/black paint suggests that attribution was in error. In Phase 3 two paint samples (red and black) were obtained from an area of frieze design protected from subsequent repaint by an overlapping board.[121] The purpose was to confirm our belief that the frieze decoration on these replacement boards could indeed be 1740s. One sample shows a layer of red paint, comprised of red earth combined with silica, calcium sulphate and charcoal black applied over a lead white ground. The other sample shows a finely divided black pigment together with some red inclusions applied over a lead white ground to the timber support. These findings conform to a possible 1740s date.

In Phase 3 we considered it likely the policy of salvaging for re-use stable sections of deteriorated boards was adopted for both the 1740s and 1830s interventions. This because it conformed with our theory that the two oak boards with a foliate design unlike anything found to date on the Ceiling were sections of original Ashlar boards (Item 8.2.5). If so they must have been inserted as replacement Ceiling boards in the 1740s because we are certain the Ashlar boards were entirely replaced at that time (see following Item).

In Phase 4 we found conclusive proof that the 1740s restorers did indeed re-used original Ceiling boards as replacements. The proof was a grey chevron board with original trefoil pattern showing in relief: also visible were the 1740s impasto embellishments to the grey chevron design.[122] As the trefoil decoration is normally found on boards painted with the later extended chevron design rather than grey chevron the curved edged board must have been re-sited by the 1740s restorers. Also in Phase 4 we found an extended chevron board with what appears to be two different designs as underpaint: wave pattern and dogtooth.[123] This board may have been re-sited twice. The dogtooth pattern occurs only on the canted panels, the wave pattern only on horizontal panels.

8.3.1.4 1740s Ashlar boards – Evidence provided by the softwood replacement Ceiling boards with frieze decoration as underpaint suggests the original Ashlar boards (probably referred to by the 1740s restorer as the *'wainscot'*) were replaced entirely during this intervention and the new boards painted with a scheme very similar to the existing 1830s frieze decoration. In turn, the 1740s Ashlar boards were entirely replaced in the 1830s (Item 8.3.2.4) when a number of the boards were salvaged for re use as replacement Ceiling boards. The possible discovery in Bay 5 of two original Ashlar boards (Item 8.2.5) would suggest the same policy of salvaging Ashlar boards for re-use had been adopted by the 1740s restorers.

8.3.2 The 1830s Restoration

Throughout the phased project we have made significant progress in determining the full extent of this major intervention to the structure and painted decoration. The discoveries and observations from each phase have been discussed in relation to previous findings culminating in the accumulate body of evidence set out below. As some of the observations reported in earlier phases have proved erroneous in the light of subsequent findings, it has been and remains necessary to relate the trail by which we have arrived at our conclusions.

The significant findings made during Phase 5 that relate to the 1830s intervention are as follows:

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[121] Davies 2000: Samples 9 and 10
[122] The Perry Lithgow Partnership and Hugh Harrison 2001: Plate553
[123] The Perry Lithgow Partnership and Hugh Harrison 2001: Plate554

- A receipt listing materials used for the repainting of the Nave Ceiling in 1835 has been discovered in the Northampton Records Office. The list includes items not identified by sample analysis for this project.
- Close inspection of the west end vertical boards has confirmed our assumption that the boarding and paint date from the 1830s intervention.
- Inspection of 1740s paint exposed from under temporarily removed 1830s Ceiling bolts and washers suggest the 1830s restorers may have made significant changes to the 1740s scheme in two figurative lozenges.
- The border pattern on a number of stepped chevron boards, both original and softwood replacement, appears to have been set out in white chalk. The 1830s overpaint paint has flaked from the powdery chalk lines (see **Plates 372, 373**)

8.3.2.1 1830s technique and materials – In our reports for Phases 1, 2 and 3 we stated that the inclusion of barium sulphate as a component of some paints provides a useful *terminus post quem* of the end of the 18th century and therefore, in the absence of any evidence to suggest more than two significant interventions to the paint layer (the 1740s being the first) paints containing barium sulphate must belong to this restoration. The identification of barium sulphate in apparently original green paint from under a missing nail head within the background of Grammar[124] - probably as a contaminant - means that we can no longer be so certain. As Davies points out barium sulphate is a naturally occurring substance and may be associated with the natural pigments used in the paint mix. We have reviewed all other instances from the ceiling where the presence of barium sulphate in a sample has caused us to identify a paint layer as from the 1830s intervention. In no case is there contrary evidence to recommend an earlier date for that paint layer.

The 1830s restorers used a variety of white paints. Lead white with and without the inclusion of barium sulphate as well as with dispersed particles of red, yellow and black has been identified. These additions cause the white paint to fluoresce differently under UV illumination thus confusing on-site investigations.[125]

Similarly, observations from the scaffold indicated the 1830s restorers had used a wide variety of black paints. Considerable effort was made to categorise these blacks and identify examples for inclusion in the Phase 2 sample strategy. Analysis has identified 4 categories of black: a composite black; a pure black; a charcoal black mixed with lead white; a resinous black [126]. Perceived variations within these categories result from slight differences in the pigment mix, the ratio of medium to pigment, the application of one black paint over another and the thickness of the layer. Observation from the scaffold and the analysis results suggest that the composite black category was used to strengthen or overpaint the 1740s brown/black while the charcoal black mixed with white lead was used mainly for the extended chevron and wave pattern decoration. To date we have no explanation for the seemingly arbitrary use of the very resinous black paint and what appears to be more of a varnish coating that has been applied carelessly over other 1830s black paint.[127] on a small number of boards in Phase 4 have been coated with a glossy clear surface coating. This unidentified layer occurs only on a small number of boards. We have no idea why it was applied but - in the absence of any substantial evidence that anyone has had access to the paint surface since the 1830s intervention – must assume it was applied immediately after the repaint.

In Phase 3 we identified what must be an 1830s composite brown/black paint that is indistinguishable in appearance from the 1740s composite brown/black.[128] Were it not that the overpaint covers losses within the underlying 1740s paint as well as overlapping the white 1830s background paint, we would have taken it to be from the earlier intervention. Throughout Phases 1, 2 and 3 it has been a mystery to us why the 1830s restorers used such a wide range of black paints. On certain boards they seemed to take care to match closely the underlying paint, yet nearby they made on effort at all.

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[124] Davies 2002: Sample 7
[125] The Perry Lithgow Partnership and Hugh Harrison 2000: Plate 468
[126] Kakoulli 1999, Table 4 (pages 16/17)
[127] Kakoulli 1999: Sample 45
[128] The Perry Lithgow Partnership and Hugh Harrison 2000: Plate 461

Prior to Phase 4 we had concluded that the matt black wave pattern paint (often associated with micro-flaking) was applied in the 1830s and that the wave pattern boards had not been repainted in the 1740s. In Bays 1-3 the black wave pattern consisted mainly of a single layer of seemingly 1830s matt black paint. Two layers of black paint were identified on most of the wave pattern boards within Bays 4, 5 and 6a, but our observations from the scaffold indicated the thin matt black generally overlaid the obviously 1830s resinous black paint. We had difficulty understanding why the 1830s restorers would find it necessary to apply two coats of black paint and in the Phase 3 report admitted the possibility that our observations were misguided and that the wave pattern was indeed first overpainted in the 1740s. Throughout Bays 6b, 7 and 8 it became increasingly clear that the matt black paint belongs to the 1740s intervention.

Archive research carried out by the Cathedral Archaeologist, Donald Mackreth, in the intervening period since Phase 4 has proved fruitful. Bundles of receipts relating to the 1830s intervention by Blore to the Nave roof and ceiling were found the Northampton Records Office.[129] The receipts listing works to the ceiling structure are discussed in Item 3.3.4. That relating to the redecoration of the ceiling is reproduced below:

Bundle 2 1834 – 1837

x. painting the Nave Ceiling

The Rev^{d} The Dean and Chapter
To Cha^{s} Layton
For repairing and decorating the Ceiling to the Nave of
Peterboro' Cathedral under the direction of E. Blore Esq 1835

lbsDay	Bill of Paint Cost				
8 ½	lbs Prussian Blue	6/6	2	15	3
9	Vermillion	1/8	..	15	9
22 ½	Turkey Umber	1/3	1	8	1½
56	Brunswic Green	7^{d}	1	12	8
43	Venetian Red	3½		12	6½
7	Vandyke Brown	1/11		13	5
2	Crome Yellow	2/4		4	8
14	Sugar of Lead	11½ ^{d}		13	5
½	Lake	12/-		6	0
48	Red Lead	3½		14	0
7	Ivory Black	7^{d}		4	1
9	Lamp Black	5^{d}		3	9
36	Stone Oker	5^{d}		15	0
14	Burnt Sienna	2/-	1	8	0
18	Brunswic Brown	6^{d}		9	0
cwt qu lbs					
6 2 14	White Lead	28/-	9	5	6
23 gallons	Linseed Oil	4/-	4	12	0
7	D^{o} Boiled D^{o}	4/6	1	11	6
15 $^{1}/_{8}$	Turpentine	5/2	4	0	1
N	2 Books Gold leaf	2/-		4	0
	Brushes, Tools, Pencils etc. etc		2	12	6
N^{o}	4 Men 117 days each	3/6	81	18	0
	1 Laborer 46 days	2/-	4	12	0
	1 Copal Varnish	37/-	1	12	0
			123	3	3
	Add 12 p^{r} Cent for Profit		14	15	7
			137	18	10

Examined <u>Edw: Blore</u>

[129] NRO Dean and Chapter Vouchers, Box 5053, Bundle 2 1834 – 1837, items IX and X

This is a particularly useful record of the materials used during the restoration of the paint scheme and of the time it took to complete. Assuming the work was continuous it would have been completed by the 4 restorers in approximately 6 months, and they were assisted by a 'labourer' for almost half of that time.

As for the materials. Paint sample analysis for the current Nave Ceiling conservation project has identified many of the pigments listed above in the 1830s paint layer and these are discussed below. One interesting aspect of the list is the variety of dark earth colours used – such as Vandyke brown, Turkey umber, Brunswick green and brown, stone ochre and burnt sienna - is remarkable and confirms our observation that the 1830s restorers took considerable to produce various different shades of black. Also it is interesting there is no mention of the pigment barites (barium sulphate) which we know was used extensively as an extender during this intervention, nor of the 'clay-based' materials that swells readily in the presence of moisture; as was demonstrated during the treatment tests by the severe blanching of some of the paint following even brief contact with water.

The pigments in the list not found in our paint samples are chrome yellow and lake:. Gold is present only on the heraldic shield on the 1880s west end vertical boards (see **Plates 354-357**). However, from our point of view perhaps the most significant materials listed are sugar of lead and copal varnish as neither has been specifically identified during analysis. Sugar of lead (lead acetate) would have been employed in this instance as a siccative (or dryer); its inclusion causing oil or varnish media to dry more quickly. The copal varnish may have been mixed into the paint to produce the very resinous black and what appears to be more of a varnish coating that has been applied carelessly in places over other 1830s black paint.[130] In Phase 4 we found that a small number of boards had been coated with a glossy clear material. We have no idea why it was applied but - in the absence of any substantial evidence that anyone has had access to the paint surface since the 1830s intervention – assumed it was applied immediately after that repaint.

Sugar of lead was widely used as an ingredient in drying oil preparations from the mid-eighteenth century to the mid-nineteenth century.[131] According to Sir Arthur Church, (Professor of Chemistry at the Royal Academy from 1879-1911) the use of sugar of lead had been widespread: '*It was a common practice to employ powdered sugar of lead or a solution of this salt in water to hasten the drying of vehicles and slow-drying pigments which have been ground in oil*'[132]. By the mid-nineteenth century there was concern that its use could cause certain colours to become dull. In 1847 Sir Charles Eastlake (President of the Royal Academy in 1850) wrote: '*The use of acetate or sugar of lead is... dangerous, on account of its tendency to re-crystallise, thereby rendering the transparent colours dull; the extreme case of its visible efflorescence can only occur when it is used in unnecessary abundance'*.[133] Earlier George Field had described a problem with sugar of lead in another application: '*The inexperienced ought here to be guarded also from the highly improper practice of some artists, who strew their pictures while wet with the acetate of lead, or use this substance otherwise in its crystalline or granular form, without grinding or solution, which, though it may promote present drying, will ultimately effloresce on the surface of the work, and throw off the colour in sandy spots*'.[134] Church also remarked on the phenomenon of efflorescence which he attributed to the use of lead acetate: '*I have seen one of the results of this commingling of sugar of lead with the medium or the paint in the production of an immense number of small spots in the picture, sometimes appearing through the surface-varnish in the form of a white efflorescence. This efflorescence consists at first of lead acetate in crystals, but these soon attract carbonic acid from the air and become lead carbonate, which, in its turn, is changed into lead sulphide by the action of sulphuretted hydrogen [hydrogen sulphide]. This tendency of*

[130] Kakoulli 1999: Sample 45

[131] *The Artist's Assistant: Oil Painting Instruction Manuals and Handbooks in Britain 1800-1900 With Reference to Selected Eighteenth-century Sources* Leslie Carlyle, Archetype Publications 2001 (pp. 42-46). Reproduced as **Appendix 22** of this report.

[132] *The Chemistry of Paints and Painting* Sir Arthur H Church, London 1915 (4th edition) (pp. 125-129)

[133] Materials for a History of Oil Painting Sir Charles Eastlake, London 1847 (Vol. 1, p. 350)

[134] *Chromatography: or, A Treatise on Colours and Pigments, and of their Powers in Painting* George Field, London 1835 (p. 56)

the lead compounds to yield brown or black lead sulphide is, indeed, the great drawback to any use of these substances as dryers'. Towards the end of the nineteenth century the general advice was to avoid sugar of lead altogether.

It may well be that the 'patchy white deposits' associated with the thick resinous 1830s black paint/coating (see Item 8.4.9.2) result from the use of some 14 lbs of sugar of lead by the 1830s restorers. Similarly the surface accretions known as 'brown/white spots' may be linked to the use of sugar of lead in the 1830s paint (see Item 8.4.9.4).

8.3.2.2 1830s lozenge border patterns – **Figure 17** is a reconstruction of the lozenge border decoration as painted in the 1830s and therefore as it appears now. Starting from the outside the 1830s decorative pattern sequence is as follows:

- On the base boards the 1740s brown/black paint was 'strengthened' but not entirely overpainted with a black pigment consisting of a mixture of lead white, barium white, ferric oxides and hydroxides and charcoal black[135]. Generally the 1830s restorers made an effort to retain or simulate the brown/black colour of the 1740s scheme on the base boards, grey chevron, stepped chevron and key pattern boards. The scroll design with trefoil ornament was overpainted in white lead. [136]

- The outer half of the grooved, coloured bands boards were entirely repainted in the 1830s; the inner half usually so, but there are many instances where the 1740s grey/brown wash appears not to have been overpainted. Two coloured bands, black (charcoal)[137] and red (red lead mixed with white lead)[138] over a lead white ground, occupy the outer half, a grey/brown thinly applied wash[139] - usually over a white lead ground but occasionally directly onto the wood support – covers the inner half of this board.

- Throughout the Ceiling the 1740s extended chevron pattern was entirely overpainted in the 1830s with a white lead ground and charcoal black with white lead and barium sulphate inclusions[140]. An additional feature to the decorative scheme, first identified during Phase 2, is that the centre of some trefoils are embellished by a raised dot.[141] The dots have a grainy texture and surface microflaking. They are prevalent on trefoils in *Panels 35-32 II and 29 II* and appear sporadically in *Rows I and III* across Bays 2 and 3; none were found in Bays 4, 5 and 6a. More were found in Bay 7[142] but, unlike those in Bays 2 and 3, the dots are on the 'stem' of the trefoil motifs rather than on the trefoils themselves. Although at first thought to be part of the original design, a sample from Bay 2 Phase 2 sample analysis indicated the embellishments are white lead paint with barium sulphate inclusions.[143] As the granular texture of these dots is so distinctive and unlike any other material added in the 1740s and 1830s interventions further samples were obtained and analysed in Phase 4.[144] Two of the samples have a single layer of lead white with a little calcium carbonate, over a thin carbon black layer, mixed with a thick translucent layer; the third sample has an additional lead white/calcium carbonate layer. Similar layers have been observed in samples from the trefoil design without the embellishment indicating the raised dots are simply impasto white lead paint probably applied by the 1830s restorers. However, this begs the question why would they go to the trouble of painting these precisely circular and precisely located white dots onto a white background and only in certain areas of the Ceiling?

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[135] Kakoulli 1999: Sample 17
[136] Davies 2000: Sample 20
[137] Kakoulli 1999: Sample 35
[138] Kakoulli 1999: Sample 36
[139] To date there has been no analysis of this paint. For inclusion in list of samples for Phase 5.
[140] Kakoulli 1999: Sample 10
[141] The Perry Lithgow Partnership and Hugh Harrison 2000: Plate 385
[142] The Perry Lithgow Partnership and Hugh Harrison 2001: Plates 555 & 556
[143] Kakoulli 1999: Sample 8
[144] Davies 2001: Sam,ples 12, 13 and 14

- The 1740s grey chevron pattern from *Rows 39-32* was untouched by the 1830s restoration except for some strengthening of the brown/black paint as happened with the base boards. From *Row 31* westwards the grey chevrons white edging and V shaped 'leaf' motif were entirely overpainted and replaced with a lighter grey (carbon black/lead white with some red, yellow and brown oxide particles)[145] chevron usually with white edging and a white motif of graduated brush strokes. A grey chevron board partially repainted but then overlooked by the 1830s restorers was notes in Phase 4.[146] The 1740s grey chevron decoration had been painted out with white paint and the black background with a brown/black. Also in Phase 4, three grey chevron boards were found with an additional paint layer forming another run of chevrons out of phase with the 1740s and 1830s decoration.[147] Even with the aid of x10 magnification it was difficult to be certain whether the additional layer was over or under the 1830s paint. There is no ready explanation for the extra paint on those boards but we suspected it must predate or is coeval with the 1830s decoration.

- The 1740s white ground on the stepped chevron pattern board was overpainted with white lead paint[148]: the white paint was carelessly applied and generally overlapped the brown/black stepped chevron pattern. The edges and where necessary other parts of the brown/black stepped chevron pattern were strengthened with a brownish matrix[149] of brown and yellow iron oxide particles combined with brilliant yellow and black[150]. On the 1830s softwood replacement boards the black chevron pattern (a brownish matrix of charcoal black, dispersed red ferric oxides, yellow ferric hydroxides, lead white and barium sulphate) covers a lead white ground.[151] In Bays 9 and 10 the border pattern on a number of stepped chevron boards, both original and softwood replacement, appears to have been set out in white chalk. The 1830s overpaint paint has flaked from the powdery chalk lines (see **Plates 372, 373**)

- It has proved particularly difficult to determine the sequence of interventions to the wave pattern boards and we now know this is because these boards were treated inconsistently by the 1830s restorers. In the eastern part of the Ceiling they did not entirely overpaint the 1740s black and white decoration. Prior to Phase 4 we had concluded that the matt black wave pattern paint (often associated with micro-flaking) was applied in the 1830s and that the wave pattern boards had not been repainted in the 1740s. In Bays 1-3 the black wave pattern consisted mainly of a single layer of seemingly 1830s matt black paint. Two samples were taken from the wave pattern decoration on original boards in Phase 2 (Bays 2 and 3). In one the 1830s black paint is directly on the wood,[152] in the other there is an intermediate white lead ground.[153] The latter sample was taken from reasonably near the edge of a black 'wave' so an overlap could account for the presence of white ground. However, a sample obtained from Bay 4 during the 1997 Emergency phase had 4 layers of paint: alternate white and black.[154] Both black layers appeared similar to other blacks associated with the 1830s intervention suggesting the board may have been decorated twice during that intervention. In retrospect it is almost certain the first white and black layers are 1740s. Two layers of black paint were identified on most of the wave pattern boards within Bays 4, 5 and 6a, but our observations from the scaffold indicated the thin matt black generally overlaid the obviously 1830s resinous black paint. We had difficulty understanding why the 1830s restorers would find it necessary to apply two coats of black paint and in the Phase 3 report admitted the possibility that our observations were misguided and that the wave pattern was indeed first overpainted in the 1740s. In Phase 4 (Bays 6b, 7 and 8) there was clear evidence that the wave pattern boards were indeed painted in both the 1740s and 1830s. A section of 1740s wave pattern was

[145] Howard 1997: Sample 28
[146] The Perry Lithgow Partnership and Hugh Harrison 2001: Plates 312-315 and 578
[147] The Perry Lithgow Partnership and Hugh Harrison 2001: Plates 579-583
[148] Kakoulli 1999: Sample31
[149] The Perry Lithgow Partnership and Hugh Harrison 2001: Plate 616
[150] Howard 1997: Sample 17. Kakoulli 1999: Sample 52 (from a 1740s softwood replacement board).
[151] Howard 1997: Sample 18. Kakoulli 1999: Sample 53
[152] Kakoulli 1999: Sample46
[153] Kakoulli 1999: Sample45
[154] Howard 1997: Sample 19

exposed from under temporarily removed 1830s Ceiling bolts and washers.[155] In Phase 5 a section of a 1740s scrolled end was similarly exposed (**Plate 369**). Interestingly, in Bay 10 there is evidence that on some boards the wave pattern design was first set out in white chalk onto the newly painted white background (**Plate 374**).

- The white background to the 1740s key pattern decoration was overpainted in the 1830s. The brown/black key pattern has for the most part been strengthened with a lustrous black layer with red and yellow inclusions.[156] In Phase 4 a small section of the 1740s paint layer was exposed from under a temporarily removed 1830s Ceiling bolt and washer.[157]

8.3.2.3 1830s central lozenge boards – In Bays 4, 5 and 6a there was much more flaking paint than in Bays 1, 2 and 3, particularly on the lozenge boards. Six samples were obtained from the central boards of the lozenges in Phase 3 to increase knowledge of the original scheme and later interventions and to identify changes in technique that may have occurred as the painters worked along the Ceiling. Analysis of paint samples taken from the lozenge boards in Phase 3 found no obvious variation in technique of either the 1740s or 1830s restorers to account for this.[158] In Phases 4 and 5 analysis of paint from central lozenge boards concentrated on paint under missing original nail heads so did not include 1830s paint.

The primary purpose of obtaining paint samples from the central lozenge boards in Phase 2 was to provide information on the low relief underpaint. The analysis has confirmed Howard's 1997 and 1998 findings with regard to the 1830s intervention on these boards but has made no significant discoveries.

Generally no preparatory ground was applied over the 1740s paint. 1830s paints identified on central lozenge boards within Bays 4, 5 and 6a include: a brownish matrix of charcoal black, dispersed red ferric oxides, yellow ferric hydroxides, lead white and barium sulphate;[159] a porous red paint consisting of red lead, ferric oxide, lead white and barium white;[160] the same red without barium white;[161] a pink paint of red ochre and lead white;[162] a blue/green paint of pure Prussian blue over a 1740s olive green;[163] and a matrix of Prussian blue, white lead and barium sulphate over a white lead layer.[164]

In our Phase 2 report we observed that the 1740s olive green backgrounds to figurative and foliate lozenges the east of *Row 34* were not overpainted in the 1830s. From *Row 34* westwards, within Bays 2 and 3, the olive green layer (a copper-bearing pigment mixed with yellow ferric oxide particles) has been overpainted with the blue/green paint (Prussian blue or a matrix of Prussian blue, white lead and barium sulphate over a white lead layer). In Bays 4-8 the 1740s olive green background has been overpainted in ca. 50% of the figurative and foliate lozenges; however, in Bays 9 and 10 all the green backgrounds were overpainted in the 1830s.

Inspection of 1740s paint exposed from under temporarily removed 1830s Ceiling bolts and washers suggest the 1830s restorers may have made significant changes to the 1740s scheme in two places. The 1740s red background paint to the Astronomy lozenge was changed to dark blue in the 1830s (see **Plate 367**). The 1740s scheme within the Eagle lozenge (*2/3/II/III*) may have been very different from the 1830s (**Plate 368**).

[155] The Perry Lithgow Partnership and Hugh Harrison 2001: Plate 589
[156] Howard 1997: Samples 13 and 25. Kakoulli 1999: Sample 13
[157] The Perry Lithgow Partnership and Hugh Harrison 2001: Plate 591
[158] Davies 2000: Samples 13-16 and 21
[159] Kakoulli 1999: Samples 34, 55
[160] Kakoulli 1999: Sample 22
[161] Kakoulli 1999: Sample 55
[162] Kakoulli 1999: Sample 44
[163] Kakoulli 1999: Sample 15
[164] Kakoulli 1999: Sample 41

8.3.2.4 1830s replacement Ceiling boards – The majority of softwood replacements appear to date from this intervention. There is some variation in the type of softwood as well as the size and manufacture of the boards making it difficult to determine the replacement date without reference to the painted decoration. Generally replacement boards that evidently have only one layer of painted decoration[165] and those with two thin layers[166] are considered to be 1830s. Softwood boards with relatively thick underpaint are thought to be from the 1740s[167]. Sample analysis has confirmed these observations. However, it is not always possible to distinguish between the different interventions through observation from the scaffold alone.

The paint on some obviously 1830s softwood boards, including the West End vertical boards (**Plates 370 and 380**), has a characteristic milky or silvery surface sheen which does not respond to surface cleaning with Wishab sponges.[168] Analysis indicates there is a thin pale coating but it remains unidentified[169]. The recent discovery that sugar of lead (lead acetate) was used extensively by the 1830s restorers suggests that material may be a factor responsible for this slightly opaque veil.

As discussed in Item 8.3.1.3/4 of this report the softwood Ceiling boards with frieze decoration as underpaint are thought to have been salvaged from the frieze, and re-used on the Ceiling, when the Ashlar boards were replaced in the 1830s. This would seem the logical interpretation of evidence to date. The underpaint is unlikely to be 1830s because the 1830s frieze decoration was painted *in situ* so there would be no surplus for use elsewhere. Furthermore, the 1830s Ashlar boards are of tongue and groove design and the Ceiling replacement boards with frieze decoration underpaint are not.

In Phase 4 we were able to establish that at least some of the oak replacement boards – re-used original Ceiling boards – were inserted during 1740s (see Item 8.3.1.3). However it is likely that the policy of salvaging for re-use stable sections of deteriorated boards was adopted for both interventions.

8.3.2.4 1830s frieze decoration on the Ashlar boards – All the Ashlar boards on the north and south side of the Nave Ceiling and the painted frieze decoration date from the 1830s decoration. In Bays 4-10 there is no evidence of the complex scrollwork decoration underpaint present on the Ashlar boards within *Rows 39 to 34*).

Investigation of the painted decoration on the Ashlar boards in Bay 1 was limited by budgetary constraints. The more complex scrollwork decoration underlying the visible frieze decoration was recorded by Donald Mackreth, the cathedral archaeologist, and reproduced in our Phase 1 report[170] but only one paint sample was analysed[171]. Within Bay 1 an overpainted name and date - W. Stallard 1838(*6?*) [172] - is visible through the covering white ground of the later scheme and the names of I Shaw and C Neal, appear on the upper layer. Despite this evidence and other recorded anomalies the underpaint (and therefore the boards) was thought to date from the 1740s intervention. This interpretation has proved false. The south side ashlar board decoration in Bay 9 is inscribed with the name and date R Layton 1835 (**Plate 377**). The names R Layton and W. Stallard both appear in painted inscriptions on the ceiling boards (see Item 8.4.6).

Analysis of a paint sample obtained from the north side Ashlar boards of Bay 2 identified barium sulphate as a component of the underpaint: a pink matrix of red, white lead and barium sulphate over two layers of white lead ground[173]. Barium sulphate was not identified in the 3 samples with

[165] Kakoulli 1999: Samples 49, 53
[166] Kakoulli 1999: Samples 10, 45, 50, 51, 52
[167] Kakoulli 1999: Sample 52
[168] The Perry Lithgow Partnership and Hugh Harrison 2000: Plates 526-528
[169] Howard 1997: Sample 18
[170] The Perry Lithgow Partnership and Hugh Harrison, January – June 1998, Vol. I: Fig. 7 (p. 48).
[171] Howard 1998: Sample 10
[172] The Perry Lithgow Partnership and Hugh Harrison 1998, Vol. II: Plate 306.
[173] Kakoulli 1999: Sample 42

underpaint obtained from the south Ashlar boards. Notwithstanding, enough evidence has been accumulated about the softwood Ashlar boards and their construction to date them with certainty to the 1830s intervention. In addition, all paint layers in the 8 samples obtained from the Ashlar boards in Previous phases are consistent with the materials and technique of the 1830s intervention to the Ceiling[174].

8.3.2.5 West End vertical boards - In Phase 5 the west end vertical boards became accessible (**Plates 352-359**). These tongue and groove softwood boards and the heraldic paint scheme date from the 1830s intervention. As the technique, materials and paint style appeared identical to those used by the 1830s restorers on the Ceiling and ashlar boards no samples were obtained for analysis. The only variation being the use of gold to decorate the shield of arms and gold is mentioned in the 1835 materials receipt (see Item 8.3.2.1). Within an area of background paint on board is an indistinct white painted inscription "…*Cobley Painter 1835*" within a small foliate cartouche, also painted in white (**Plate 380**). The name Cobley appears in two other painted inscriptions on the Ceiling: on an East End infill board (*40 I c*); and with the date 1834 on open book held by archbishop (2) (*19 II/III*). A centrally placed door in the West End vertical boards allowed limited access to the vertical boards and *Panel 0 III*. Hence there are a number of pencilled inscriptions with a post-1830s date. The location and text of all graffiti and painted inscriptions found on the ceiling are listed in Item 8.4.6.

8.3.3 1880s rebuilding of the tower wall

Having had the opportunity to revisit the east end of the Ceiling during the Restoration of Fire Damage Phase in 2002 we now have a better (but still not complete) understanding of the 1880s intervention. It appears that all the east end infill panels, and possibly the two east sections of the ashlar boards, were removed and re-fixed in the course of the tower reconstruction. *Panel 40 IV* is composed entirely of 1880s boards, while in *Panels40 I/II/III* only the narrow boards abutting the tower wall are 1880s and therefore have 1880s paint; although the other infill boards were not all re-fixed in their previous location repainting of those boards was kept to a minimum.

In Bay 2 there was evidence to suggest that the nave was screened off during the rebuilding of the tower. A band of thick dirt across the Ceiling boards in *Row 32* coincided with vertical strips of masking tape adhered to the north and south Ashlar boards.[175] Three examples of graffiti written in pencil were found in *Row 33*, immediately to the east of the masked off area. One example is dated - *Wm George Higgs January 16 1883*. Similar pencilled graffiti was discovered on the Ceiling boards in Bay 1, including one dated 1885. No graffiti was found to the west of the dirt band on the Ceiling boards; although on the Ashlar boards in Bays 1 to 6a, there are a number of examples dated 1890. This graffiti on the Ashlar boards records that limewash was scraped from the nave walls during 1890. As no 1890s graffiti exists above the frieze it is likely that the workers did not have access to the Ceiling boards at that time.

8.3.4 1920s intervention to the structure

In the 1920s a great deal of work was carried out to the Ceiling structure from above (within the roofspace) but there was no access to the Ceiling from below and therefore no alterations to the painted decoration. Nevertheless, the 1920s intervention has had a limited impact on the paint scheme in addition to the unsightly patch repair within the Anthropophagus lozenge (Bay 2).[176] When some of the original joists were replaced a number of central lozenge boards lost all their original fixings. In what must have been a very complicated operation these boards were repositioned and re-attached with screws inserted from above (Item 3.3.5). Not surprisingly, some are no longer perfect alignment.

[174] Howard 1998: Sample 10. Kakoulli 1999: Samples 3-7, 42, 43.
[175] The Perry Lithgow Partnership and Hugh Harrison 1999, Vol. II: Plates 439-445
[176] The Perry Lithgow Partnership and Hugh Harrison 1999, Vol. II: Plate 352.

8.3.5 Discovery of Paint on Joist 1 in the Roofspace

While carrying out additional investigations of the Ceiling structure upper side during the Restoration f Fire Damage works in 2002, Hugh Harrison's team discovered an area of decorative paint surviving on the west side of the easternmost joist of Bay 1 (*Joist No. 1*). The decoration takes the form of red and black circles, triangles and lines on an off-white background.[177] It exists only on the central section of the east facing vertical side of the joist *(c*2 meters in length). It cannot be a coincidence that this paint covers the only part of the joist that - in the absence of the east end infill panels - would be visible from floor level following the remodelling of the crossing arch in the fourteenth century.

What with the east end infill boards sloping upwards away from this joist and it being so close to the east wall it is very difficult to inspect and photograph this area of painted decoration from the roofspace. Nevertheless it does not appear to be simply a continuation of the scheme on the ceiling boards below. The red and black colours and the white background are similar but there is nothing resembling the circles and triangles in the main ceiling scheme or on the ashlar boards.

Samples of the red, black and off-white paint were obtained from the joist and sent to Jane Davies for analysis.[178] The results suggest:

- The off-white background is a single layer directly over the timber support. It is composed largely of lead white, with a few iron oxide particles and some carbon black as well as a few transparent white calcium containing particles.
- The red paint is iron oxide red pigment together with some calcium-based transparent particles, also calcium based.
- The black paint contains a carbon black pigment together with some iron oxide. Calcium is also present.

The red and black designs do not appear to be from the thirteenth century; however, from the analysis results it is not possible to determine at what point after that the east face of Joist 1 was painted. The off-white background paint on the joist has iron oxide and black inclusions, whereas on the ceiling boards the white lead background in every instance is either pure white lead or white lead with barium sulphate inclusions. Neither is the presence of calcium containing particles in each sample a clue. Calcium carbonate and calcium sulphate have been identified in paint on the ceiling boards from each intervention.

Noggins supporting the east end infill panels date from when the tower was rebuilt in the 1880s. The present infill panels include boards from the 1740s, 1830s and 1880s. Empty birds beak joints on the east side of Joist 1 indicate there may have been additional noggins in this area and perhaps a different arrangement of boarding at the east end before the tower was rebuilt in the fourteenth century. All these factors would suggest that if the east side of Joist 1 were ever visible from floor level it would have been after the fourteenth century tower rebuild and before the 1740s intervention.

8.4 CONDITION SURVEY

A detailed board by board condition survey of the painted decoration within Bays 1 to 10 has been recorded on tabulated sheets (see example in **Appendix 7**) and is presented in graphic form in Part 13 of this report. This section defines the categories of damage, surface accretions and other phenomena; most of which are plotted on the graphics.

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[177] The Perry Lithgow Partnership and Hugh Harrison 2002, Plates 9-11

[178] *Peterborough Cathedral Nave Ceiling Roofspace: Investigation of Painting Materials and Techniques* Jane Davies, May 2003

8.4.1 Flaking Paint (Graphics 10A/B & 15)

The primary cause of flaking paint on the Nave Ceiling was long term water infiltration leading to deterioration of the wood support and subsequent loss of adhesion. We now have a graphic record of all flaking paint within Bays 1 to 10. Paint sample analysis has corroborated some of our observations from the scaffold regarding materials, technique and the extent of each intervention. Not surprisingly, these factors have had a direct bearing on the pattern of flaking paint across the Ceiling. A study of the graphic record reveals that the lead white background to the lozenge border patterns is generally stable: as are the paints which overly this layer. The paints susceptible to flaking are:

- The characteristic thick brown/black 1740s paint– a composite of large charcoal black particles, ferric hydroxide and lead white.[179] This paint has flaked only where it does not overly a white lead ground: i.e. the base, grey chevron and stepped chevron boards. The black/brown paint has tended to delaminate and lift where the wood support has a slightly spongy surface. Where the underlying board has been affected by wet rot the paint surface looks like alligator skin with cracks through the paint layer and associated lifting following the decayed checkerboard structure of the affected wood. In Phase 3 we observed for the first time that all nail heads and Ceiling bolts covered by this paint without an intervening white lead ground have corroded to the extent that little or none or the covering paint survives. Whereas many of the nail heads with the 1740s red and green paints are similarly corroded, with the 1740s brown/black paint it occurs in almost every case. [180]

- In Bays 1, 2 and 3 where the thin 1740s velvety black paint of the wave pattern decoration is directly on the wood support without an intervening white lead ground it was susceptible to micro-flaking and loss[181]. Similar microflaking occurs on some outline drawing of the figurative and foliate lozenges where the same paint, apparently without an intervening white lead ground, has been used.[182] It was clear that any moisture in the boards resulting from water infiltration was unable to escape through the resistant white lead paint but was able to do so by disrupting this thin black paint layer. This observation is corroborated by the very characteristic efflorescence like a drawn chalk line only found on boards decorated with the wave border pattern.[183] In Bays 4-10 there were very few instances of micro-flaking of the black wave pattern since there are generally two layers of black paint on the those boards.

- Within the figurative lozenges the 1740s granular, olive green background paint and the black line drawing are particularly prone to flaking; and the red less so - the detached green paint does not tend to lift and curl as much as the red or black. The extent of paint flaking in Bays 6b, 7 and 8 was similar to that found in Phase 3; that is, considerably more than in Phases 1 and 2, particularly on the lozenge boards. Results of Phase 3 paint sample analysis showed no obvious variation in technique to account for this.. This paint damage was generally in the form of large flakes that had lifted rather than the micro-flaking found in Phases 1 and 2 and the scrolling or cupping flakes treated in the Emergency phase. One could speculate that environmental factors in the past, such as the position of heating boilers, may have contributed. During the Emergency Phase of works in 1997 we observed that severe flaking had occurred on the flesh tones of St Peter's face, hands and feet and treatment was concentrated in these areas.[184] We did not find a specific reason why the flesh tones on this figure were so affected beyond the possibility that restorers applied thicker paint to these features and that the thickened paint had contracted and lifted away from the support. However, from the information gathered during the Phase 2 condition survey it was apparent that the painted decoration on *Panels 30 II & II, 31 II & III* had been particularly badly affected presumably as a result of water infiltration. The St. Peter lozenge lies at the junction of these four panels.

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[179] The Perry Lithgow Partnership and Hugh Harrison 2001, Vol. II: Plates 174 and 616
[180] The Perry Lithgow Partnership and Hugh Harrison 2001, Vol. II: Plates 622 and 623
[181] The Perry Lithgow Partnership and Hugh Harrison 1999, Vol. II: Plate 424.
[182] The Perry Lithgow Partnership and Hugh Harrison 2000, Vol. II: Plate 505.
[183] Howard 1998: Sample 9. Kakoulli 1999: Sample 21
[184] The Perry Lithgow Partnership 1997, Plates 13-37

- Nail heads. Many of the metal fixings visible on the underside of the Ceiling have corroded to some degree and caused the overlying paint to flake. The percentage of paint remaining on each nail head was recorded graphically. As mentioned earlier in this item, all nail heads and Ceiling bolts covered by the 1740s brown/black paint without an intervening white lead ground have corroded to the extent that little or none or the covering paint survives. Whereas many of the nail heads with the 1740s red and green paints are similarly corroded, with the 1740s brown/black paint it occurs in almost every case.

- Flaking paint caused by the contraction of overlying glue deposits is described in Item 8.4.7.

1740s and 1830s paint on softwood replacement boards throughout the ceiling was generally stable. The significantly larger proportion of softwood replacement boards within Bays 9 and 10 meant there were less incidences of paint flaking generally.

8.4.2 Powdering Paint (not shown on graphics)

To date on the Nave Ceiling powdering paint has been found on only one panel of the east end infill boards. Generally the 1740s and 1830s oil-based paints are adequately bound.

8.4.3 Paint loss (not shown on graphics)

Except where the painted decoration is missing due to wood loss (in which case it is recorded under the wood loss category) recording the loss graphically would be difficult and the results inaccurate unless marked on extremely large scale graphics. All significant instances of paint loss since the 1830s repaint are recorded in the tabulated board by board paint survey. Small losses have occurred as a result of flaking paint, impact damage and the insertion of nails and screws during previous interventions.

8.4.4 Pigment/paint alteration (not shown on graphics)

Paint sample analysis by Howard in 1997 identified some evidence of pigment alterations in both the original and later phases of painting. This includes the transformation of natural azurite to copper oxalate[185], 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. Similarly, the alteration of verdigris to form copper chloride[186]. It seem likely that Silvertown treatment, applied in 1926 as an insecticide, may also be implicated in this alteration, since it would have provided a ready source of chlorides. There is no evidence of paint alteration within the visible 1740s scheme. As discussed in Item 8.3.2.1, the unidentified patchy white surface accretions associated with the thick resinous 1830s black paint coating may be associated with the use of sugar of lead (lead acetate). Early in the project the deposits were considered to be some form of microbiological growth (MBG) but analysis by Ridout[187] indicates they are accumulations of irregularly shaped, translucent, plate-like crystals.

8.4.5 Surface discoloration (not shown on graphics)

The extent of surface discoloration since the 1830s restoration was indicated by the condition of paint exposed from under temporarily removed 1830s Ceiling bolts and washers (**Plates 366-369**). The 1740s paint has been protected from subsequent overpaint and surface accretions. These examples indicate the condition of the paint surface immediately prior to the 1830s intervention and provide visible confirmation of the analysis findings and our interpretation of the conservation history. The yellowed surface discoloration overall the Ceiling is likely to have resulted from

[185] Howard 1997: Sample 23
[186] Howard 1997: Samples 3, 4, 8
[187] Dr B Ridout. Unpublished letter to J Limentani, 16 June 1999.

products of combustion emanating from coke fired boilers. These deposits were not entirely removed by surface cleaning with Wishab sponges.

8.4.6 Graffiti (Graphics 9A/B & 15)

8.4.6.1 Pencilled graffiti - In Bays 1 and 2, where the Ceiling boards were accessible during the rebuilding of the tower wall in the 1880s, there are examples of graffiti written in pencil dated between 1883-1885. Along the Ashlar boards of Bays 1-6a there are a number of pencilled inscriptions dated 1890. This graffiti records that limewash was scraped from the nave walls during 1890: for instance '*H. Butler age 18 years 1890. Worked at this Cathedral scraping the whitewash off the walls'*. . Several names appear more than once. There is also a cartoon/portrait? of a bearded man with glasses.[188] Mackreth suggested that the gentlemanly air of the figure may indicate a portrait of either the architect or some other 'important' figure, rather than a self-portrait of one of the labourers.

The only example of pencilled graffiti on the Ceiling boards within Bays 6b, 7 and 8 (*board 17 II s*) is a small naive sketch of an animal, possibly a sheep or a dog,[189] There is nothing to indicate when this was drawn although it is likely to have been in 1890. However, as no other 1890s graffiti exists above the frieze, it is unlikely the workers had general access to the Ceiling boards at that time.

There is a considerable amount of pencilled graffiti at the west end of the Ceiling. Some are simply random lines but others give the names of carpenters and painters working on the ceiling in the 1834/5: for instance "*W. Gamlyn 1835*" and "*J. Duddington Carpenter at this roof 1834*". In addition, the centrally placed door in the West End vertical boards allowed limited access to the vertical boards and *Panel 0 III*; hence there are a number of pencilled inscriptions with a post-1830s date. All these are listed in the table below.

8.4.6.2 Painted inscriptions – These record the names of at least some of the painters involved in the 1834/5 intervention. Some inscriptions are integrated into the decoration: such as within the archbishop (2) lozenge where '*COBLEY 1834'* is painted on the pages of an open book, and '*R.D. LAYTON 1834 SEXTON*' is on the lower border of the archbishop's robe.[190] Other are painted in simple lettering on the plain background. The names W Stallard, R Layton, W Gamlyn and Cobley occur two or three times across the ceiling (**Plates 377, 378, 380**); the names I Shaw C Neal appear once only on an Ashlar board at towards the east end of the Ceiling;[191] similarly, the monogramme "I CO" (Cobley?) which is at the west end (see **Plate 399**).

Pencilled Graffiti and Painted Inscriptions on the Nave Ceiling

Panel #	Ref. # on Graphics	Graffiti Text
40-36/I	40 I c	BLEY (in black paint)
40-36/I	Ash 36 I 13	STALLARD (in abraded in red paint, abraded)
40-36/I		Various vertical and horizontal pencil lines and a 3¼" figure
40-36/IV	Ash 39 IV 3	W STALLARD 1836(?) (painted inscription beneath the off-white overpaint)
40-36/IV		Pencil graffiti Illegible signature
40-36/IV		I SHAW C NEAL painted inscription in black
37iv e		Pencil graffiti J BULLOCK, JULY 28TH 1885
38iv		Pencil graffiti ? HALES, JULY 27TH 1885
33ii	t/1	Pencil graffiti GILBERT
33ii	u/2	Pencil graffiti WM GEORGE HIGGS

[188] The Perry Lithgow Partnership and Hugh Harrison 2000, Vol. II: Plate 471.
[189] The Perry Lithgow Partnership and Hugh Harrison 2001, Vol. II: Plate 589
[190] The Perry Lithgow Partnership and Hugh Harrison 2000, Vol. II: Plate 414
[191] The Perry Lithgow Partnership and Hugh Harrison 1998, Vol. II: Plate 305

Panel #	Ref. # on Graphics	Graffiti Text
		January 16 1883
33iv	d	Pencil graffiti G LIVER (?) G DIVER (?)
Ash 28 -31/l	1	Pencil graffiti GEORGE BARBER
Ash 28-31/l	2	Pencil graffiti BARBER
Ash 28-31/l	3	Pencil graffiti JAPHERTH ABBOTT AGE 40 1890 HELPED TO SCRAPE THIS CATHEDRAL 1890
Ash 28-31/l	4	Pencil graffiti GEORGE STAPLETON HELPED TO SCRAPE THIS CATHEDRAL IN 1890
Ash 28-31/l	5	Pencil graffiti G G
Ash 28-31/l	6	Pencil graffiti GEORGE STAPLETON
Ash 28-31/l	7	Pencil graffiti **"**G.W.BLOODWORTH HELPED TO SCRAPE THIS CATHEDRAL IN 1890 AGE 19"
Ash 31-28IV	1	Pencil graffiti BARBER GEORGE
Ash 31-28IV	2	Pencil graffiti A. WENLOCK WORKED AT THIS CATHEDRAL SCRAPING THE STONEWORK MARCH 1890 AGE 24 YEARS
18 II/III		Painted on open book held by archbishop (2) 'COBLEY 1834'
18/19 II/III		Painted on border of archbishop (2)'s robe 'R$^{D.}$ LAYTON 1834 SEXTON'
Ash 19 I	9	Pencil graffiti JACOB MUNTON AGED 18 YEARS 1890
Ash 20 I	10	Pencil graffiti G.W.BLOODWORTH AGE 18 YEARS 1890
Ash 21 I	11	Pencil graffiti J MUNTON 1890 AGED 18 YEARS
Ash 23 I	12	Brown crayon line
Ash 26 I	13	Pencil graffiti JACOB MUNTON SENIOR 1890 AGED 41 YEARS
Ash 26 I	14	Pencil drawing – head and shoulders of a bearded man.
Ash 27 I	15	Pencil graffiti GEORGE STAPLETON SCRAPING AT THE CATHEDRAL MARCH 20TH 1890 AGED 40 YEARS
Ash 27 I	16	Pencil graffiti JACOB MUNTON JUNIOR WORKED AT THIS CATHEDRAL 1890 AGED 18 YEARS
Ash 27 IV	4	Pencil graffiti JOSEPH HALL (?) AGE 20 1890
Ash 27/26 IV	5	Random pencil lines and incision lines, foliate in form
Ash 26 IV	6	Pencil graffiti J. HARBOUR AGE 50 YEARS 1890
Ash 25 IV	7	Pencil graffiti H. BUTLER AGE 18 YEARS 1890. WORKED AT THIS CATHEDRAL SCRAPING THE WHITEWASH OFF THE WALLS.
Ash 24 IV	8	Pencil graffiti JACOB MUNTON AGED 18 YEARS 1890
Ash 23 IV	1	Pencil graffiti G.W.BLOODWORTH AGED 18 YEARS 1890
Ash 23 IV	2	Pencil graffiti CHARLES MILLS SEXTON EYE GREEN (?) AGE 46 1890
Ash 23 IV	3	Pencil graffiti JACOB MUNTON AGED 40 YEARS 1890
17ii	17 II s	Pencil drawing of a sheep(?)/dog(?)
13i	13 I l	W STALLARD 1835 (painted in off-white paint on a base board)

Panel #	Ref. # on Graphics	Graffiti Text
Ash 0 IV	board 45	Pencil graffiti "R.D. 1890"
Ash 1 IV	board 42	"I CO" painted inscription in red and black
Ash 5 IV	boards 41/41	Paint in black on foliate tendril 'R. LAYTON 1835'
7 II	m	Painted graffiti name wearer south end west side 'W.GAMLYN'.
0 II	l	Graffiti on face of board. Two dates 1834 & 1835.
7 I	f	Graffiti in pencil 29 5½
7 II	m	Painted in white paint "W Gamlyn"
7 III	o	Faint painted inscription- " W.GAMLYN 1834 " partly picked out in white patch MBG.
7 IV	b	Crude pencil lines for design setting out & graffiti head of a dog.
2 II	x	Inscription "T K" in black paint beneath the off-white overpaint. Possibly 1740s?
1 III	j	Pencil graffiti, random patterns
0 II	l	Pencil graffiti "W. Gamlyn 1835" and "J. Duddington Carpenter at this roof 1834".
0 II	r	Pencil graffiti - " J. Duddington 1835", "J. Duds", "J. Duddington Carpenter 1835".
0 III	d	Pencil setting-out lines. Graffiti "J. Garwood Bourne* at Peterboro (sic) Lincolnshire February 1827" * possibly word Born - misspellt.
0 III	i	Pencil graffiti several names - "James Garwood 1870 and 1879", "Y. Spachey (?)1854", "W.Burton" also "G---" - difficult to read.
0 III	l	Pencil graffiti - "William Dixey" "G.Baren" "James ? (unsure of surname).
0 III	p	Pencil graffiti - "W.Gamlyn 1835".
0 III	r	Pencil graffiti - "W. Gamlyn 1835 Peterboro Carpenter".
West end	board 36	"W. Gamlyn 1835".
West end	board 18	Indistinct white painted inscription "…Cobley Painter 1835" within a small foliate cartouche, also painted in white

By intention the examples of pencilled graffiti were not removed during surface cleaning.

8.4.7 Glue (Graphics 10A/B, 15)

Liquid glue used in the 1920s as an adhesive for the hessian backing material has in places penetrated between the boards, dried on the painted surface and caused the paint to flake. Ultra-violet light was particularly helpful when checking for glue residue. On the horizontal central panels the glue tended to travel vertically down the edge of a board and drip onto the floor below; often leaving thick, raised droplets over the paint on the edge of a board. Many of these thick droplets have contracted in the dry environment and detached from the surface pulling away the underlying paint (see **Plates 386, 387**). On the canted side panels and ashlar boards the glue residue was more extensive. On penetrating the boards the glue travelled in rivulets across the canted surface before drying (see **Plate 396**). In general, the glue has caused paint flaking only where it has collected in thick droplets or runs. The white background paint was less liable to flake as a result of surface glue deposits. In Bays 9 and 10 there was noticeably less glue on the paint surface than on the remainder of the Ceiling, Ashlar boards excepted (see **Plate 396**). It may be that the greater proportion of softwood replacement boards in these Bays is a reason for this: perhaps the gaps between the softwood boards are generally smaller. Another explanation would be that the glue was marginally less dilute when applied in this area.

Some glue drips have a sugary/crusty texture, possibly resulting from the glue having been altered by the action of another chemical. In Phase 2 a sample of this 'adulterated' or crystalline glue drip was obtained and subjected to FTIR analysis[192]. This confirmed the presence of animal glue, although a specific type was not identified. FTIR analysis of a sample of hessian and glue considered to date from the 1920s intervention and another of hessian and glue from an earlier intervention produced similar results.[193] A piece of glue impregnated hessian adhered to the reverse of the Ceiling boards in 1926 and some drips of glue that had run through the gaps in the boards onto the paint surface were sent to Dr Brian Singer of the University of Northumbria, Department of Chemical Life Sciences for Protein Analysis. The results from all three samples confirmed the presence of animal glue.[194]

8.4.8 Surface Staining (Graphics 10A/B, 15)

All stains on the painted decoration resulted from liquid material penetrating down between the boards or through cracks in deteriorated boards. Stains found on the paint surface across the Ceiling fell into three categories:

- Water stains - Where water has run across the paint surface leaving distinctive trails of blanched paint and brown surface deposits. These occured more on the Ashlar boards than on the Ceiling panels (see extensive examples in **Plates 399-401**). They are not particularly visible under UV illumination.

- Chemical stains – These have resulted from treatment to the Ceiling structure above.[195] For the most part they were dark brown in colour: FTIR analysis of a sample obtained from Bay 1 indicated the presence of shellac.[196] There are also a small number of 'clear' stains which saturate the paint surface without causing undue discoloration. This type of stain has not been analysed. A sample obtained during the Emergency Phase from unstained grey paint on a grey chevron board also indicated the presence of shellac in the upper portion of the paint layer[197]. It is not clear whether the shellac, in that instance, is from an applied coating or an accidental accretion. The other characteristic staining prevalent across the ceiling are light brown drips frequently found on the edge of Ceiling boards or around holes and splits in the boards.[198] A sample of this material was analysed in Phase 2. Results were inconclusive beyond indicating the substance is organic.

- Resin – These occur around knots in the softwood replacement boards where resin that has exuded through the paint layer from a knot.[199]

- Bat excreta – On the north side Ashlar boards at the junction of Rows 19-20 we found staining and surface accretions consistent with bat urine and degraded faeces.[200]

8.4.9 Surface Accretions

8.4.9.1 Efflorescence (**Graphics 10A/B & 15**) - In Bays 1, 2 and 3 most efflorescence took the form of a white chalk line. This was only found on boards decorated with the wave border pattern. The chalk line follows the shape of the decoration and occurs on the white lead background paint; although, it was always associated with microflaking of adjacent, deep velvety black, wave pattern paint. XRD analysis of a sample obtained from Bay 1 provided a clear and strong pattern for

[192] Kakoulli 1999: Sample 9
[193] Kakoulli 1999: Samples 24, 25
[194] *Investigation of Adhesive Samples for The Perry Lithgow Partnership* Dr Brian W Singer, April 2001
[195] The Perry Lithgow Partnership and Hugh Harrison 1998, Plates 345 and 346; PLP & HH 2001, Plate 640
[196] Howard 1998: Sample 11
[197] Howard 1997: Sample 28
[198] The Perry Lithgow Partnership and Hugh Harrison 2001, Vol. II: Plate 639
[199] The Perry Lithgow Partnership and Hugh Harrison 2000, Vol. II: Plate 497
[200] The Perry Lithgow Partnership and Hugh Harrison 2000, Vol. II: Plates 498 and 499

ammonium lead sulphate and a little sodium sulphate[201]; a further sample taken from Bay 2 was inconclusive[202].

In Bays 4-10 there were very few instances of micro-flaking of the black wave pattern since there are generally two layers of black paint on the those boards. As a result we found no examples of chalkline efflorescence associated with the wave pattern. Instead we found an efflorescence very similar in appearance to 'chalkline', but occurring on other boards particularly around the edges of splits. All instances of efflorescence are recorded in the tabulated board by board survey of the paint.

Prior to surface cleaning the paint surface on the west end vertical boards was partially obscured by a white efflorescence **(Plate 384**). This was largely removed during the cleaning process.

NB In the Phase 1 condition survey instances of what we now refer to as 'patchy white deposits' were included in the efflorescence category.

8.4.9.2 Patchy white deposits (**Graphic 12)** - Associated with the thick resinous 1830s black paint/coating remain unidentified (**Plates 372, 383**) Initially they were considered to be some form of microbiological growth (MBG) but analysis by Ridout indicates they are accumulations of irregularly shaped, translucent, plate-like crystals. [203] The recent discovery of a list of materials used the 1830s restorers would suggest that the inclusion of sugar of lead (lead acetate) in the paint may be a factor. As discussed in Item 8.4.4 - and more fully in **Appendix 22** - sugar of lead was widely used as an ingredient in drying oil preparations from the mid-eighteenth century to the mid-nineteenth century. However, by the time of its use on the Nave Ceiling reservations were expressed that its use could cause certain colours to become dull; also that it could result in '*an immense number of small spots in the paint, sometimes appearing through the surface-varnish in the form of a white efflorescence*.' Towards the end of the nineteenth century the general advice was to avoid sugar of lead altogether. As it is, we remain uncertain whether these patchy white deposits are the result of seepage from the paint layer or a reaction caused by adverse environmental conditions.

NB In the Phase 1 condition survey this deposit/surface accretion was generally classified as a surface bloom and in some instances as efflorescence.

8.4.9.3 Tendril deposits (**Graphic 12)** - These resemble miniature spider web, joining larger elements together.[204] These deposits were relatively rare across the ceiling. Ridout suggests they have originated through microbiological action as some collapsed strand material was found in samples analysed.

NB Throughout the Phase 1 condition survey this deposit/surface accretion was classified as a MBG.

8.4.9.4 Brown/white spots and blotches (**Graphic 12)** - These accretions were widespread across the Ceiling.[205] Ridout describes them as irregularly shaped, translucent granules. Observations from the scaffold suggest the blotches have a fuzzy edge: under x15 magnification the paint surface does not appear disrupted, but a fine white dust was noticeable within the paint texture. The spots were generally brown and at the centre there appears to be a dark brown particle, like a grain of sand, around it was a lighter brown or off-white halo with a fuzzy edge. As with the patchy white deposits, it may be the inclusion of sugar of lead in the 1830s paint was responsible. In 1835 George Field described a problem with sugar of lead as follows: '*The inexperienced ought here to be guarded also from the highly improper practice of some artists, who strew their pictures while wet with the acetate of lead, or use this substance otherwise in its crystalline or granular form,*

[201] Howard 1998: Sample 9
[202] Kakoulli 1999: Sample 21
[203] Dr B Ridout. Unpublished letter to J Limentani, 16 June 1999.
[204] The Perry Lithgow Partnership and Hugh Harrison 1998, Plates 337; PLP & HH 2001, Plate 602
[205] The Perry Lithgow Partnership and Hugh Harrison 1998, Plates 334, 335; PLP & HH 2001, Plate 601

without grinding or solution, which, though it may promote present drying, will ultimately effloresce on the surface of the work, and throw off the colour in sandy spots'.[206]

NB Throughout the Phase 1 condition survey this deposit/surface accretion was classified as a MBG.

8.4.9.5 Purple grains – This suspected MBG residue found in Bay 1[207] was not present in Bays 2 to 10.

8.4.9.6 Surface dirt - There was a layer of surface dirt overall the painted decoration. Interestingly the layer was conspicuously thicker and more discoloured within the western Bays of the ceiling: possibly due to their proximity to the west doors which act as the main entrance to the building. In addition, within the western half of the Ceiling it was noticeable that less surface dirt had accumulated where the Ceiling boards are backed by structural elements. As a result before surface cleaning it was just possible to discern the position of some Ceiling joists from below.[208] This preferential accumulation of dirt was particularly noticeable on the North and South Transept Ceilings prior to the recent surface cleaning as a consequence of the November 2001 fire damage. Bays 9 and 10 were the only bays not treated prior to the 2001 fire in the building. Consequently, within the Phase 5 area, the soot was mingled with and largely indistinguishable from the surface dirt layer.

8.4.9.7 Surface Bloom (**Graphic 12**) - The paint on some obviously 1830s softwood boards has a characteristic milky or silvery surface sheen.[209] Analysis indicates this is a thin pale coating as yet unidentified[210]. It does not respond to surface cleaning with Wishab sponges. In previous phases this was recorded as surface bloom but in Phases 3 -5 it has been recorded only in the tabulated board by board survey of the paint.

The only surface bloom recorded on the Phase 3 graphics was that occurring on the repainted backgrounds of central lozenge boards, where the 1830's red and blue has been laid over the olive green or red of the 1740's.[211] It was patchy, white and matt in appearance could be reduced with a Wishab.

NB Where similar looking patchy, white deposits occur on what appears to be a glossy coating it has been categorised as 'patchy white deposits' (see above).

PART 9: TREATMENT TESTS: THE PAINTED DECORATION

9.1. PREVIOUS TREATMENT TESTING

Hirst Conservation conducted extensive cleaning trials using solvent solutions: these tests are documented in Hirst Conservation's 1995 report[212].

As part of the Emergency Conservation Treatment Phase in 1997 the Perry Lithgow Partnership carried out an extensive series of tests to determine appropriate techniques, materials and methods of application for the re-attachment of flaking paint, the removal of glue film and surface cleaning. Our report of October 1997 includes detailed records of these trials.

[206] *Chromatography: or, A Treatise on Colours and Pigments, and of their Powers in Painting* George Field, London 1835 (p. 56)
[207] The Perry Lithgow Partnership and Hugh Harrison 1998, Vol. II: Plate 336
[208] The Perry Lithgow Partnership and Hugh Harrison 2000, Vol. II: Plates 473 and 474
[209] The Perry Lithgow Partnership and Hugh Harrison 2000, Vol. II: Plates 526-528
[210] Howard 1997: Sample 18. For inclusion in list of samples for Phase 5.
[211] The Perry Lithgow Partnership and Hugh Harrison 2001, Vol. II: Plate 561
[212] *Peterborough Cathedral. Nave Ceiling Vol.1*. Hirst Conservation (Oct.1995)

From the analysis, testing and treatment conducted in 1997 the painting was known to be profoundly sensitive to moisture. Traces of calcium sulphate were identified at the wood/paint interface and also at varying concentrations throughout the paint layers. In addition, some 19th-century paint layers were also found to contain high concentrations of both calcium sulphate and clay-rich minerals. The clay-based materials swell readily in the presence of moisture as was demonstrated by the severe blanching of some of the paint following even brief contact with water. This discovery was highly significant and affects all aspects of treatment. Only certain of the nineteenth century paint colours are prone to blanch after contact with water; these are identified in the table below.

1997 tests identifying paint layers susceptibility to water-induced blanching

ST PETER	**POSITION**	**EFFECT/BLANCHING**
Red drapery	To east of central lozenge etc.	Insignificant
Pink shading on red drapery	To west of left hand	Present when swab used; not present when wiped with damp slurped
Yellow/white highlight on red drapery	Sleeve of left arm	Minor
Flesh tones	Left hand	Minor
Flesh tones	Left foot - after full consolidation	Present
Light blue drapery	Over left foot - after full consolidation	Present
Black outlines	Several areas	Insignificant or not present, unless already present
Dark blue drapery	Over left foot - after full consolidation	Insignificant
White/cream	Background to 'patterns'	Insignificant with swab, but present after prolonged treatment
Light blue/green	Background to figure	Insignificant/acceptable; but earlier tests were affected by prolonged heat/moisture
Yellow/brown/white	Hair	Minor; mainly appears on the brown, tho' may simply be cleaner
ST PAUL	**POSITION**	**EFFECT/BLANCHING**
Green	Background to figure, by foot	Minor. Previous tests show it can be removed
Yellow/brown	Drapery by sword handle	Took a long time to dry but no apparent blanching
Light blue	Cusped frame	After full consolidation it was very evident, but only occurred occasionally
White/yellow	Sword - after full consolidation	No obvious blanching
Brown/grey	Hair	Possible blanching- or is it just cleaner?
PSALTERY	**POSITION**	**EFFECT/BLANCHING**
Light green	Background to figure	Minor; previous tests indicate it can be removed
Pale pink/cream	Cusped frame	Minor - acceptable

PSALTERY (cont)	POSITION	EFFECT/BLANCHING
Red	Background	Minor/insignificant
Grey/brown	Frame of instrument	Present
Blue/green	Repaint on background	Minor
Cream	Background to key pattern	Insignificant

9.2. PHASE 1 TREATMENT TESTS

Visual examination of the painted decoration during the condition survey and analysis of paint samples removed from the Eastern Bay confirmed that the same original and added materials were present.[213] Subsequent treatment tests conducted on *Panel 39 IV* corroborated the 1997 findings.

The methods and materials identified as appropriate in 1997 were re-tested before the start of Phase 1 treatment. Paint on *Panel 39 IV* exhibited typical examples of damage and deterioration so was chosen as a trial area. On completion of the tests the entire panel was treated to a finished level and approved by members of the project team.

9.2.1 Paint Re-attachment

This process was the subject of exhaustive trials in 1997. The methods and materials chosen and used to re-attach flaking paint on the St Peter, St Paul and Psaltery Player lozenges were re-tested successfully on *Panel 39 IV*. The following is a summary of the 1997 test results:

9.2.1.1 Paint relaxation - Preliminary trials with a Preservation Pencil established that moisture was the prime cause of surface blanching. The Preservation Pencil, used with an ultrasonic humidifier, is capable of providing a fine, delicate jet of moisture or dry air from ambient temperature to 100ºC. Blanching depends on the type of moisture output which is controlled by the varied heat and moisture settings, and types of nozzle, available on the Preservation Pencil. Moisture, rather than temperature, causes the nineteenth century paint to blanch. It was found that warm dry air can be used to relax the paint flakes without adverse effect. A satisfactory level of paint relaxation is achieved using the larger nozzle on the Preservation Pencil at 40ºC and on minimum moisture setting - any moisture emitted by the Pencil at this temperature setting evaporates without affecting the paint surface. The nozzle is held close to the surface for 3-5 minutes, depending on the thickness of the paint and the level of distortion. Immediately following this process undiluted industrial methylated spirits (IMS) is injected behind the flake to pre-wet the void. IMS applied in this way does not cause surface blanching or adversely affect the adhesives effectiveness.

9.2.1.2 Adhesives - Trials were conducted using three fixatives - Plextol B500, Paraloid B72 and Isinglass - each known to have good ageing properties and an ability to withstand at least some variation in environmental conditions. The tests were to establish appropriate solution strengths and devise effective methods of application in these circumstances, rather than to test the properties of various fixatives. Plextol B500 was .been identified as the most suitable material for re-adhering paint flakes on the Nave Ceiling. Plextol B500 is an acrylic dispersion and therefore water-based: its stability is good and it has appropriate handling properties. It is now widely used as a paint fixative on both wall paintings and panel paintings. Through testing we were able to identify an efficient method of applying the adhesive and pressing back the flakes which involved minimal contact of moisture with the paint surface. A 15% solution in deionised water is required when re-laying large, distorted flakes where the paint layer is relatively thick; a 5-10% solution is adequate for securing the small thinner flakes. Following paint relaxation and pre-wetting very small droplets of the adhesive solution were injected, through a fine syringe needle, behind an individual

[213]Howard 1998

paint flake. The flake is then pressed back into place with a small pad of dry cotton wool covered by Japanese tissue. The dry cotton wool immediately absorbs the majority of excess adhesive displaced as the flake is re-laid. The tissue is carefully peeled from the surface after the cotton wool is removed. Cleaning tests established that any residual adhesive on the surface following re-attachment by this method will not significantly impair subsequent removal of surface dirt.

A different method is necessary for re-laying distorted paint flakes underlying thick glue deposits. Glue has to be very soft before the underlying paint flake becomes relaxed enough to be re-laid. The best results were obtained by carefully dabbing the coated flake with a small piece of sponge to remove as much glue as possible; then - using the same sponge - delicately easing the relaxed flake back into position. Injecting Plextol B500 solution behind such flakes is less successful than relying on residual animal glue alone as the adhesive. There is some risk of failure: if a flake detaches while the glue is being removed, any attempt to re-position it fails because the remaining surface glue sticks to the intervention layer. However, these tests were conducted on very distorted paint flakes: where the paint is only slightly cupped or lifted on one side there is little risk of loss.

9.2.1.3 Flaking paint on nail heads - Flaking and lifting paint on nail heads was found to be brittle; there was no flexibility in the paint. Tests revealed that to secure the flaking paint up to two applications of Paraloid B72 (10% in acetone) had to be applied by syringe. Once the solvent had evaporated a localised heat source (Preservation Pencil) was applied to the flakes relaxing them sufficiently and enabling them to be secured by gently pressing into place with a small spatula. Sufficient B72 was required to allow the flake (sometimes bent back at 90' to the original position) to be eased back into position. Tests indicated that a single application of 10% B72 in acetone would provide an adequate protective coating for unpainted and corroded metal fixings.

9.2.2 Consolidation of the Paint Layer

With the exception of *Panel 40 III*, paint on all boards within the Eastern Bay was adequately bound and required no further consolidation. Much of *Panel 40 III* had a thin and very powdery layer of decoration painted directly onto the softwood boards. Trials were carried out using different dilutions of Paraloid B72 in both xylene and acetone. Paraloid B72 is an ethyl methacraylate co-polymer which through tests has been classed as one of the most stable synthetic resins available to conservators and is a preferred material for this treatment process. The consolidant was applied by brush through Japanese tissue paper: the paper was carefully peeled away from the paint surface immediately after application. A 5% solution of B72 in acetone was identified as the most appropriate solution. Generally the powdery pigment was consolidated adequately after a single application. The process did not darken the paint or result in a shiny surface. It was found that more than one application of a similar strength solution of B72 in xylene was required to achieve the same effect. The less volatile solvent apparently caused the consolidant to penetrate further into the support where it was not required.

9.2.3 Surface Cleaning

Tests in 1997 indicated that a 'dry' method of cleaning using Wishab sponges produced good results[214]. This cleaning technique was preferable for a number of reasons: some solvent-based solutions were ineffective; all proved difficult to control and produced different cleaning levels on the various colours and paints; most caused the paint surface to shine; in addition, much of the paint surface blanched after contact with water. By contrast, cleaning tests with Wishabs demonstrated it was relatively easy to achieve an uniform level of clean; the majority of the paint was stable and withstood the gentle surface abrasion necessary without need for preliminary consolidation; surface dirt could be removed without causing the paint surface to shine; Wishab cleaning is not thought to deposit significant, potentially harmful residues on the paint surface.

[214] Wishab sponges are cakes of synthetic rubber granules that collect the dirt and self-abrade when rubbed across a surface.

As part of their preliminary technical examination of the paint surface within the Eastern Bay Howard and Heritage tested the effect on the paint surface of cleaning with Wishab sponges[215]. The trials areas were examined on-site using a video microscope and samples were taken for further testing in the laboratory. Results indicated:

- No significant residues were deposited on the paint surface by the Wishabs.
- In general, an appropriate cleaning level could be achieved using the medium and hard grades of Wishab with minimal damage to the paint surface.
- Variations in texture, colour and the condition of the paint would lead to differences in both *real* and *apparent* cleaning levels unless care is taken to ensure that the white is not cleaned to greater level than other colours that are less easy to clean, and for which such a 'good result' is not possible.

Howard recommended the following procedures for Wishab use on the Nave Ceiling:

- Brush surface with soft sable brush before use of Wishab.
- Use small, shaped piece of the sponge which can be applied to a small area, and with considerably more delicacy than the whole sponge surface.
- Monitor cleaning process by regular checking at magnification (at approx. 8-10x, perhaps with *Binomag*. or similar apparatus).
- Brush off surface with soft brush after application of Wishab to remove any residual particles of the sponge and loosened dirt.

9.2.4 Glue Removal

The techniques identified as most successful during extensive trials in 1997 were re-tested and found to be appropriate for use in Phase 1. The following is a summary of the 1997 test results:

Tests indicated that there is no alternative but to use water to remove the animal glue film. Solvents had no effect; heat, rather than having a softening effect, made the glue brittle and contract further. The glue is more easily removed using warm rather than cold water; although, on vulnerable colours the shorter contact time is not noticeably reflected by a lessening of surface blanch.

It appears that the liquid glue affected some of the paint surface before it dried. In one test area the off-white paint appears cleaner following glue removal than an adjacent area that had not been coated with glue but was intentionally cleaned with a warm water swab for a comparable time as a control.

Where the glue deposits are relatively thin and the underlying paint stable, the glue is best removed using warm water (c.a. 55ºC) on small cotton wool swabs. This method is more precise than using the Preservation Pencil which may affect adjacent non-glue covered areas. For the thick, raised droplets of glue, whether or not the underlying paint is flaking, it is necessary to use the Preservation Pencil on maximum moisture setting at 40ºC and gradually dab the dissolved glue away with a small sponge. Warm water on a cotton wool swab does not remove the thick runs or droplets completely, even when applied for a considerable period. Tests have shown that glue removal, using warm water on cotton wool swabs, leaves the treated areas noticeably 'cleaner' than their surroundings and causes some of the paint to blanch. It is necessary to disguise this effect with water-colour paints.

9.2.5 Removal of Surface Staining

The removal of staining was not an objective for Phase 1 treatment. Only during the surface cleaning process did it become evident that some stains were particularly distracting and would be apparent from floor level. In consultation with members of the Project Team a decision was made

[215] *Peterborough Cathedral Nave Ceiling - Tests to determine the effects of surface cleaning with Wishab* Helen Howard, unpublished notes, 1998.

to remove, reduce or disguise a limited number of stains. Tests revealed the dark brown material could be reduced using acetone swabs; the dark grey stains in the Ashlar boards were removable using deionised water swabs but had the same effect on the underlying paint as glue removal.

9.2.6 Reintegration

As part of the Phase 1 testing on *Panel 38 IV* the Hirst Conservation cleaning tests were reintegrated with water-colour paints to match the surrounding Wishab cleaned paint surface. The 'blanched' or 'cleaner' areas of paint resulting from glue removal on *Panel 38 IV* were similarly treated. As with all other tests conducted as a preliminary to treatment the results were inspected and approved by members of the project team.

9.3. PHASES 2-5 TREATMENT TESTING

No further structured tests were required as no new treatment materials were used during subsequent phases. With the benefit of increasing experience some methods of application and techniques were modified slightly. These modifications are detailed in the following section.

PART 10: TREATMENT: THE PAINTED DECORATION

For most categories the extent and location of treatment is plotted on the graphics in Part 13.

10.1. PAINT RE-ATTACHMENT

All the flaking paint plotted on **Graphics 10A/B & 15** - including flaking paint underlying thick glue deposits (categorised as 'Flaking & Glue') - was re-attached in Phase 5 and in all previous phases. The methods and materials used were devised to minimise water contact with the paint surface and identified as appropriate through the testing procedure. Where possible the flakes were treated individually; although areas of micro-flaking and some interconnected larger flakes had to be re-laid in groups.

Distorted, thicker paint flakes were relaxed to a point where they could be eased back into place without fracturing. This degree of flexibility was achieved by applying a delicate jet of warm dry air from a Preservation Pencil, set at 40ºC and to minimum moisture output. The nozzle was held close to the surface for up to 5 minutes. During Phase 2 we found that by adding a percentage Industrial Methylated Spirits (IMS) to the adhesive solution it was usually possible to dispense with the pre-wetting process. Only rarely was it necessary to pre-wet the void behind paint flakes with neat IMS following paint relaxation. The adhesive solution comprised a 5% or 10% solution of Plextol B500 (depending on the distortion and thickness of the paint) in a mixture of deionised water and IMS (85:15 mix) [216]. Small droplets of the solution were injected into the void behind each flake. The flake was then eased back into place with a small pad of dry cotton wool through Japanese tissue: the dry cotton wool absorbing excess adhesive displaced as the flake was pressed back. Preliminary relaxation with the heat source was not always necessary for the less distorted or thinner paint flakes; particularly the 1830s black paint on the wave pattern boards.

Treatment of flaking paint underlying thick glue deposits is addressed in Item 10.3 below.

In **Graphic 11** the visible nail heads are grouped according to the percentage of paint surviving (100-70%, 70-30%, 30-0%). The groupings do not signify whether or not the remaining paint on

[216] Plextol B500 is a product of Röhm. It is an acrylic dispersion of a thermoplastic acrylic resin its stability is good and it has appropriate handling properties. Plextol B500 is widely used as a paint fixative on both wall paintings and panel paintings.

each nail was flaking. Recording that information was considered unwarranted given that the same material in the same solution (B72: 10% in acetone) was used both to re-attach flaking paint on nail heads and to coat exposed metal. Flaking paint on the nail heads was brittle: there was no flexibility in the paint. Up to two applications of the B72 solution by syringe were required to secure the flakes; the solvent was allowed to evaporate before the paint was relaxed with warm air from the Preservation Pencil (40ºC) then pressed back into place with a small spatula.

In 2002, during the fire damage restoration works, we had the opportunity to revisit the eastern Bays of the Ceiling and assess the effectiveness of the paint reattachment treatment over time. Generally we found the paint to be in the same stable condition as we had left it: in the case of Bay 1 four years beforehand, and in Bays 2 and 3 three years. However occasional individual paint flakes (28 recorded) were discovered and these were re adhered using the same method as previously. Although we were able to refer to the relevant condition surveys and treatment graphics we were seldom able to determine whether a particular flake had been treated in the past. Prior to the first treatment flaking had occurred in clusters and these were plotted on the 1:15 scale graphics accordingly. Whether a particular flake within that cluster was overlooked during treatment or whether it had subsequently lifted again was impossible to tell. Only where there was a flake where none had been recorded on the graphic could we be sure it had not been treated before. Gratifyingly these instances were few and far between.

10.2. SURFACE CLEANING (Plates 388-391)

The guidelines recommended by Howard for Wishab use on the Nave Ceiling were followed throughout[217]. Loose surface dust particles and the soot layer resulting from the 2001 fire in the building were brushed from the surface, using small and very soft brushes; the dust sucked into a vacuum cleaner nozzle held close by. Small, shaped pieces of the Wishab sponge were applied to the paint surface with gentle circular strokes; with constant attention to guard against surface shine as well as disruption of loose paint or raised, granular particles. The particles of Wishab remaining on the surface were removed with a soft brush. This method achieves a satisfactory and uniform level of clean, removing much of the efflorescence and bloom as well as most surface dirt; however, a slight surface discoloration remains. Cleaning with deionised water would remove this surface deposit - as proved by previous tests and the paint surface where glue has been removed - but this was not an appropriate option given the extreme moisture sensitivity of the paint. As it is, the slightly yellowed deposit will serve to isolate the paint from future accretions.

10.3. GLUE REMOVAL (Plates 386, 296)

Thin deposits of the glue film were removed by swabbing with warm deionised water. Raised droplets and thick runs overlying flaking paint would not be dissolved completely by this method. It was necessary to use the Preservation Pencil on maximum moisture setting at 40ºC and gradually stroke dissolved glue away with a small sponge. Using the smaller of the two round-ended nozzles confined the spread of the moisture. This advantage was somewhat off-set as the moisture output was considerably reduced, thus slowing the process: the small area of paint surrounding the glue was subjected to less moisture but for a longer period.

Re attaching distorted paint flakes underlying thick glue deposits involves some risk of failure: if a flake detached while the glue was being removed, any attempt to re-position it fails. A small number of paint flakes were lost during this process but the majority were re-attached successfully. The glue was softened by warm moisture from the Preservation Pencil and, as far as possible, absorbed into a small sponge stroked carefully across the surface. Each paint flake was eased back into place with the sponge once most of its overlying glue had been removed. Residual glue carried behind the flake as a result of the softening process serves as the adhesive.

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[217] *Peterborough Cathedral Nave Ceiling - Tests to determine the effects of surface cleaning with Wishab* Helen Howard, unpublished notes, 1998.

10.4. REMOVAL OF SURFACE STAINING (Plates 399-404)

The approach adopted throughout the project has been that stains considered to be particularly distracting and visible from the ground should be removed, reduced or disguised. The treated stains - other than brown drips or stains caused by water infiltration, all of which were removed or disguised - are identified on **Graphics 13A/B & 15**. Almost all stains were reduced rather than removed. On the original boards it was possible to reduce the smaller water stains using warm deionised water. Water alone was not effective in reducing the chemical stains or the more extensive water stains. For these a variety of materials or combination of materials were used including: a 2% to 5% solution of ammonium carbonate, IMS, acetone or a mixture of these two solvents (50:50). All categories of stains on the replacement boards were more difficult to reduce. None of the solvents mentioned above were effective in reducing these stains without affecting the paint layer. Cleaning with solvents causes a dark halo to appear around the stain which itself was then difficult to remove. In addition, attempts to remove stains on these boards resulted in a shiny surface.

The method and materials used to remove each stain treated across the Ceiling have been recorded on the hand plotted, 15:1 scale graphics. These graphics are included in the source material for this project.

10.5 CONSOLIDATION OF SURFACE SPLINTERS AND SPLITS

Graphics 7A/B & 14.

Where possible splinters of wood that had been displaced by protruding screw ends were repositioned and adhered with a solution of Plextol B500[218] (diluted 1:1).

Many surface splinters could not be repositioned as the offending protruding screw could not removed. In instances where the splinter was clearly unstable but the protruding screw remained it was necessary to assess whether there would be a benefit in cutting a section from the splinter, so that at least part might be replaced, or whether it would be preferable to stabilise the splinter in its displaced position. Although cutting a splinter results in an inevitable loss of material for larger splinters this was adjudged as warranted.

The processes involved in the re-attachment of splinters and detached wood fragments were as follows:

- Remove Dust.
- Pre-wet support and fragment/splinter with IMS.
- Inject or apply the adhesive material to all surfaces to be joined. Solutions of Plextol B500. Generally Plextol B500 (1:1 in water) was sufficient, but more substantial fragments sometimes required the use of neat Plextol B500.
- Allow the adhesive material to become tacky.
- Reposition fragment/splinter and apply pressure. Remove excess adhesive material from surface a.s.a.p. with IMS or acetone.
- Very small fragments can be held in position by hand; larger ones are best held by thin tape strips, wedges or battens. It was important to use an intervention layer e.g. melenex to avoid sticking 'pads' to the surface.
- Remove any excess consolidant that may have squeezed out under pressure.
- .Repeated applications may be necessary.
- Where necessary presses were applied overnight to ensure a firm bond.

Unstable splits in the boards were consolidated in the same manner but required more use of wedges, battens and/or stainless steel fixings to hold the split together until adhesion was achieved.

[218] Plextol B500 is an aqueous dispersion of a thermoplastic acrylic resin. A product of Röhm.

10.6 CONSOLIDATION OF WOOD LOSS

Although this aspect of treatment was ostensibly to the structure rather than the paint, the work was carried out by the Perry Lithgow Partnership team since the materials involved could affect the paint layer.

To prevent further wood loss from small areas of boarding that were unstable due to decay or infestation, exposed wood was consolidated with infusions of Paraloid B72[219] (10% in acetone)

As an added precaution against loss of both wood and overlying paint, following consolidation treatment, a filler was inserted to secure vulnerable edges where appropriate. All wood loss fills are identified in **Graphics 7A/B & 14**. The filler consisted of: 1 part Polyfilla, 1.5 parts fine oak dust, 1.5 parts Plextol B500 (10% solution). The filler was applied in thin coats (up to ca. 5 mm) to avoid cracking, gradually building up deeper losses.

10.7 REINTEGRATION

The 'blanched' or 'cleaner' areas of paint resulting from glue or stain removal were toned down with water-colour paints to match the surrounding Wishab cleaned paint. In Phase 5 particularly there was extensive reintegration necessary following removal of stains and glue trails across the north and south Ashlar boards (see **Plates 392-404**).

All visible stainless steel fixings inserted during Phases 1 to 5 of these works were painted in neutral colours using acrylic-based paints.

Continuing the policy adopted across the rest of the Ceiling, some areas of distracting wood loss and unpainted gaps between Ceiling boards were disguised by inpainting the exposed edge of damaged board or underlying structural elements such as softwood patch, hessian and, at the junction between canted and horizontal panels, noggins) (**Graphics 13a/b & 15**).

Twelve new oak patches were inserted in Phase 5 to repair the larger, visually distracting areas of wood loss (**Plates 109-134**). After considerable discussion with members of the Project Team during earlier phases it was agreed that the painted detail of the border patterns and central lozenges should be recreated, but in a manner that does not disguise the new timber inserts under close inspection. In Phase 2 no attempt was made to recreate the missing figurative detail on the relatively large area of new timber inserted within the Anthropophagus lozenge (*33/34/ I/II*) as too much conjecture was involved.[220] In that instance the repair was painted in the adjacent background colours. For the much smaller timber repairs made during Phase 3, with one exception, it was merely a matter of filling in the gaps between existing detail. The exception being missing detail within a lion's mask.[221] To avoid the need for conjecture, we first attempted to blend neutral colours across the missing section of eye, nose and muzzle but the result was unsatisfactory. We arrived at a compromise that, in retrospect, simply fudges the issue. Prior to the Phase 4 works the Project team asked us to draw up a list of criteria for repairing missing sections of Ceiling boards: the list is included as **Appendix 12** of this report. The criteria were followed Phases 4, 5 and for Bays 1, 2 and 3 when some additional timber repairs were made area during the fire damage restoration works.

A white acrylic primer was applied to the new wood patches followed by numerous applications of differently toned, resin and tempera paints applied as thin glazes. We found it necessary to use these different paint media on the new timber inserts to achieve the very matt appearance of the existing scheme.

Acrylic-based paints were used to reintegrate the repairs material (filler) used to consolidate the small areas of wood loss resulting from wet rot and/or insect damage. A primer of Plextol B500

[219] Paraloid B72 is an ethyl methacrylate co-polymer. A product of Röhm Hass.
[220] The Perry Lithgow Partnership and Hugh Harrison 1999, Vol. II: Plates 152-154
[221] The Perry Lithgow Partnership and Hugh Harrison 2000, Vol. II: Plates 174-175

(20% solution in water) used in some areas, otherwise 2-3 layers of paint were required to give adequate depth of colour.

10.8 SURFACE COATING

Following the removal of loose rust particles a single coating of 10% B72 in acetone was applied as an isolation layer to all corroded metal exposed as a result of paint loss from metal fixings. No surface coating was applied to the painted decoration on the Ceiling or Ashlar boards.

10.9 NAVE CEILING PROJECT INSCRIPTION

To commemorate the nine year long Nave Ceiling Conservation Project the following inscription was painted in red onto the reintegrated off-white background of the north side Ashlar boards above the west end stone ledge:

PETERBOROUGH CATHEDRAL NAVE CEILING CONSERVATION PROJECT
1994 – 2003

ARCHITECT: JULIAN LIMENTANI *ADVISER: GILLIAN LEWIS*
CONSERVATORS: THE PERRY LITHGOW PARTNERSHIP WITH HUGH HARRISON

RICHARD LITHGOW, MARK PERRY, DAVID PERRY, PETER MARTINDALE, CRISTINA BERETTA, LOUISE BRADSHAW, CAROLINE BAINES, BIANCA MADDEN, NATALIA SEGGERMAN, GREG HOWARTH, SASA KOSINOVA, SARAH LIVERMORE.
HUGH HARRISON, BOB CHAPPELL, CAMERON STEWART, PETER FERGUSON, JONATHAN PORTER, BRETT WRIGHT, CLAIRE CULLY, STUART ANDERSON.

PART 11: THE NAVE CEILING: MAINTENANCE PROGRAMME

11.1 MONITORING AND MAINTENANCE

11.1.1 Monitoring

Monitoring the environmental conditions above and below the Ceiling began in 1995 under the auspices of English Heritage. Since June 1999 Tobit Curteis Associates has been responsible for this aspect of the project. In his interpretation of the recorded data, set out in annual reports, Curteis has demonstrated the actual and potential effects of the variable temperature and humidity levels above and below the Ceiling.[222] In 2001, Following a review of the data by the Project Team and comments made by Al Brewer during his visit and subsequent paper,[223] Curteis installed equipment to measure the dimensional response of the ceiling boards to fluctuations in environmental conditions. In January 2003 he also installed light monitoring equipment to record lux and UV levels.

Temperature and humidity monitoring showed that conditions above and below the ceiling varied significantly (due to dramatically different heating and ventilation levels), placing significant stress on the thin wooden ceiling boards. The most extreme conditions occurred when direct sunlight from the glass panels in the roof fell directly onto the back of the boards. During Phases 4 and 5 hardboard sheets were fitted onto the underside of the rafters to screen the glass panels along the whole south side and prevent direct sunlight falling on the Ceiling. This intervention has

[222] *Peterborough Cathedral: Environmental Monitoring of the Nave Ceiling – March 1998-May 2000; June 2000-May 2001; June 2001-May 2002; June 2002-October 2003* Tobit Curteis Associates.
[223] Reproduced as **Appendix 5** of this report.

eliminated the sudden fluctuations in temperature but has not reduced ventilation and the thermal buffering in the roofspace remains low.

Measuring the dimensional response of the ceiling boards has demonstrated there is low level movement in response to changes in Relative Humidity which last over approximately 5 days. When RH decreases, the boards expand, and when it increases they contract. The fact that such movement has not caused the paint to delaminate may be due to the ability of the paint layer to absorb the low level of movement. Nevertheless, as Curteis warns, there is a risk that in the long term the paint layer may become more brittle and this flexibility will be reduced.

The results of the light monitoring have shown that lux levels are acceptably low. UV radiation (from daylight and tungsten halogen sources) is slightly higher than the recommended levels. However given the low level of photosensitivity of the paint layer, it is not anticipated that this will cause any short term damage. Nevertheless, the design of the proposed lighting system should include suitable filters in order to reduce the UV levels.

11.1.2 Schedule of Inspection and Maintenance

The Ceiling Structure, Upper Side – Following the fire the whole upper side of the Ceiling has now been cleaned with a vacuum. As the Ceiling has been left open, it will probably need vacuuming every 5 years. Pieces of white card with half the upper surface protected have been laid in various places throughout the ceiling. These can be inspected after 5 years, and should provide a more accurate visual appraisal of deposition of dust.

The telltales were all inspected during the Phase 5 works and none were seen to have recorded any movement. It is suggested that all telltales should be inspected every 5 years.

The Ceiling Structure, Lower Side and the Painted Decoration – The previous programme of inspection and monitoring has been overtaken by the fire. Thus the inspection of the ceiling from the clerestory is no longer required, neither is that from a mechanical hoist in 2003. On revisiting the east end of the Ceiling for the fire damage restoration works we found the paint generally to be in the same stable condition as we had left it: in the case of Bay 1 four years beforehand, and in Bays 2 and 3 three years. However occasional individual paint flakes were discovered during the surface cleaning process and these were re adhered using the same method as previously. Although we were able to refer to the Phases 1 and 2 condition surveys and treatment graphics we were seldom able to determine whether a particular flake had been treated in the past. Prior to the first treatment flaking had occurred in clusters and these were plotted on the 1:15 scale graphics accordingly. Whether a particular flake within that cluster was overlooked during treatment or whether it had subsequently lifted again was impossible to tell. Only where there was a flake where none had been recorded on the graphic could we be sure it had not been treated before. Gratifyingly these instances were few and far between.

By 2008, when 5 years will have elapsed since completing Phase 5, a close inspection of the surface should be carried out from a mechanical hoist. By that time, there should be useful information on the stability of the structure and paint as well as the effectiveness of treatment measures, albeit over a relatively short term. In addition, there will be an opportunity to assess the rate of dust accumulation under present conditions in the building. These factors will determine a schedule for inspection and maintenance thereafter.

Although tests on dust deposition can quite accurately be carried out with a Wishab on the underside of the ceiling, it will be far more difficult to measure deposition on the upper side.

11.1.3 Action

October 2008	A close inspection of the underside of the Ceiling from a mechanical hoist.
January 2009	Inspect tell-tales and dust test cards above the Ceiling. Take action on the tell-tales and vacuum ceiling if dust deposition considered damaging.

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PART 13: CONDITION AND TREATMENT GRAPHIC RECORD

The following **Graphics 1 - 15** constitute detailed condition and treatment records of the painted decoration and the Ceiling structure upper and lower sides.

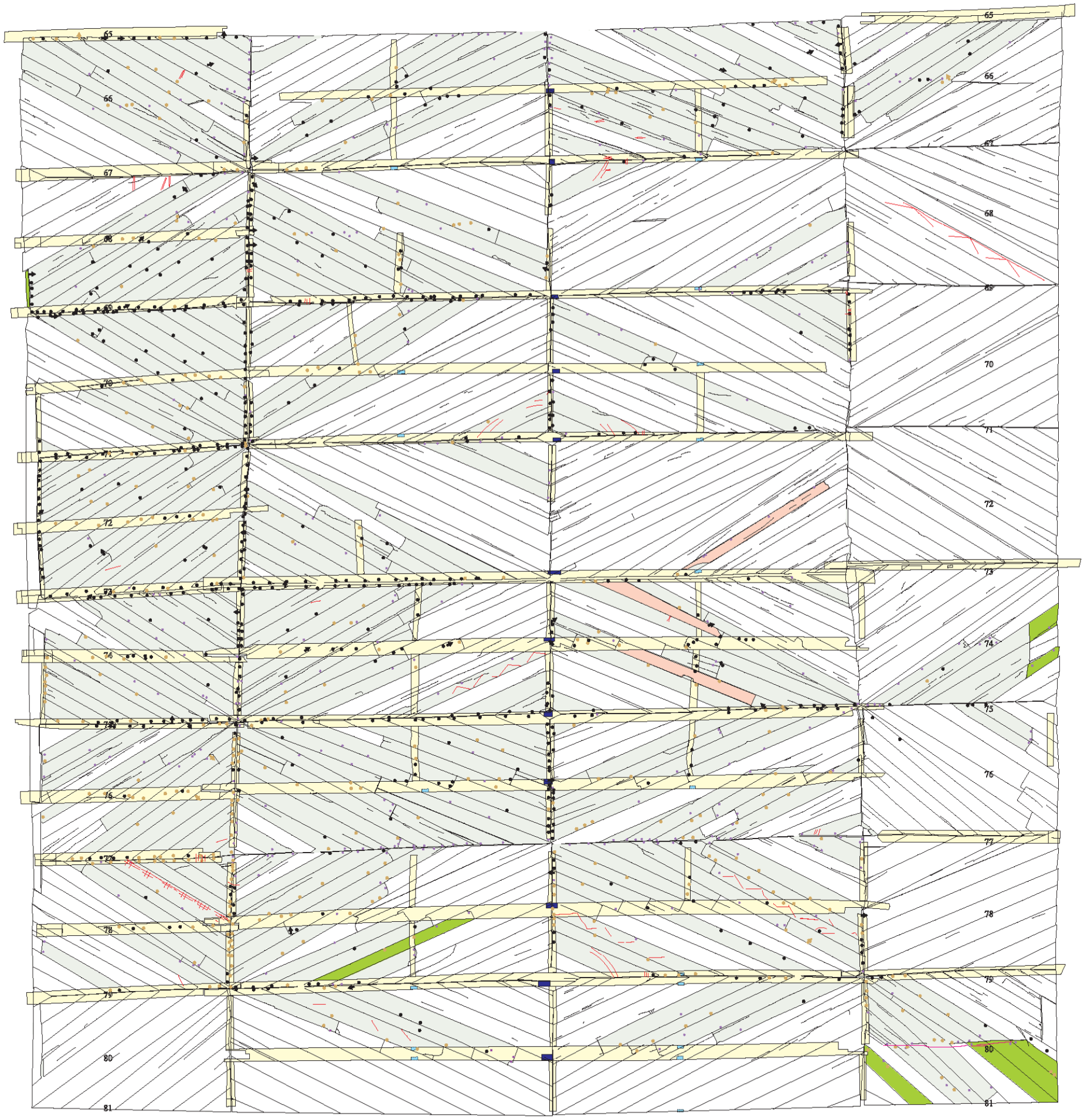
BAYS 9 & 10 CEILING BOARDS
(reflected view)

EAST

I II III IV

NORTH

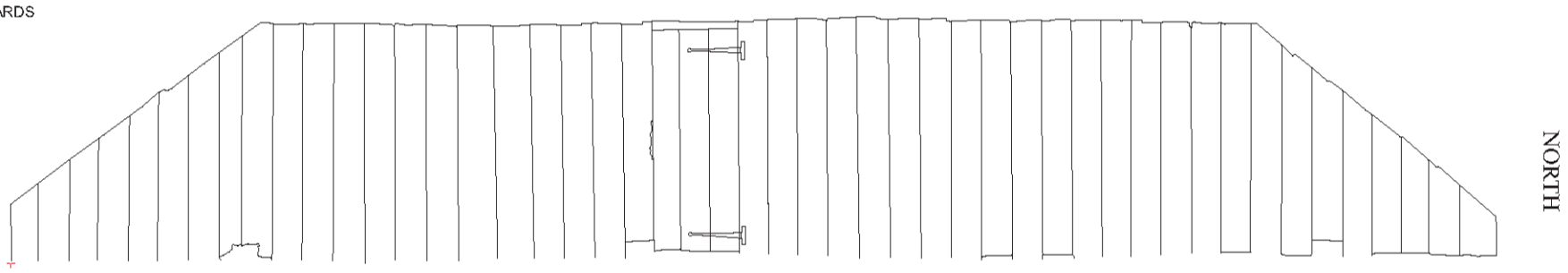
SOUTH



WEST

I II III IV

WEST WALL VERTICAL BOARDS
(non-reflected view)



West Wall Vertical Boards
(non-reflected view)

KEY

- Original large nail heads
- Protruding original large nail heads
- Original small nail heads
- Protruding original small nail heads
- Dovetail joints
- Birdsbeak joints
- Original joists
- Original noggins
- Notched base boards
- Original ceiling boards
- Oak repositioned ceiling boards
- Original alignment grooves
- Original incision lines
- Edges of all ceiling boards

NOTES Flat ceiling joist 73 is shaped and jointed differently to all other joists, and flat joists 74-80 are wider than others. This would seem to mark the extension of the cathedral from 9 bays to 10. The construction at the north west corner is slightly different to accommodate the north west tower. Hessian was not removed above every noggin, so the categorisation of noggins as original or from a later intervention is not always precise.

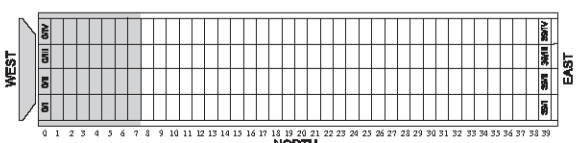
GRAPHIC NO: 1

CEILING STRUCTURE

SCALE 1:50

0 1m 2m 3m 4m

POSITION Bays 9 & 10



TITLE
PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE TECHNICAL SURVEY

DESCRIPTION Surviving Original Ceiling Elements

Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

The Perry Lithgow Partnership
1 Langston Lane, Station Rd, Kingham,
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BAYS 9 & 10 CEILING BOARDS
(reflected view)

EAST

I II III IV

NORTH

SOUTH

WEST

I II III IV

WEST WALL VERTICAL BOARDS
(non-reflected view)

SOUTH

NORTH

West Wall Vertical Boards
(non-reflected view)

KEY

- Trusses
- Binder with ceiling bolts
- Collars
- 1830s reinforcements
- Oak replaced ceiling boards
- 1740s softwood replacement boards
- 1830s softwood replacement boards
- Original joists
- Original noggins
- 1926 composite joist
- Position of conjectural patches
- Nail holes (ex nail ends)
- Edges of all ceiling boards
- Vertical post
- Added sq. nail heads
- Added sq. nail ends
- Added flat nail heads
- Added flat nail ends
- Added nail heads

NOTES All the 1740s and 1830s boards are correctly identified, as are 1830s repairs that survive the 1920s restoration. Note the number of 1830 replacement sloping joists and the flat joist 81. The 1830s roof structure is shown in blue, from which the painted ceiling is suspended by the hanging bolts. The patches drawn around groups of nails driven from above the ceiling are entirely speculative, but they are intended to indicate 1830s patches taken out in the 1920s and the number of patches is not exhaustive. Note the reduction in the use of square headed nails and the huge increase in the category "Added nails" as it is no longer possible to accurately categorise the added nails.

GRAPHIC NO: 2

N

CEILING STRUCTURE

SCALE 1:50

0 1m 2m 3m 4m

POSITION Bays 9 & 10

WEST EAST NORTH

TITLE
PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE TECHNICAL SURVEY

DESCRIPTION Extent of Surviving C18/19th Work

Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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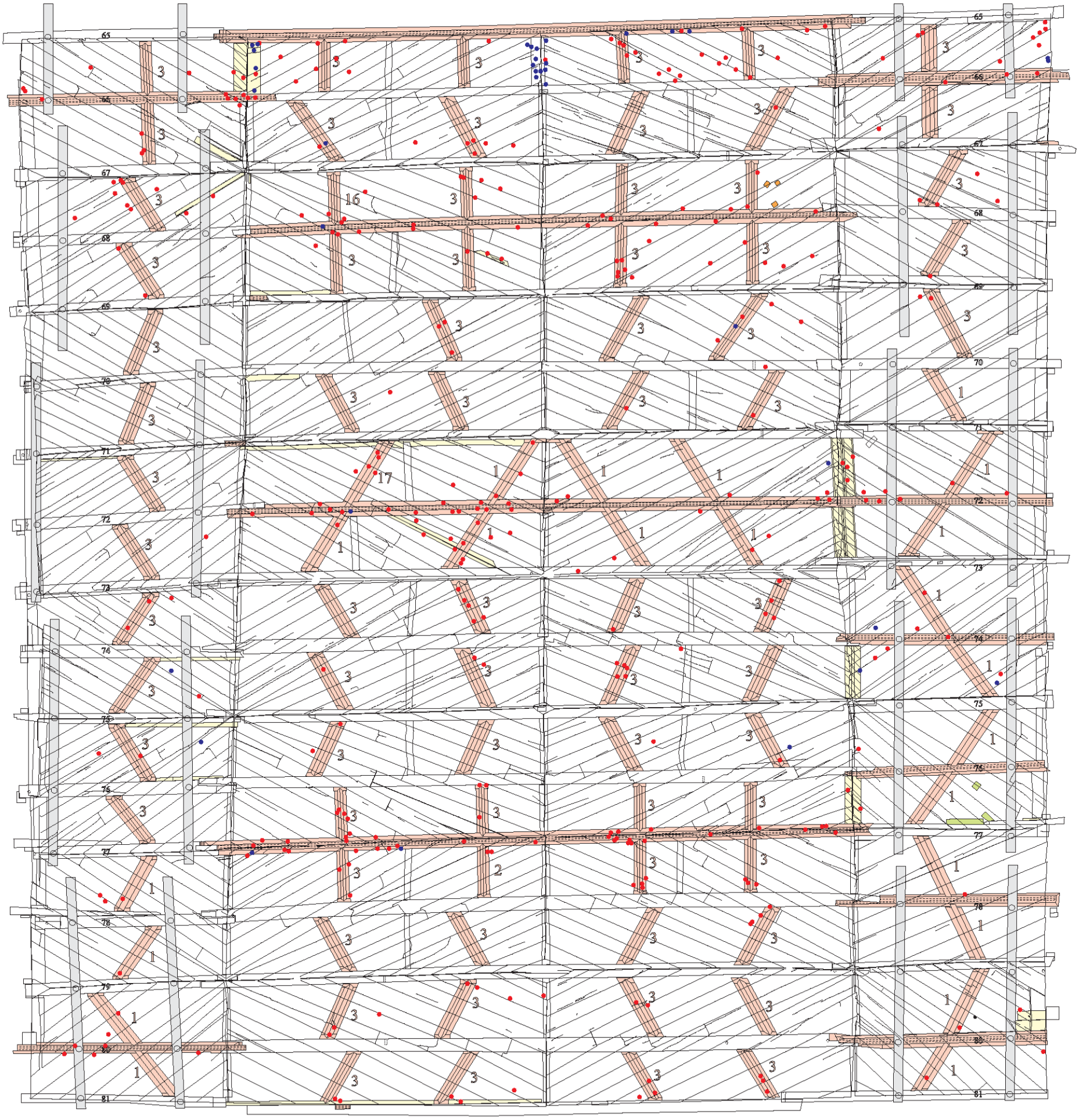
BAYS 9 & 10 CEILING BOARDS
(reflected view)

EAST

I II III IV

NORTH

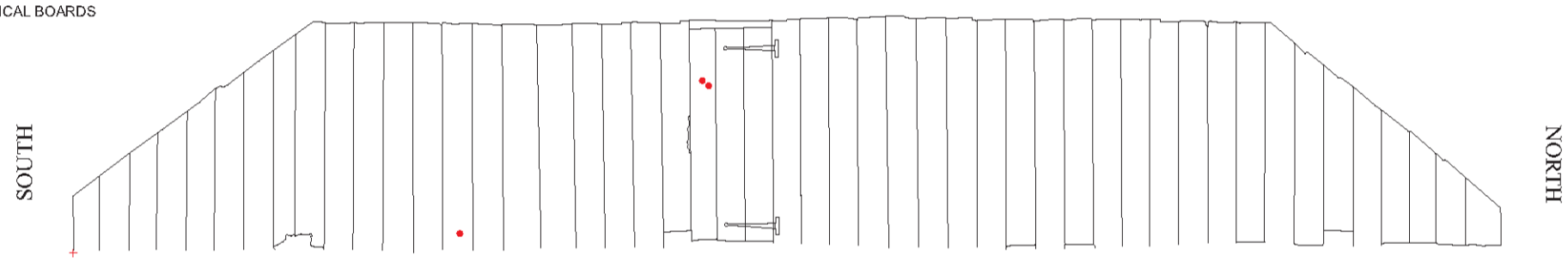
SOUTH



WEST

I II III IV

WEST WALL VERTICAL BOARDS
(non-reflected view)



West Wall Vertical Boards
(non-reflected view)

KEY

- Binder with coach screw
- Original joist
- Original noggin
- 1830s reinforcements
- 1926 composite joist
- 1926 softwood patch
- Canvas strip
- Hessian patch
- Hessian patch over timber structure
- Hessian patch continuing under timber
- Iron screws
- Galvanised screws
- Edges of ceiling boards
- 1926 noggins & additions
- Vertical post
- Pinholes

NOTES The 1926 restoration is characterised by the addition of binders to carry the sloping joists, and laminated noggings and composite joists. All the 1920s work was carried out using 6" x ½ " treated softwood, laminated as shown in various Drawings and mostly screwed. Integral with the timber repairs was the application of layers of hessian over the whole upper surface of the ceiling. Considerable damage was caused to the face of the painted boards by splintering due to screws projecting through the face of the boards as there was no access below the ceiling to see what damage was occurring.

GRAPHIC NO: 3

N

CEILING STRUCTURE

SCALE 1:50

0 1m 2m 3m 4m

POSITION Bays 9 & 10

WEST EAST NORTH

TITLE
PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE TECHNICAL SURVEY

DESCRIPTION Extent of 1926 Restoration

Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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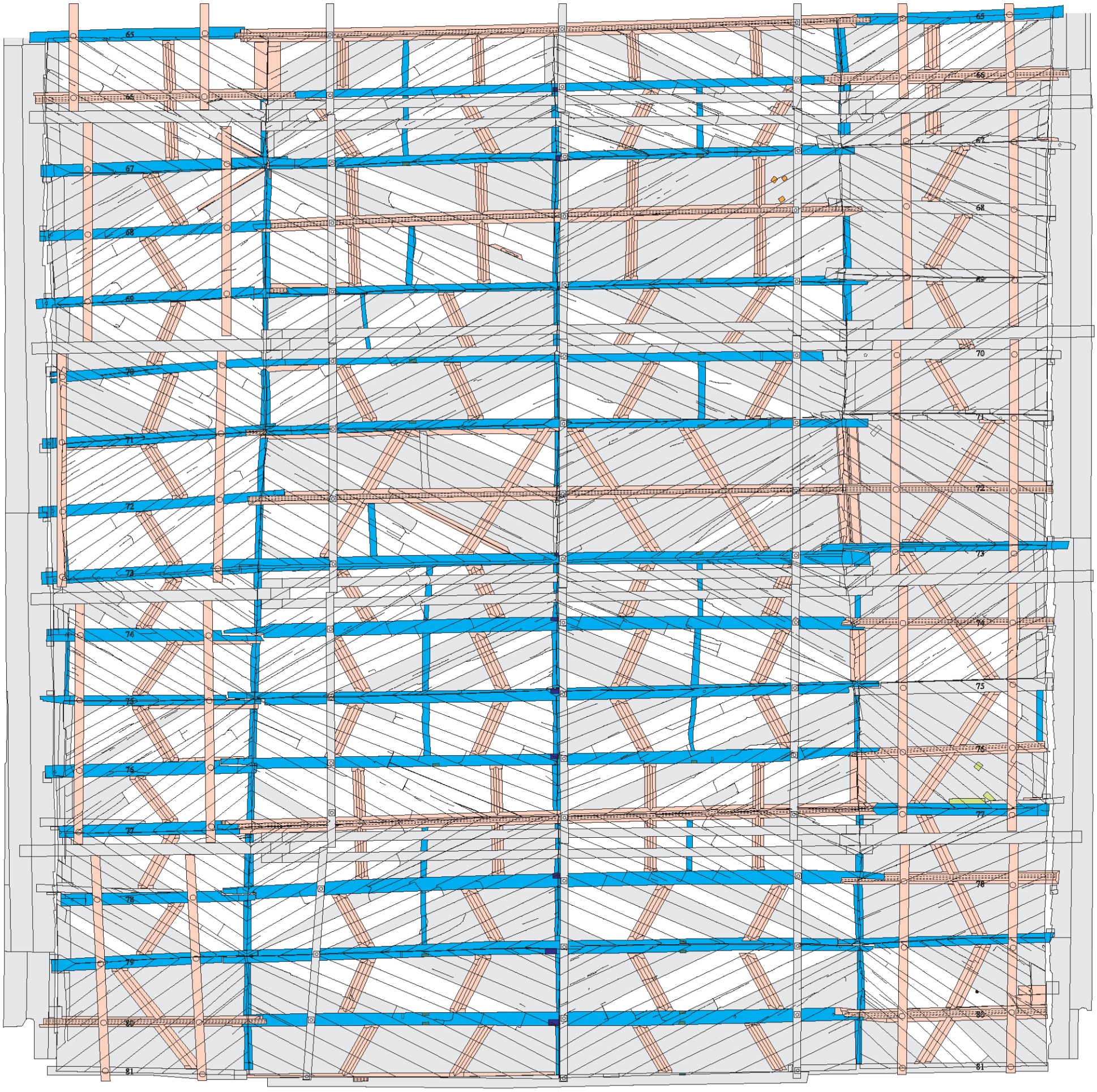
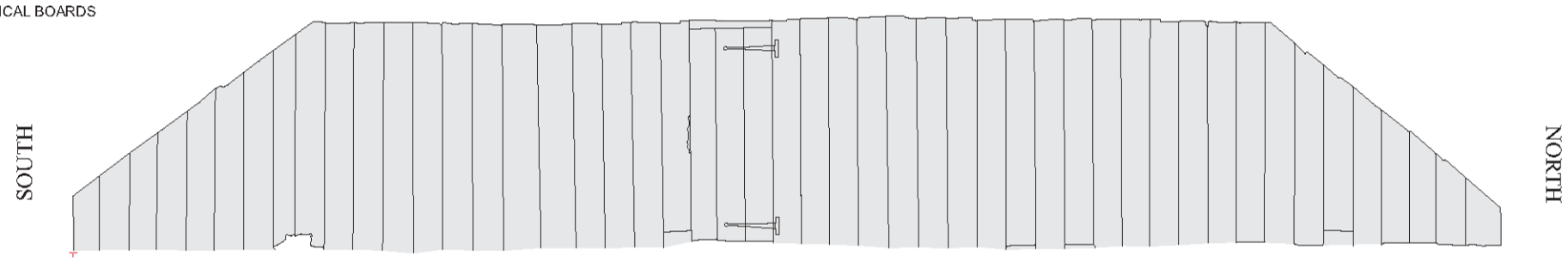
BAYS 9 & 10 CEILING BOARDS
(reflected view)

EAST



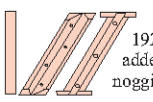
WEST WALL VERTICAL BOARDS
(non-reflected view)



West Wall Vertical Boards
(non-reflected view)

KEY

- Original joists
- Original noggins
- Original oak ceiling boards
- Softwood Replacement boards
- Oak repositioned ceiling boards
- 1830 truss
- 1830 collar
- 1830 binder with ceiling bolt
- 1830s reinforcements
- 1926 binder with coach screw
- 1926 composite joist
- 1926 softwood patch
- Canvas strip
- Hessian patch
- Hessian patch continuing under timber
- Dovetail joints
- Empty joints
- Vertical post



NOTES
This Graphic shows the total extent of current structure with all the original material coloured blue, all the 1740s/1830s in grey and the 1926 restoration in pink. The hessian covering is not shown, although the additional hessian patches and canvas strips are shown.

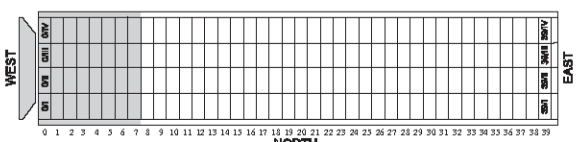
GRAPHIC NO: 4

UPPER SIDE OF CEILING STRUCTURE

SCALE 1:50

0 1m 2m 3m 4m

POSITION Bays 9 & 10



TITLE
PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE TECHNICAL SURVEY

DESCRIPTION Current Extent of Ceiling Structure

Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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BAYS 9 & 10 CEILING BOARDS
(reflected view)

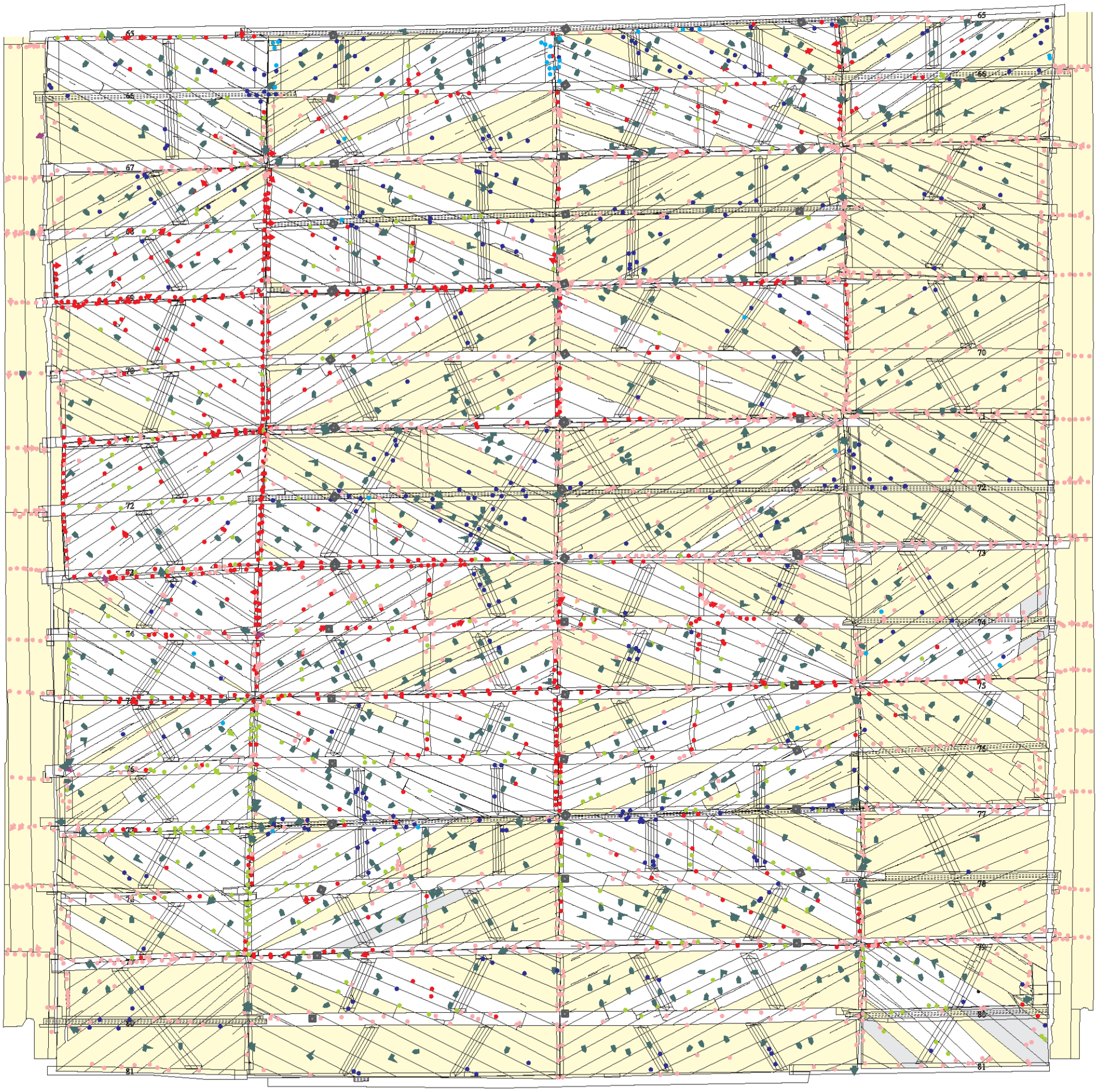
EAST

I II III IV

7 6 5 4 3 2 1 0

NORTH

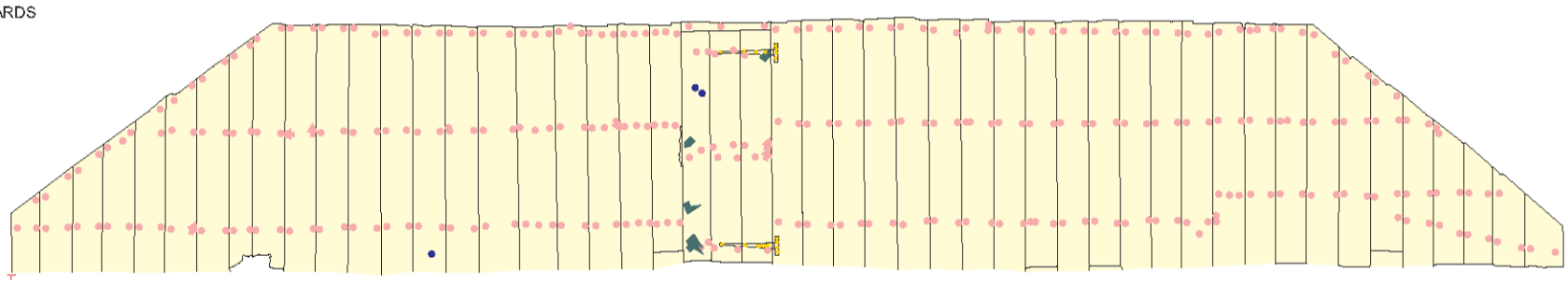
SOUTH



I II III IV

WEST

WEST WALL VERTICAL BOARDS
(non-reflected view)



SOUTH NORTH

West Wall Vertical Boards
(non-reflected view)

KEY

- Vertical post
- Softwood Replacement boards
- Repositioned oak ceiling boards
- Original joists
- Original noggins
- 1830s reinforcements
- 1926 composite joist
- 1926 softwood patch
- Added sq. nail heads
- Added sq. nail ends
- Added flat nail heads
- Added flat nail ends
- Added nails
- Projecting nail heads
- Projecting nail ends
- Edges of all ceiling boards
- 1926 added noggins
- Ceiling bolts
- Original nails
- Small headed original nails
- Galvanised screws
- Iron screws
- Screw heads

NOTES This Graphic shows the extent of fixings that currently exist attaching the ceiling boards to the structure above. It should be remembered that this Graphic does not include nail holes, so that when these are added, the full extent of the incursion into the painted surface by nails and screws past and present, can be appreciated. Note the reduction in projecting screws.

GRAPHIC NO: 5

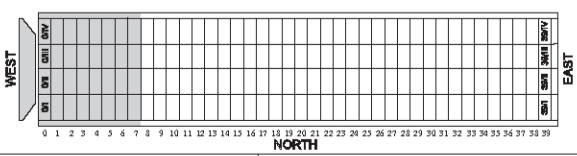
N

LOWER SIDE OF CEILING

SCALE 1:50

0 1m 2m 3m 4m

POSITION Bays 9 & 10



TITLE
PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE TECHNICAL SURVEY

DESCRIPTION Extent of Metal Fixings

Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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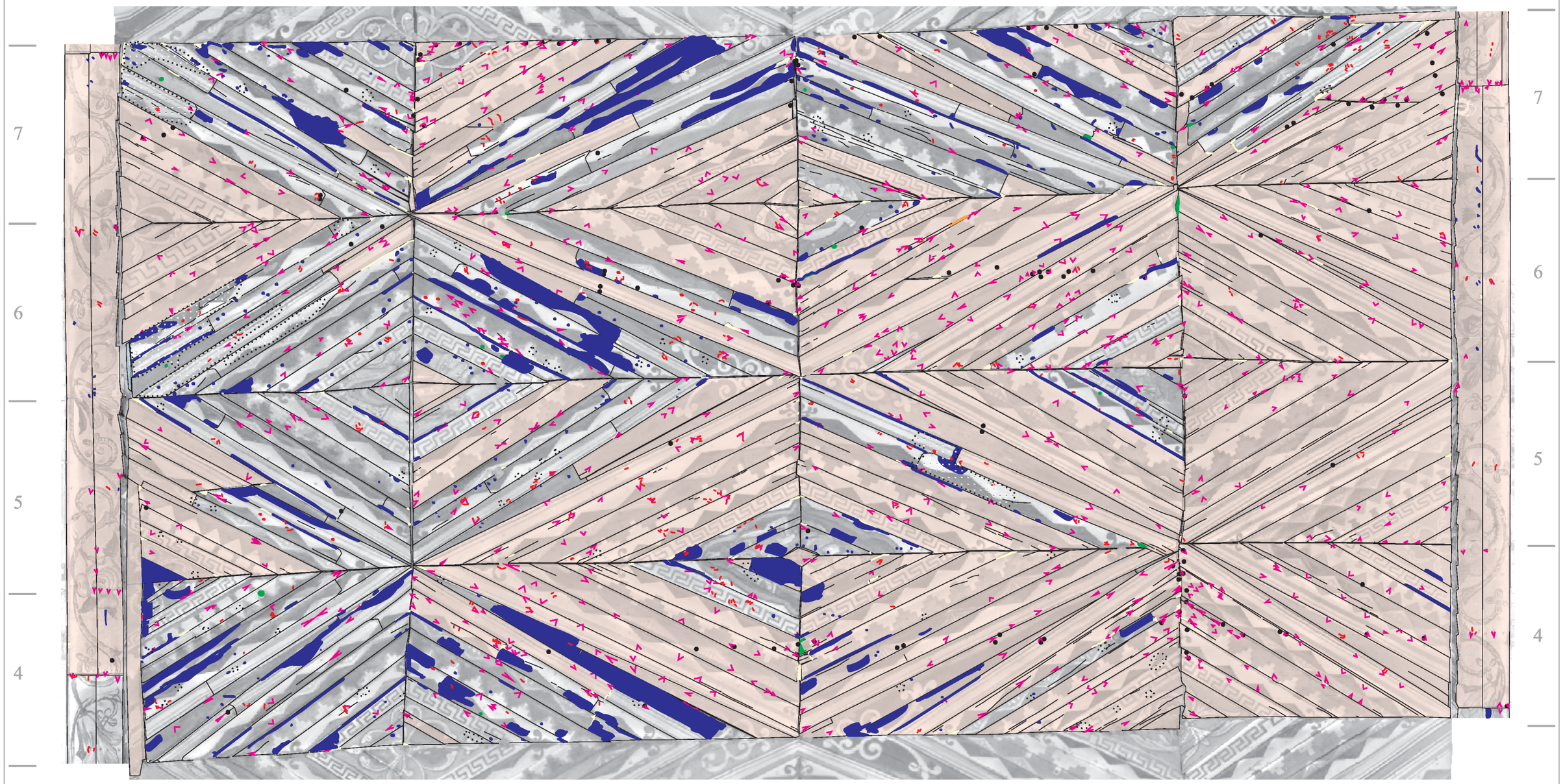


KEY FOR DAMAGE TO CEILING BOARDS

- Wood loss
- Nail holes (ex nail heads)
- Intended wood loss
- Shot damage
- Insect damage
- Wet rot & insect damage
- Impact damage
- Softwood boards
- Repositioned oak boards
- Surface splintering

GRAPHIC NO: 6A

N

SCALE 1:35

0 1m 2m 3m

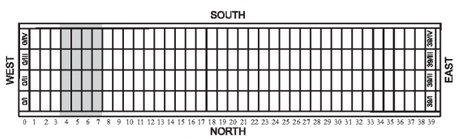
TITLE

PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE CONDITION SURVEY AND TREATMENT

DESCRIPTION Damage to Ceiling Boards

POSITION Bay 9 Ceiling Panels



Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

The Perry Lithgow Partnership
1 Langston Lane, Station Rd, Kingham, Oxon OX7 6UW Tel. 01608 658067

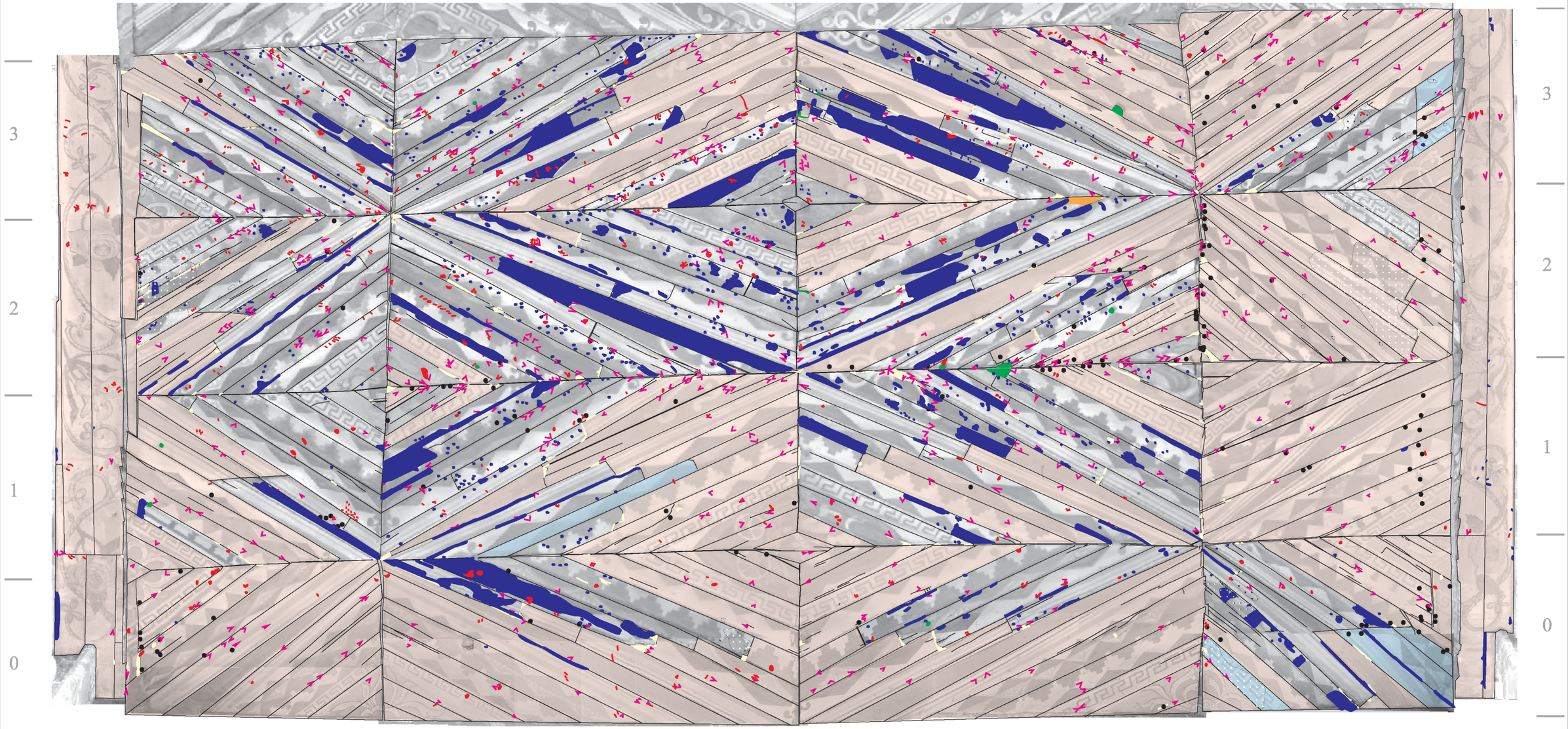
NOTES

Decay - Very little decay has been found in this phase of work, and the pattern of insect damage is similar to Phase 4 and is split with a greater concentration in the north half of the ceiling than the south. Note the low survival of original boards on the south side of the ceiling.

Shot - The shot damage has been assessed as pre- or post the 1830s restoration depending on whether there is paint in the shot holes. As in Phase 4 there is no shot in the ashlar boards and virtually none in any post 1830s board. This shows that the predominance of shooting occurred in the 18th century or earlier.

Wood loss - Note the holes etc. cut in the ceiling boards marked as Intended wood losses, the pattern follows that of previous phases.

Repositioned oak boards - Not many of these boards are found in this phase.



KEY FOR DAMAGE TO CEILING BOARDS

- Wood loss
- Nail holes (ex nail heads)
- Intended wood loss
- Shot damage
- Insect damage
- Wet rot & insect damage
- Impact damage
- Softwood boards
- Repositioned oak boards
- Surface splintering

GRAPHIC NO: 6B

SCALE 1:35

0 1m 2m 3m

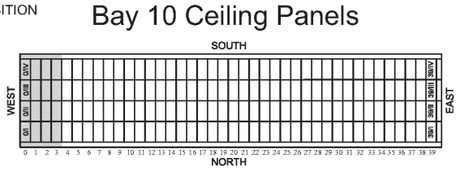
TITLE

PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE CONDITION SURVEY AND TREATMENT

DESCRIPTION Damage to Ceiling Boards

POSITION Bay 10 Ceiling Panels



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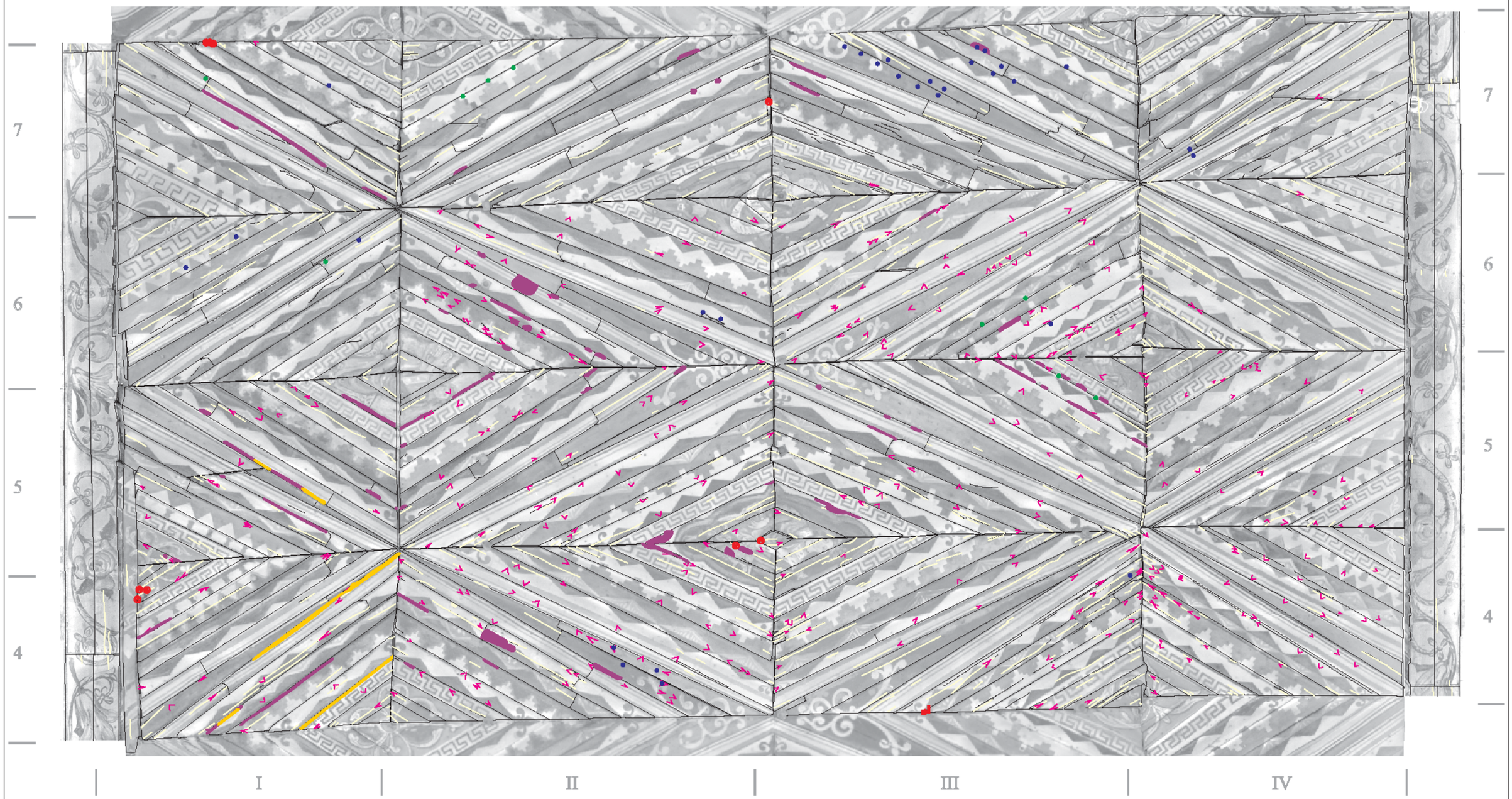


KEY FOR REPAIRS TO CEILING BOARDS

- Timber inserts
- Softwood Patches Removed
- Splits in boards
- Screws Replaced
- Screws Removed

Consolidation:

- B72
- Fills
- Bencon 19
- B500 Adhesive

Stainless steel fixings:

- Screw & Washer
- Threaded Rod
- Angled Rod
- Bolt

GRAPHIC NO: 7A

SCALE 1:35

0 1m 2m 3m

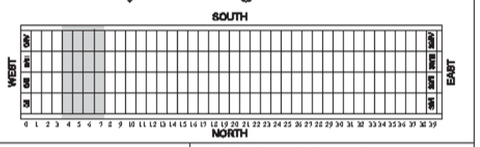
TITLE

PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE CONDITION SURVEY AND TREATMENT

DESCRIPTION Repairs to Ceiling Boards

POSITION Bay 9 Ceiling Panels



Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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NOTES

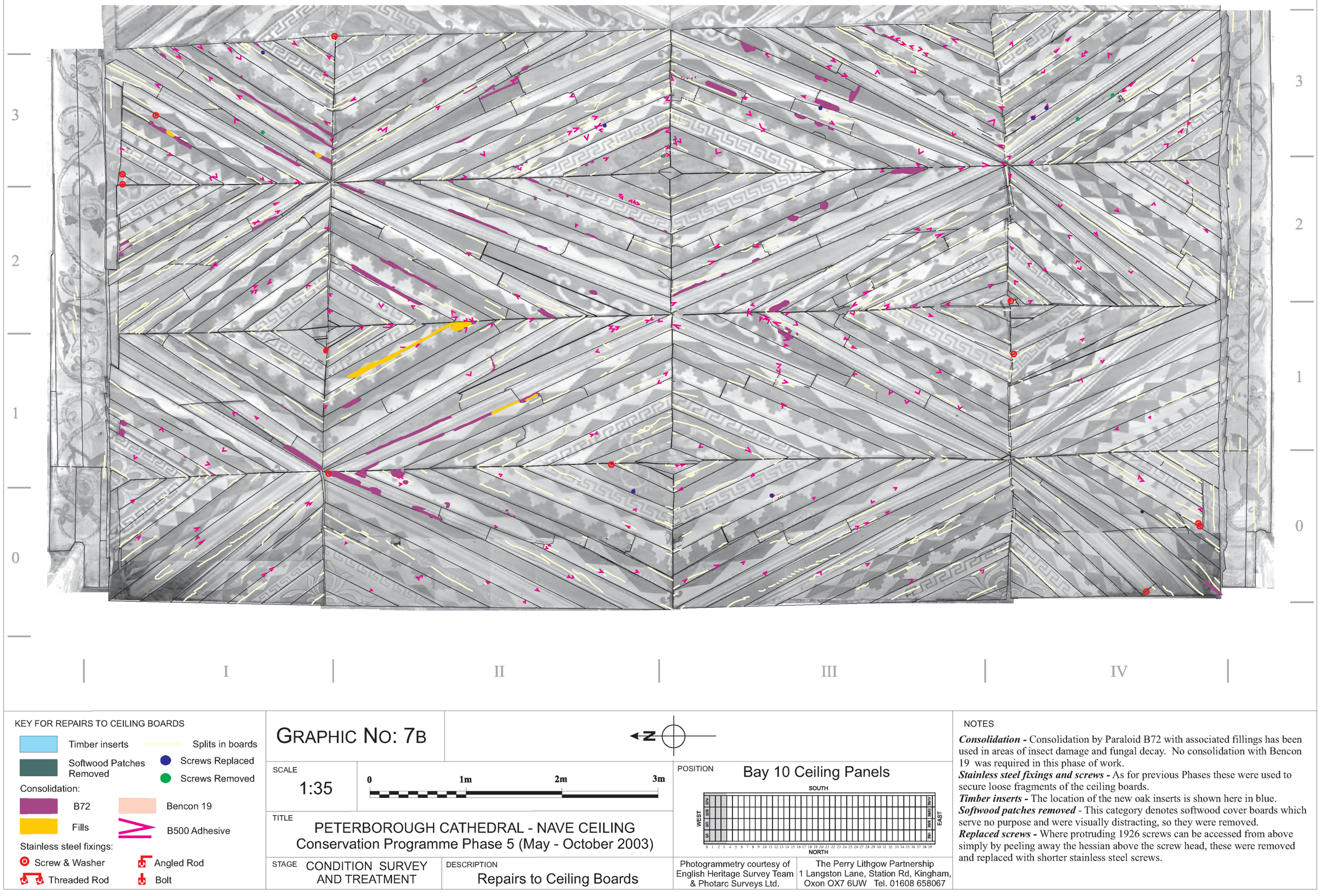
Consolidation - Consolidation by Paraloid B72 with associated fillings has been used in areas of insect damage and fungal decay. No consolidation with Bencon 19 was required in this phase of work.

Stainless steel fixings and screws - As for previous Phases these were used to secure loose fragments of the ceiling boards.

Timber inserts - The location of the new oak inserts is shown here in blue.

Softwood patches removed - This category denotes softwood cover boards which serve no purpose and were visually distracting, so they were removed.

Replaced screws - Where protruding 1926 screws can be accessed from above simply by peeling away the hessian above the screw head, these were removed and replaced with shorter stainless steel screws.



KEY FOR REPAIRS TO CEILING BOARDS

- Timber inserts
- Softwood Patches Removed
- Splits in boards
- Screws Replaced
- Screws Removed

Consolidation:

- B72
- Fills
- Bencon 19
- B500 Adhesive

Stainless steel fixings:

- Screw & Washer
- Threaded Rod
- Angled Rod
- Bolt

GRAPHIC NO: 7B

SCALE 1:35

0 1m 2m 3m

TITLE

PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE CONDITION SURVEY AND TREATMENT

DESCRIPTION Repairs to Ceiling Boards

POSITION Bay 10 Ceiling Panels

Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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NOTES

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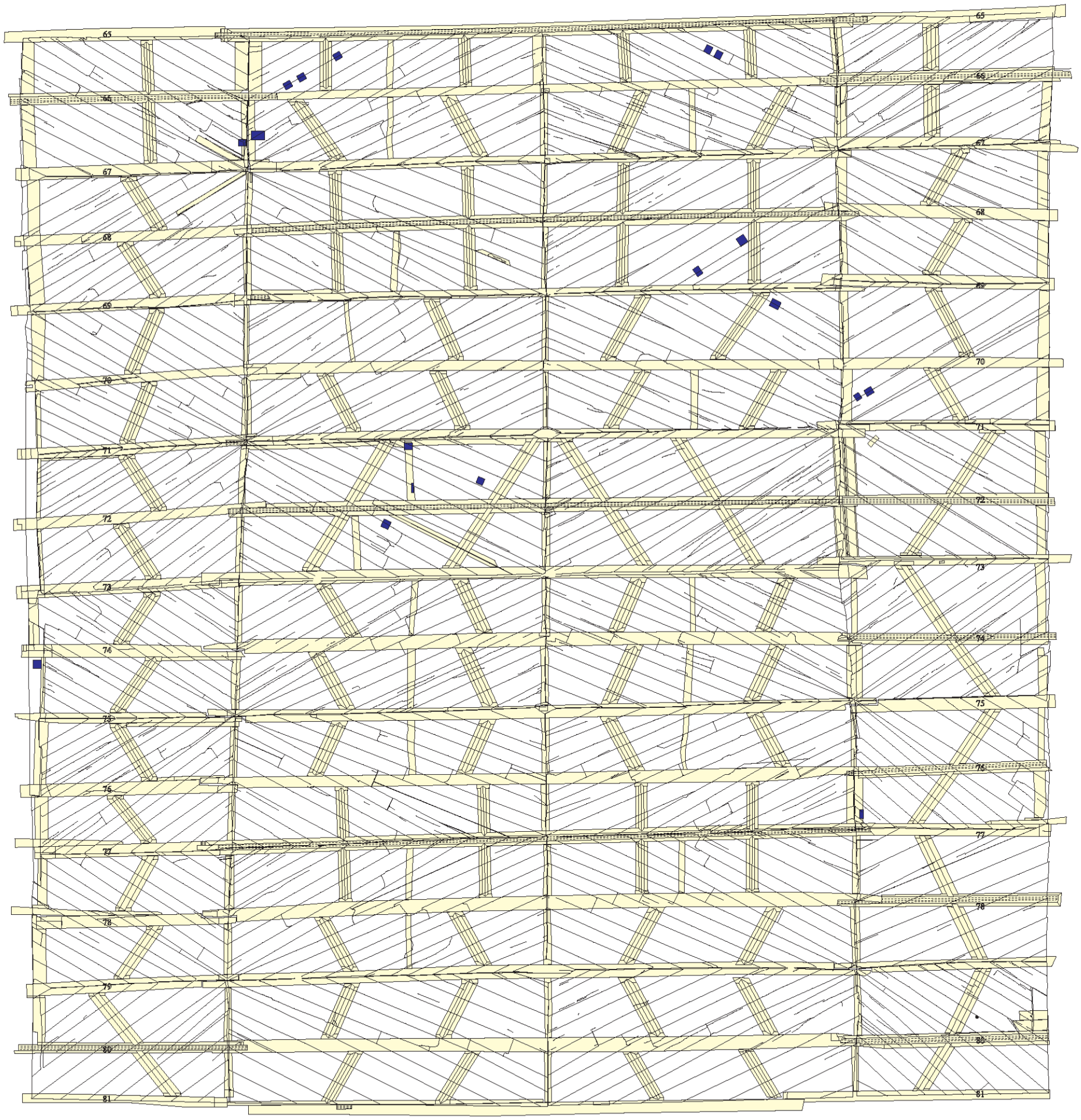
BAYS 9 & 10 CEILING BOARDS
(reflected view)

EAST

I II III IV

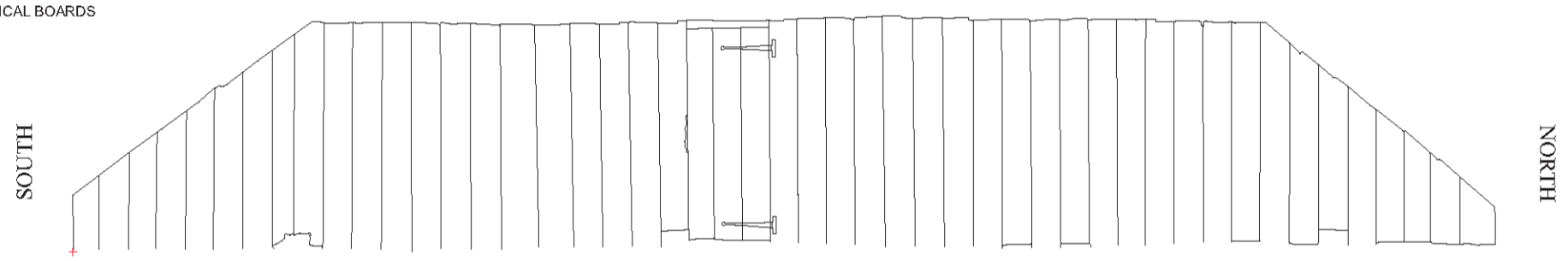
NORTH

SOUTH



WEST

WEST WALL VERTICAL BOARDS
(non-reflected view)



West Wall Vertical Boards
(non-reflected view)

KEY FOR NEW SAILCLOTH

- Original joists
- Original noggins
- 1830s reinforcements
- 1926 composite joist
- 1926 softwood patch
- Sailcloth
- Edges of all ceiling boards
- Added noggins

NOTES

This graphic marks the position of all new sailcloth patches applied to repair the hessian where this has been removed to expose screw heads, or for investigative purposes.

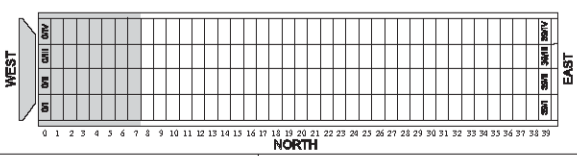
GRAPHIC NO: 8

N

SCALE 1:50

0 1m 2m 3m 4m

POSITION Bays 9 & 10



TITLE

PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE TECHNICAL SURVEY

DESCRIPTION New Sailcloth Patches

Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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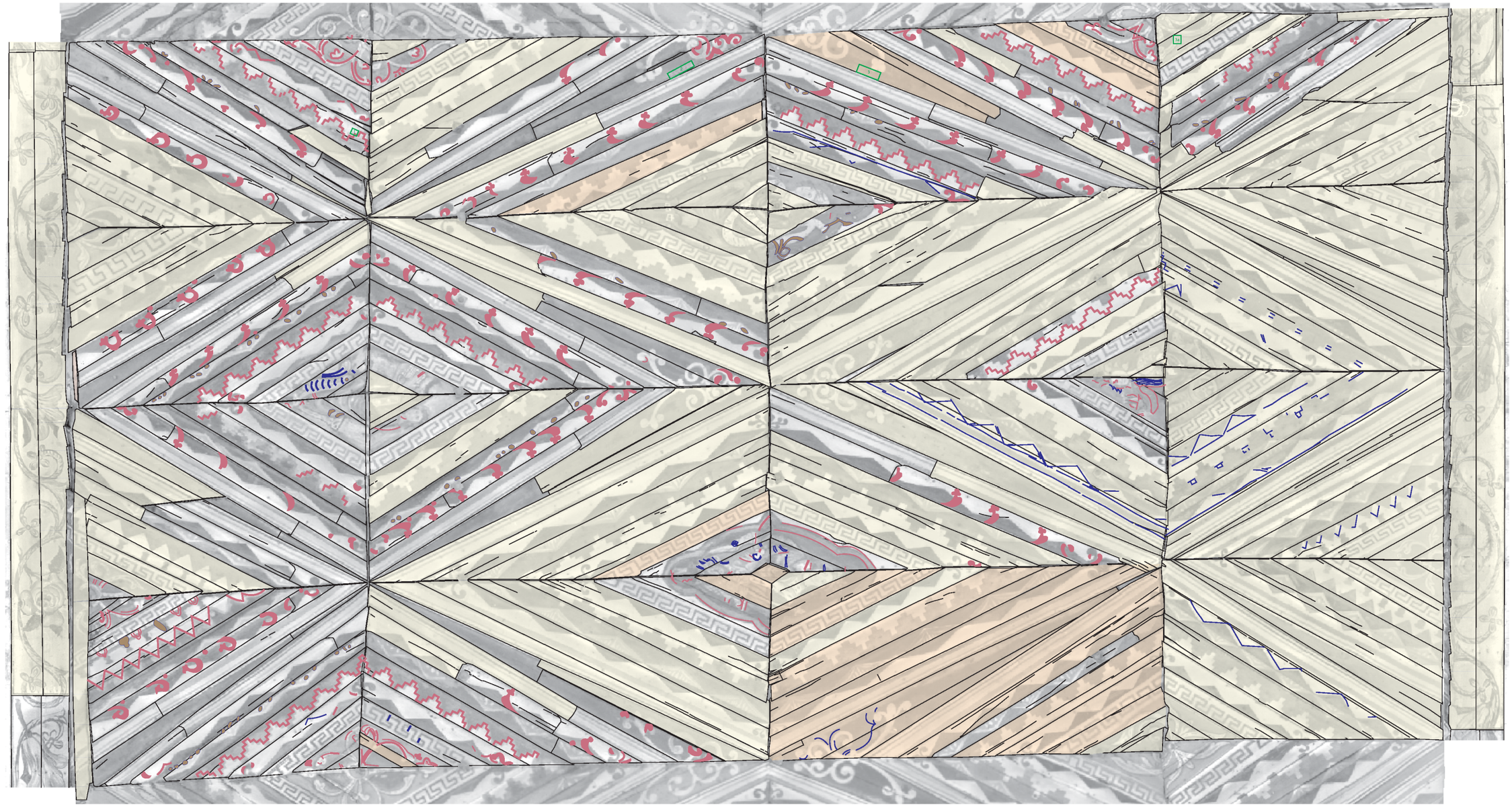


KEY FOR VISIBLE UNDERPAINT

- # Graffiti
- Original designs
- 1740s and 1830s designs
- Repositioned oak boards
- Repositioned oak boards with possible original frieze underpaint
- Possible 1740s softwood ceiling boards
- 1830s softwood ceiling boards
- Softwood ceiling boards with 1740s frieze design underpaint
- Edges of ceiling boards

GRAPHIC NO: 9A

N

SCALE 1:35

0 1m 2m 3m

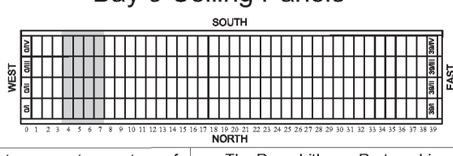
TITLE

PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE CONDITION SURVEY AND TREATMENT

DESCRIPTION Graffiti, Visible Underpaint & Replacement Boards

POSITION Bay 9 Ceiling Panels



Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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NOTES

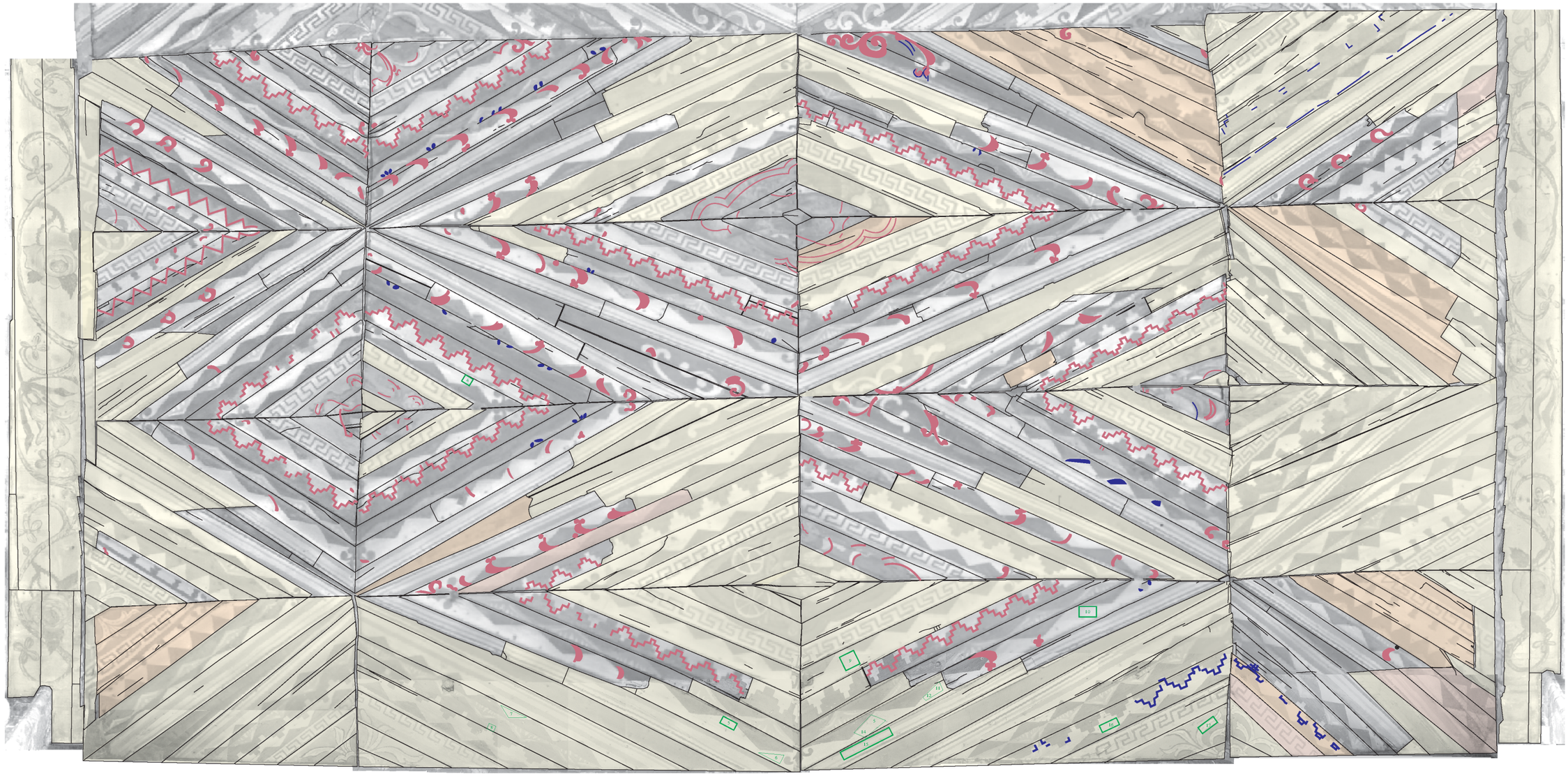
Graffiti - There is a considerable amount of graffiti at the west end of the ceiling giving the names of carpenters and painters working on the ceiling in the 1834/5. Also, the centrally placed door in the West End Vertical boards allowed limited access to the vertical boards and *Panel 0 III*; hence there are a number of pencilled inscriptions with a post-1830s date.

Replacement Boards - All added softwood boards, from the 1740s and 1830s interventions, as well as original oak boards that have been repositioned, are marked.

Visible Underpaint - All evidence of the original and 1740s painted scheme visible in raking light beneath the 1830s repaint is plotted on this graphic, including the 1740s frieze scheme visible as underpainting on a number of softwood replacement ceiling boards .

I II III IV

3 2 1 0



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- # Graffiti
- Original designs
- 1740s and 1830s designs
- Repositioned oak boards
- Repositioned oak boards with possible original frieze underpaint
- Possible 1740s softwood ceiling boards
- 1830s softwood ceiling boards
- Softwood ceiling boards with 1740s frieze design underpaint
- Edges of ceiling boards

GRAPHIC NO: 9B

N

SCALE 1:35

0 1m 2m 3m

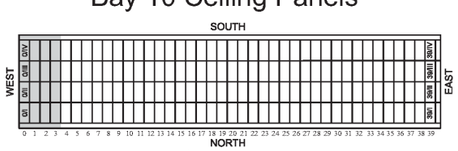
TITLE

PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE CONDITION SURVEY AND TREATMENT

DESCRIPTION Graffiti, Visible Underpaint & Replacement Boards

POSITION Bay 10 Ceiling Panels



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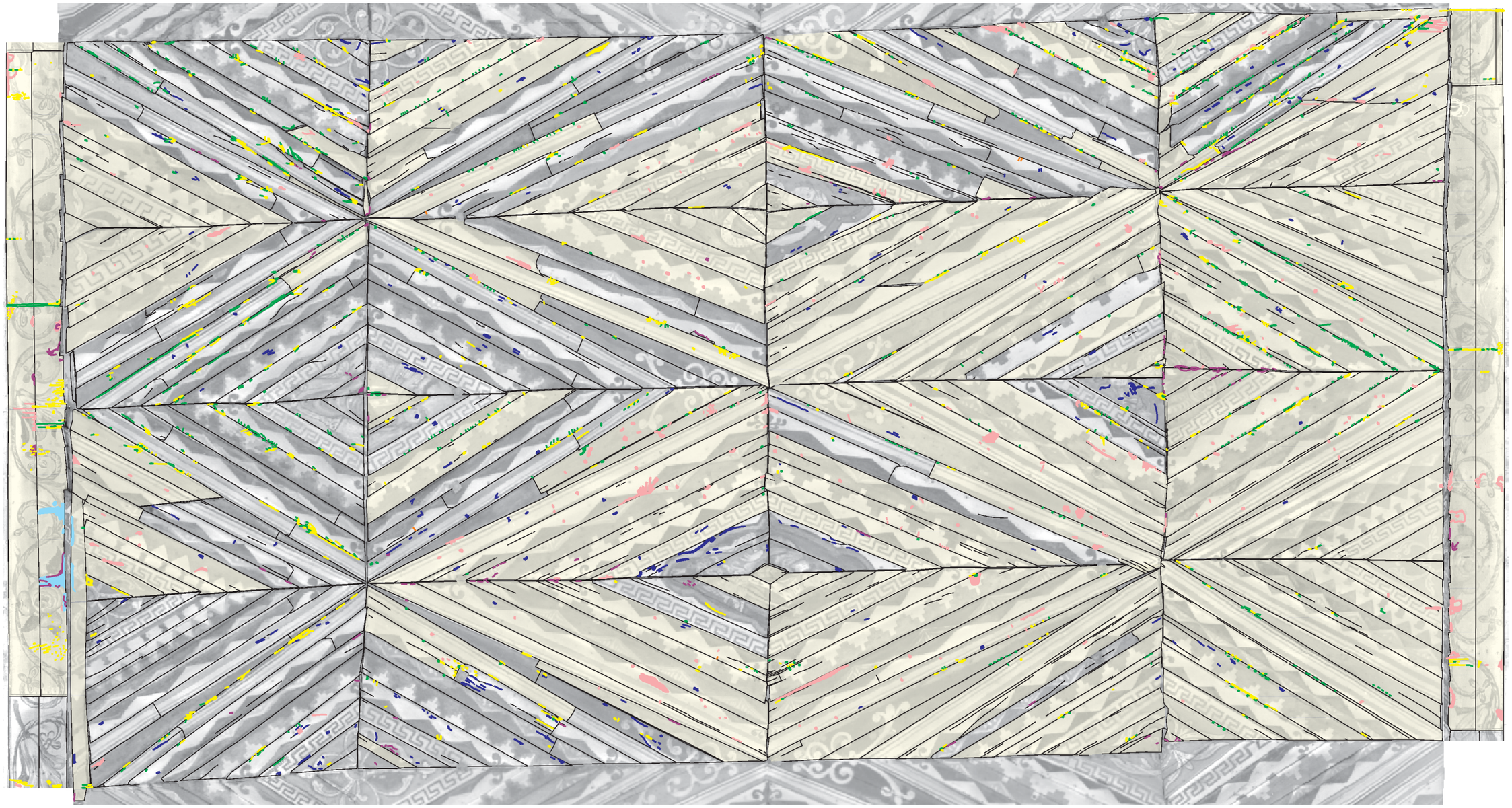
I II III IV

7 6 5 4



I II III IV

KEY FOR PAINT & SURFACE ACCRETIONS

- Flaking Paint and Glue
- Surface Glue
- Flaking Paint
- Brown Drips
- Water Damage
- Chemical Stains
- Efflorescence
- Softwood ceiling boards

Edges of ceiling boards

GRAPHIC NO: 10A

N

SCALE 1:35

0 1m 2m 3m

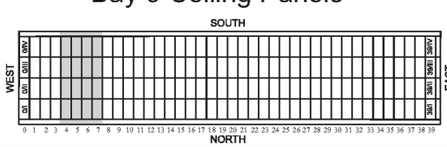
TITLE

PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE CONDITION SURVEY AND TREATMENT

DESCRIPTION Paint & Surface Accretions

POSITION Bay 9 Ceiling Panels



Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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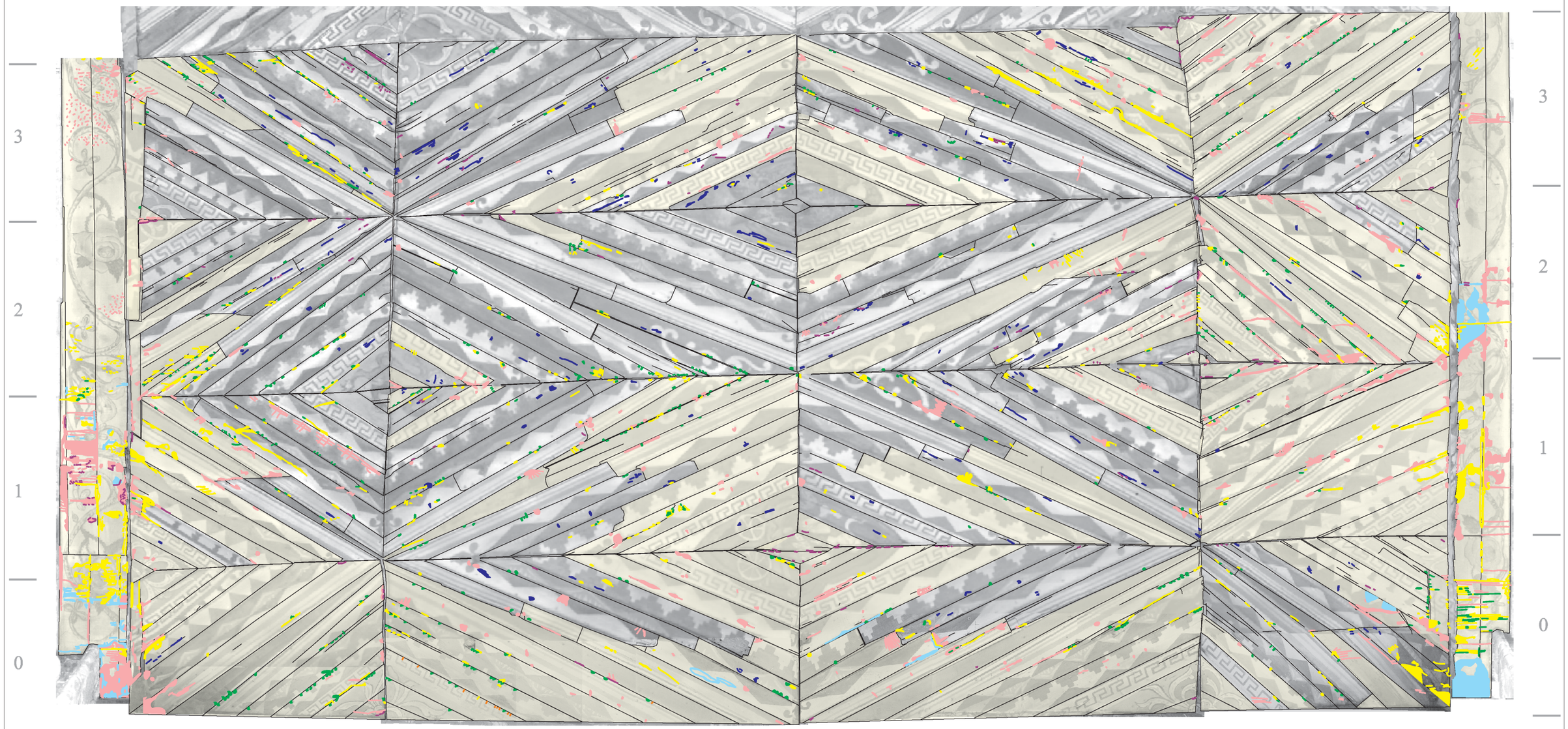
NOTES

Flaking Paint - The primary cause of flaking paint on the Nave Ceiling is long term water infiltration leading to deterioration of the wood support and subsequent loss of adhesion. All flaking paint was re-attached during treatment.
Glue - The extensive glue deposits on the edges of straight-edged boards cannot be shown here. As far as is possible all glue deposits on the surface were removed.
Flaking & Glue - In general, the glue caused paint flaking only where it had collected in thick droplets or runs. Glue deposits are less likely to cause flaking of the more robust white background paint.
Staining - All stains on the painted decoration result from liquid material penetrating down between the boards or through cracks in deteriorated boards.
Efflorescence - In Bays 4-10 the 'white chalk line' efflorescence (in previous phases associated microflaking on the wave pattern boards) was found on other boards particularly around the edges of splits : at least two different salts are present, chloride and sulphate. All efflorescence was removed.



KEY FOR PAINT & SURFACE ACCRETIONS

- Flaking Paint and Glue
- Surface Glue
- Flaking Paint
- Brown Drips
- Water Damage
- Chemical Stains
- Efflorescence
- Softwood ceiling boards

Edges of ceiling boards

GRAPHIC NO: 10B

N

SCALE 1:35

0 1m 2m 3m

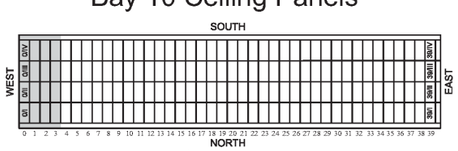
TITLE

PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE CONDITION SURVEY AND TREATMENT

DESCRIPTION Paint & Surface Accretions

POSITION Bay 10 Ceiling Panels



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BAYS 9 & 10 CEILING BOARDS
(reflected view)

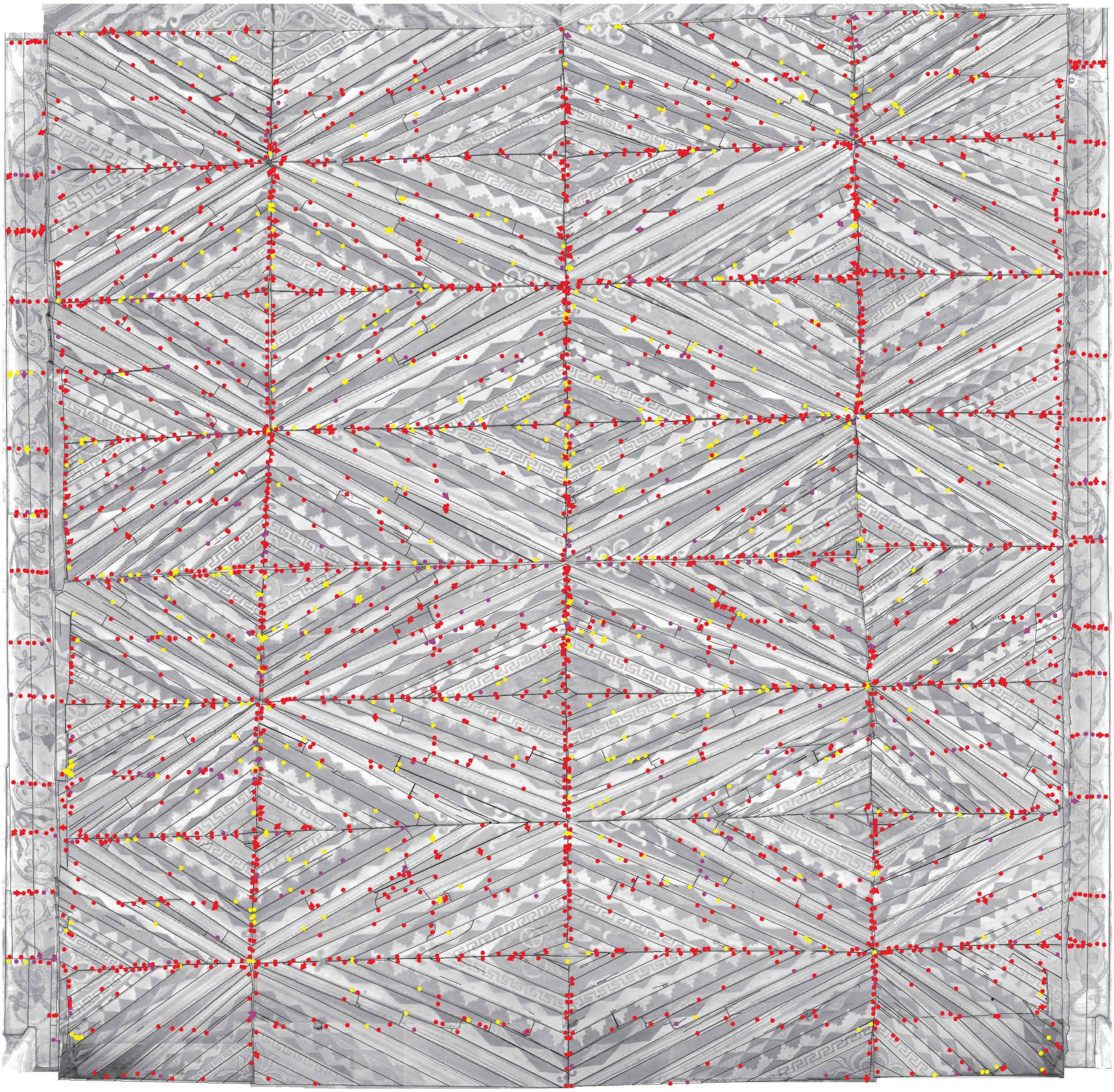
EAST

I II III IV

7 6 5 4 3 2 1 0

NORTH

SOUTH

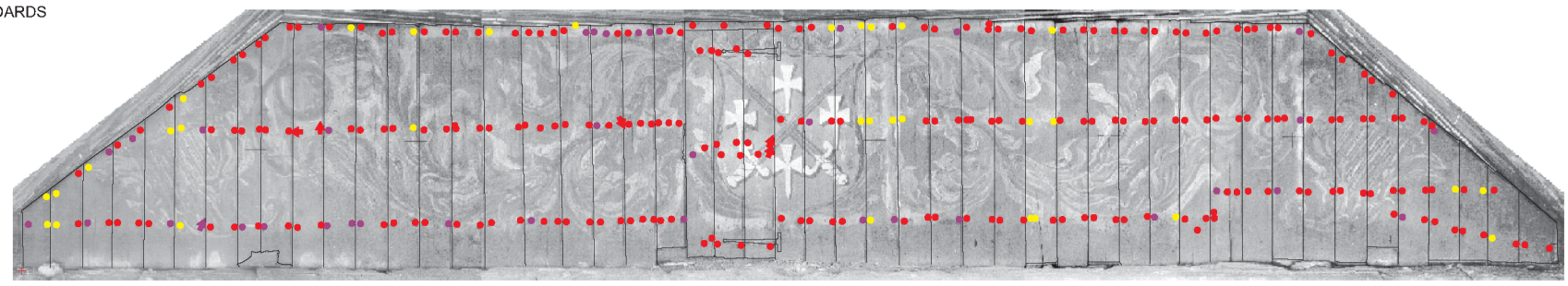


I II III IV

WEST

WEST WALL VERTICAL BOARDS
(non-reflected view)

SOUTH



NORTH

West Wall Vertical Boards
(non-reflected view)

NOTES ***Paint Surviving on Nail Heads*** -The nail heads are shown here as oversized to aid visibility. The groupings signify the percentage of paint remaining on each nail but do not indicate whether the surviving paint was flaking. The same material in the same solution (Paraloid B72: 10% in acetone) was used both to re-attach flaking paint on nail heads and to coat exposed metal. In Phase 3 we observed for the first time that all nail heads and ceiling bolts covered by this paint without an intervening white lead ground have corroded to the extent that little or none or the covering paint survives. Whereas many of the nail heads with the 1740s red and green paints are similarly corroded, with the 1740s brown/black paint it occurs in every case.

KEY FOR PAINT ON NAILS

Paint Surviving on Ceiling Bolts & Nail Heads:

70-100%

30-70%

0-30%

Edges of ceiling boards

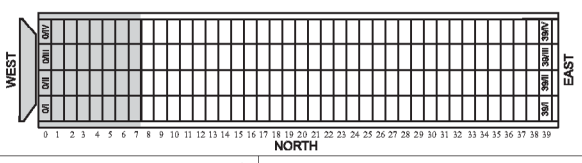
GRAPHIC NO: 11

N

SCALE 1:50

0 1m 2m 3m 4m

POSITION Bays 9 & 10



TITLE
PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE TECHNICAL SURVEY

DESCRIPTION Paint on Nail Heads

Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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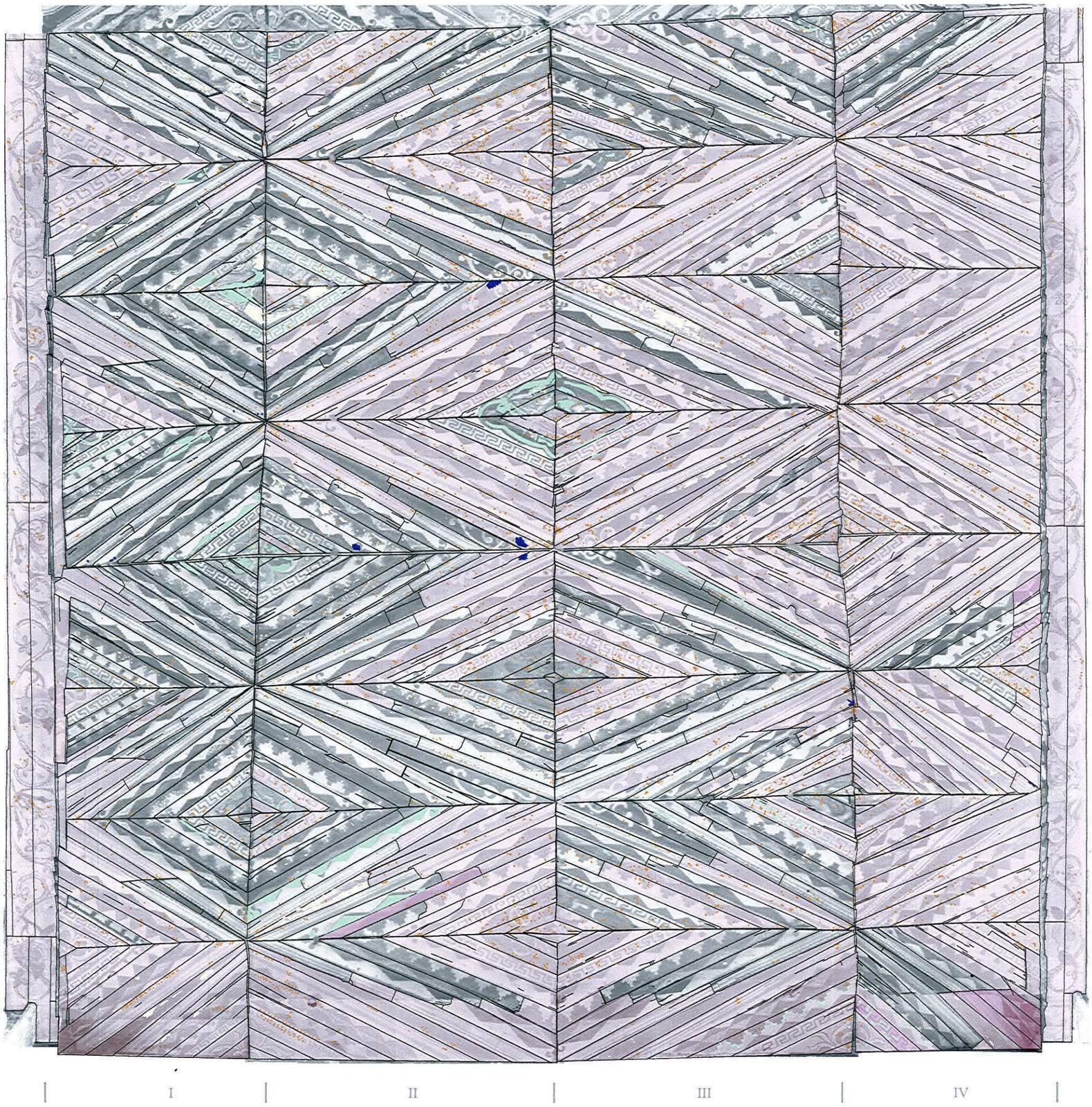
BAYS 9 & 10 CEILING BOARDS
(reflected view)

EAST

I II III IV

NORTH

SOUTH

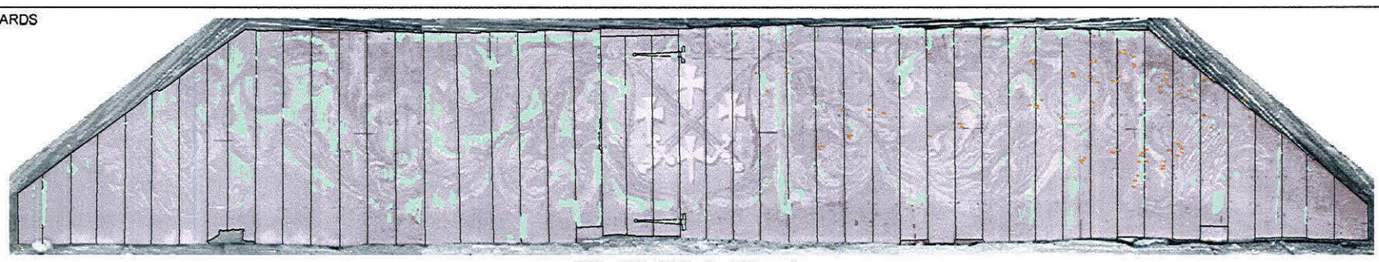


I II III IV

WEST

WEST WALL VERTICAL BOARDS
(non-reflected view)

SOUTH



NORTH

West Wall Vertical Boards
(non-reflected view)

NOTES ***Patchy white deposits*** - Associated with the thick resinous 1830s black paint/coating remain unidentified Initially they were considered to be some form of microbiological growth (MBG) but analysis indicates they are accumulations of irregularly shaped, translucent, plate-like crystals. The recent discovery of a list of materials used the 1830s restorers would suggest that the inclusion of sugar of lead (lead acetate) in the paint may be a factor. ***Matt white patches*** - These have a grey/white, powdery, matt surface and are generally found on the black of the wave and extended chevron boards. Often associated with the application of other paint layers. It can usually be removed or reduced with a Wishab. ***Tendril deposits*** - These resemble miniature spider web, joining larger elements together. This type of deposit may have originated through microbiological action: analysis found some collapsed strand material. ***Brown/white blotches*** - These accretions were widespread across the Ceiling. They are irregularly shaped, translucent granules. The spots were generally brown and at the centre there appears to be a dark brown particle, like a grain of sand, around it was a lighter brown or off-white halo with a fuzzy edge. As with the patchy white deposits, it may be the inclusion of sugar of lead in the 1830s paint is responsible. Surface Bloom - From Phase 3 onwards this has been re-defined to exclude the overall milky veil on some softwood replacement boards. Surface bloom occurs generally but is particularly evident on repainted backgrounds of the lozenge boards, where the 1830's red and blue has been laid over the olive green or red of the 1740's. It is patchy, white and matt . It can be reduced with a Wishab.

KEY FOR SURFACE ACCRETIONS

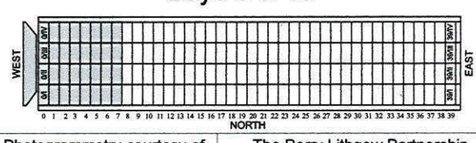
- Patchy white deposits
- Matt white patches
- Tendril deposits
- Brown/white blotches
- Surface bloom
- Softwood ceiling boards
- Edges of ceiling boards

GRAPHIC NO: 12

SCALE 1:50

0 1m 2m 3m 4m

POSITION Bays 9 & 10



TITLE
PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE TECHNICAL SURVEY

DESCRIPTION Surface Accretions

Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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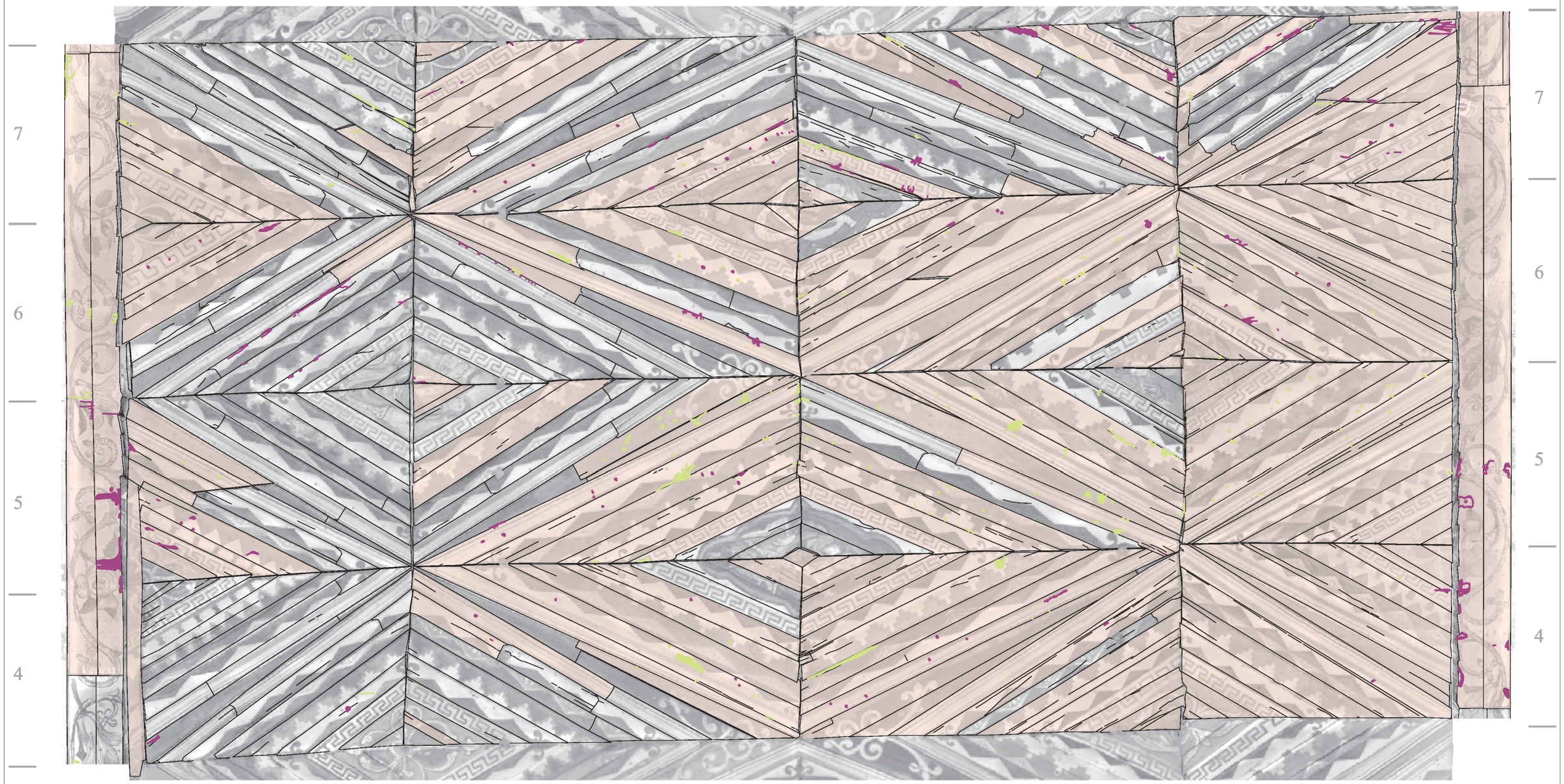


KEY FOR TREATED STAINS & REINTEGRATION

- Edges of ceiling boards
- Treated Chemical Stains
- Untreated Chemical Stains
- Reintegration of unpainted structure
- Softwood ceiling boards

GRAPHIC NO: 13A

N

SCALE 1:35

0 1m 2m 3m

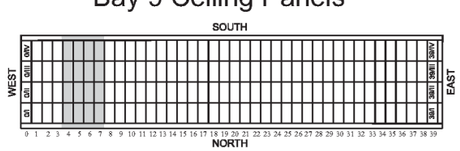
TITLE

PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE CONDITION SURVEY AND TREATMENT

DESCRIPTION Treated Stains & Reintegration

POSITION Bay 9 Ceiling Panels



Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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Oxon OX7 6UW Tel. 01608 658067

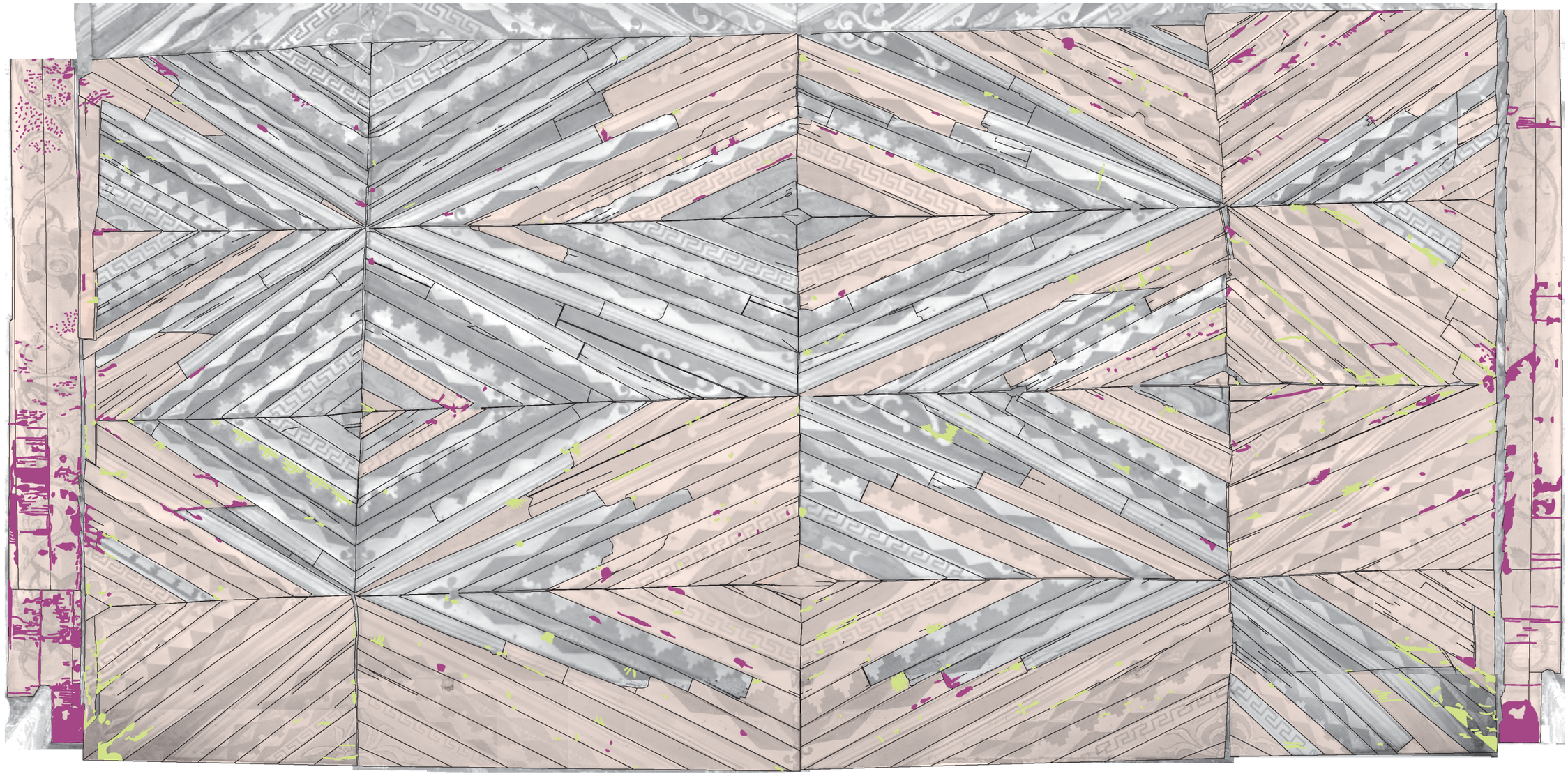
NOTES

Treatment of stains - This graphic does not include the brown drips or stains caused by water infiltration, all of which were removed or disguised during treatment. The policy adopted for this project has been that other surface staining considered to be particularly distracting and visible from the ground should be removed, reduced or disguised. Almost all stains were reduced rather than removed. The method and materials used to treat each stain have been recorded on the hand plotted, 15:1 scale graphics. These graphics are included in the source material for this project.

Reintegration of unpainted structure - Throughout the project some areas of distracting wood loss and unpainted gaps between ceiling boards were disguised by inpainting the exposed edge of damaged board or underlying structural elements such as softwood patch, hessian and, at the junction between canted and horizontal panels, noggins).

I II III IV

3 2 1 0



KEY FOR TREATED STAINS & REINTEGRATION

- Edges of ceiling boards
- Treated Chemical Stains
- Untreated Chemical Stains
- Reintegration of unpainted structure
- Softwood ceiling boards

GRAPHIC NO: 13B

N

SCALE 1:35

0 1m 2m 3m

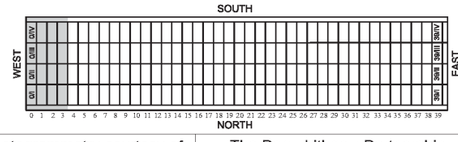
TITLE

PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE CONDITION SURVEY AND TREATMENT

DESCRIPTION Treated Stains & Reintegration

POSITION Bay 10 Ceiling Panels



Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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Oxon OX7 6UW Tel. 01608 658067

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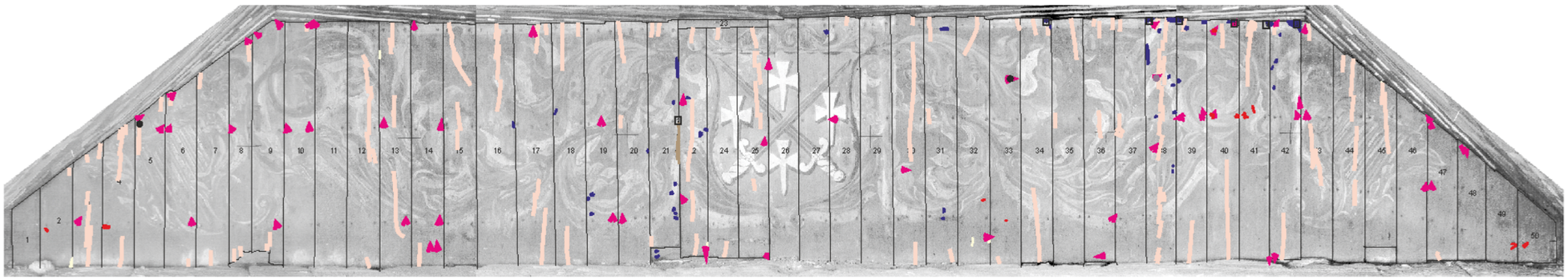
I II III IV

3 2 1 0



KEY FOR DAMAGE TO CEILING BOARDS

- Wood loss
- Intended wood loss
- Insect damage
- Impact damage
- Splits in boards
- Surface splintering
- Nail holes (ex nail heads)
- Screw holes
- Edges of ceiling boards

GRAPHIC No: 14

N

SCALE 1:35

0 1m 2m 3m

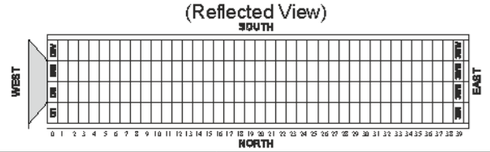
TITLE

PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE CONDITION SURVEY AND TREATMENT

DESCRIPTION Damage to Ceiling Boards

POSITION West Wall Vertical Panels (Reflected View)



Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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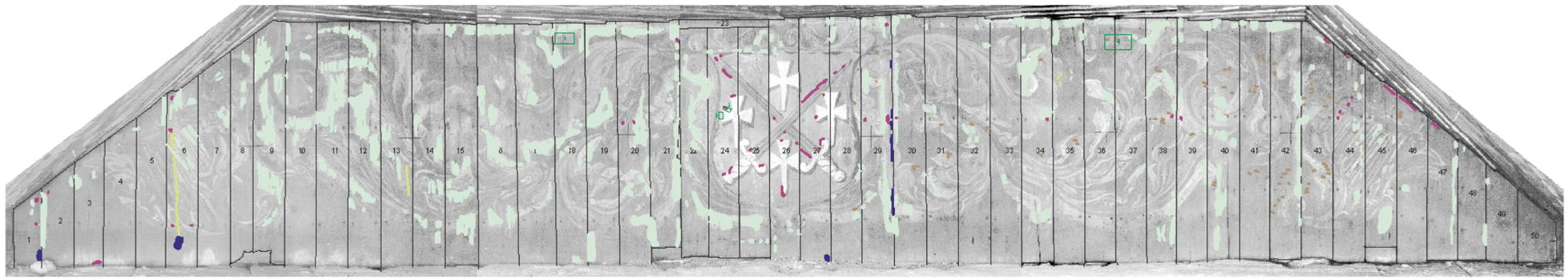
NOTES

I II III IV

3 2 1 0



KEY FOR PAINT & SURFACE ACCRETIONS

- # Graffiti
- Flaking Paint
- Efflorescence
- Stains (other)
- Surface bloom
- Brown/white blotches
- Edges of ceiling boards

GRAPHIC No: 15

N

SCALE 1:35

0 1m 2m 3m

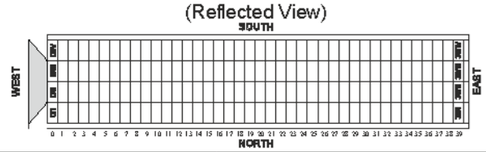
TITLE

PETERBOROUGH CATHEDRAL - NAVE CEILING
Conservation Programme Phase 5 (May - October 2003)

STAGE CONDITION SURVEY AND TREATMENT

DESCRIPTION Paint and Surface Accretions

POSITION West Wall Vertical Panels (Reflected View)



Photogrammetry courtesy of English Heritage Survey Team & Photarc Surveys Ltd.

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NOTES ***Graffiti*** - The most interesting graffiti on the West End Vertical boards is an indistinct white painted inscription " ...Cobley Painter 1835" within a small foliate cartouche, also painted in white.

Flaking Paint - The primary cause of flaking paint on the Nave Ceiling is long term water infiltration leading to deterioration of the wood support and subsequent loss of adhesion. All flaking paint was re-attached during treatment.

Staining - All stains on the painted decoration result from liquid material penetrating down between the boards or through cracks in deteriorated boards.

Brown/white blotches - These accretions were widespread across the Ceiling. They are irregularly shaped, translucent granules. The spots were generally brown and at the centre there appears to be a dark brown particle, like a grain of sand, around it was a lighter brown or off-white halo with a fuzzy edge. As with the patchy white deposits, it may be the inclusion of sugar of lead in the 1830s paint is responsible.

Efflorescence - Prior to surface cleaning the paint surface on the west end vertical boards was partially obscured by a white efflorescence. This was largely removed during the cleaning process.

APPENDICES

APPENDIX 1

List of Plates (Volume II)

1. THE CEILING STRUCTURE

TECHNICAL SURVEY:
THE ORIGINAL CEILING STRUCTURE, UPPER SIDE

Plate 1 *Panel 3 I* , another example of the original boards originally stopping approximately 100mm short of the ashlar boards. The same feature is reflected in the 1740s boards in *Panel 0 IV* which also stop well short of the ashlar boards. The irregularity of this feature can be understood when comparing the substantial distance in Rows 0 south side, and 3-5 north side, with Rows 6 and 7 north side where the original boards extend right down to the ashlar boards.

This plate is inserted at the beginning of the List of Plates because it could demonstrate the movement of the building as a whole. The plates referring to this can therefore neither be classified as ceiling structure or is related to the boards or their subsequent restorations.

Width of nave
Row 17 10.922
Row 12 10.861
Row 8 10.803
Row 0 10.580

Plates 2 –17 Upper side of the ceiling before treatment. **Plates 2-5** show *Panel I*, rows 7 to 0; **Plates 6-9** show *Panel IV*, rows 7 to 0; **Plates 10-13** show *Panel II*, rows 7 to 0; and **Plates 14-17** show *Panel II,* rows 7 to 0.

Plate 18 North end of sloping joist 70, showing the mortice for the original ashlar post.

At the time of sorting the photographs, it was not understood that joist 81 was an 1830s replacement. **Plates 22 – 23** relating to this joist are therefore described in the 1830s section. Similarly it was not realised that joist 73 was original so **Plates 63** and **65** put in the 1830s section are described below in their correct place.

Plates 19-20, These plates are of flat joist 73. This joist is unique. The size of the timber is quite different to all others being 6" x 6" (150mm x 150mm) in comparison to 7" x 5" (175mm x 125mm) for all other flat joists. It is also straight cut not cambered. **Plate 63** shows there to have never been a halving joint at the junction with south sloping joist, though the mark on the upper face looks to show that the original sloping joist was halved on its west face. On the other hand, **Plate 65** shows that the flat joist is halved at the north junction but as there are marks of a timber passing the joist on the east side, I am wondering if the halving joint was made after the flat joist was first installed, and that when originally erected, both scissor braces were halved over and pinned to the east side of this flat joist. **Plate 19** shows the wide dovetail in the middle of joist 73 with normal round pin. The unusual width dovetail is therefore significant in emphasising the individuality of this joist. Compare with **Plate 31** Phase 4 Report, and **Plate 30** Phase 3 Report.

The empty birds beak for the panel noggin (now missing) in the underside of joist 73 can be seen in **Plate 20** . Note also the semi circular cut out (notch) in the edge of the board. As this is a repositioned original board, the cut out may not be a notch (the term as used for these radiused cut-outs) but only a loss where the board was decayed before it was moved, this loss now being covered by the adjacent board.

Plate 21 The south scissor brace joint of joist 75 showing a beautifully fashioned pin securing the joint driven from the east side. Note the pin emerging in the centre of the sloping face of the halving joint (it must have been driven from the underside) and the pale patch in the

top edge of the halving joint in the ceiling joist which is a hole bored for a dendrochronological core.

Plates 23 – 23 See under **Plates 62 – 66**. .

Plates 24-25 These two plates are record shots to show the pit at the west end of the north side of the roof which is much shorter than the normal because the west wall returns beneath the quoin of the north tower. **Plate 24** shows the end of joist 78 which has much of the side lap still surviving, and is cut short of the ashlar so is supported by a sprocket piece bearing on the stone plinth for the truss shoe.

Plates 26-27 These two plates show the over-sailing stonework for the original roof. Note how the eaves detail, can be traced in the discoloured stonework below. The short post and beam in line with the inside face of the wall support the rafter feet along to the west end of the roof.

Plates 28-29 **Plate 28** is a record of a nail in an empty birds beak joint in *Panel 2 I (e).* In the very centre of **Plate 29** in the gap between the two boards in *Panel 3 I (q),* a nail head can just be seen which is attaching a noggin to the joist above. Note the tight joint of the noggin within the birds beak.

Plate 30 A typical example of the profile of a curved edged board board *(f) Panel 7 IV*. Note the shallow shamfer made to accommodate the adjacent board running out from the empty nail hole to the right side of the board (as seen in this plate).

Plate 31 *Board z, Panel 2 II***.** Note the radiused cut out of the board.

Plate 32 A typical square pin in the butt joint of the base boards.

Plate 33 Judder marks probably caused by the scratch stock catching in the hard and soft grain between medullary rays, note also **Plate 39**.

Plate 34 Occasionally boards just short of the required length were not extended with scarfed pieces, but this was rare and confined normally to pieces not more than 1" (25mm) long. Either they were apparently left short or as it appears in this case extended with another piece nailed separately. There is a composite joist above this joint so it is likely that in the course of renewing the joist the original extension was lost. Note the close grain exposed.

Plate 35 Note the scratch line in the grooved board just to the right of the round edged board. This can only have been made when the ceiling was originally assembled and appears to show that the boards were part assembled, then taken down and then final fixed as a separate operation.

Plates 36 - 38 Further examples of torn grain (**Plate 37**) and rough conversion (**Plates 36** and **38**). The frequency of use of these boards damaged at the time of their original production is similar in this Phase of work as in the previous. It is still worth pointing out that these damaged boards were used, in contrast with the care taken to fit them into the ceiling. It may of course merely point to the value of the timber and the fact that none could be wasted, although one cannot see why the affected boards could not have been cut into two short boards, therefore allowing the damaged piece to be discarded at the end of a board. It is also surprising for so many of the surfaces of the boards to be perfectly flat, and to then come across isolated examples of really poor workmanship.

Plates 39 - 42 This group of plates illustrates different types of scarf joint and varying nailing patterns used to attach them. **Plate 39** shows a beautifully fitted scarf, with both boards moulded to the same profile as though they are temporarily fixed together and moulded and then fixed on site presumably as two separate pieces. **Plate 40** shows a scarf fixed with three nails with obviously no attempt to run the moulded edge along both boards

simultaneously. The top board *(i Panel2 II*) has a regular slow rounded profile, whilst the adjoining board (*j Panel 2 II*) that at the bottom of the photo has a rather rough quick round hardly more than a pencil round. In **Plate 42** the upper scarf is quite standard but with only one nail, but the lower has two nails one standard original and one small headed original. Here the right hand board (*q Panel 4 I*) has been crudely shamfered, but it seems that after fixing on site, a further shamfer does run across the joint of both boards (*q* and *p*) in an attempt to run the mould across the scarf. **Plate 41** is a good example of standard nailing of original board ends with two standard original nails per board.

Plate 43 Note the unused pre-drilled nail hole in the left hand lower base board. The hole immediately beneath looks to have been used but without the nail being driven home as there is no mark from the nail head, the hole has been opened slightly as can be seen by the splits in the board on either side of the hole. Note the other unused pre-drilled nail hole in **Plate 40** in the right hand edge of the grooved board opposite the scarf.

Note the frass edges in Plates 40 and 43.

Plate 44 An example of double nails, there is no evidence below the ceiling of why two nails were driven side by side.

1740's / 1830's RESTORATION

Plates 45 - 60 **Plates 45** to **52** show the junction of the flat ceiling with the sloping ceiling on the south side, and **Plates 53** to **60** show the same junction on the north side on the ceiling. Each pair of photographs consists of one taken obliquely facing west (first) and east (second). These photographs demonstrate a much more thorough and logical repair strategy carried out in the 1920s. ALL the junctions are now linked either with 1920s laminate system or are complete original joints or those made in the 1830s when 8 sloping joists and one flat joist were renewed with reused ceiling/roof timbers.

Plates 45/46	South sloping joists 67, 68, 69
Plates 47/48	South sloping joists 70, 71, 73
Plate 51	South sloping joist 81
Plate 59	North sloping joist 81

The 1920s link repairs between the flat and sloping joist are interesting for showing the laminated system used, and the apparent desire to hide them with covers.

Plate 61 Evidence of a reused piece to make an ashlar post as the pin hole in the ashlar post has no matching hole in the sloping joist which it is meant to be supporting.

At the time of sorting the Plates, it was not understood that joist 73 was an original joist, so photographs relating to it were put under the 1830s section. **Plates 63** and **65** are therefore described earlier in the Original Construction section with **Plates 19** and **20**. Similarly it was not realised that joist 81 was an 1830s replacement, so Plates 23 and 213 relating to it are described below in their correct position.

Plates 62, 22, 64 Halving joints cut out of joist 71 (**Plate 62**), joist 81 (**Plate 22**). Note the halving joint, the hole bored for the pin and a 1920s laminated infill and joist 73 (**Plate 64**) showing that they are reused scissor truss timbers.

Plates 63, 65 See under **Plates 19 – 20.**

Plates 23, 66 South sloping joist 81, again a replacement by Blore. The evidence of the remnant of noggin still nailed in the birds beak in the top of the joist seems to indicate that this timber was a ceiling joist, and has been merely turned over. The pattern of nailing on this face has been recorded and is shown on **Drawing 2**.

Plate 67 Alignment line drawn on adjacent original board from edge of 1740s board.

Plate 68 The left hand board with the underpainted greek key is a 1740s board in a whole panel of 1740s boards. There is no evidence of nail holes showing that these boards have been moved in the 1830s so it can be assumed that the nails are also 1740s. This is a good example of nails of this date showing that they have faceted heads that come to a point in the middle of the head just like the flat headed 1830s nails. Here all similarity stops as the 1740s nails are irregular in size and shape, note the two small headed nails and the three large headed.

Plate 69 An unprepared 1830s softwood board similar to those found previously, note **Plate 64** Phase I.

Plates 70 - 71 All these nail heads are 1830s flat headed nails. Note the faceted heads and regularity of shape and size. It is interesting to see the partly planed surfaces of both boards in the upper part of **Plate 70** and the left board in **Plate 71** where the rough surface similar to that shown in **Plate 69** is still partly visible.

In addition, **Plate 70** shows some long splits emanating from nails driven from above in the extended chevron board. There is also a very long split from the original nail in the edge of the same board. The first mentioned splits look to have been made when the nails were driven, and the long one has formed as the board has shrunk following the introduction of heating. **Plate 71** shows in addition incision marks made in the 1830s when they were setting out the extended chevron. Note also the very clear raised linear "underpaint".

Plates 72 – 73 Further examples of impact damage from careless use of hammers. This damage is less common in this phase, so no doubt the damage was made by one or two workmen only rather than the whole gang. The hammer marks in **Plate 73** are unexplained as there are no nails near where the hammer marks are.

Plate 74 1830s nails presumably originally driven into a patch above and then clenched over the top of the patch, driven back down by Moore when the patches were removed and now hang from the clenching.

Plates 75 – 78 In previous phases 1830s repairs have been criticised for poor workmanship. In this phase there is one example of a very sympathetic 1830s repair (**Plate 75**), and one of a repair of good intent even if not terribly well finished (**Plate 76**). Plate 77 is interesting because it shows a 1740s repair carried out very sympathetically.

Plate 75 shows where the whole left panel (as seen in the plate) was renewed taking care to scribe the new boards over the existing sloping boards. This seems to have included springing the ends of two of the sloping boards so that the new boards would fit behind/above them. An extraordinary feature of the half lozenge board is that a single board was curfed on the line where the angle of the flat ceiling becomes sloping, and then bent on the curf line to accommodate the change in angle. In **Plate 77** we see an insert scarfed at both ends let into an original board also scarfed twice to receive the insert. This would be unusual for an 1830s repair which is why it is an important example of a 1740s repair, of which there are very few similar. Note the length of the scarves which are much longer than original scarves in original boards. **Plate 76** shows an insert that has no apparent fixing and must be rebated over the board in which it is inserted. Although the original board was cut out rather crudely, the new piece was inserted sensitively. The grooved incision line in **Plate 78** marks a patch of boards renewed with reused original boards and one 1830s board. This type of patch has rarely been seen except in Bay 1. In the reassessment written following the fire, it was strongly suggested that the vertical saw cuts were associated with 1740s work as they always marked patches of 1740s boards or reused original boards. These latter were far more frequently associated with 1740s repairs than 1830s. It is suggested that this patch of inserted boarding is therefore 1740s and the incision line must be the same date.

Plates 79 – 81 The west wall boarding was fairly consistently nailed with two nails per board at the top middle and bottom of each board. Boards 17-21 were nailed with three nails instead of two. **Plate 79** shows some boards with three nails (flat heads) and **Plate 80** two nails (uncategorized, but more like square heads). **Plate 81** shows a curious cut out in the bottom of boards 8-9, a similar cut out is found at the other end of the boarding in board 45, and another in the centre of the boarding in board 21. There is no surviving evidence for the reason for these cut outs.

1926 REPAIRS

Plates 82 – 84 Examples of laminated joists. **Plate 82** is the junction of a laminated joist to the reused sloping joist 68. **Plate 83** shows the carefully fitted laminates, which must be purely cosmetic? **Plate 84** shows the laminated construction inside a Composite joist.

Plate 85 Another noggin variant. In this case the centre noggin is supported on bearers which are nailed to battens fixed to the sides of the joists. The bearers are recessed below the top laminate.

Plate 86 A record plate showing an original noggin supported by angle brackets fixed to the side of an original joist.

CONDITION

Plate 87 A typical Intended wood loss in *Panel 2 III (x).* This cut out is contiguous with many others discussed previously.

Plates 88 - 89 Another example of the so far unexplained pattern of "weathering" to the baseboards. In many cases, the wide part of the baseboard is deeply weathered but the narrow tapered end is quite flat. These two plates show the difference along the same board, **Plate 88** being at the wide part and **Plate 89** at the narrow.

Plates 90 - 91 Examples of weathering to the surface. Both plates are excellent examples of alternative weathering on the same board in adjacent areas. The extent of the weathering is seemingly determined by the colour on the surface. In both plates, the dark areas are deeply weathered whereas the white areas are almost smooth.

Even more noteworthy is the fact that the line itself is raised above both the black surfaces and the white surfaces. On the basis that present research shows that no areas of the surface were ever painted (in the areas of the pattern) it would seem that the original lines have protected the original surface the most, and that either the white areas were painted next and many centuries later the black were painted. Or both the black and white areas were painted simultaneously and the white paint protected the surface well whereas the black did not. Alternatively, the black paint might even have attacked the timber surface due to some ingredient which proved to be damaging to the timber substrate. See also **Plate 71** for raised linear decoration.

Plates 92 – 95 These plates display various types and levels of beetle infestation. **Plate 92** shows the timber loss due to infestation by Death watch beetle of a sap edge. **Plate 93** is a good example of the typical infestation of the sap edge of a board. Cathy Groves has identified these edges not actually as sap but as the boundary between the sap and the heartwood. See also **Plates 40** and **43**.

Plates 94 and **95** show general quite intense levels of infestation in original boards, with greater than expected levels of Common furniture beetle infestation only in **Plate 94** and mixed with DWB in **Plate 95**.

Plates 96 - 100 These plates all show varying types of commonly found split. Each example appears to be the result of subsequent shrinkage rather than due to the force of a nail being driven into the wood. (See also **Plate 70** where splits are discussed) **Plate 96** shows an 1830s nail driven from above through an original board, the black painted part of the board has shrunk away from the grooved section, which being restrained by the nail has caused the board to split. In **Plate 97** the edge of the raised board has split off completely allowing the board to shrink away from the nail, the extent being easy to gauge as the position of the nail pre the last repaint being clearly visible. **Plate 99** shows a split in a 1740s board which being heavily infested with CFB has crumbled along the split line.

Note the stainless steel screw inserted to hold the split fragment.

The long split in the Greek key painted board in **Plate 100** shows the shrinkage of a softwood board restrained by nails across its width.

Plate 98 A crude wood loss of indeterminate age. The loss of paint on some edges would indicate that this is cut out has been made since the 1830s, but the blue paint in the right hand chisel cut in the bottom board seems to contradict this.

Plate 101 A large knot in a 1740s softwood board, with a shrinkage split caused by the nail nearby.

REPAIRS

Plate 102 A temporary ceiling bolt with plasterzote protective washer, note the earlier paint layer revealed.

Plate 103 Bob Chappell removing a hanging bolt prior to conservation. Self adhesive dots were applied to both the bolt head and washer to ensure they both returned to their original orientation.

Plate 104 A stainless steel rod fitted and shaped to hold the fractured board end. The rod is held by the screw beyond the end of the board (below it the photograph).

Plate 105 Fills inserted in decayed edges of boards before retouching.

Plate 106 In several instances the screws fixing the top carrying-noggin to the noggin laminates fixed to the ceiling were too short so there was no attachment between the two. These noggins were well designed so that the top carrying-noggin did pick up the weight of the laminates and the ceiling and pass it back to the joists. For there to be no attachment between the carrying-noggin and the noggin laminates therefore completely negates the structural design of the noggin. The short screws were taken out and normally exchanged for stainless steel. In this case the bigger gauge stainless screws were not available, so the original screws were reinserted more deeply countersunk to achieve the connection required.

Plate 107 Two screws are shown removed and replaced with stainless steel. The third was incorrectly located and was not projecting, so it was not replaced. A small sailcloth patch is shown.

Plate 108 In places where screws had been removed near a roof light, light could sometimes be seen twinkling through the hole even from the floor. These holes were covered with Plasterzote tabs.

TIMBER INSERTS

Plates 109 – 111	Lozenge *6/5 I/II*	Before and after fitting and inpainting timber insert.
Plates 112 – 114	*Panel 6 II*	Before and after fitting and inpainting timber insert.

Plates 115 – 116	*Panel 4 I*	Before and after fitting and inpainting timber insert.
Plates 117 – 119	*Panel 3 II*	Before and after fitting and inpainting timber insert.
Plates 120-121,119	*Panel 3 II*	Before and after fitting timber insert (**Plates 120-121**)and inpainting (**Plate 119**).
Plates 122 – 124	*Panel 3 III*	Before and after fitting and inpainting timber insert.
Plates 125 – 126	*Panel 3 IV*	Before and after fitting and inpainting timber insert.
Plates 127 – 129	*Panel 2 IV*	Before and after fitting and inpainting timber insert.
Plates 130 – 132	*Panel 1 III*	Before and after fitting and inpainting timber insert.
Plates 133-134	*Panel 1 III*	Before and after fitting and inpainting timber insert.

GENERAL

Plate 135 Dennis Burrows filming Bob Chappell

Plate 136 Cameron Stewart vacuuming at the bottom of the ceiling with vacuum cleaner suspended from roof purlin.

Plate 137 Joist carrier set up with joist held in clamp.

2. THE PAINTED DECORATION

CONDITION SURVEY AND TREATMENT RECORD

Plates 138 to 297 Sections of the Ceiling structure lower side and painted decoration in before and after treatment sequence. Refer to Plate Reference Sheets for locations.

Plates 298 to 335 The thirteen full figurative lozenges and four half lozenges within Bays 6b, 7 and 8 in before and after treatment sequence. All ultra-violet (UV) illumination photographs taken before treatment. Refer to Plate Reference Sheets for locations.

Plates 336 to 351 Sections of the Ashlar boards and painted decoration in before and after treatment sequence. Refer to Plate Reference Sheets for locations.

Plates 352 to 359 Sections of the West End Vertical boards and painted decoration in before and after treatment sequence. Refer to Plate Reference Sheets for locations.

VISIBLE UNDERPAINT & ALIGNMENT MARKS

Plates 360 to 363 Examples of the original scheme visible in raking light beneath the 1740s and 1830s overpaint. It is now generally agreed that the receded background is the result of 'weathering' of the wood surfaces not protected by oil paint prior to the 1740s restoration. From this we must conclude that the oil-based paint layer did not extend overall the central lozenge boards. **Plate 360**, detail of a heavily weathered stepped chevron board with the original linear pattern out of phase with the overpainted decoration. Generally, the black areas on stepped chevron boards are more weathered than the white; although both sides have receded more than the surface protected by the oil painted linear stepped chevron pattern. This is significant as it suggests that the white areas on these boards may have been partially protected by a non oil-based paint while the black areas were unpainted. For some reason difference in weathering between the white and black areas is

particularly exaggerated on a number of boards at the west end of the Ceiling (see also **Plates 90 and 91**). **Plate 361 and 362** are raking light details of figurative lozenge boards showing the original outlines of some mandorlas are visible through differential weathering of the board surface. From this we must conclude that the oil-based paint layer did not extend overall the central lozenge boards. We know from tracing the 'visible underpaint' on the central lozenge boards that the C18th and C19th restorers copied closely the original figures. It is difficult to believe that only part of the figures would have been painted in the original scheme so the accumulated evidence suggests the original painting was of mixed media. It had seemed logical to suggest oil-based paints were used for flesh tones and other detailed features of the composition and distemper for the remainder. However the identification of original oil-based paint forming the plain red background to the Rhetoric figure,[1] together with the unpredictable pattern of weathering on central lozenge boards, and the general use of oil-based paints for the linear border decoration do little to corroborate this observation. Paint sample analysis carried out for this project has found no definitive evidence for the use of distemper paint on the ceiling. The incised alignment marks visible in **Plates 361 and 362** are considered to be original because in many instances the boards have C13th nails in place and therefore have not been repositioned. The incised setting out lines describing the wave pattern shown in **Plate 363** appear to have been made in the 1830s.

Plates 364, 365 Photographs showing original paint under original nail heads (now missing). Numerous examples were found within Bays 6b, 7 and 8 on central lozenge boards and border decoration, while in previous phases very few were found and then only on grooved boards with border decoration. This visual evidence and analysis of the nineteen paint samples taken in Phase 4 from under missing original nail heads has changed our understanding of the original scheme. We had considered it unlikely that the central lozenge boards were painted before being fixed in place but there is now ample evidence in the form of original paint under missing original nail heads to prove that they were. **Plate 364** shows red paint within the outer groove of two key pattern boards. Accumulated evidence suggests the three grooves in these boards were originally painted red white and red. Similar records of sixteen grooved, grey chevron boards indicate the middle groove was red and the inner and outer grooves usually white but on one board red. **Plate 365** shows white paint in an outer groove. A notable finding in our survey of weathering on original ceiling boards is that the raised areas either side of the grooves on grey chevron boards are consistently less weathered than equivalent areas on the coloured bands and key pattern boards. This finding would indicate that in the original scheme the raised areas on this board were painted; however there is no other visual evidence to corroborate this and it has not been substantiated by paint sample analysis.

1740S/1830S REPAINTING

Plates 366-369 Examples of the paint layer exposed from under temporarily removed 1830s Ceiling bolts and washers. The 1740s paint has been protected from subsequent overpaint and surface accretions. These examples indicate the condition of the painted decoration immediately prior to the 1830s intervention and provide visible confirmation of the analysis findings and our interpretation of the conservation history. **Plate 366** shows a fragment of original board with 1740s paint inserted as a packer in a hole cut into 1830s boards to accommodate the bolt washer. **Plate 367** shows 1740s red background paint to the Astronomy lozenge. This would suggest the background colour was changed in the 1830s. **Plate 368** shows the 1740s scheme within the Eagle lozenge may have been very different from the 1830s. **Plate 369** shows the 1740s scroll detail on the corner of a wave pattern board. The scroll detail was omitted in the 1830s in this instance only, presumably due to the positioning of the Ceiling bolt.

Plate 370 Throughout Bays 1-5 of the Nave Ceiling we have identified a number of softwood replacement boards with a scheme very similar to the existing 1830s frieze decoration visible in raking light beneath 1830s overpaint. These we consider to be 1740s Ashlar boards salvaged in the 1830s, and re-used as Ceiling boards. Eight of these boards were

[1] The Perry Lithgow Partnership and Hugh Harrison 2000, Vol II: Plate 561

identified in Bay 1; seven in Bays 2 and 3; eleven in Bay 4 (seven within one panel alone); only four boards in Bay 5; none in Bays 6-9 and one only in Bay 10 shown here.

Plate 371 Shows a section of 1740s or 1830s painted softwood replacement board used as an insert the 1920s. As there was no access to the underside of the Ceiling in the 1920s the insert was lowered from above and is held by a piece of hessian.

Plates 372, 373 In Bays 9 and 10 the border pattern on a number of stepped chevron boards, both original and softwood replacement, appears to have been set out in white chalk. The 1830s overpaint paint has flaked from the powdery chalk lines.

Plates 374. 377 In Bays 9 and 10 there is evidence that the wave pattern design was first set out in white chalk onto the newly painted white background (**Bay 374**); also in pencil (**Plate 375**) and red crayon (**Plate 376**).

GRAFFITI

Plates 367-380 A number of painted inscriptions on the Ceiling boards record the names of at least some of the painters involved in the 1834/5 intervention. Some inscriptions are integrated into the decoration: such as within the archbishop (2) lozenge where '*COBLEY 1834'* is painted on the pages of an open book, and '*R[D.] LAYTON 1834 SEXTON*' is on the lower border of the archbishop's robe.[2] Other are painted in simple lettering on the plain background. The names W Stallard, R Layton, W Gamlyn and Cobley occur two or three times across the ceiling (**Plates 377, 378, 380**); the names I Shaw C Neal appear once only on an Ashlar board at towards the east end of the Ceiling;[3] similarly, the monogramme "I CO" (Cobley?) which is at the west end (see **Plate 399**). **Plate 379** shows a possible 1740s inscription: "T K" in black paint beneath the off-white overpaint.[4]

Plate 598 There is a considerable amount of pencilled graffiti at the west end of the Ceiling. Some are simply random lines but others give the names of carpenters and painters working on the ceiling in the 1834/5: for instance "*W. Gamlyn 1835*" and "*J. Duddington Carpenter at this roof 1834*". In addition, the centrally placed door in the West End vertical boards allowed limited access to the vertical boards and *Panel 0 III*; hence there are a number of pencilled inscriptions with a post-1830s date. **Plate 381** shows one of these inscription "*J. Garwood Bourne at Peterboro* (sic) *Lincolnshire February 1827*". **Plate 382** shows a small naive sketch of an animal, possibly a dog or a mouse.

SURFACE ACCRETIONS

Plate 383 This photograph also belongs in the 'Repainting' item (above) as it shows 1830s white chalk setting out lines for a trefoil on a base board. It also shows the original trefoil in shallow relief, the background having receded through weathering. However it also shows the Patchy white deposits that are associated with the thick resinous 1830s black paint/coating remain unidentified. Initially they were considered to be some form of microbiological growth (MBG) but analysis by Ridout indicates they are accumulations of irregularly shaped, translucent, plate-like crystals. The recent discovery of a list of materials used the 1830s restorers would suggest that the inclusion of sugar of lead (lead acetate) in the paint may be a factor. Sugar of lead was widely used as an ingredient in drying oil preparations from the mid-eighteenth century to the mid-nineteenth century. However, by the time of its use on the Nave Ceiling reservations were expressed that its use could cause certain colours to become dull; also that it could result in '*an immense number of small spots in the paint, sometimes appearing through the surface-varnish in the form of a white efflorescence*.' Towards the end of the nineteenth century the general advice was to avoid sugar of lead altogether. As it is, we remain uncertain whether these patchy white deposits are the result of seepage from the paint layer or a reaction caused by adverse environmental conditions.

[2] The Perry Lithgow Partnership and Hugh Harrison 2000, Vol. II: Plate 414
[3] The Perry Lithgow Partnership and Hugh Harrison 1998, Vol. II: Plate 305
[4] The Perry Lithgow Partnership and Hugh Harrison 1998, Vol. II: Plate 306.

Plate 384 Prior to surface cleaning the paint surface on the west end vertical boards was partially obscured by a white efflorescence as shown in this photograph. This efflorescence was largely removed during the cleaning process. Nevertheless a characteristic milky or silvery surface sheen which does not respond to surface cleaning with Wishab sponges remained. Analysis of this on other 1830s boards indicates there is a thin pale coating but it remains unidentified. The recent discovery that sugar of lead (lead acetate) was used extensively by the 1830s restorers suggests that material may be a factor responsible for this slightly opaque veil.

Plate 385 Detail showing small patches of white chalky efflorescence at the junction of central lozenge boards. This moisture related accretion was removed during surface cleaning.

SURFACE GLUE

Plates 386, 387 Details before treatment in incidental light (**Plate 386**) and UV illumination (**Plate 387**) showing typical damage caused by thick glue drips over the paint surface before treatment. The water-soluble animal glue was used to adhere hessian to the Ceiling boards upper side during the 1926 intervention. The liquid penetrated between the boards, accumulating on the horizontal board edges and in places running across the surface of the Ashlar boards and canted ceiling boards. In many instances the thick glue had contracted and detached from the surface pulling away the underlying paint.

SURFACE CLEANING, STAIN REMOVAL AND REINTEGRATION

Plates 388-391 Details of the Ceiling boards, West End Vertical boards and Ashlar boards during the removal of surface dirt and soot resulting from the 2001 fire in the building. There was a layer of surface dirt overall the painted decoration. Interestingly the layer was conspicuously thicker and more discoloured within the western Bays of the ceiling: possibly due to their proximity to the west doors which act as the main entrance to the building. Bays 9 and 10 were the only bays not treated prior to the 2001 fire in the building. Consequently, within the Phase 5 area, the soot was mingled with and largely indistinguishable from the surface dirt layer.

Plates 392-401 These images show sections of the Ashlar boars within Bays 9 and 10 during and after surface cleaning, glue/stain removal and reintegration. In Phase 5 particularly there was extensive reintegration necessary following removal of stains and glue trails across the north and south Ashlar boards. All stains on the painted decoration resulted from liquid material penetrating down between the boards or through cracks in deteriorated boards. On the Ashlar boards it was largely water that had run across the paint surface leaving distinctive trails of blanched paint and brown surface deposits. The approach adopted throughout the project has been that stains considered to be particularly distracting and visible from the ground should be removed, reduced or disguised. The 'blanched' or 'cleaner' areas of paint resulting from glue and/or stain removal were toned down with water-colour paints to match the surrounding Wishab cleaned paint.

Plate 402 Detail of a canted ceiling panel showing extensive patches of staining over several boards.

Plates 404, 405 Details showing a section of softwood replacement board during stain removal (**Plate 403**) and following reintegration (**Plate 404**).

Plate 402 Detail of a new timber insert in a grey chevron board following reintegration . For further examples of new timber insert reintegration see **Plates 109-134**.

NAVE CEILING PROJECT INSCRIPTION

Plates 406-409 To commemorate the nine year long Nave Ceiling Conservation Project the following inscription was painted in red onto the reintegrated off-white background of the north side Ashlar boards above the west end stone ledge:

PETERBOROUGH CATHEDRAL NAVE CEILING CONSERVATION PROJECT
1994 – 2003

ARCHITECT: JULIAN LIMENTANI *ADVISER: GILLIAN LEWIS*
CONSERVATORS: THE PERRY LITHGOW PARTNERSHIP WITH HUGH HARRISON

RICHARD LITHGOW, MARK PERRY, DAVID PERRY, PETER MARTINDALE, CRISTINA BERETTA, LOUISE BRADSHAW, CAROLINE BAINES, BIANCA MADDEN, NATALIA SEGGERMAN, GREG HOWARTH, SASA KOSINOVA, SARAH LIVERMORE.
HUGH HARRISON, BOB CHAPPELL, CAMERON STEWART, PETER FERGUSON, JONATHAN PORTER, BRETT WRIGHT, CLAIRE CULLY, STUART ANDERSON.

NAVE CEILING PROJECT PHASE 5 SCAFFOLDING

Plates 410, 411 Two views of the Phase 5 scaffolding taken from floor level in the Choir.

Sheet # 8	PETERBOROUGH CATHEDRAL NAVE CEILING: Phase 5 (2003)	Print Film No: 8
Date Started: 10-9-03		Film Type: SUPERIA
Date Completed: 3-10-03	Comments: Appendix 2	ISO: 100
Cameras: Canon EOS1000 FN ~~Olympus OM1N~~		Slide Film Nos: 21 CONT; 22; 23; 24
Flash: Cobra 700 AF		Film Types: SENSIA
		ISO: 100

Frame Nos. Print	S/F	Slide	Location/Description	Flash Position Height	Dir/Dist
24 A	21 CONT.	18-17-16-15	TEMPORARY CEILING BOLT IN POSITION - i III w	3'	↑ 4'
23 A		14-13-12-11	HOOVERING - GREG	CN	ART
22A		10-9-8-7	REMOVAL OF BOLT - BOB	"	"
21A		6-5-4-3	6 III c - TYPICAL SOFTWOOD SHAKES	3'	↑ 4'
20 A	22	2-1-37-36	2 II s - CHALK SETTING OUT LINES, HAMMER MARKS (IMPRINT);	5'	N 7'
			2 TYPES OF NAILS; VISIBLE ORIG. UNDERPAINT; VISIBLE 1740's		
			UNDERPAINT		
19 A		35-34-33-32	i II c #d - PENCIL SETTING OUT LINES; INSECT DAMAGE		
18 A		31-30-29	2 II x - PAINTED GRAFITTI: 'T K' (1740's?) #A CONSOLIDATED SPLIT;		
			DELIBERATE WOOD LOSS; VISIBLE 1740's PAINT		
X	23	37-36-35	RETAINED SLIDES OF PREVIOUS SHOT ↑ - IN CASE		
			SLIDES FOGGED. X		
17 A		34-33-32-31	2 IV q - TIMBER INSERT WITH PELLETS/CORKS IN PLACE	4'	SS'
16 A		30-29-28-27	DENNIS & DAVE VACUUMING BOB	CN	ART
15 A		26-25-24-23	1 III j - TIMBER INSERT BEFORE RETOUCHING	FLOOR	↑
14 A		22-21-20-19	3 II j - " " " "	"	"
13 A		18-17-16-15	3 III b - " " " "	"	"
12 A		14-13-12-11	6 I v - " " " "	2'	N 4'
11 A		10-9-8-7	6 II i - " " " "	FLOOR	↑
10 A		6-5-4-3	i II d #e - FILLS INSERTED IN CONSOLIDATED INSECT DAMAGE	"	"
			(BEFORE RETOUCHING)		
9 A	24	2-1-37-36	I III/2 III - AREA FOR TIMBER INSERT NB - LOSS IS DELIBERATE		
			AS IS SHOWN BY STRAIGHT CUTS		
8 A		35(WOOD)34-33-32-31	3 II j - TIMBER INSERT HELD WITH WEDGES		
7 A		30-29-28-27	I III 2/III - RETAKE OF 8/9 - AFTER INSERT & RETOUCHING (NB NO PIC BEFORE RETOUCHING)		
6 A		26-25-24	2 III i - EARLIER INSERT - BEFORE RETOUCHING;		
5 A		23-22-21-20	4 I c #d - NEW TIMBER INSERTS IN PLACE, HELD BY		
			SS FIXINGS - AFTER RETOUCHING (NB NO PIC BEFORE		
			RETOUCHING)		
4 A		19-18-17-16	6 II i - NEW TIMBER INSERT (SEE 9/11) AFTER RETOUCHING		
3 A		15-14-13-12	3 II j - " " " AFTER RETOUCHING (NB - NO		
			PIC BEFORE RETOUCHING).		
2 A		11-10-9	ASHLAR 0 I - AFTER TREATMENT (RETAKE OF 7/13A)	2'	N 5'
1 A		8-7-6	" 1 I - " " (" " 7/15A)	2'	"

APPENDIX 3

Photographic Equipment and Graphics Software

Photography

Cameras	2 x Canon EOS1000 FN
Lens	2 x Canon 28-105 AF
Flash	Cobra 700 F
Slide film	Fuji Provia 100
Print film	Fuji Reala 100
Slide film for UV photography	Fuji Provia 1600

All visible light photography was carried out using the Cobra 700 F flashlight either on or off camera. Photography under UV illumination was carried out at night using 4 CLE blacklight long-wave, ultra-violet tubes (4 ft). A Lee UV2B filter together with a Hoya Haze-UV filter were used on the camera lens for all UV photography.

Software

Graphics	Corel Draw 7 and 9.
Word Processing	Microsoft Word, Version 6.
Spreadsheets	Microsoft Excel, Version 6

APPENDIX 4

OBSERVATIONS ON WOOD EFFECTS FOR THE NAVE CEILING OF PETERBOROUGH CATHEDRAL
J. A. Brewer November 2000

First 1 would like to address the **receded/weathered surface of the planks.**

The majority of oak planks show prominent medullary rays between which the cells (mainly fibre and vessel cells) appear to recede. The rays appear plate-like and smooth ranging from large irregular shapes where the radially- cut surface is through relatively straight-grained wood (Plate 382) to quite small, squarish islands where the grain becomes more irregular, almost as if the wood had been chopped with a blade, though it has not.

There is also a difference in relief between the annual rings, the latewood from the end of the growing season being more prominent than the earlywood cells. Latewood/earlywood relief differences are shown by nested arcs on tangentially-cut faces (Plate 383). In fresher timber, these arcs can be distinguished by colour and texture rather than a relief pattern as here.

Thus we have two types of relief pattern which I would tend to ascribe to a weathering process. Appearance alone suggests the kind of weathering one encounters on ring- porous hardwoods such as oak and in the annual rings of exposed softwoods due to exposure to the relative extremes of external conditions of UV light, erosion from rain, and extreme moisture content changes which tend to fracture differing cell types in adjacent areas due to swelling (moist) and desiccation (dry). Old fence timber and telegraph poles show similar effects.

How could this happen on internal surfaces of what is currently a relatively stable interior? There are very few finished oak surfaces of this age in similar circumstances that I know of, though I am not well- informed on the subject. Time and unknown environmental conditions in the past are the main explanation I would propose for this weathering. Perhaps there was a period of decades when the roof was leaky from degradation or when it was partially removed, offering insufficient protection of the timbers below.

Fungal infection (rot) was suggested as a possible cause of these relief patterns. Dinwoodie (see below) offers little discussion specifically in reference to oak so that I would really need to go to a good wood science library (British Library or that of the Building Research Establishment) to research it. European oak heartwood is considered to be durable to fungal attack in ground contact (Table 6.1, p.160) so we can assume that these "sky-born" timbers are durable. But there are few comparable structures whose history are known from which one could get a realistic indication of the deterioration factors.

Wet rots are the only rot I would expect at such a height even though so-called dry rot has been known to spread several meters over other surfaces than wood. Though not a rot expert, 1 do not believe it to be the cause of the relief pattern. Here is my reasoning. First, the patterns are related directly to the wood structure, while wet rot causes generalised damage not simply confined to the softer cells' walls.

Second, one needs a moisture content of 20% or greater for infection and resulting damage to occur. This is not likely to have occurred for the necessary extended periods in the roof timbers even if they were exposed to rain. Moisture could have been retained in the wood by paint coatings to the extent that rot could occur beneath the paint, but I think that we are searching too far for arguments if we follow this line. The planks would have to have been fully coated on one side at least, probably both larger sides, as oak does not transmit water quickly across the grain (witness oak casks; see below). In addition the planks would still be exposed to strong drying conditions after rain, such as from the (probably) exposed upper side. Or, possibly the roof leaked water everywhere like a sieve but somehow sheltered the exposed sides of boards from drying. Again I think this line of argument is too complicated. We should, as always, expect the obvious even though we may overlook it for that very reason.

Third, I would expect rot to have caused more irregular depths of structural damage in several areas, not as in the homogeneous relief pattern we observe overall. I believe we did note an area toward the middle of the ceiling where rot/insect damage has occurred (insects often inhabit rotting areas) but I would expect just such an obvious damage to be more widespread.

For more on rots, see the excellent book below. You could ask a rot expert to have a look. Mr Ridout was quoted and perhaps he could settle the rot question with a sample, as he suggested. I would also suggest the

Building Research Establishment. The problem is that the evidence to explain the relief pattern by rot is probably long gone even though various spores will always be on wood surfaces. Following Mr Ridout's comments further, a differential collapse of wood cells needs it's cause defined. Chemical deterioration from the coke stoves is not my area but judging from your environmental monitoring 1 doubt that sufficient effluent was deposited on the ceiling surface, other than some smoke. The stoves are relatively recent additions too so their effect might be in evidence in the paint layer analysis.

Another possible argument which 1 imagined for wood surface degradation is in relation to coatings or paint media. Now, I am not a wall paintings specialist either, but here are my thoughts. Interestingly, Thompson mentions St. Alban's painted ceiling ("Structural Woodwork. p. 41) saying that these wooden surfaces were either unprepared or given a size or general oil coat to equalise absorption of the painted design. (There's your oil content!) What paint media are likely? Oil would not do it. It is possible that a distemper (collagen glue) might have been applied and simply disappeared since. Glue is subject to Quite rapid degradation from the acidic nature of oak. However, it would not strip away such a depth of wood with it.

Finally there is lime, which would indeed have been alkaline until it had been completely reacted with atmospheric carbon dioxide. This initial period of alkalinity could degrade the lignin and hemicellulose molecules in the wood cells as they are apparently quite susceptible to alkaline agents. I do not believe that this would remove such a depth of wood either, though I have no examples. Again, the evidence would seem to be non-existent or long gone. However, it may be that an initial loss of wood surface overall by one or more of these postulated mechanisms- wet rot, degrading distemper or alkaline chemical reaction, could contribute to a much greater weathering effect than would occur if the surfaces had remained in a bare or coated but essentially finished state. Rough wooden surfaces weather more quickly.

Superficially viewed, the trefoil designs, because they are in relief, can be confused with the rays, as they tend to meld together in some areas and exposed rays can take on fascinating shapes in themselves. Looking at the surface from my experience in the technology of art and the conservation of paintings, I would attribute the relief of the trefoil designs to a masking effect of a painted surface. That is, the trefoils were painted, thus protecting them from a degrading factor such as weathering, while the surrounding was less protected, though not necessarily unpainted. The trefoils may simply have been painted with a more protective medium such as oil, as your research indicates, while the surrounding may have been a water-based medium, such as a distemper. The latter may have entirely disappeared.

Shallow carving to set out the painted design has been suggested as a possible cause of the relief pattern (Howard, 1998; **p.** 2). I am essentially in agreement with your report (Phase 2 Survey and Treatment, section 8.2.3, paragraph 2). Though 1 have done no serious wood carving, 1 have examined carved surfaces and have some practical experience in wood tooling and painting. 1 accept that adjacent planks are likely to have been grooved with a plane-like bladed tool or simply a chisel, mallet and straight-edge, to set out the alternating red/black linear design, as grooves would greatly facilitate linear brushwork. However 1 do not think that the relatively laborious carving away of the surrounding wood surface would have facilitated painting such a cursive design as the trefoils (even given the glory it might have assured the carver(s)). Also, the uniformity of the curvature of the edges do not suggest tooled surfaces to me. They do suggest the flow and swell of a painter's brushwork. Therefore 1 think we see the remnants of a design simply brushed on the wood surface. 1 would look for some other signs of setting-out, possibly shallow scribe marks or punctures to locate trefoil positions, though these have probably disappeared if they existed at all.

Next I address the **probable dimensional response in individual boards resulting from environmental fluctuations,** referring to Curteis' Preliminary Report March 1998- January 2000. He discusses diurnal and seasonal (between midsummer and midwinter) conditions in three places: externally; in the roof space above the ceiling; in the space on the underside of the ceiling. The last two affect the ceiling planks directly. The present range of temperature (T) and relative humidity (RH) recorded by the sensors is probably no greater than during any period in the past. The ceiling environment has probably seen greater extremes than these over both the short and long term. it is possible, for example, that greater levels of heating occurred when the coke stoves were in use which would have caused dryer conditions in winter and subsequently greater periodic variations at ceiling level. Or, if the roof had ever been open for reconstruction then the interior would have been exposed to conditions more like the exterior.

The environmental extremes are important in determining the dimensional response of the overall wooden structure and of individual planks. The wood type and plank section are also important factors. If 1 recall, the oak planks are on the order of 20-25mm thick. I think the planks would still respond overall to environmental

changes to about the same degree as when they were first painted. (There is some evidence in the literature that moisture response does not diminish greatly with age.) In my research, though response to RH change at the plank surface is virtually instantaneous, it took about ten days for the moisture content of an oak plank about 3.5mm thick to equilibrate, as indicated by a cessation of wood deformation (i.e. warping and expansion/contraction). One could expect that planks 6 or 7 times this thickness would take a correspondingly greater time to equilibrate.

The manner of converting the planks from timber is relevant too. Unlike the ceiling planks, which were riven, the planks used in my research were planed and sanded flat thus leaving a more rapid avenue for moisture transfer through the sectioned vessels. Riven surfaces force moisture to traverse the cell walls, a slower process.

Considering these factors, I would make a broad estimate that equilibration to a change in RH would take from 50- 100 days for the ceiling planks. Thus, for each plank as a unit and for the lozenge structures, I would tend to think in terms of a relatively slow response time more on the seasonal order.

Diurnal RH varied by up to 20% in the roof space in winter and 25% in summer (p. 7). Below the ceiling, diurnal variations were stable in winter and about 6% in summer (p. 6-7). With the rate of equilibration on the order of 50 to 100 days broadly speaking, as discussed above, diurnal variations would change neither overall plank dimensions nor affect the lozenge structures appreciably. The clinker-built, clinched nail construction would accommodate any minor movement of this sort. If I may diverge to seasonal changes of average RH/T, a lack of obvious splitting in the planks indicates that dangerous restraint of plank movement or of the lozenges in relation to the supporting beams is no longer likely, again thanks to this type of nailed construction.

Diurnal changes will, however, affect wood movement at the plank surface and to a certain depth, depending on moisture gradients. Moisture traverses the plank section as a gradient. A greater change in wood moisture content at the surface, due to an RH change, will provoke a greater difference in MC between the surface and underlying cell layers, thus creating a steeper moisture gradient. In freshly cut wood, cell distortions occur at the plank surface because the swelling or contraction of the surface cells is restrained by the more slowly reacting cells beneath. Steeper gradients cause greater restraint, provoking compression of swelling surface cells during rising RH and fissuring between contracting surface cells during drying conditions. These effects are generally termed "set" and are considered to be permanent cell deformations.

For relatively rapid RH changes these effects are confined to the surface and thicker planks as a whole would not be likely to undergo much deformation as a result. Over several centuries, a maximum degree of set would have been attained, only increasing if planks were subjected to greater extremes than were experienced before. They have been extremely "well seasoned". Over centuries, set and possibly the slow loss of volatile extractives causes a slight permanent decrease in dimensions, as shown by painted oak panels of the 15th and 16th century. This exceedingly slow contraction has long since been accommodated by the original paint and the lozenge structure.

So, as regards direct effects of diurnal changes on wood movement and long-term set, the original paint layers have probably long since adapted through craquelure and losses. If securely consolidated now they should remain well conserved. It seems to me highly unlikely that current conditions expose the planks and the paintings to greater extremes than they have already experienced. There may be some danger from the restraint or differential movement of overpaint or encrusted layers, such as the glue drips have caused. Beneficially, however, I think that the overlying paint of the 18th and 19th centuries also acts to retard moisture transfer to the wood, decreasing wood movement beneath.

Seasonal averages at the ceiling underside indicate stable conditions in winter (Preliminary Report 1998- 2000, section 4.2, paragraph 2) and summer. On average, there is about a 13%RH difference (59%RH in July minus 46% in winter months). To cause movement corresponding to equilibration at These extremes would have to be maintained for 50-100 days to cause the full range of movement if equilibrium moisture content (EMC) were attained, assuming the above reasoning is correct. Instead, relative humidity is likely to show a rough shift between these averages so that the planks never really equilibrate to either the winter months or July average value. The plank moisture contents and therefore changes in dimension will instead lag considerably behind, oscillating relatively little over the year. Again, 1 see little threat to the paint or lozenge structures.

The options for measuring any related movement are numerous, varying greatly in sensitivity, cost, ease of use and general practicality. Making a few estimates based on the above reasoning, European oak moves about 2.5% in the tangential direction, across the grain (the most reactive axis), in equilibrating from 60%RH to 90%RH.

For a 10%RH range, which roughly represents the 13% seasonal average range cited above, a maximum of about 1% movement could be expected. So, a plank 200mm wide would expand or contract about 2mm. I think even this is overestimated. Anyway, you would have to detect changes of .1-.2mm to plot curves and statistically this means you need resolution of 0.05mm.

I will suggest only two relatively simple methods to repeat a linear measurement of this type. One utilises a Vernier style caliper and the other a linear transducer. If you can place a couple of nails about 100mm apart (no greater than 90% of the calipers maximum range) in a plank, or use existing nails, drill a small-diameter hole in each nail head to accept the a caliper tip. The tips must bed at exactly the same points for each measure. Then record measurements relative to the initial span between the holes. Place the points according to the grain direction you wish to measure.

The linear transducer is a sort of plunger that varies an applied voltage i.e. a potentiometer. It will give a linear response over a certain range of movement of the plunger and this can be easily converted to a linear measure using a known length. Some types give much greater resolution than you will need. The transducer can be mounted on a plank and the plunger, which can be a sprung type, may be butted against a fixed metal stop. Voltage changes can be periodically recorded using a computer. A colleague of mine has used a similar set-up to measure gap changes in a panel joint, though I believe he used a radial transducer linked to a stiffish cord. I enclose a slightly dated catalogue (TML) of these sorts of things. Some are not potentiometric but are based on resistance, incorporating strain gauges. These can resolve rather too much for your purposes.

Concerning degradation of the hessian/animal-glue covering, 1 would say that it will continue to degrade, providing little or no support to the planks since the glue's adhesion is virtually spent. The oak tannins are quite acidic and *when exposed* to air a glue on oak will degrade quite rapidly, probably within 50 years at best and definitely within 100 years, according to my experience with canvas strips applied to reinforce oak panels that have been rejoined. (Animal glue in oak joints that were planed well and joined tight will survive much longer because a minimal glue line is exposed to the air and it is more flexible than a thicker glue line. Stresses and glue degradation from acidic tannins at the glue/wood interface often cause even these joints to pop.)

The fabric/glue may slow moisture exchange to a minor degree. It forms a pretty good dust cover too so I would not be inclined to remove or replace it yet.

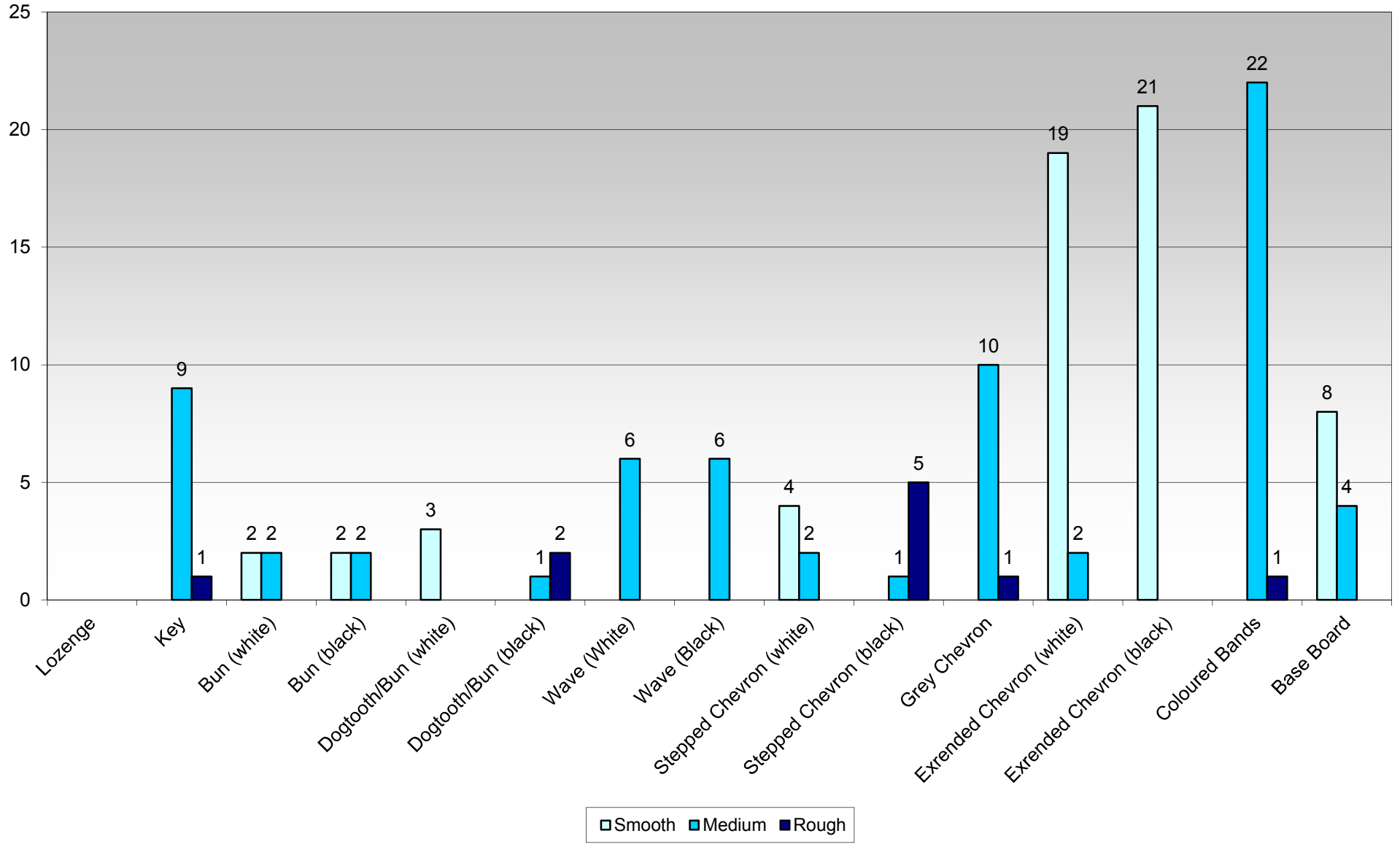
REFERENCES

Dinwoodie, J.M. 1981. *Timber, its nature and behaviour.* Van Nostrand Reinhold Co. Ltd., Berkshire, England.

Bravery, A.F., Berry, R.W., Carey, J.K., and Cooper, D.E. 1992. *Recognising wood rot in buildings* (2nd ed.), Building Research Establishment, Garston, Watford.

Thompson, D.V. 1956. *The materials and techniques of medieval painting,* Dover, New York.

Panel No:	Lozenge	Key	Bun (white)	Bun (black)	Dogtooth/Bun (white)	Dogtooth/Bun (black)	Wave (White)	Wave (Black)	Stepped Chevron (white)	Stepped Chevron (black)	Grey Chevron	Exrended Chevron (white)	Exrended Chevron (black)	Coloured Bands	Base Board
7I		M					S	S	M	R	M	S	S	M	M
												S	S	M	
												S	S	M	
														M	
6I												S	S	M	S
												S	S	M	
														M	S
		M					S	S	S	R	M	S	S	M	
											M	S	S		
5I		M					S	S	M	M	M	S	S	M	M
											M	S	S	M	S
											M	S	S	M	
												S	S		
4I		R	M	M	S	M					R	S	S	M	M
												S	S	M	S
		M					S	S	S	R	M	S	S	M	
												S	S	M	
3I		M					S	S	S	R	M	S	S	M	S
		M	M	M	S	R					M	S	S	M	
2I		M	S	S	S	R						S	S	M	S
														M	S
		M					S	S	M	R	M	M	S	M	
												S	S		
1I		M					S	S	S	R	M	M	S	M	M
														M	S
			S	S										R	
0I															
Totals 7-0 I (Phase 5)															
Smooth			2	2	3				4			19	21		8
Medium		9	2	2		1	6	6	2	1	10	2		22	4
Rough		1				2				5	1			1	
TOTAL	0	10	4	4	3	3	6	6	6	6	11	21	21	23	12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22 1
8 4
Lozenge
Key
Bun (white)
Bun (black)
Dogtooth/Bun (white)
Dogtooth/Bun (black)
Wave (White)
Wave (Black)
Stepped Chevron (white)
Stepped Chevron (black)
Grey Chevron
Exrended Chevron (white)
Exrended Chevron (black)
Coloured Bands
Base Board
Smooth
Medium
Rough

Panel No:	Lozenge	Key	Wave (White)	Wave (Black)	Stepped Chevron (white)	Stepped Chevron (black)	Grey Chevron	Exrended Chevron (white)	Exrended Chevron (black)	Coloured Bands	Base Board
7 II								S	S	M	M
										M	M
								S	S	M	M
								S	S		
6II							M	S	S		M
							M	S	S	M	M
		M	S	S	M	R	M	S	S	M	
							M				
5II		M					S	S	S	M	R
							S	S	S	M	
4II		M									M
		M	S	S	S	R	M	S	S	M	M
							M	M	S		
3II		M	S	S	M	R	M	S	S	R	R
							M	S	S	R	R
			R	M				S	S	M	R
2II		M	S	S	M	R	M	S	S	R	R
					R	R		M	S	R	R
			S	S	M	M	R	M	S	M	R
							R			M	
1II			S	S	M	R	M	S	S	M	
							M	S	S		
					R	R	R	S	S	M	
0II					M	R	M	S	S		

Panel No:	Lozenge	Key	Wave (White)	Wave (Black)	Stepped Chevron (white)	Stepped Chevron (black)	Grey Chevron	Exrended Chevron (white)	Exrended Chevron (black)	Coloured Bands	Base Board
7III					S	R	M	S	S	R	R
										M	
			S	S	S	S				R	
6III		M			S	R					
5III		R	S	S							
								S	S	M	
								S	S		
4III							M				
3III			S	S						M	M
					M	R	M	S	S	M	M
							M	S	S	M	M
2III					M	M	M	S	S	M	
					S	R	M	S	S	M	
								S	S	M	
			M	R	M	M		M	S		
1III					R	R	M	S	S	M	R
							M	S	S	M	R
		M	S	S				S	S	M	
								S	S		
0III					M	R	M	S	S	M	

Totals Column II

S			6	6	1		2	17	20		
M		6		1	6	1	12	3		13	7
R			1		2	8	3			4	7
TOTAL	0	6	7	7	9	9	17	20	20	17	14

Totals Column III

S			4	4	4	1		13	14		
M		2	1		4	2	8	1		12	3
R		1		1	1	6				2	3
TOTAL	0	3	5	5	9	9	8	14	14	14	6

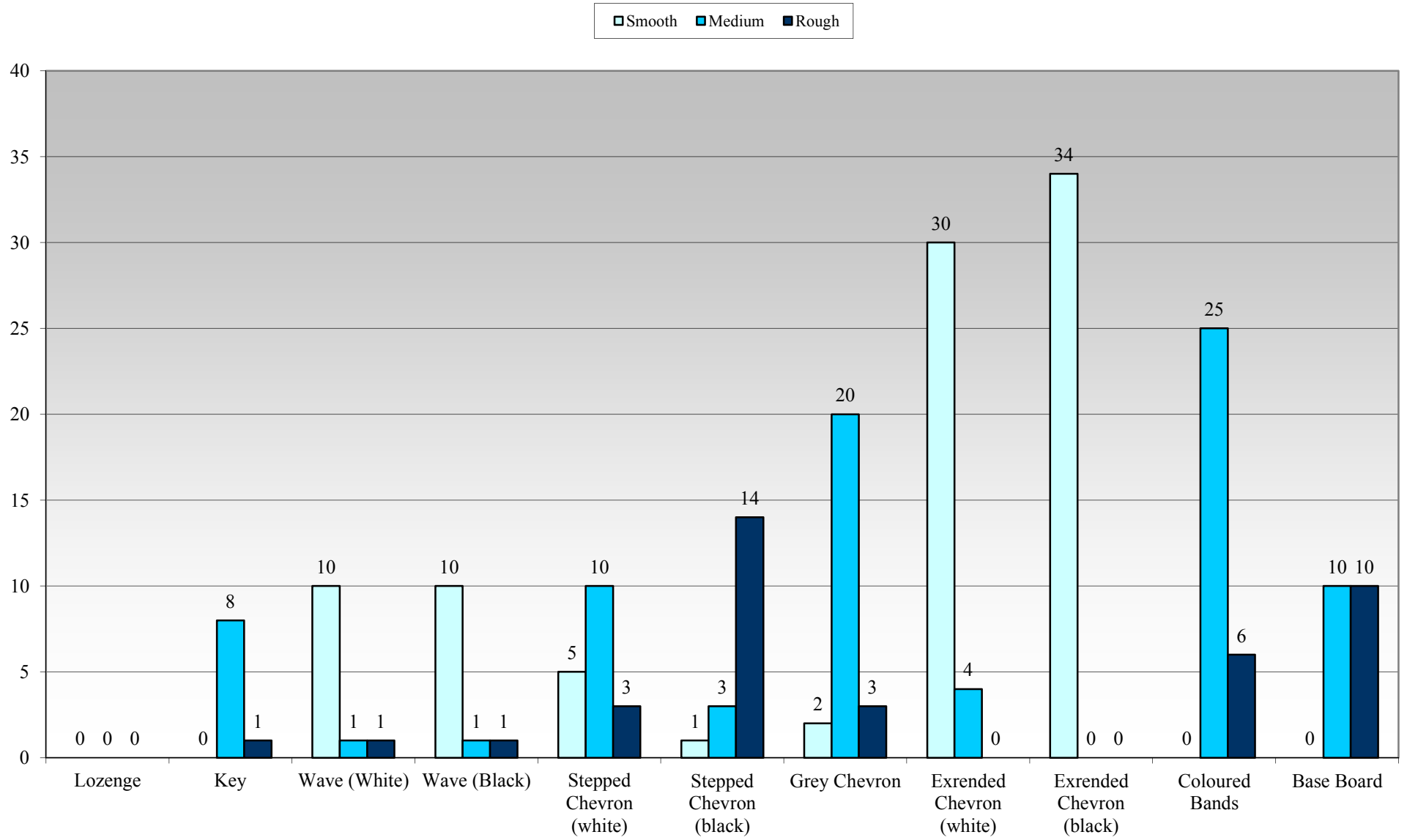
Boards Scarfed Together

Boards Scarfed Together

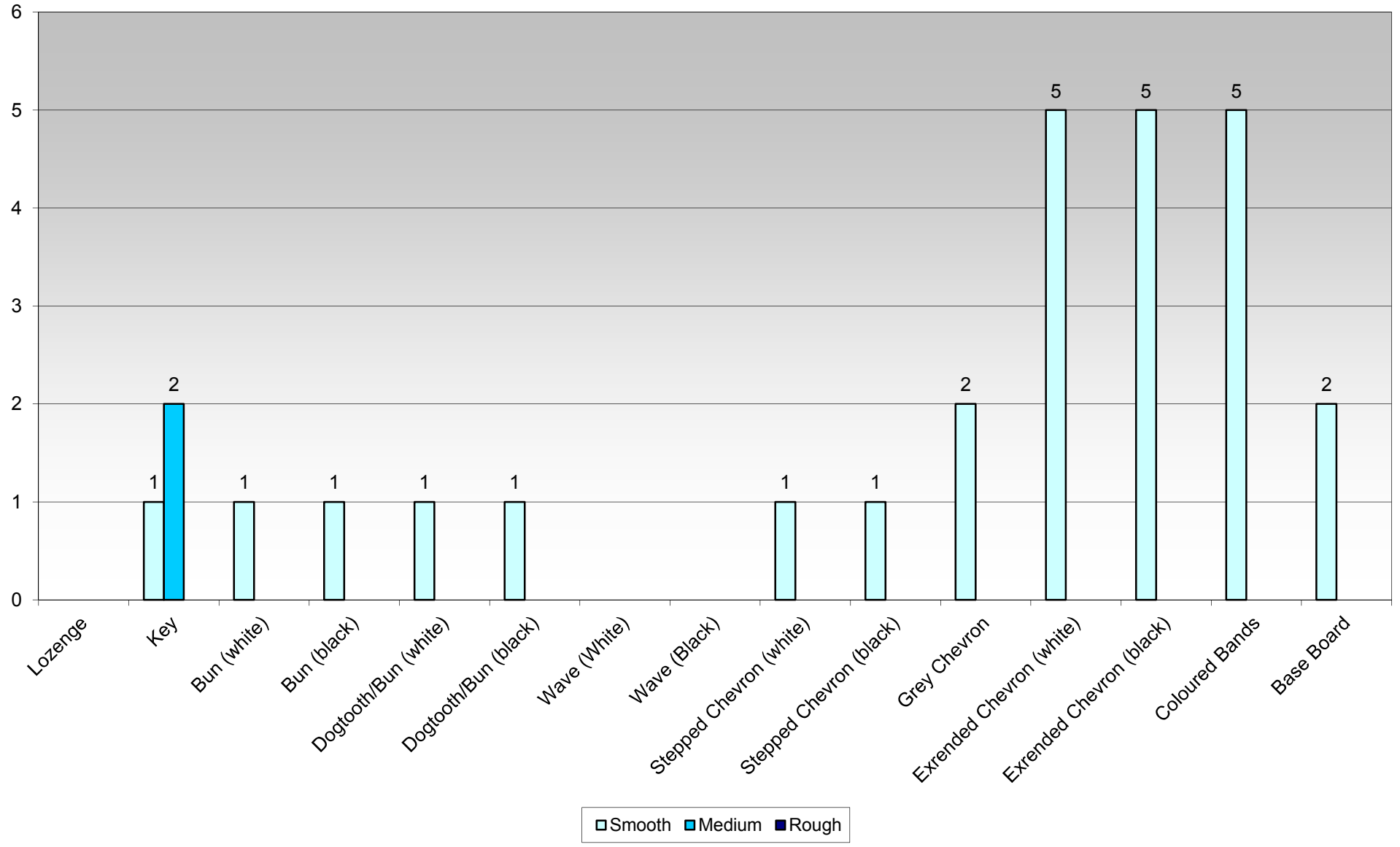
Combined Totals

Smooth	0	0	10	10	5	1	2	30	34	0	0
Medium	0	8	1	1	10	3	20	4	0	25	10
Rough	0	1	1	1	3	14	3	0	0	6	10
Total	0	9	12	12	18	18	25	34	34	31	20

Pre-Treatment Condition Survey
Board Weathering Analysis



Panel No:	Lozenge	Key	Bun (white)	Bun (black)	Dogtooth/Bun (white)	Dogtooth/Bun (black)	Wave (White)	Wave (Black)	Stepped Chevron (white)	Stepped Chevron (black)	Grey Chevron	Exrended Chevron (white)	Exrended Chevron (black)	Coloured Bands	Base Board
7IV		M							S	S	M	S	S	M	
3IV												S	S	M	
2IV		M	S	S											
0IV					S	S						S	S	M	S
												S	S	M	S
		S									M	S	S	M	
Totals 17-8 IV (Phase 5)															
Smooth		1	1	1	1	1			1	1	2	5	5	5	2
Medium		2													
Rough															
TOTAL	0	3	1	1	1	1	0	0	1	1	2	5	5	5	2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1
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5
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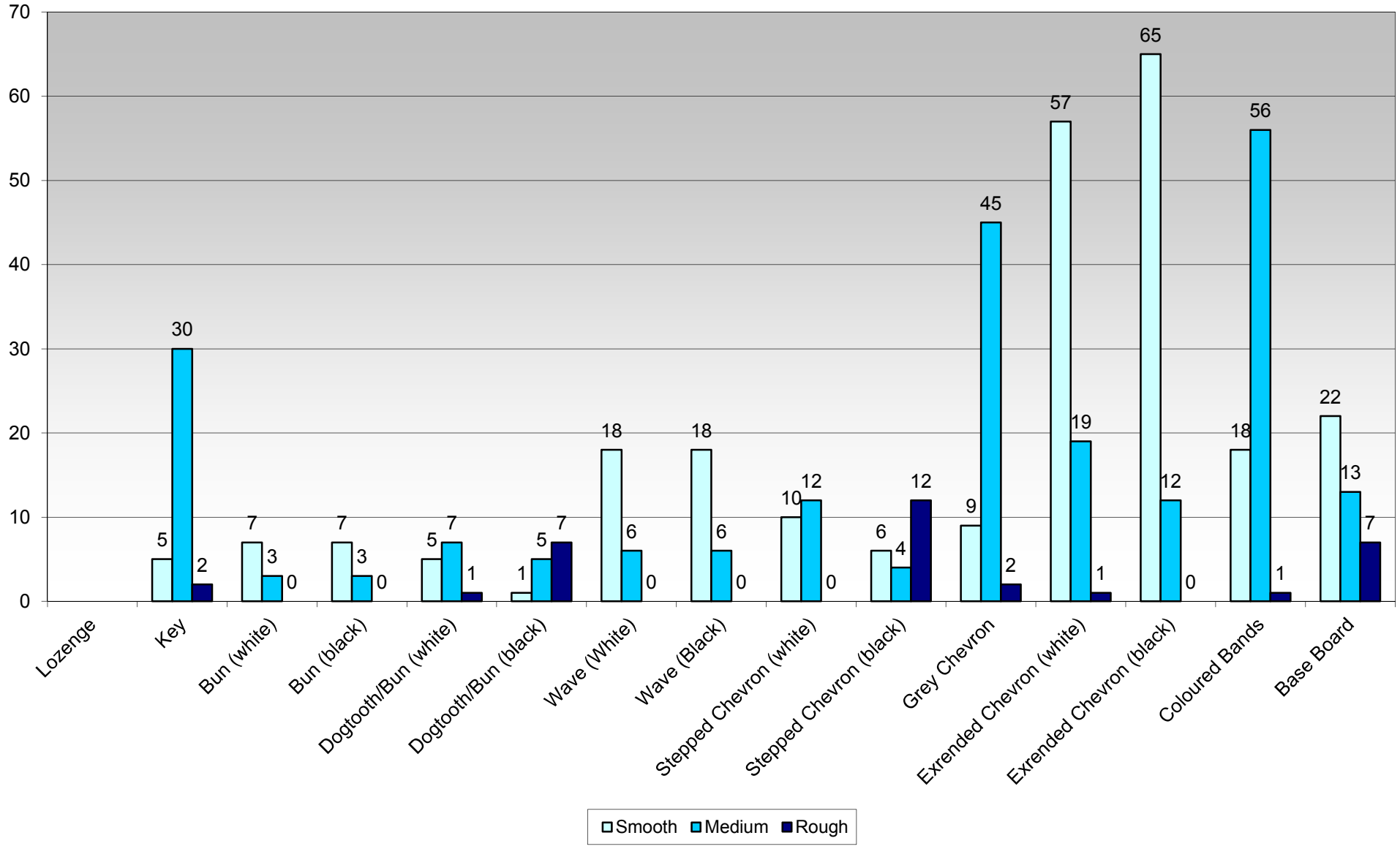
5
2
Lozenge
Key
Bun (white)
Bun (black)
Dogtooth/Bun (white)
Dogtooth/Bun (black)
Wave (White)
Wave (Black)
Stepped Chevron (white)
Stepped Chevron (black)
Grey Chevron
Exrended Chevron (white)
Exrended Chevron (black)
Coloured Bands
Base Board
Smooth
Medium
Rough

Panel No:	Lozenge	Key	Bun (white)	Bun (black)	Dogtooth/Bun (white)	Dogtooth/Bun (black)	Wave (White)	Wave (Black)	Stepped Chevron (white)	Stepped Chevron (black)	Grey Chevron	Exrended Chevron (white)	Exrended Chevron (black)	Coloured Bands	Base Board
Totals 27-18 I (Phase 3)															
Smooth		3	3	3	2		9	9	4		8	19	19	18	6
Medium		10			2				4	1	9	5	5	3	6
Rough		1				4				7					2
TOTAL	0	14	3	3	4	4	9	9	8	8	17	24	24	21	14
Totals 17-8 I Phase 4)															
Smooth		2	2	2		1	9	9	2	6	1	19	25		8
Medium		11	1	1	5	4			6	2	26	12	7	31	3
Rough					1	1					1	1			5
TOTAL	0	41	9	9	14	14	27	27	24	24	62	80	80	73	44
Totals 7-0 I Phase 5)															
Smooth			2	2	3				4			19	21		8
Medium		9	2	2		1	6	6	2	1	10	2		22	4
Rough		1				2				5	1			1	
TOTAL	0	10	4	4	3	3	6	6	6	6	11	21	21	23	12
Combined Totals Panels 27-0 I (Phases 3, 4 &.5)															
Smooth		5	7	7	5	1	18	18	10	6	9	57	65	18	22
Medium		30	3	3	7	5	6	6	12	4	45	19	12	56	13
Rough		2	0	0	1	7	0	0	0	12	2	1	0	1	7
TOTAL	0	37	10	10	13	13	24	24	22	22	56	77	77	75	42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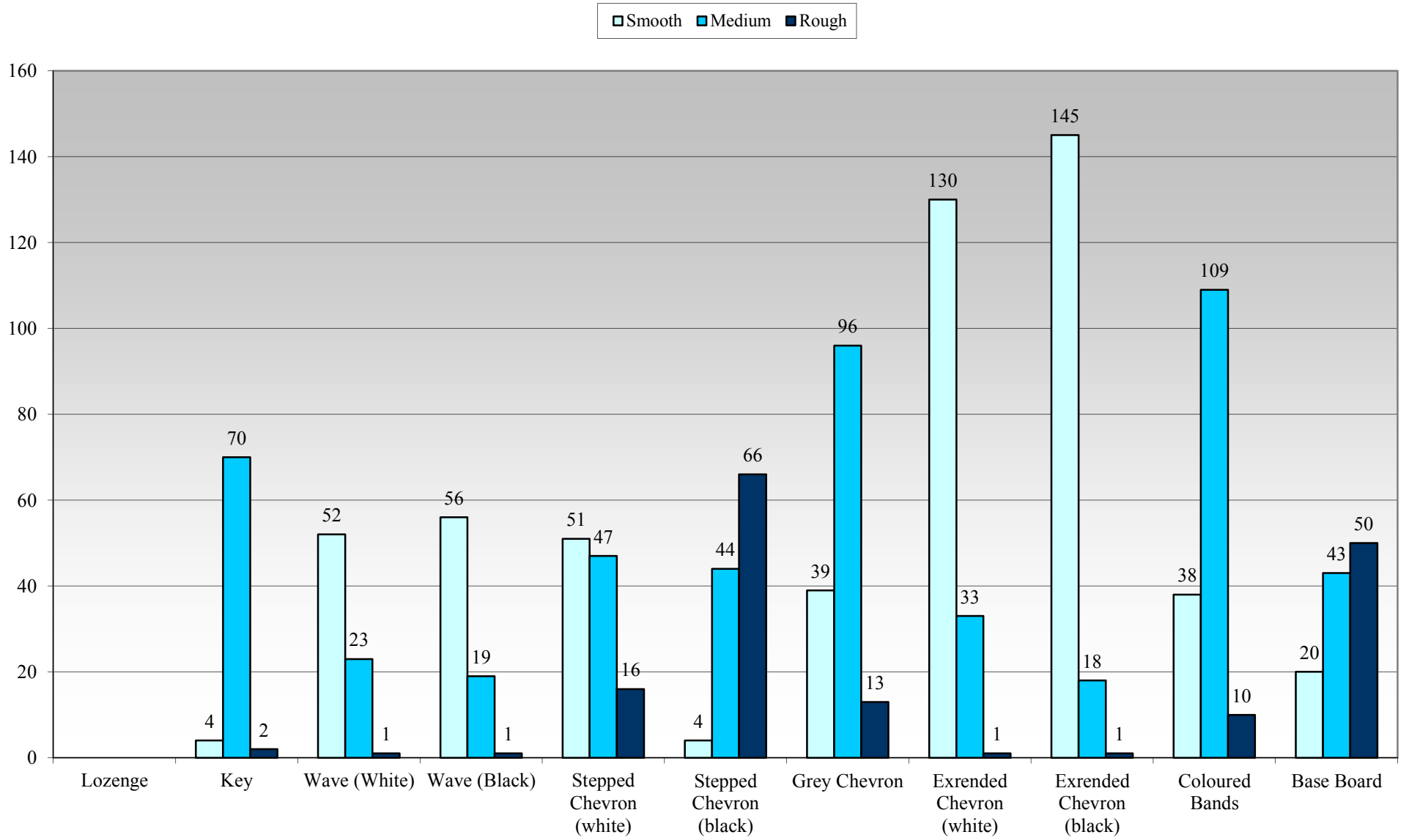
19
1
65
12
0
18
56
1
22
13
7
Lozenge
Key
Bun (white)
Bun (black)
Dogtooth/Bun (white)
Dogtooth/Bun (black)
Wave (White)
Wave (Black)
Stepped Chevron (white)
Stepped Chevron (black)
Grey Chevron
Exrended Chevron (white)
Exrended Chevron (black)
Coloured Bands
Base Board
Smooth
Medium
Rough

Panel No:	Lozenge	Key	Wave (White)	Wave (Black)	Stepped Chevron (white)	Stepped Chevron (black)	Grey Chevron	Exrended Chevron (white)	Exrended Chevron (black)	Coloured Bands	Base Board
Totals 27-18 II (Phase 3)											
S		2	11	14	3		17	18	21	2	1
M		14	5	2	13	5	9	11	8	28	3
R					7	18	5	1	1	1	20
Totals 17-8 II (Phase 4)											
S					18	2	7	34	34	36	11
M		14	14	14	7	10	25				8
R					1	14	1			1	
Totals 7-0 II (Phase 5)											
S			6	6	1		2	17	20		
M		6		1	6	1	12	3		13	7
R			1		2	8	3			4	7
TOTAL	0	36	37	37	58	58	81	84	84	85	57

Panel No:	Lozenge	Key	Wave (White)	Wave (Black)	Stepped Chevron (white)	Stepped Chevron (black)	Grey Chevron	Exrended Chevron (white)	Exrended Chevron (black)	Coloured Bands	Base Board
Totals 27-18 III (Phase 3)											
S		1	16	17	9		13	23	29		2
M		18	2	1	12	11	15	10	4	26	8
R		1			3	13	2				15
Totals 17-8 III (Phase 4)											
S		1	15	15	16	1		25	27		6
M		16	1	1	5	15	27	8	6	30	14
R					2	7	2			2	5
Totals 7-0 III (Phase 5)											
S			4	4	4	1		13	14		
M		2	1		4	2	8	1		12	3
R		1		1	1	6				2	3
TOTAL	0	40	39	39	56	56	67	80	80	72	56

	Lozenge	Key	Wave (White)	Wave (Black)	Stepped Chevron (white)	Stepped Chevron (black)	Grey Chevron	Exrended Chevron (white)	Exrended Chevron (black)	Coloured Bands	Base Board
Combined Totals 27-0 II/III (Phases 3 & 4)											
Smooth		4	52	56	51	4	39	130	145	38	20
Medium		70	23	19	47	44	96	33	18	109	43
Rough		2	1	1	16	66	13	1	1	10	50
Total	0	76	76	76	114	114	148	164	164	157	113


Smooth
Medium
Rough
160
140
120
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20
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23
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19
1
51
47
16
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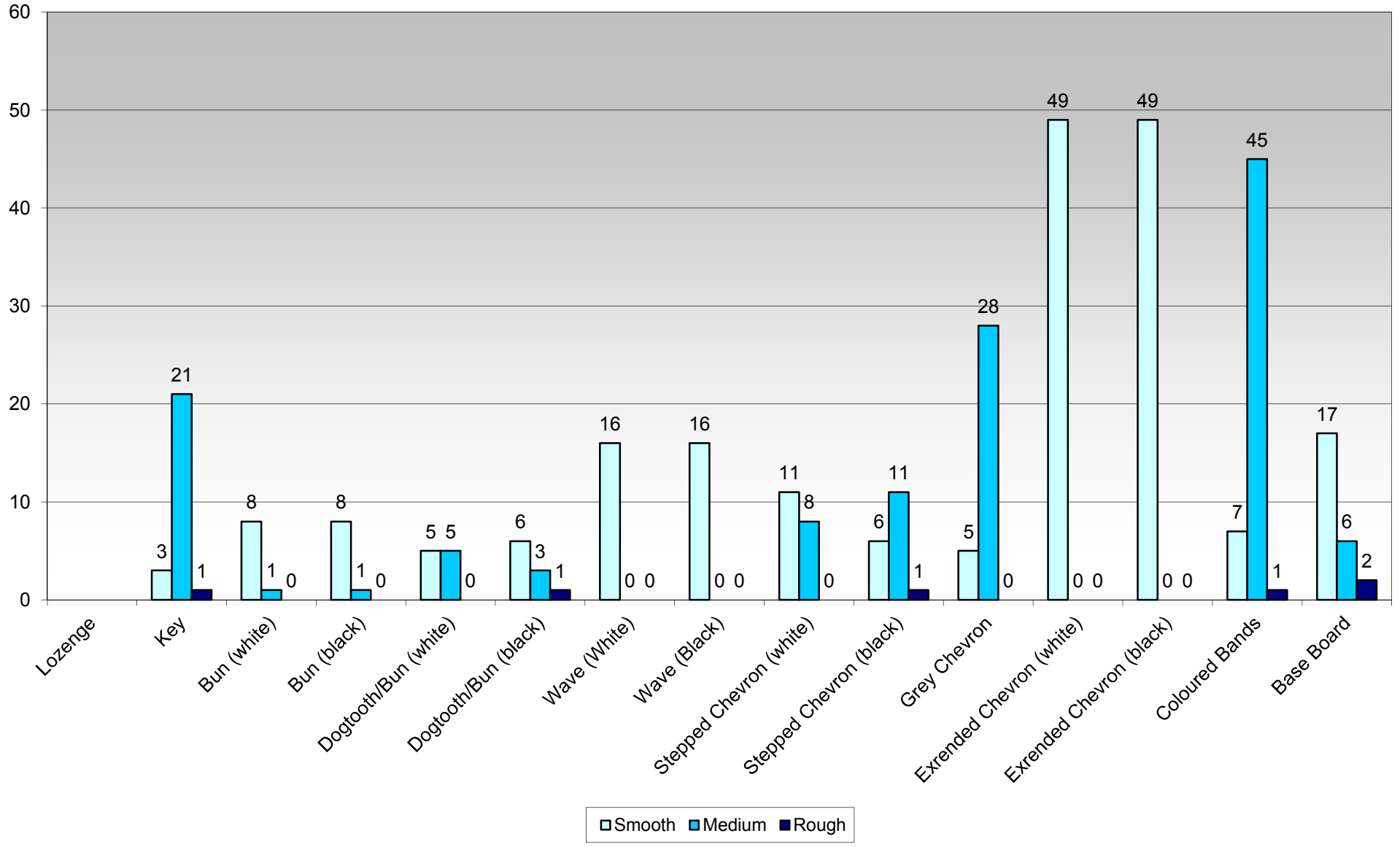
66
39
96
13
130
33
1
145
18
1
38
109
10
20
43
50
Lozenge
Key
Wave (White)
Wave (Black)
Stepped Chevron (white)
Stepped Chevron (black)
Grey Chevron
Exrended Chevron (white)
Exrended Chevron (black)
Coloured Bands
Base Board

Panel No:	Lozenge	Key	Bun (white)	Bun (black)	Dogtooth/Bun (white)	Dogtooth/Bun (black)	Wave (White)	Wave (Black)	Stepped Chevron (white)	Stepped Chevron (black)	Grey Chevron	Exrended Chevron (white)	Exrended Chevron (black)	Coloured Bands	Base Board
Totals 27-18 IV (Phase 3)															
Smooth			4	4	3	4	9	9	6	5	3	24	24	2	10
Medium		11	1	1	2	1			4	4	17			23	
Rough		1								1					
TOTAL	0	12	5	5	5	5	9	9	10	10	20	24	24	25	10
Totals 17-8 IV (Phase 4)															
Smooth		2	3	3	1	1	7	7	4			20	20		5
Medium		8			3	2			4	7	11			22	6
Rough						1								1	2
TOTAL	0	10	3	3	4	4	7	7	8	7	11	20	20	23	13
Totals 7-0 IV (Phase 5)															
Smooth		1	1	1	1	1			1	1	2	5	5	5	2
Medium		2													
Rough															
TOTAL	0	3	1	1	1	1	0	0	1	1	2	5	5	5	2
Combined Totals 27-8 IV (Phases 3, 4 & 5).															
Smooth		3	8	8	5	6	16	16	11	6	5	49	49	7	17
Medium		21	1	1	5	3	0	0	8	11	28	0	0	45	6
Rough		1	0	0	0	1	0	0	0	1	0	0	0	1	2
TOTAL	0	25	9	9	10	10	16	16	19	18	33	49	49	53	25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0 0
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0 0
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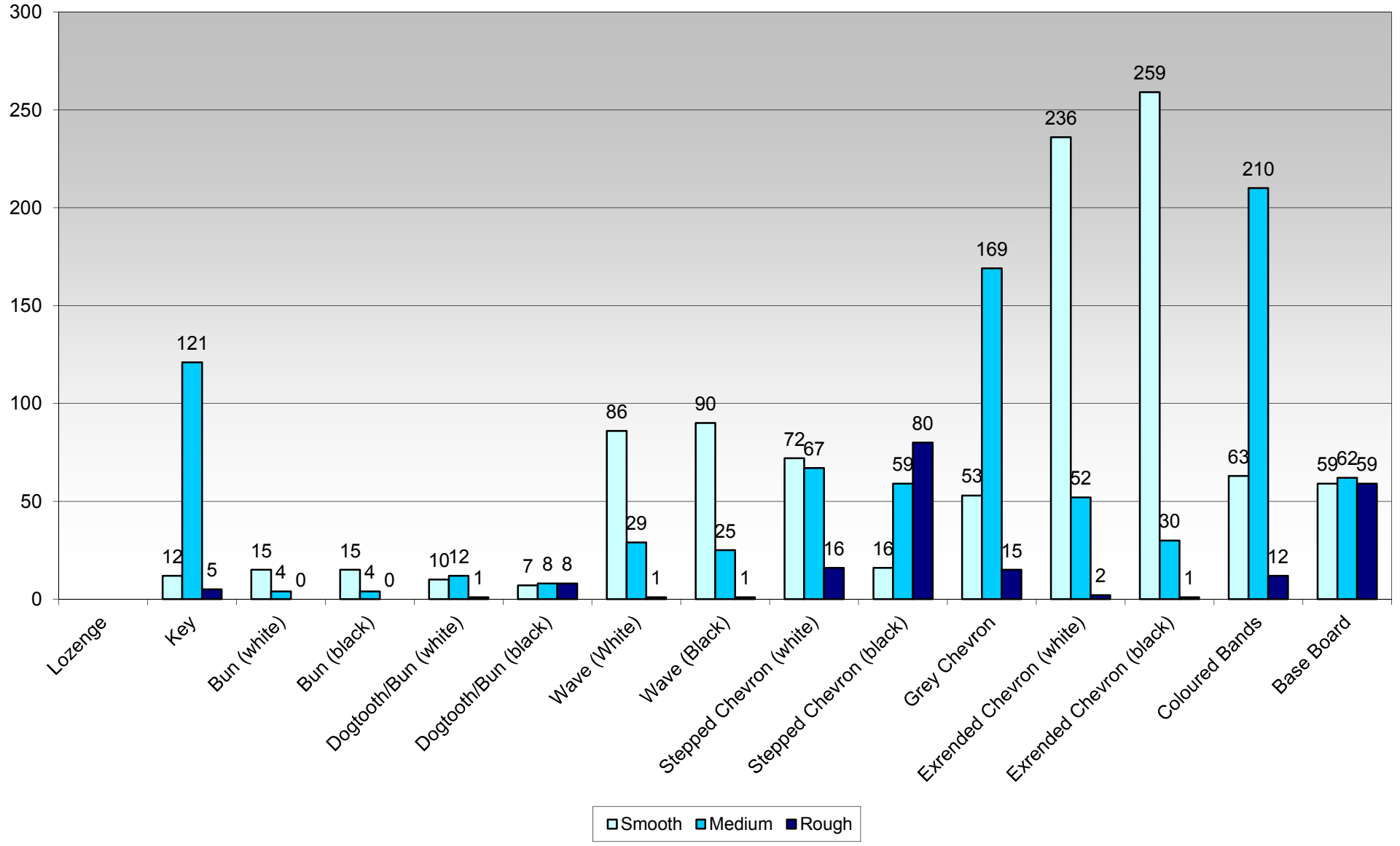
17
6
2
Lozenge
Key
Bun (white)
Bun (black)
Dogtooth/Bun (white)
Dogtooth/Bun (black)
Wave (White)
Wave (Black)
Stepped Chevron (white)
Stepped Chevron (black)
Grey Chevron
Exrended Chevron (white)
Exrended Chevron (black)
Coloured Bands
Base Board
Smooth
Medium
Rough

Panel No:	Lozenge	Key	Bun (white)	Bun (black)	Dogtooth/Bun (white)	Dogtooth/Bun (black)	Wave (White)	Wave (Black)	Stepped Chevron (white)	Stepped Chevron (black)	Grey Chevron	Exrended Chevron (white)	Exrended Chevron (black)	Coloured Bands	Base Board
Totals 27-18 IV (Phase 3)															
Smooth			4	4	3	4	9	9	6	5	3	24	24	2	10
Medium		11	1	1	2	1			4	4	17			23	
Rough		1								1					
TOTAL	0	12	5	5	5	5	9	9	10	10	20	24	24	25	10
Totals 17-8 IV (Phase 4)															
Smooth		2	3	3	1	1	7	7	4			20	20		5
Medium		8			3	2			4	7	11			22	6
Rough						1				1				1	2
TOTAL	0	10	3	3	4	4	7	7	8	8	11	20	20	23	13
Totals 7-0 IV (Phase 5)															
Smooth		1	1	1	1	1			1	1	2	5	5	5	2
Medium		2													
Rough															
TOTAL	0	3	1	1	1	1	0	0	1	1	2	5	5	5	2
Combined Totals 27-0 IV (Phases 3, 4 & 5)															
Smooth		3	8	8	5	6	16	16	11	6	5	49	49	7	17
Medium		21	1	1	5	3	0	0	8	11	28	0	0	45	6
Rough		1	0	0	0	1	0	0	0	2	0	0	0	1	2
TOTAL	0	25	9	9	10	10	16	16	19	19	33	49	49	53	25
Combined Totals 27-0 II/III (Phases 3, 4 & 5)															
Smooth		4					52	56	51	4	39	130	145	38	20
Medium		70					23	19	47	44	96	33	18	109	43
Rough		2					1	1	16	66	13	1	1	10	50
TOTAL	0	76	0	0	0	0	76	76	114	114	148	164	164	157	113
Combined Totals 27-0 I (Phases 3, 4 & 5)															
Smooth		5	7	7	5	1	18	18	10	6	9	57	65	18	22
Medium		30	3	3	7	5	6	6	12	4	45	19	12	56	13
Rough		2			1	7				12	2	1		1	7
TOTAL	0	37	10	10	13	13	24	24	22	22	56	77	77	75	42
Combined Totals 27-0 1-IV (Phases 3, 4 & 5)															
Smooth		12	15	15	10	7	86	90	72	16	53	236	259	63	59
Medium		121	4	4	12	8	29	25	67	59	169	52	30	210	62
Rough		5	0	0	1	8	1	1	16	80	15	2	1	12	59
TOTAL	0	138	19	19	23	23	116	116	155	155	237	290	290	285	180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169
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259
30
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63
210
12
59
62
59
Lozenge
Key
Bun (white)
Bun (black)
Dogtooth/Bun (white)
Dogtooth/Bun (black)
Wave (White)
Wave (Black)
Stepped Chevron (white)
Stepped Chevron (black)
Grey Chevron
Exrended Chevron (white)
Exrended Chevron (black)
Coloured Bands
Base Board
Smooth
Medium
Rough

Panel No: 2 III	
Board No.	**Observations**
A	Insect DWB one exit holes as on graphics. Some heavy weathering on NW corner and west edge. Condition good. Two predrilled holes.
B	Condition good.
C	Torn grain due to planing against grain. Condition good.
D	Torn grain due to planing against grain. Condition good. All splits caused by nails below and above.
E	Insect DWB one exit hole north end. Unused predrilled nail hole south end. Weathering heavy in black painted areas. Impact due to hammer blows. Condition good.
F	Insect DWB two exit holes. Unused predrilled nail hole NW corner. Weathering heavy in black painted areas. Two parallel carpenters marks diagonal towards NE corner. Impact due to musket ball. Condition good.
G	Insect DWB eleven exit holes mainly south end also some wet rot. My feelings are that this is an original board but from another position, reason - the scarf joint is not quite right. Condition good.
H	Insect DWB heavy south half. Moderate north half. Soft wood insert east edge 'I'. Weathering between grooves. Some splitting along W edge caused by nails. Condition good.
I	Softwood insert original board sawn from above. Creosote finish.
J	Insect DWB heavy in patches shown on graphics. Timber loss west edge 995mm from south end. Size of loss 55 x 30mm. Some tool marks on round edge. Impact cause unknown.
K	Insect DWB exit holes and tracking along whole of west edge. Heavy tool marks on face. Two diagonal marks very deep most likely caused by corner of plane blade. Two boards displaced 45mm west at south end. Scribe marks to show position of painted pattern. There are also diagonal lines, eleven in all, do not think they are carpenters marks or for any other purpose. Condition good.
L	Insect DWB two exit holes NW corner. Light weathering between grooves. Timber loss W edge 500mm from N end. Loss 90 x 15mm. Condition good.
M	Insect DWB five exit holes overall. CFB surface tracking along face W side of board. Weathering medium between grooves. Condition good.
N	Planed face saw marks showing through W side mid board. Chamfer west side and north end. This is because softwood board over top of original. Condition good.
O	Insect DWB two exit holes overall. Condition good.
P	Planed face saw marks showing through centre of board. Condition good.
Q	Insect DWB heavy north and south ends. Moderate rest of bard. Diagonal joint with 'P'. Saw cut parallel with joint 50mm in. 140mm long across face from east edge. Weathering heavy between grooves. Condition good. Timber loss east edge mid board due to nail. Timber loss south end east edge, cause unknown.
R	Insect DWB heavy south end west side. Rest of board moderate. Weathering medium mainly in white paint. Tool marks showing on round edge east. Condition good.
S	Weathering mainly in white paint. Timber loss north end man made 50mm x 50mm. Impact mark looks very much like a square washer with rounded corners, like washer in north and south transepts. Also another impact mark right beside other impact mark look like end grain of timber under pressure. Condition good.
T	Torn grain due to planing against grain. Condition good.
U	Insect DWB moderate. Weathering between groove. Condition good.
V	Condition good.
W	Insect DWB one exit hole. Weathering between grooves. Condition good.
X	Insect DWB light. Man made hole 30mm diameter but worn NS too 35mm, 820mm in from S end. Timber loss north end. Man made cut out rest of corner broken off. Impact due to hammer blows. Scratch S end of board 430mm in on E side 60mm long. Condition good.
Y	Torn grain due to planing against grain. Condition good.
Z	Torn grain due to planing against grain. Condition good. Chamfered edge.
AA	Insect DWB two exit holes. Weathering very heavy. Condition good.
BB	Torn grain due to planing against grain. Rounded edges east and west. Condition good.

Panel No: 2 III

DESCRIPTION								JOINTS				CONDITION							
								Scarf			Butt	Damage				Displaced			
																Vertical		Lateral	
Board No.	Tapered/Sq./ Loz./BB/T&G	Rnd/Straight/Grooved	Orig/Rep/Pat/Ash	Wood type: Oak/Softwood	Sight size undisturbed oak boards (mm)	Full width of original oak board (mm)	Thickness softwood board (mm)	Long Board mm	Scarf length mm	Scarf to	Jointed to	Weathering	CFB (C)	DWB (D)	C/D Holes per 25mm sq	mm	N/S/E/W	mm	N/S/E/W
A	L	R	O	O								H		D					
B	S	S	R	S			11												
C	S	S	R	S			11												
D	S	S	R	S			11												
E	T	S	O	O				2090	60	F		H		D					
F	T	S	O	O		200			60	E		H		D					
G	T	WG	O	O					50	H				D	D2				
H	T	WG	O	O				2120	80	G		H		D	D5				
I	S	S	P	S															
J	T	R	O	O				1772	70	K		H		D	D4				
K	T	R	O	O					70	J				D				45	W
L	T	WG	O	O				2120	60	M				D	D2				
M	T	WG	O	O					60	L			C	D	D2				
N	S	S	R	S			12												
O	BB	S	O	O								H		D					
P	S	S	R	S			12				QR								
Q	T	WG	O	O							P	H		D	D3				
R	T	R	O	O					70	S	P			D	D3				
S	T	R	O	O					70	R									
T	S	S	R	S			14				U			D					
U	T	WG	O	O			14				TV	H		D	D2				
V	S	S	R	S							UW								
W	T	WG	O	O							V			D					
X	T	S	O	O		182						H		D	D2				
Y	S	S	R	S			11												
Z	S	S	R	S			12												
AA	L	R	O	O										D					
BB	S	S	R	S			15												

Panel Number: 2 III

Board No	Pattern	Replacement Y/N	Visible Underpaint	Observations on Painted Decoration
a	Loz	N	Figurative	Underpaint, original and 1740's impasto. Green gritty. Numerous brown spots. In general paint is thick & dark.
b	Loz	Y	1740's Figurative	Underpaint, brush texture of 1740's. Paint thick, combination of layers and gritty
c	Key	Y		Milky bloom. Brown setting out/snap lines. Key lines with brown spots, gritty alligatoring, brush mark evident through gritty paint. Generally paint thin, in areas thick (beginning of brush strokes).
d	Wave	Y		Milky bloom. Incised setting out lines. Brown black generally, in thicker areas darker/shiny with small white patches. Paint absence on face E side. Minor brown staining at S end associated with knots. The slightly gritty paint reveals brush strokes in dark wave
e	S.C.	N	Step Chevron	Step chevron underpaint out of phase. Composite black strengthened with resinous/shiny black (white patches). Brown spots. Pentimenti, adjustments to shape of Step chevror
f	S.C.	N	Step Chevron	Smaller board than "e" but similar description
g	G.C.	N	Leaf	1740's leaf just discernable. Minor insect damage. Very minor brown spot. Black dull composite, green/yellow shiny
h	G.C.	N	Leaf	Similar to "g", underpaint just discernable, slightly more insect damage. There are some white patches at S end associated with resinous/shiny paint. Brown spots. Gritty particles in paint.
I	None	Y		A repair or infill. Black matt paint - uniform
J	E.C.	N	T	Incised mark at N end, seems to be initials. Pentimenti to wave & scroll. White notably thicker in these areas of change. Insect damage grouped at N & S ends. Black generally a uniform dull metallic but areas of thicker resin paint & associated white patches. Peeling glue associated with fixing hole- centre of board. Brown spots
k	E.C.	N	T	Composite black, strengthened with dull metallic black. Paint absence of dull metallic black on face - E side. Incised lines for setting out wave. A group of score (incised lines) in middle, purpose unknown. E side of face dusty with some stains. Efflorescence associated with S wave and adjacent E side of board face. Some paint flaking. Brown spots. W side of face, grey paint & incised line to define location of grey line.
L	Bands	N		Paint quality opaque throughout & even, a couple of thicker areas where brush marks start, e.g. grey at N end. Brown spots, more evident in red & black. Slight gritty areas
m	Bands	N		Thick dust at E side of face. Pentimenti to black line. Areas of paint flaking associated with fixings. Brown spots
n	Base & Bands	Y		Setting out line marking junction of base & bands. Board dirty at S end, especially at S edge. Milky bloom. Staining & spattering glue from underside board "l". Charcoal black background generally matt & smooth, in areas shiny & in impasto, minor white patches
o	Base	N	F	Pentimenti to scroll design in charcoal black. Background composite black strengthened with resinous shiny black with associated white patches. Glue drip flaking at S end. Earlier paint 1740's can be seen under "n".
p	Bands/ E.C./ G.C.	Y		Pencil setting out line with chalk line. Brown stains at N end with solvent edge. Generally single thin paint application. Milky bloom. Minor efflorescence at N end, dirt/dust deposits heavy at N end (raked edge). Tendrils at S end. Brown spots.
q	Bands	N		Brown spots. Paint flaking associated with clenched nail at N end, paint under nail end, white & black, possible photo and sample. Insect damage in grey, minor
r	E.C./G.C./ & Trace of bands	N		Very minor insect damage. Pentimenti to wave, dark ghostly presence visible under thicker white. Brown spots. See "x"
s	E.C./G.C.	N		Pentimenti to scroll, thick white adjustments. One of two shiny instances in dull metallic black
t	S.C.	Y		Milky bloom. Charcoal black, couple of instances of white patches where paint thicker. Minor impasto in generally dull surface of black. Heavy dust/dirt on face, W side of board
u	S.C./G.C.	N		Black paint generally uniform & matt, slight impasto, where impasto heavy there are white patches. Glue drip through fixing hole at N end. Staining associated with split at S end, minor efflorescence. See "x".
v	S.C./G.C.	Y	Foliate	Milky bloom. Paint similar to "u", minor white patch. Underpaint is 1740's, appears to be foliate, discernable in underlying impasto. Red paint visible under removed nail head and associated with paint flaking on W edge of board, 1740's. Paint. So three paint layers visible, likely to be a ground/primer under the red. Brown spots
w	S.C./G.C.	N		Paint similar to "U" & "v". Brown spot.
x	Wave/S.C.	N	Step Chevron	Underpaint shows this board has been moved. It is likely that both boards "u" and "r" have also been moved. Black charcoal colour, generally dull & matt with shiny patches of impasto, minor white patches. Flaking associated with splits & fixings at N end. Glue drips at E edge N end. Earlier step chevron design detectable under board "y". The black is a more chocolate colour.
y	Key	Y		Milky bloom. Brown setting out lines. Key paint generally matt & flat, brown spots, some mottling. Paint solvent edge to stains, (stains possibly chemical). Glue drip at N end
z	Loz	Y		Whitish stain associated with split (possibly chemical) at S end. Paint absence on face at E side. The red flower is shown in impasto, chackuleure in the impasto show how bright the original red was. Brown spots. Very minor efflorescence at N end.
aa	Loz	N	Figurative	Possible original underpaint, difficult to determine. Gritty paint in dark colours & red. Score/incised lines at N end. Possible carpenters working marks. Dirt/dust on recessed surface at S end. Brown spots. Glue drip on W edge from underside.
bb	Loz	Y		Incised lines for location of small board to S. Minor efflorescence on E edge, heavy dirt/dust

APPENDIX 8

Peterborough Cathedral Nave Ceiling – Phase 5
Definitions for the Board by Board Surveys

The reason for conducting the board by board survey is to expand upon the graphic documentation where it is appropriate to do so. It is also to record phenomena not documented elsewhere and any anomalies.

Key:- F = frieze, T = trefoil, S = scroll, K = key, W = wave, L = leaf, B = bands, SC = stepped chevron.
Special note if there are dots in the underpaint, in this case draw a tiny circle above the main letter. To date dots are only associated with scroll or trefoil.
Shorthand notes in margin: P = photograph, SA = sample analysis

PHOTOGRAPH AND SAMPLE ANALYSIS

If it is a good example of a phenomena, discuss with others, and note it for photography or sample. Note it by putting a **red S or P** beside it in the margin and by underlining the actual note in red.

SUMMARY OF CATEGORIES

1. Surface Accretions
2. Stains
3. Paint
4. Paint Condition
5. Paint Absence
6. Pattern Sequence
7. Mechanical Damage
8. Structure
9. Damage to the Wood

CATEGORY

1. SURFACE ACCRETIONS

1.1. GLUE
In Phases 3 and 4 the previous categories of 'Edge' and 'Face' have been united under Surface Glue. The previous category of 'Adulterated Glue', indicating glue drips with a sugary/crusty texture, possibly resulting from the glue having been altered by the action of another chemical, is ***not*** *recorded on the Graphics, but* ***is*** *recorded on the board by board survey*

- **Surface Glue**
  Drips of glue are often found on the edges and faces of boards. This occurs where glue has penetrated through gaps between boards, knots, holes or splits. Occasionally glue might penetrate from the lap-over from one board to another. These drips are excess material from when the hessian backing was stuck to the reverse of the boards. They clearly fluoresce in U.V. light.

- **Flaking and Glue**
  This happens where paint has been severely affected by glue drips. Glue drips can hang from the surface on a length of peeled paint.

1.2. MICRO-BIOLOGICAL GROWTH (MBG)
Previous phases have included a number of phenomena under this heading. Research carried out during Phase 2 has concluded that only ***'Tendrils'*** *can now be definitely categorised as MBG.*

- **Tendrils**
  Tendrils of MBG, like miniature spider web, joining larger elements together. Detectable without the aid of magnification. The tendrils appear to lie on the surface of the paint. The larger white elements are fuzzy under magnification and appear as a fine white dust on the surface of the paint.
  Very occasional occurrence in Bays 4,5,6.

- **Grains**
  Purple (or mauve) grains visible as a group on the surface. Grains are distinct but they are in a group. During Phase 1 detectable without magnification. None found in Bays 2-6. These were previously categorised as MBG.

1.3. BROWN SPOTS
The categories 'Blotchy' and 'Spots' have been united under 'Brown Spots' for Phase 3. Both definitions in the

CATEGORY

Phase 2 Report are still valid.
These can usually be removed with a Wishab. The spots can be either white or brown and often have a fuzzy edge and a central, raised particle. Previously categorised as MBG. Ridout describes the brown spots as irregularly shaped, translucent granules. He has not confirmed them as being organic in composition. Several examples of insect bodies at the centre of spots have been found in Bays 4,5,6.

1.4. EFFLORESCENCE *(In Phase 3 this refers only to Chalk Line)*
Very characteristic thick, bright white surface deposit, like a drawn chalk line. Found on boards decorated with wave or stepped chevron design. The chalk line follows the shape of the decoration, and occurs in the off white (lead) background. It can be removed with a Wishab.
In Bay 4 we have noted an efflorescence very similar in appearance to 'Chalk Line', but occurring on other boards e.g. 25 1 – Grey chevron (replacement); 27 1V – Extended Chevron. It appears around the edges of splits.

1.5. OTHER EFFLORESCENCE (Define)
- **Crystals**
  Small crystal like deposits associated with micro flaking of the paint layer.

Two other types occurred in Bays 4,5,6:
- Numerous tiny white deposits are visible on the red band of 26 111 r, some have black heads which suggests dirt. The white deposits are likely to have erupted through the paint surface.
- A bright white 'deposit' that has apparently seeped through cracks in the thick 1740's paint layer of the Grey Chevron - 26 111 v.

1.6. GRAFFITI
Any marks, written or otherwise, in paint or in pencil.

1.7. DUST
- **Thick**
  Loosely adhering dust is found where drafts have deposited material. This happens where there are gaps or voids in the ceiling allowing air movement between the nave and the roof space above.
- **Compacted**
  Compacted accretions of dust that have build up on the surface. They resist removal with a Wishab, and appear to have been caused as a result of penetration of another material e.g. water.

2. STAINS

2.1. CHEMICAL
Generally brown in colour, having penetrated as a result of a treatment to the boards above. One such preservative was 'Silvertown'. These stains do not fluoresce. Clear stains resemble paint saturation.

2.2. WATER DAMAGE
Water staining occurs where there has been water infiltration. This is particularly noticeable on the ashlar boards and the walls, but less obvious on the board edges. The stains do not show up in UV.

2.3. BROWN DRIPS
Light brown in colour, frequently found on the edge of ceiling boards or around holes or splits in the boards. Organic.

2.4. RESIN
Most often clear staining around knots, very rarely thick drips of resin. This is only found on the softwood replacement boards.

3. PAINT

3.1. WHITE PATCHES
Patches of white generally found on areas of black metallic/impasto paint. This has previously been recorded as MBG but analysis indicates this is not the case: Ridout describes them as irregularly shaped , translucent plate-like crystals. They have a grey centre with white halo around edge and when viewed under x15 magnification

CATEGORY

the edge consists of tiny white circles or as shards/frost-like crystals. Exclusively associated with 1830's outline repaint and retouching. Can occasionally be reduced with a Wishab. Generally found on stepped chevrons and base boards; however sometimes also found on other blacks.

3.2. BLANCHING
This is a permanent change in the paint structure, possibly affected by moisture. It occurs particularly on the composite brown/black of the Base boards, Stepped & Grey chevrons. The visual appearance includes the washed-out, white 'spotting' and the denser white areas often found on the edges of boards with brown/black paint. Previously marked as MBG.

3.3. BLOOM
In Phases 3 and 4 this has been defined as that occurring on the repainted backgrounds of the lozenge boards, where the 1830's red and blue has been laid over the olive green or red of the 1740's. It is patchy, white, matt . It can be reduced with a Wishab.

3.4. MILKY BLOOM
Previously recorded as 'Surface Bloom'. Particularly noticeable on some of the 1830's softwood replacement boards. The boards appear to have an overall white coating. It can not be removed or reduced with a Wishab. This bloom can also be occasionally found on oak boards e.g. 19 1V 'e' and seems to be associated with a particular paint application (1830's?)

3.5. OTHER BLOOM (Define**)**
This will include patches/zones of bloom, less than general/overall. These may be discussed and covered under other categories. For example areas of the ashlar affected by water bloom will be marked as '**Water**' in the '**STAINS**' category.

- **Matt White Patches**
  These have a grey/white, powdery, matt surface and are generally found on the black of the wave and extended chevron boards. Often associated with the application of other paint layers i.e. the matt white often appears underneath a later layer (19/11). Can frequently be removed or reduced with a Wishab.
  Do not confuse with 'Bloom' as found on the (1830's?) red and blue backgrounds to lozenge panels; or 'White Patches' as described above.

3.6. VISIBLE UNDERPAINT
This includes *all* underpaint from any period of decoration.
Note pattern and any anomalies. Check all boards including grey chevron, some of which have impasto underpaint beneath present off white layer.
If wave or stepped chevron is encountered note only if it is out of phase with the overpaint.
If trefoil or scroll is encountered look out for 'raised' dots. These are found in the centre of the trefoil 'leaf', and within the cusps of the scrolls. The surface of the dots is sometimes apparently flaking or deteriorating, perhaps indicating the presence of a different material beneath. This was first noted in Phase 2; no examples have been found in Bays 4,5,6. The distinctive appearance of this phenomenon suggests that we were unlikely to have overlooked it in Bay 1; so far it seems only to have occurred in Bays 2&3.

4. PAINT CONDITION

4.1. FLAKING PAINT
In Phase 3 this includes *all* flaking paint and associated losses. For example in Bays 4,5,6 the paint layer is *delaminating* into *large* flakes, up to 50mm long and is far more extensive than in previous phases. The Emergency Treatment Phase – uniquely - revealed extensive flaking and *scrolling* of the paint layer on St Peter. *Micro-flaking* has, to date, been found only in the black areas of wave pattern. The black is matt and saturated. The flakes are very small and clustered together and are associated with crystalline efflorescence. *Delamination* of the paint layer is most often found in black areas; especially the base boards, stepped chevron, grey chevron. The paint often delaminates in a regular rectangular pattern not that dissimilar to the wet rot pattern.

4.2. POWDERING PAINT
Powdering paint has not been encountered since the first phase when it was found on the canted ashlar boards at the east end. Wishab cleaning removed the paint.

CATEGORY

4.3. METALLIC SHEEN
Only occurs on black paint; especially on the stepped chevron, and to a lesser extent on the wave/extended chevron/grey chevron & base boards. It would appear to relate to one of the most recent repaints and is associated with '**3.1. White Patches'**. Where the sheen is most noticeable the paint is in impasto. This paint fluoresces mauve in UV light.

4.4. GRITTY
This paint looks like it might be friable/powdery, but it is relatively secure and withstands cleaning with a Wishab. Gritty paint is generally found in the central figurative lozenges, and is noticeable without the aid of magnification.

4.5. IMPASTO
Mostly associated with the black shiny metallic paint. The impasto varies in thickness, generally thicker on the edges of the design. It is also associated with off-white areas of the grey chevron pattern where the 'leaf' underpaint can be seen.

4.6. SHRINKAGE CRACKS
These occur where the paint has shrunk and crazed. To date only found on replacement boards, and very infrequent.

4.7. SURFACE CHEQUERING
A very characteristic damage where there has been wet rot decay. The surface of the paint looks like alligator skin, and follows the decayed structure of the wood. There may be flaking and loss of the paint layer.

4.8. INSECT DAMAGE
Where wood boring insects have attacked boards causing paint loss. In some places sections of board have been lost through insect damage.

5. PAINT ABSENCE

5.1. BOARD ALIGNMENT
Where boards have not been repositioned properly, leaving zones of bare wood along edges and/or ends of boards.

6. PATTERN SEQUENCE

6.1. MISTAKES
Where the decorative order of the painted boards has been incorrectly altered

6.2. ALTERATIONS
Where there have been definite alterations to the order or pattern of the painted boards. This typically occurs in the off-white triangles within the grey chevron pattern; changes in 'bun' shape across N & S; lack of base boards in the canted sections.

7. MECHANICAL DAMAGE

7.1. SHOT
Damage from lead shot fired at the ceiling boards. May occur on single boards on the ceiling: this can be an indication of a re-used ashlar board. Do not confuse with insect damage.

7.2. IMPACT
Surface impact damage is recorded as accurately as possible on the graphics. Further explanations are recorded in the board by board survey.

- Damage from blows to the surface of the boards e.g. hammer marks.
- Damage from previous actions, including that caused from erecting the scaffold.

CATEGORY

8. STRUCTURE

8.1. INCISION LINES

These are to be plotted on the graphics and described on the board by board survey.

- **For Painting**
  Narrow lines incised into the wood to mark out a design for painting.
  Only one example was found in Bay 1 - on the replacement ceiling board with frieze decoration underpaint.
  Only 2 clear examples were recorded in Bays 2&3.
  There are numerous instances in Bays 4,5,6, particularly for marking frames/borders on figurative lozenges.
- **For Construction**
  Note probable reason for each mark (e.g. carpenters mark; circular/semi-circular/crescent alignment grooves; incision to mark line of joist).

9. DAMAGE TO THE WOOD

9.1. INSECT INFESTATION

- **Categories**
  Moderate = Even spread of exit holes but at no point as much as 2 per 25mm sq.
  Light = 2 per 1 ft length
  Sporadic = 1 per 1 ft length
  Negligible = 1 per 2 ft length
  For anything less - state number of exit holes on board.
- **Density**
  On the graphic enter the maximum number of holes per 25 mm square using the template provided, and if the board has both infestations, indicate with (C) or (D) which type of infestation has been measured.

9.2. FRACTURE

Fractures in the boards as opposed to splits. Fractures will normally be characterised by being breaks across the grain rather than parallel to the grain. Note the probable cause of the fracture (i.e. board weakened by insect/distortion/pressure/decay).

9.3. CROSS CHECKING

This phenomenon can be recognised by a number of small fractures adjacent to each other, either along the edge of a board, or at random within an area of a board. There will always be a number of fractures and some may run parallel with the grain. They will all be much the same size, probably approx. 10mm in length. It is always associated with surface decay. See also **Surface Decay,** where the surface is merely soft but not cross checked.

9.4. SCORING

As described above under Incision Lines. Note probable reason for each mark (e.g. carpenters mark; circular/semi-circular/crescent alignment grooves; incision to mark line of joist; to outline painted decoration etc.). They will be plotted also on the graphics.

9.5. WOOD LOSS

Wood loss will be plotted on the graphics but note on the board by board survey the probable cause of each loss (e.g. insect attack; wet rot; loss resulting from a split/fracture in the board; hole made for construction purposes). Do not include nail holes.

9.6. SURFACE DECAY/WET ROT

Where the wood surface is soft probably due to wet rot. This tends to be associated with paint flaking and/or loss; particularly where there is the thick brown/black 1740s paint.

9.7. SAW CUTS

Note probable reason for saw cut.

9.8. SPLITS

CATEGORY

All splits in the boards are marked on the graphic.

Original Boards - Almost all the splits are associated with the wood drying and contracting after being fixed in the Ceiling, e.g. where the nail is restraining a softwood board where one fragment is moving away from the piece that is held. By the same token the oak boards are only split once to relieve the tension in the wood whereas if the splits happened when the nails were first driven, it is likely that splits would have formed between the nails and the ends of the boards.

Replacement Boards - Although the replacement boards are split for the same reasons as the oak boards, the characteristics of the splits are quite different. These splits are not so wide, but they are very much longer. Splits between nails are also narrower and often they are very long – sometimes extending for the full length of the board. As there are knots in the softwood boards, there are also curved splits around the knots (see **Graphics 7A/B/C**).

9.9. WOOD LOSS

Nearly all wood losses in Original boards can be attributed to decay and infestation where the infestation has been so acute that the timber has been sufficiently reduced and weakened that it has freckled away, or detached by contact or rough handling during previous restorations A few other losses have occurred when boards were cut back and moved around when the replacement boards were inserted

All wood losses in the replacement boards are those incurred during fitting or subsequent restoration, none are attributable to beetle infestation or decay.

- **Intended Wood Loss**
  A number of holes or extended holes have been cut through the ceiling boards, the reason for which is not always clear. These are recorded on the graphics and board by board survey sheets. There may be patterns to the losses. They may be associated with repairs or fitting the boards.

9.10. SURFACE SPLINTERING

All splintering is marked on the graphics. It is predominately associated with fixings, particularly from above. Where the splinters are very small/minor and specifically associated with a fixing they are marked separately.
Also includes layer separation of medullary ray on the grooved boards, or any other original board.

9.11. OTHER DAMAGE (Define)

APPENDIX 9

Peterborough Cathedral Nave Ceiling - Phase 5: Pre-Treatment Condition Survey – Boards

HEADING	CRITERIA
DESCRIPTION	
Board No.	This is the number on the graphic.
Tapered/	These are boards which are tapered in section, made by splitting radially off a log. Only the original oak boards will be in this category. See Figure 3 in the first Report. Enter "T"
Square/	This covers all boards which are square in section, which covers the base boards*, the softwood boards, and a few oak patches. If the softwood boards have subsequently been shaped to a taper or part taper, this should be recorded on the back of this sheet. See Figure 3 in the first Report. *These are the flat boards which delineate each lozenge, and in the flat ceiling comprise three boards, a single board at the narrow end, which is scarfed over two boards at the wide end. The two boards are butt jointed and fixed with dowels. Where the dowels can be seen, mark them on a graphic, and if the whole length of a dowel is exposed, record the length on the reverse of this sheet. Enter "S", or "BB" if it is a base board.
Loz.	The lozenge boards are those in the centre of the lozenge, which have been worked so as to create boards which when placed next to each other provide a "flat" surface to paint figurative features. See Figure 3 in the first Report. Enter "L"
Rnd/	See Figure 3 in the first Report. Enter "R"
Straight	See Figure 3 in the first Report. Enter "S"
Grooved	See Figure 3 in the first Report. Enter "G"
Orig/	Original oak board. Enter "O"
Rep/	Replacement softwood board. Enter "R"
Pat	Patch in either softwood or oak. Enter "P"
Ash	Oak replacement board with original Ashlar underpaint
Wood type	
Oak/	Identify by the character of the grain. Enter "O"
Softwood	Identify by the character of the grain Enter "S"
Sight size undisturbed oak boards (mm)	Measurement of visible width in mm. of full, undisturbed, original oak boards
Full width of original oak board (mm)	Measurement of full width in mm. of undisturbed, original oak boards where (because of damage or displacement to adjacent board) it is possible to see the full width
Thickness softwood board (mm)	Measurement in mm. of thickness of all softwood boards.

HEADING	CRITERIA
JOINTS	
SCARF	
Long Board	Where a single mould has been made up in length by scarfing two or more boards together, measure the length of the longest original board in mm including the chamfered end if it is the under joint . This is to ascertain a possible pattern of supply the original boards to certain set lengths.
Scarf Length	Measure the length of the scarf joint. Where the joint has pulled apart, only measure the length of the chamfer that has been worked at the end of each board.
mm	Length in mm
Scarf to	Insert the number of the board with chamfered end beneath. In the case of the base boards, insert the numbers of both boards to which the single board is scarfed.
BUTT	
Jointed to	Only inserted patches or replacement boards will be butt jointed, except the base boards which need not be entered here. Enter the number of the board to which this one is butt jointed.
CONDITION	
Weathering	Categorise as H (heavy)if original board has prominent medullary rays, visible underpaint or other evidence of surface weathering
Insect Damage	
CFB (C)	Common furniture beetle.
DWB (D)	Death watch beetle.
C/D	Common furniture beetle and death watch beetle.
Holes per 25 mm sq.	Enter the maximum number of holes per 25 mm square using the template provided, and if the board has both infestations, indicate with (C) or (D) which type of infestation has been measured.
Displaced	
Vertical	
mm	If this board has been displaced vertically, enter the distance here in mm.
N/S/E/W	Enter which end or side of the board has been displaced.
Lateral	
mm	If this board has been refixed or moved out of alignment, enter here the distance it is out of alignment.
N/S/E/W	Enter here the direction it has been moved or refixed.

APPENDIX 10

PETERBOROUGH CATHEDRAL NAVE CEILING
NAIL SURVEY 2003

INTRODUCTION

An additional survey was carried out in rows 10 (1-4) and 11 (1-4). This focussed on noting shafts, where visible, and corresponding heads.

The majority of added nails in the ceiling seem to date from the 1830s restoration. In previous phases added nails have been categorised as dome heads (flat shank) or lost heads (square shank). The shape and size of the heads within both types of nails now seems to vary considerably, so attempting to separate them into the two categories by the shape of their heads would be inaccurate.

It is often difficult to distinguish 1830s added nails from Small Headed Original nails.

A small number of square shanked added nails have been found in both 1740s replacement and original boards. These are thought by PLP to date from the 1740s restoration. They cannot be distinguished from 1830s added nails unless the shank is visible or other evidence - such as 1740s paint on the nail head - exists.

For the 2001 survey added nails are categorised as follows:

- Added flat heads – only where the flat shank is visible.
- Added square heads – only where the flat shank is visible. Two of these are 1830s square.
- Added nail heads – shank not visible

ADDED NAILS - PHASE 4 SURVEY FINDINGS

- **1740s Lost heads** (thin square shank)

- **1830s Dome heads** (flat shank but with spade end):

- **1830s** **Lost heads** (square shank) – Four types:
  Square – thick square shank and long (1 example only found)
  Small Square – small square shank and smaller (but not as thin as the lost heads)
  Rectangular Square – as Small Square but with rectangular shank but not as pronouncedly thin and flat as the dome head (*P Martindale uncertain whether this category exists*)
  Large Square - Recently (8.6.01) found in the roof space, longer and fatter than the other 1830s nails. None of these have been identified in the ceiling boards.

INTERPRETATION OF SURVEY FINDINGS

Original - 1230s

Standard original	examples very similar to each other – BG identified as being made from high quality ore.
Small Head Original	varied examples – some much smaller than others – smallest used for securing edge of short length boards – largest used in Base Boards. All seem to have flat shanks – large heads have thicker shanks, small heads thinner shanks. These nails have high levels of impurities (sulphur), not such good ore as for standard originals. Suggest change of name to other original and define the range of types – photo/text/drawing. The shank of a SHO can be seen in 11/II/k.

1740s

1740s square shank/Lost head *(HH) lost head square shank.*	Evidence from this phase (2001) indicates that the nails only occur in 1740s or original boards. They have distinctly shorter and thinner shanks than the 1830s small square nails. Problem with positive ID as their heads are similar to the heads of 1830s Small Square nails. The only way to be certain these

are 1740s nails would be to extract one of the examples of non-protruding obviously 1740s nails accessible in this phase.

1830s

Flat shank/Domed heads	Many examples from Limentani/Lewis and from survey of ceiling. Nails have been used for clenching over from above and have been used from below as well. Heads seem to conform to HH flat dome head.
Square shank/Lost heads	Three sizes identified. Small Square, Square and Large Square. A number of Small Squares were found amongst those removed by Limentani/Lewis. Five given to BG one kept for reference – heads varied but all small. Two Squares found in position at 10/III/u and 10/I/e. Only one Large Square found by BC and CS in roof space. All findings from roof space are being kept separate from other nails. These nails seem to be different lengths of the same basic form – the larger are used for structural fixing purposes. Examples of the Small Square in situ with projecting or visible shanks have yet to be found – it would be good to find examples in situ to confirm the 1830s date. Heads conform to HH lost heads.

NAILS TAKEN FOR ANALYSIS BY BRIAN GILMOUR ON 7 JUNE 2001

Nails removed from boards

11/III/aa	standard nail removed
11/III/e	(PLP) 1740s nail removed (HH) lost head square shank
14/III/x	standard removed
10/IV/I	(PLP) 1740s nail removed (HH) lost head square shank
17/I/n	Small Head Original from edge of board – (small nail fine shank – shank not noted but likely to be square – check with BG)
14/III/m	Small Head Original from edge of board – (small nail fine shank – shank not noted but likely to be square – check with BG)
17/III/n	Small Head Original from Base Board – (large nail flat shank – head and part of shank only - sample broke during removal – the nail is driven into a noggin and is well secured)
15/III/n	Small Head Oringinal – junction of Bands Board and Base Board – (large nail flat shank – used for securing edge of Bands Board to Base Board)

NAILS ALREADY REMOVED (Limentani/Lewis + findings during conservation – nails on wall plate)

Five examples of 'spade' flat – (PLP) 1830s added flat
Two examples retained by PLP for reference

Five examples of square shank, variety of head sizes – (PLP) 1830s added square – (HH) lost head
One example retained by PLP for reference – the head size is mid way between the five taken by BG

Two Small Head Originals
No reference nails

One copper nail
No reference nails

NAILS TAKEN FOR ANALYSIS BY BRIAN GILMOUR ON 11 OCTOBER 2001

17/III/u	(PLP) 1740s nail removed (hacksaw)
16/II/m	1830s nail removed
8/IV o	(PLP) 1740s nail removed

APPENDIX 11

PETERBOROUGH CATHEDRAL NAVE CEILING

Criteria for Repairing Missing Sections of Ceiling Boards (May 2001)

Our approach to the conservation and documentation of the Nave Ceiling was adopted in the light of the initial survey, treatment tests and treatment carried out to the St Peter, St Paul and Psaltery Player lozenges during the Emergency Phase in 1997. That approach is in essence one of minimal intervention.

As our knowledge of the Ceiling has developed we have adapted our condition recording methods to account for the changing significance of particular aspects, but the techniques, methods and materials used in treatment have evolved very little throughout the four phases of work to date. The main exception being our approach to the replacement of missing sections of the ceiling boards.

For the Phase 1 works, to the easternmost Bays of the Ceiling, no such repairs were made. At that time, we did not consider it would be appropriate, given the conservation principles agreed by the Project Team.

In Phase 2, Bays 2 and 3 of the Ceiling, a large rectangular section through the Anthropophagus lozenge was missing. The gap had been filled by bare wood inserted from above, presumably during the 1926 intervention when they had no access to the ceiling from below. This crude and unsightly repair was a considerable distraction obvious from the ground, so had to be addressed notwithstanding the approach to date. The 1926 bare wood patch was replaced by new oak timber inserts shaped to match the adjacent ceiling boards. The smooth surface of the oak inserts, as well as the careful scribing and fitting, distinguishes them clearly from repairs made during previous interventions. Following consultation with members of the Project Team it was agreed there should be no conjectural reconstruction of missing figurative detail but that the inserts should be painted to match the lozenge background colours.

This process prompted a reconsideration of our policy on the replacement of missing timber. By this stage we had determined the full extent of the previous interventions (1730s, 1840s and 1926) and all members of the Project Team agreed that limited replacement would not compromise further the integrity of the Ceiling. Reviewing from ground level the area treated in Phase 1 - during a site meeting involving Julian Limentani, Gillian Lewis, Richard Lithgow and Hugh Harrison - we regretted not having repaired the more obvious areas of timber loss. It was agreed that for the remainder of the Ceiling we should make good those losses deemed sufficiently visible and distracting from floor level. As a result three further sections of new timber were inserted during the Phase 2 works: one within a foliate lozenge board, one within a base board and one within a coloured bands board. It was agreed that the missing painted designs should be recreated on these oak inserts since it involved simply filling lacunae in a repeating pattern. A detailed written, photographic and graphic record of these repairs forms part of the Phase 2 Conservation Record.

During the condition survey stage of Phase 3, Bays 4, 5 and 6a, a list of potential new timber inserts was prepared for discussion at a site meeting. Julian Limentani, Gillian Lewis, Richard Lithgow and Hugh Harrison inspected the areas involved and reached a consensus decision on the appropriate action in each case. The main options being:

1. No intervention

2. Insert new timber and paint to match surroundings

3. Reposition displaced existing ceiling board

4. Paint bare wood or hessian exposed by the wood loss to match surroundings

5. Remove 1830s softwood patch and insert and paint new timber as required. These patches were used in the 1830s to cover wood loss or gaps between ceiling boards (particularly at the junction between horizontal and canted panels). Most of these interrupt the pattern of overlapping boards and affect the visual balance of the ceiling .The option of removal was considered because we found that four of the softwood patches covered minor damage relative to the distraction caused by the patches themselves.

Throughout Phases 3 and 4 the following criteria has been adopted for determining the appropriate option in each case:

- The purpose is to achieve an overall balance visually when viewed from ground or clerestory level. Overall balance means the patterned sequence of the Ceiling as a whole, and also the individual figurative images in each lozenge. Only the minimal intervention necessary to achieve this balance shall be approved.

- Any such intervention must be approved by consensus between Julian Limentani, Gillian Lewis, Richard Lithgow and Hugh Harrison.

- A detailed written, photographic and graphic record to be made of all interventions.

- 1830s softwood patches should be removed only if: earlier/original boards and paint can be detected behind; the patch is too big, too crude and too obtrusive; it interferes unnecessarily with the sequence of overlapping boards; the removal will expose hidden earlier/original work which the Project Team regard as more significant than the crude 19th century repairs.

- Missing sections of ceiling board to be repaired only if the wood loss is deemed sufficiently visible and distracting from floor or clerestory level, or where necessary for structural reasons.

- New timber inserts to be of new oak, shaped to match the adjacent ceiling boards and scribed to fit the available space without damage to existing timber. Fixings to be stainless steel screws, countersunk and hidden by oak plugs.

- In general, inserts are not to be used to repair small losses except within figurative or foliate lozenges, as these tend to be the focus attention when the Ceiling is viewed from the ground or reproduced photographically.

- In general, inserts are not to be used to repair losses in areas of dark border pattern, as they are not obvious from a distance.

- In general, inserts are not to be used to repair losses that may be adequately disguised by retouching onto the exposed bare wood of adjacent ceiling boards and/or hessian backing. A similar approach was adopted during the 1740s and 1830s intervention.

- In general, inserts are not to be used to repair losses that are backed by original or later structural timbers, particularly within the lower sections of the canted panels. These may be adequately disguised by retouching onto the exposed timber structure. A similar approach was adopted during the 1740s and 1830s intervention.

- The smooth surface of the new oak inserts, as well as the careful scribing and fitting, distinguishes them clearly from repairs made during previous interventions. As a result it is not necessary to make the retouching/re-integration artificially distinctive. Missing border pattern and repeating foliate decoration may be recreated, but there should be no conjectural reconstruction of missing figurative detail. In these instances inserts should be painted to match the lozenge background colours.

APPENDIX 12

PETERBOROUGH CATHEDRAL, NAVE CEILING - PHASE 5
NEW TIMBER INSERTS/ REINTEGRATION OF PAINTED DECORATION

PANEL REF	BOARD	TREATMENT
7 I	**p**	New timber insert
6 I	**v**	New timber insert
6 II	**j**	New timber insert
4 I	**c**	New timber insert
4 I	**d**	New timber insert
3 II	**h**	New timber insert
3 II	**j**	New timber insert
3 III	**b**	New timber insert
3 IV	**j**	New timber insert
2 IV	**v**	New timber insert
1 III	**e**	New timber insert
1 III	**j**	New timber insert

9 Providence Row,
Durham,
DH1 1RS
Tel. 0191 386 5523

6. 10. 99

Dear Ms. Harrison,

May I now send you written confirmation of the fibre identifications which I have previously reported verbally.

The material which you refer to as hessian is made from jute, a species of Corchorus. The canvas strip attached to it is made from cotton, a species of Gossypium.

I am surprised that you found no deterioration of the hessian. Is it possible that the quality of the fibre varies within the fabric? The sample which you sent to me is severely degraded. Jute is a lignified baste fibre and is notorious for its deterioration.

Unfortunately, I am unable to suggest a date for the manufacture of these materials.

I enclose an invoice for my consultancy fee.

I hope you will accept my report in this hand written form. Although I am an Honorary Research Fellow at Durham University, fibre identifications are entirely my responsibility.

Yours sincerely,
Dorothy Catling.

DR. D. M. CATLING.

From: Lieutenant Colonel (Retd) A WILSON MBE

OIC The Weapons Collection
Headquarters Small Arms School Corps
Headquarters Infantry
Warminster Training Centre
WARMINSTER
Wiltshire
BA12 0DJ

CIVILIAN TELEPHONE: 01985 222487
FAX: 222211

MILITARY TELEPHONE: (9)4381 2487
FAX: 2211

Hugh Harrison
Ringcombe Farm
West Anstey
SOUTH MOLTON
Devon EX36 3NZ

Your reference:

Our reference: Q/Shot

Date: 29 June 1999

Dear Hugh.

Many thanks for you letter dated 22 Jun 99 reference 'shot'. Needless to say the contents excited many of the 'natives' here!

Being a military weapons establishment the 'shotgun' does not feature highly as it was/is used sparingly for service use. That stated we still have a historical interest.

We know that in 1524 a certain Benvenuto Cellini mentions the use of 'hail shot' which was produced by cutting sheets of lead into cubes! There is also reference to the making of shot (dropping molten lead from a certain height - shot towers) in the last quarter of the 17th Cent. So shot has been around for some time.

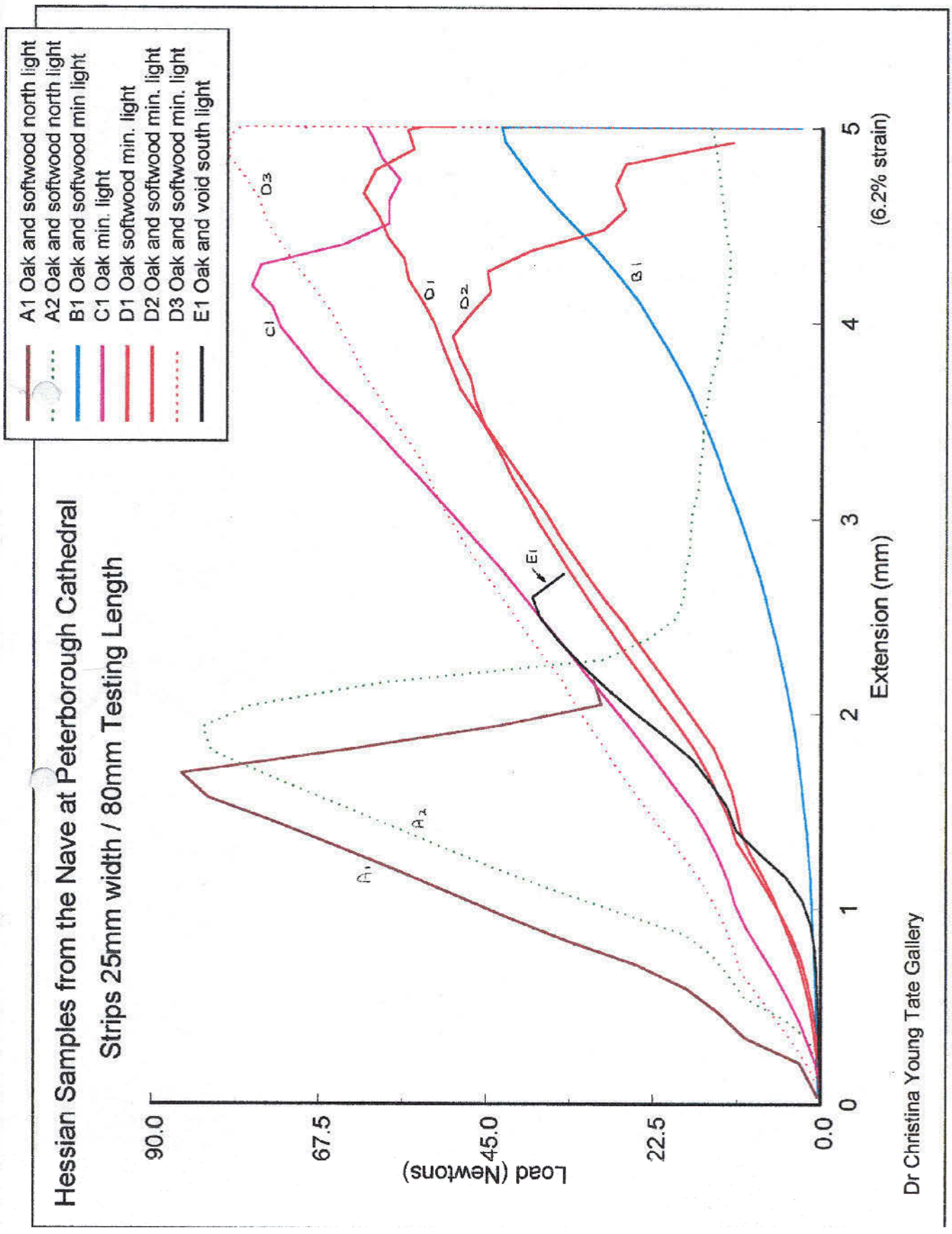
Shotgun performance varies so much from shot to shot, load to load and gun to gun, and shot size varies between makers. From your samples we can make a fairly accurate guess as to the shot size, however, the information you gave regarding spread is insufficient to determine possible range of firing and type of 'weapon'. Needless to say - all of the above cannot produce the information you seek - the date of the shot.

I do not know if lead can be 'carbon dated'? I doubt it, however, even if it could be done it would be a costly exercise!

You asked when the first 'shotgun cartridge' appeared - in the early stages of the 19th Cent.

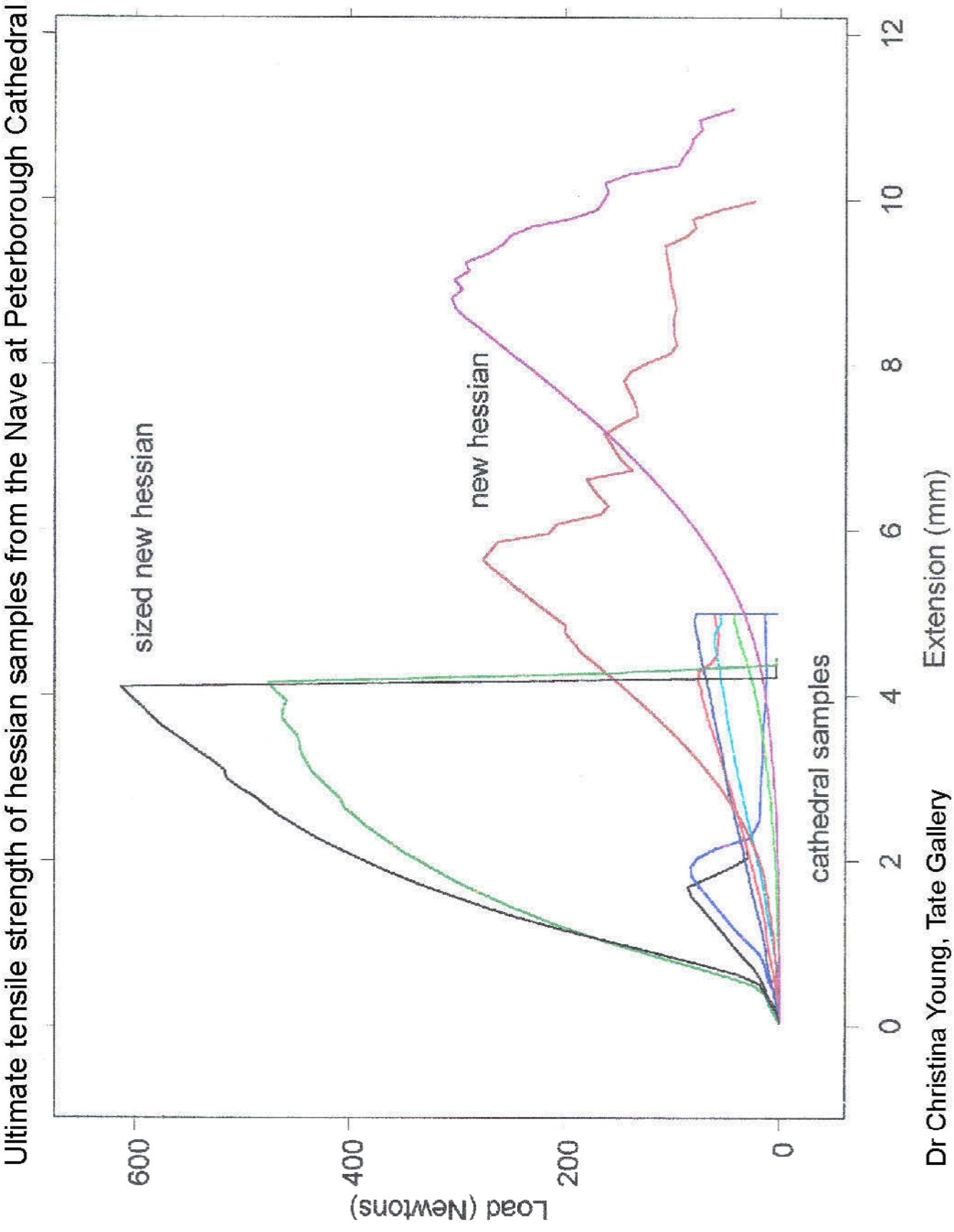
Sorry I could not be more helpful.

Yours aye
Tug.



APPENDIX 15

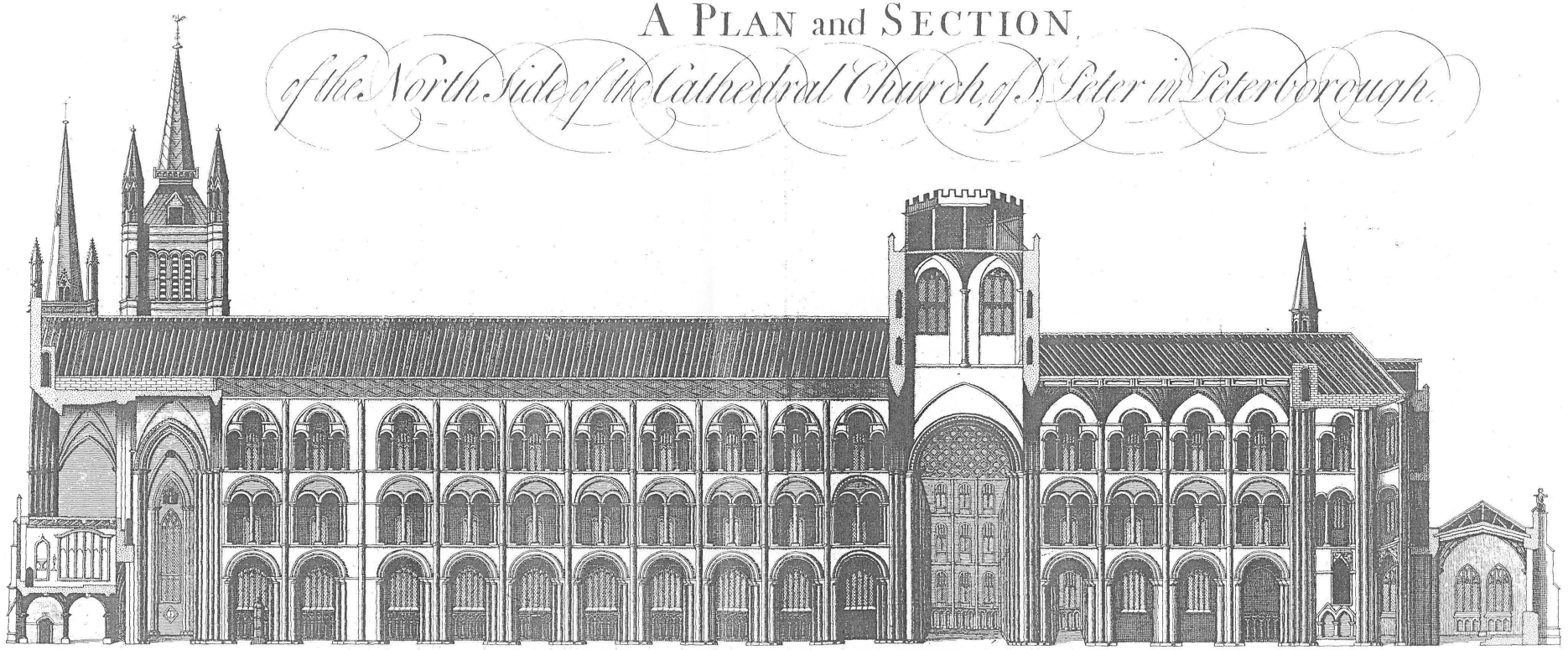
Hessian samples from the Nave at Peterborough Cathedral Dr Christina Young, Tate Gallery



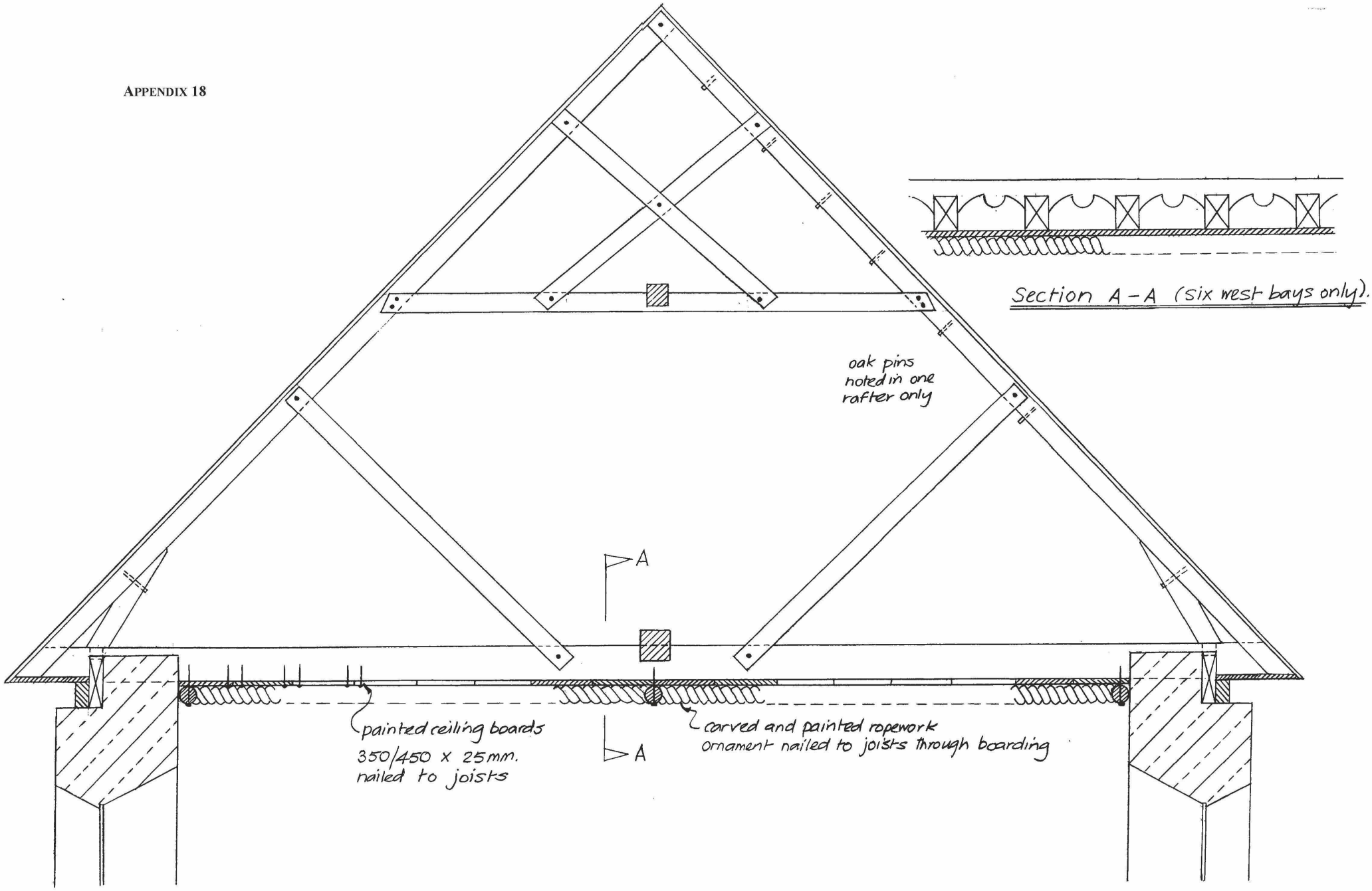
APPENDIX 16

Ultimate tensile strength of hessian samples from the Nave at Peterborough Cathedral Dr Christina Young, Tate Gallery

APPENDIX 17



J. Bridges (published 1791)



Section A-A (six west bays only).

PETERBOROUGH CATHEDRAL roof details from Dädesjö Church, Sweden.

HUGH HARRISON CONSERVATION drawn Peter Ferguson April 2001

PETERBOROUGH CATHEDRAL - NAVE CEILING

MEETING TO LOOK AT THE ICONOGRAPHY AND ATTRIBUTES HELD AT 9, KINGS PARADE, CAMBRIDGE, 3 SEPEMBER 2001

Present: Paul Binski, Gillian Lewis, Richard Lithgow, Don Mackreth, Ian Harper (for part of the meeting) Julian Limentani

1. Purpose of meeting to review and interpret new information about subject matter recovered since the start of the main project.

2. Working with the colour photographs made by the conservators, plus conservation notes specifying any visible early delineations, and referring to the large scale orthophotographs made by Paul Bryan's team at English Heritage, the painted subjects and patterned boundaries were examined, west to east (omitting the last two western bays as photography has yet to be completed here).

3. All distinguishable underpaint had been marked on the layouts on site by the conservators, in so far as it can be detected. Unfortunately, the easternmost bay (Phase 1) was not included at the start of the project.

4. Paul Binski's reference material was used for comparison and identification of closely related images, patterns and subjects. See also his 1999 paper on the ceiling.

5. Paul Binski indicated that there is no known standard cycle of representations of the Liberal Arts; this ceiling has the only major extant one in Britain for the period.

6. The Liberal Arts: Here we have seven (Laon has eight in stained glass) identified as:-

    - Grammar - holding a palmer, for striking the pupil's palm (actual examples of these in wood have been found at Lubeck) and seated on a chair/throne.

    - Geometry - seated on pedestal bench with cushion, holding set square and dividers.

    - Arithmetic - holding a counting board/abacus (9 dots) and another unidentified object.

    - Logic/Dialectic - seated on arc bench with terminals at sides, with pupil on pedestal holding up a pinnacle (?); this latter most unusual perhaps represents architecture (?).

    - Rhetoric - holding the tabula and stylus (direct Roman derivation), sitting on arched bench.

    - Music - tuning an organistrum.

    - Astronomy - holding a planet(?) or globe(?).

7. The Central Figures are an alternating sequence of State and Church at the time of the early history of Peterborough Minster. They comprise archbishops (2), bishops and kings, paired, facing each other, probably associated with the foundation and benefaction of Peterborough. They may represent the mythology of the Golden Age, perhaps Mercy and Co-operation supporting the foundation of the House. Close association here with the same representations in the psalters of Ramsey and Crowland.

8. King with cresset, facing St. Paul, holding sceptre, is a clearly significant figure, who might be teaching the saint. Could he be King Oswald?

9. The four Musicians/Heavenly Players (refer: Grove "Dictionary of Music", also recent discussions with Zachary Taylor and Mary Remnant). Direct comparison can be made with instruments depicted in the Peterborough and Lindsay psalters of the same period. It is typical that the musicians be shown tuning their instruments.

    - Fiddle - with 1835 hat, probably had more hair and may have had wings; fiddle formerly called a viol, as a result of overpainted additions.

- Cornetto - formerly misidentified as a trumpet; a wooden instrument, bound in several places. The musician is probably not an angel as no wings visible as underpaint.

- Symphony - formerly misidentified as organistrum.

- Dulcimer - clearly a double hammered dulcimer (examples shown in several other illuminated manuscripts), formerly misnamed as psaltery. Close comparison of the musician's head with similar heads (eg St John the Baptist) in illuminated gospels was demonstrated by Paul Binski.

10. St Peter, the Agnus Dei and the Devil are central to the next section moving east, with images round them possibly representing vices such as:

    - Goat ridden by Ape holding Owl, representing ignorance/lechery (?). This is very similar to an illumination in the Peterborough psalter.

    - Fiddle player, barebreasted, but not female, just generously overpainted; foolish antics.

    - Ass with Harp is a satire on Folly; the strings originally ran diagonally on the harp and are visible in the underpaint.

    - Dragon - now re-identified as a Fox, and after comparison with a margin illumination in Peterborough psalter, may be carrying a cockerel. In turn this may be connected with the allegories of Aesop's Fables - further investigation needed.

    - The Anthropophagus - representing Greed(?)

    The Agnus Dei stands between St. Peter and the Devil: in Paul Binski's view the Agnus Dei is one of the most convincing images here.

11. The Janus Head has much new boarding and repainting in the upper half, so the image may differ considerably from the original. The four lions and fish, flanked by two images of Green Men, complete the eastern section.

12. Border patterns These too are readily comparable with examples in the early psalters, showing crocketting and finials and other flowery terminations.

13. All the above study enabled a clearer view of what is clearly a crude reconstruction from the 18th and 19th centuries already so visible in the archbishop figure labeled "COBLEY 1834, R. LAYTON 1834 SEXTON"), as against the tight relationships of much of the painted surface to its early origins, emphasising the enormous significance historically of this astonishing relic.

14. It gave considerable encouragement to note that in most lozenges the visible underpaint and the figures overpainted coincided to a very high degree. The only one that did not was the Dragon, which was originally a Fox.

15. Action: Paul Binski is requested to select comparative images from the material he knows and to obtain photographic duplicates for the team to work with, as soon as possible, before the November international COMPOTEC seminar.

16. When the next section, Phase 5, is complete, we will need to go through all the new information on the depictions, review and agree what can be learnt about the overall scheme, and hopefully produce a final presentation and illustrated written description.

Julian Limentani September 2001

APPENDIX 20

PETERBOROUGH CATHEDRAL, NAVE CEILING - PHASE 5
Strategy for Sample Analysis (July 2003)

1 PAINT SAMPLE ANALYSIS

The Phase 4 Condition Survey/Treatment Record[5] included a tabulated inventory of all paint samples analysed from the Emergency Phase to Phase 4. To facilitate the interpretation of findings the inventory includes basic stratigraphy, pigment identification and the analyst's comments. The samples have been grouped according to the boards from which they were obtained: the eight different border patterns, central lozenge boards and replacement boards.

To date 152 paint samples have been analysed during this conservation project:

Board	Original	Replacement	Frieze
Lozenge Boards	54	2	
Base Boards	3		
Coloured Bands Boards	6	4	
Extended Chevron boards	12		
Grey Chevron Boards	10	4	
Stepped Chevron Boards	18	5	
Wave Pattern Boards	9	1	
Dogtooth/Bun Boards	4	2	
Key Pattern Boards	7		
No Pattern Boards		3	
Frieze Boards			8
Total	**123**	**21**	**8**

Total samples .=.152
Samples from original boards = 123
Samples from replacements = 21
Samples from Ashlar boards = 8

Extract from PLP Phase 4 Report
Investigations for Phase 5
The equivalent section in the Phase 3 report contained a long list of list of proposed investigations largely because the Phase 3 analysis results were not available at the time of writing. However, the Phase 3 and Phase 4 analysis findings were submitted prior to the completion of this report so the majority of queries marked for further investigation have now been answered. Those that are outstanding are considered low priority. The sample strategy prepared for Phase 4 and appended to this report (**Appendix 21**) has been annotated with observations made during site meetings. Those investigations considered a low priority and therefore not carried out to date will be addressed during Phase 5 (if time and budget allow) once the main objectives have been achieved.

The main objective for paint analysis within Bays 9 and 10 (Phase 5) will be:

- To concentrate on identifying paint found under missing original nail heads particularly on the central lozenge boards. These instances provide an excellent opportunity to develop our understanding of the original scheme.

- The vertical boards at the west end of the Ceiling are thought to date from the 1830s intervention. A number of paint samples should be obtained from these boards to for confirmatory purposes.

[5] *Peterborough Cathedral: The Nave Ceiling, Phase 2: rows 8 – 17. Condition Survey and Conservation Treatment, May – October 2001, Vol. I,* The Perry Lithgow Partnership and Hugh Harrison.

- Any anomalies in technique, materials and surface accretions found in Bays 9 and 10 will be investigated through sample analysis.

1.1 THE ORIGINAL SCHEME

1.1.1 Original figurative and foliate decoration

During the Phase 5 works to date nothing has been found on central lozenge boards that would warrant further paint sample analysis. However, while removing smoke damage from the Phase 3 area in September 2002 we obtained 11 samples of paint from under original nail heads that are now missing. These were overlooked during Phase 3 but all appear to be of original paint and should serve to increase knowledge of the original figurative and foliate decoration. At the time of writing these are the only paint samples proposed for analysis as part of this final phase.

Previous Samples from Central Lozenge Boards:

Emergency Phase
(20 Loz. Samples)
'Results indicate that original paint layers exist in a number of areas, usually beneath layers of rather crude overpaint, as in the flesh tones of St. Peter. It also appears that some original layers remain exposed - though juxtaposed with cursorily applied overpaint - as in the Psaltery Player, where parts of the instrument appear to be of 13th-century date. 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.
Of particular interest is the use of green underpainting for some of the flesh tones, in azurite combined with lead white and yellow iron oxide. 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.
The results of the 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.'

Phase 1
(Loz. Samples 1, 2, 3, 7, 8, 12)
Preliminary 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 *k* 12) where, as for St. Peter, azurite combined with yellow ochre and lead white was employed for the green underpainting of the flesh.
As in the first phase of sampling, the original palette has been found to include natural azurite, lead white, verdigris and vermilion. Analysis of the binding medium for these layers has not yet been undertaken, though it is expected to be oil, as identified in comparable areas in sampled in April 1997.
The presence of calcium sulphate at the wood/paint interface, and also at varying concentrations throughout the paint layers, confirms that this area of the ceiling is also profoundly sensitive to moisture.
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.

Phase 2
(8 Loz. Samples)
Original paint was identified in three of the samples: deep red ochre and charcoal black (IK Sample 14); a deep red haematite-rich ochre over a reddish orange layer (IK Sample 44); charcoal black (IK Sample 20). In contrast to the findings of analysis carried out in 1997 and 1998 on samples from central lozenge boards where original paint exists Kakoulli found no evidence of an intermediate preparatory layer at the interface of the wood and paint layer. The effects of subsequent interventions have so far made it impossible to determine this aspect of the original technique with any certainty.

Phase 3
*Loz. Samples 13, 14, 15, 16, 21, 22***:**
4 of the 6 samples had traces of original paint. Charcoal black underdrawing on three of them.
Sample 13 - Two layers of lead white and vermilion.
Sample 16 – Lead white/charcoal black/red iron oxide. lead white/red iron oxide. Carbon black.
Sample 21 – Natural azurite/yellow ochre. Basic verdigris(?). Carbon black.
Sample 22 – lead white/carbon black. Lead white/iron oxides.

Phase 4
(11 Loz. Samples)
In Phase 4 eleven samples were obtained from central lozenge boards: all of paint exposed from under original nail heads (now missing). Only one of these samples[6] contained no original paint. Five findings are particularly significant in that they have altered our perception of the original scheme:

- In previous phases most of the surfaces exposed by missing original nail heads in central lozenge boards had been overpainted in the 1840s leaving no indication of original paint beneath. However in Phase 4 a larger proportion of original nails must have been lost during the 1926 intervention when some of the ceiling joists were replaced. As there was no access to the underside of the ceiling in 1926 any original paint surviving under the missing nail heads remained exposed. We had considered it unlikely that the central lozenge boards were painted before being fixed in place but there is now ample evidence in the form of original paint under missing original nail heads to prove that they were
- The discovery of realgar in two samples obtained from the organistrum player lozenge boards in Phase 4: one from the base of the instrument, the other from green drapery which also included orpiment. This puts into context the identification of arsenic in a sample of green paint from Phase 3[7]. No trace of the Emerald green pigment - with which arsenic is normally associated - was found; however Davies had suggested the arsenic could arise from the inclusion of yellow orpiment (or reddish orange realgar). Orpiment, although not common, was in use in European painting from 1300 to 1900.
- Previous findings had led us to believe the original painted detail within the central lozenge boards was over an oil-bound white lead ground while the background paint may have been distemper. It is now clear there was no uniform white lead ground for the figurative detail. Many of the Phase 4 samples show original, oil-bound paint in varying colours directly over the timber surface or occasionally on what may be a preparatory drawing layer of carbon black.
- The clear cut finding of original red lead oil paint under a missing nail head within the background to the Rhetoric figure[8] proves that at least some of the backgrounds were covered with oil-based paints.
- Barium sulphate identified in apparently original green paint from under a missing nail head within the background of Grammar[9] appears to be present as a contaminant. As Davies points out barium sulphate is a naturally occurring substance and may be associated with the natural pigments used in the paint mix. Hitherto it has been suggested that barium sulphate would be found in nineteenth century paint only. **It will be necessary to review all 23 samples from the ceiling where the presence of barium sulphate has caused us to identify a paint layer as from the 1830s intervention, notwithstanding evidence to the contrary.**

[6] Davies 2002: Sample 1
[7] Davies 2000: Sample 21
[8] Davies 2002: Sample 8
[9] Davies 2002: Sample 7

1.1.2 Original lozenge border decoration

The original lozenge border designs differed significantly from their present appearance. During Phase 1 it was noted that a trefoil pattern terminating in an elaborate scroll design existed under the extended chevron pattern on many original oak boards. Other examples of underpaint showing the outlines of border designs in relief on boards with otherwise 'weathered' surfaces were also noted. In Phase 2, as a consequence of the detailed examination required to accurately record the visible underpaint and with the results or extensive paint sample analysis we developed greater understanding of how the essentially linear border designs evolved through at least two restorations. In Phase 3 ten paint samples were taken in an attempt to resolve outstanding queries relating to the original border designs and in Phase 4 a further 20 paint samples, of which 12 were from stepped chevron boards.

The results of Phases 3 and 4 analysis have significantly altered our interpretation of the original border patterns. **Figure 15** (see page 81) is an amended reconstruction of what is now consider to be the 13th century lozenge border decoration. Starting from the outside the original decorative pattern sequence was as follows:

- The base boards filling the space between the diamond-shaped compartments had a white scroll design with trefoil ornament. A sample obtained in Phase 3[10] shows two layers of white lead paint. There is a marked difference in the particle sizes of the upper and lower layers. The lower layer is similar to other paint identified as original being composed mainly of lead white but also contains a few carbon black and iron oxide yellow pigment particles. Prior to this finding it had been assumed this scroll would be in black: this because, assuming the background was unpainted, a white design would be difficult to see against the light colour of new oak boards. However, as there is now evidence that white was used for the stepped chevron and dogtooth linear designs and on the coloured bands clearly this was not a factor. **(Nothing further required)**

- A grooved board with the alternating red (red and white lead)[11] and white (white lead)[12] bands intersected at the corners by an elaborate black scroll with trefoil ornament. Previously we had it in our minds the inner band was black but in Phase 4 we recorded fourteen examples of apparent original paint in the grooves (of what we now refer to as coloured bands boards) exposed as a result of missing original nail heads. In addition, a single example was found in both Phases 2 and 3. Thirteen of the sixteen examples are within the outer of the three grooves: all show red paint. Two from the middle grove show white paint and the single example from the inner groove is of red paint. Black paint has been identified in one sample from a raised area between the grooves[13] but this should be considered an aberration as generally, the raised areas between grooves on these boards are considerably weathered: indicating the oak surfaces were not protected by overlying paint until the 1740s restoration. **(In Phase 5 all examples of original paint exposed as a result of missing original nail heads will be added to the existing records.)**

Paint under original nail heads (now missing) found on grooved boards

Grooved Board Pattern	Board Ref	Groove	Colour
Phase 2			
Coloured bands	32 II l	Outer	Red
Phase 3			
Coloured bands	21 I o	Middle	White
Phase 4			
Coloured bands	16 II r	Middle	White
Coloured bands	11 II j	Outer	Red
Coloured bands	17 I j	Outer	Red
Coloured bands	17 I p	Outer	Red
Coloured bands	10 I h	Outer	Red
Coloured bands	15 I k	Outer	Red
Coloured bands	15 I o?	Outer	Red
Coloured bands	16 I o	Outer	Red

[10] Davies 2000: Sample 20
[11] Kakoulli 1999: Sample 26. Davies 2001: Sample 9.
[12] Davies 2000: Sample 6.
[13] Davies 2000: Sample 7.

Coloured bands	14 I j	Outer	Red
Coloured bands	10 III k	Outer	Red
Coloured bands	11 III p	Outer	Red
Coloured bands	17 II l	Outer	Red
Coloured bands	14 II j	Outer	Red
Coloured bands	14 III l	Inner	Red

- A series of regularly spaced black (carbon black)[14] trefoil motifs springing from a black band along the inner edge of the board. At each corner a black elaborate scroll extends onto the outer coloured bands board. This pattern is mirrored in the opposite quarter of the lozenge so that the trefoil motifs spring out towards the extended corners forming an impression of crocketed gables. The trefoil motifs vary considerably in shape - in some cases even along one board. Examples of the different shapes found have been traced and are reproduced at smaller scale in **Figure 13**. **(Nothing further required)**

- A grooved board with the alternating white and red bands[15]. Previously we had assumed that the series of three grooved boards within each lozenge quarter had the same decoration but in Phase 4 we recorded thirteen examples of apparent original paint in the grooves (of what we now refer to as grey chevron boards) exposed as a result of missing original nail heads. In addition, two were found in Phase 2. Three of the four outer groove examples are white; the fourth, inconsistently, being red. All five from the middle groove are red and five out of six examples from the inner groove are white. The two inconsistent finding in the series are on the same board (12 I v). A notable finding in our survey of weathering on original ceiling boards (see Item 8.2.4) is that the raised areas either side of the grooves on grey chevron boards are consistently less weathered than equivalent areas on the coloured bands and key pattern boards (see example in **Plate 54**). This finding would indicate that in the original scheme the raised areas on this board were painted; however there is no other visual evidence to corroborate this and it has not been substantiated by paint sample analysis. **(In Phase 5 all examples of original paint exposed as a result of missing original nail heads will be added to the existing records.)**

Paint under original nail heads (now missing) found on grooved boards

Grooved Board Pattern	Board Ref	Groove	Colour
Phase 2			
Grey Chevron	28 IV o	Outer	White
Grey Chevron	Plate 391	Outer	White
Phase 4			
Grey Chevron	12 I v	Outer	Red
Grey Chevron	17 IV e	Outer	White
Grey Chevron	11 I f	Middle	Red
Grey Chevron	11 I s	Middle	Red
Grey Chevron	17 III g	Middle	Red
Grey Chevron	16 IV r	Middle	Red
Grey Chevron	17 III g	Middle	Red
Grey Chevron	12 I v	Inner	Red
Grey Chevron	14 I s	Inner	White
Grey Chevron	17 I g	Inner	White
Grey Chevron	9 IV f	Inner	White
Grey Chevron	15 IV	Inner	White
Grey Chevron	11 III t	Inner	White

- A linear stepped chevron design in white. Prior to the phase 4 works we had been unable to establish to the original paint colour for this design and had assumed it would be black. The six paint samples obtained from stepped chevron boards previously showed two layers of white lead paint but it was impossible to determine whether the earliest layer was original or belonged to the 1730s repaint. Only in Phase 4 where we found three examples of apparently original white paint outlining the stepped chevron design exposed from under missing original nail heads could we be

[14] Howard 1997:Sample 27. Kakoulli 1999: Samples 16 and 39. Davies 2000: Sample 17. Davies 2001: Samples 13 and 14.
[15] Kakoulli 1999: Samples 37, 57. Davies 2001: Samples 10 and 11.

reasonably certain of the original scheme (see **Plates 562 to 564**). Both samples of exposed white paint[16] shows a very thinly applied white lead layer directly on the timber substrate. Its microscopic appearance is consistent with it being of thirteenth century date. Two samples of apparent black paint adjacent to the white under the missing original nail heads in fact contained dirt and iron corrosion products, probably from the absent nail heads. Before finding the exposed original paint eight samples from the linear decoration visible in relief through the later repaints. Most of these show two layers of lead white, no different from previous samples. Interestingly three of the eight samples included a beige layer at the base of the sample that appears to be calcium sulphate in an animal glue binder. **(Nothing further required)**

- A linear wave pattern in red with scrolled ends[17]. In Phase 3 a further sample[18] confirmed the previous finding. On the smaller, half-lozenges immediately over the Ashlar boards the wave pattern is substituted with linear keyhole and dog-tooth patterns: the linear keyhole in black (charcoal black)[19]; no original paint was identified in the sample taken from a board with relief linear dogstooth[20] in Bay 1. In Phase 3 an exposed area of seemingly original linear dogstooth pattern in white was discovered on *22 IV e*[21]. The white tips of the original chevron/dog tooth design is partially obscured by the displaced adjoining keyhole/bun pattern board[22]. The original linear pattern extends onto bare wood that had been protected from subsequent repaint by the overlapping board. This visual corroborates our theory that the background to the linear border decoration must have been unpainted: The original white paint follows the raised linear 'visible underpaint' of the dog tooth pattern on this board. Similar linear original white paint can be seen in the adjacent missing nail head, which adds to the now overwhelming evidence that most of the scheme was painted before the boards were nailed in place. **(Nothing further required)**

- A grooved board with the alternating red and white(?) bands. As already stated we had assumed that the series of three grooved boards within each lozenge quarter had the same decoration; but having established the outer two are different we cannot be certain of this one. To date we have found five examples of apparent original red paint in the grooves of the key pattern boards: all within the outer groove (see example in **Plate 567**). That photograph also shows apparent black paint on the raised sections either side of the groove; however a sample taken from this area detected accretions of dust and debris, rather than a deliberately applied paint finish[23]. **(In Phase 5 all examples of original paint exposed as a result of missing original nail heads will be added to the existing records.)**

Paint under original nail heads (now missing) found on grooved boards

Grooved Board Pattern	Board Ref	Groove	Colour
Phase 2			
Key	32 I e	Outer	Red
Key	Plate 390	Outer	Red
Phase 4			
Key	11 I c	Outer	Red
Key	12 I x	Outer	Red
Key	13 I d	Outer	Red

All these findings help to explain the curious ship-lapped sequence of grooved, straight edged and curved edged boards. Each of the three grooved boards in the sequence were painted with alternating colours. The existence of the shallow grooves, which are certainly not visible from any distance, may be explained as a guide for the painting of these coloured bands. The straight edges on the grooved and stepped chevron boards mark the division between tiers of decoration and help to create an illusion of depth. The shallow curved edges of the central boards minimises the impact of the ship-lap

[16] Davies 2001: Samples 23 and 25
[17] Kakoulli 1999: Sample 18
[18] Davies 2000: Sample 4
[19] Kakoulli 1999: Sample 19
[20] Howard 1998: Sample 6. In the light of subsequent findings this sample should be re-examined.
[21] Davies 2000: Sample 3
[22] The Perry Lithgow Partnership and Hugh Harrison 2000: Plate 444
[23] Davies 2000: Sample 7

construction on the figurative decoration. Similarly, the slightly steeper curved edges of the linear, stepped chevron and trefoil pattern boards act to reduce the appearance of a division between patterns on the same 'tier'.

1.2 THE 1740S SCHEME

Close inspection of the Phase 5 area and review of relevant section in PLP Phase 4 report indicate no further sample analysis required. **(Nothing further required)**

1.3 THE 1830S SCHEME

(extract from PLP Phase 4 report)
The vertical boards at the west end of the Ceiling are thought to date from the 1830s intervention. A number of paint samples should be obtained from these boards to for confirmatory purposes.
(Close inspection of these boards confirms they are 1830s. Nothing further required.)

(extract from PLP Phase 4 report)
An additional feature to the decorative scheme, first identified during Phase 2, is that the centre of some trefoils are embellished by a raised dot.[24] The dots have a grainy texture and surface microflaking. They are prevalent on trefoils in *Panels 35-32 II and 29 II* and appear sporadically in *Rows I and III* across Bays 2 and 3; none were found in Bays 4, 5 and 6a. More were found in Bay 7 but, unlike those in Bays 2 and 3, the dots are on the 'stem' of the trefoil motifs rather than on the trefoils themselves (**Plates 555/556**). Although at first thought to be part of the original design, a sample from Bay 2 Phase 2 sample analysis indicated the embellishments are white lead paint with barium sulphate inclusions[25]. As the granular texture of these dots is so distinctive and unlike any other material added in the 1740s and 1830s interventions further samples were obtained and analysed in Phase 4.[26] Two of the samples have a single layer of lead white with a little calcium carbonate, over a thin carbon black layer, mixed with a thick translucent layer; the third sample has an additional lead white/calcium carbonate layer. Similar layers have been observed in samples from the trefoil design without the embellishment indicating the raised dots are simply impasto white lead paint probably (because of the barium sulphate inclusions) applied by the 1830s restorers. However, this begs the question why would they go to the trouble of painting these precisely circular and precisely located white dots onto a white background and only in certain areas of the Ceiling?
(No trefoil embellishments found in Phase 5 area. Nothing further required.)

Close inspection of the Phase 5 area and review of relevant section in PLP Phase 4 report indicate no further sample analysis required. **(Nothing further required)**

1.4 MATERIALS AND ACCRETIONS

- Nature of 1926 glue –**Phase 4 observations – Analysis of samples by Dr Brian Singer confirms the adhesive present in each sample is animal glue. No further analysis required.**

- Nature of any applied surface coatings - Further research will be required to establish whether or not a surface coating was applied to this black paint. NB Shellac was present on one sample taken from a grey chevron board in 1997. Could this have been unintentionally applied when coating the adjacent black or is the shellac seepage of a timber treatment applied to the upper side? *(Recommended for investigation in Phase 2 report but no example found in bays 4, 5 and 6a).* **Phase 4 observations – Site meeting decision taken not to attempt further identification of this coating. A discoloured coating/resinous grey paint found on some grey chevron boards in Bays 6b, 7 and 8. Also a thin wash/coating visible in UV light found on 1740s grey chevron pattern. Analysis of this not considered a priority.**

[24]The Perry Lithgow Partnership and Hugh Harrison 2000: Plate 385
[25] Kakoulli 1999: Sample 8
[26] Davies 2001: Sam,ples 12, 13 and 14

- Nature of surface accretion - The patchy white surface accretions associated with the thick resinous 1830s black paint/coating remain unidentified. These were considered to be some form of microbiological growth (MBG) but analysis by Ridout[27] indicates they are accumulations of irregularly shaped, translucent, plate-like crystals. Further investigations are required to determine whether these crystalline deposits are the result of seepage from the paint layer or a reaction caused by adverse environmental conditions. *(Recommended for investigation in Phase 2 report but no samples obtained in Phase 3 as not considered a priority).* **Phase 4 observations – Still as not considered a priority.**

- Nature of chemical stains – A characteristic staining prevalent across Bays 1, 2 and 3 but which occur much less frequently in Bays 4, 5 and 6a are light brown drips frequently found on the edge of Ceiling boards or around holes and splits in the boards. A sample of this material was analysed in Phase 2. Results were inconclusive beyond indicating the substance is organic. *(Recommended for investigation in Phase 2 report but no samples obtained in Phase 3 as not considered a priority)* **Phase 4 observations – Still as not considered a priority.**

- Nature of surface bloom - The paint on some obviously 1830s softwood boards has a characteristic milky or silvery surface sheen. Analysis indicates this is a thin pale coating as yet unidentified[28]. It does not respond to surface cleaning with Wishab sponges. In previous phases this was recorded as surface bloom but in Phase 3 it has been recorded only in the tabulated board by board survey of the paint. *(Recommended for investigation in Phase 2 report but no samples obtained in Phase 3 as not considered a priority).* **Phase 4 observations – Still as not considered a priority.**

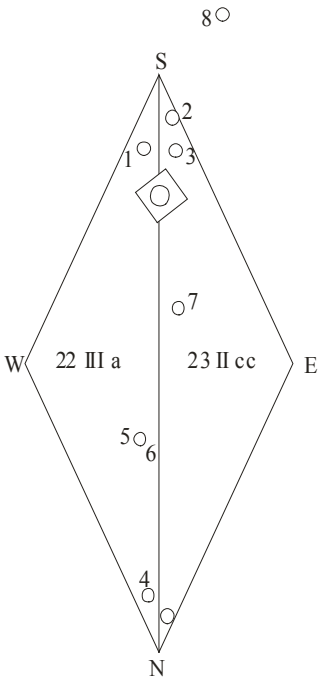
[27] Dr B Ridout. Unpublished letter to J Limentani, 16 June 1999.
[28] Howard 1997: Sample 18.

APPENDIX 21

PETERBOROUGH CATHEDRAL, NAVE CEILING PHASE 5 PAINT SAMPLES

Samples obtained by R Lithgow (Sept. 2002) During Fire Damage restoration Works from Bays 5 and 6

Sample #	Location	Photo Neg #	Description of Areas Sampled
1	22 III a Lozenge	3/6	Paint under original nail head (now missing) — Flesh tone on neck of Archbishop (1). Identification of original paint scheme if present.
2	23 II cc Lozenge	3/6	Paint under original nail head (now missing) – Green with red stripe within hair of Archbishop (1). Identification of original paint scheme if present.
3	23 II cc Lozenge	3/6	Paint under original nail head (now missing) – Flesh tone with red edge on neck of Archbishop (1). Identification of original paint scheme if present.
4	22 III a Lozenge	3/5	Paint under original nail head (now missing) – Light red from within lower robe drapery of Archbishop (1). Identification of original paint scheme if present.
5	22 III a Lozenge	3/5	Paint under original nail head (now missing) – Light red from within lower robe drapery of Archbishop (1). Identification of original paint scheme if present.
6	22 III a Lozenge	3/5	Paint under original nail head (now missing) – Dark red from within lower robe drapery of Archbishop (1) (same hole as Sample 5). Identification of original paint scheme if present.
7	23 II cc Lozenge	3/4	Paint under original nail head (now missing) – Off white from white edging of drapery of Archbishop (1). Identification of original paint scheme if present.
8	23 II aa Lozenge	3/6	Paint under original nail head (now missing) – White paint from mitre of Archbishop (1). Identification of original paint scheme if present.
9	21 III e wave	4/24	Paint under original protruding nail head – Black from an apparent black line on outer curved edge of board. Identification of original paint scheme if present.
10	21 I c Lozenge	4/23	Paint under original nail head (now missing) – Red paint from within white background of angel with cornetto lozenge. Identification of original paint scheme if present.
11	18 I ee Lozenge	4/22	Paint under original nail head (now missing) – Green paint from within drapery (?)of Grammar lozenge. Identification of original paint scheme if present.



APPENDIX 22

THE ARTIST'S ASSISTANT: Oil Painting Instruction Manuals and Handbooks in Britain 1800-1900 With Reference to Selected Eighteenth-century Sources **Leslie Carlyle, Archetype Publications 2001 (pp. 42-46)**

SUGAR OF LEAD (LEAD ACETATE)

As will been seen in Chapter 6, sugar of lead was recommended frequently as an ingredient in vehicles, particularly in recipes for 'gumtlon' and variations of this medium. It was also called for in drying oil preparations (see Appendix 8) and was sold by the colourmen in bladders and tubes as a ready-made 'drier'. Sugar of lead in its powdered or crystalline form was also recommended for grinding with pigments in raw oil. The most common instructions were to grind it in oil or a prepared medium prior to mixing with prepared paint. Mixing could be carried out on the palette using the palette knife or by grinding on a stone slab; consequently, the amount used and the degree of grinding could have varied considerably. Fielding remarked that its drying properties are increased if it is ground 'exceedingly fine'.

Some medium recipes called for sugar of lead to be dissolved in water prior to being mixed with varnish and oil. Field also recommended that a weak solution in water be washed over the ground prior to painting and mentioned that some artists 'strew their pictures while wet with the acetate of lead' (1835, p. 56). He noted as well that it could be dissolved in spirit or turpentine prior to use with prepared paint (1850, p. 133).

It appears that sugar of lead was easily available to the artist from a very early period. Dossie described how it could be made by dissolving lead with vinegar and evaporating the salt remaining to crystals and remarked, '...but it Is to be had so constantly, and at so much less expense at the shops of chemists and druggists, than it can be made in small quantities, that it is needless to give any more particular recipe...' (1758, Vol. 1, p. 152).' He stated that it need only be mixed well with oil for use, but recommended purchasing it in crystalline form rather than in powder which could be adulterated. According to Dossic, it was used as a drier for oils and 'on that account is very frequently used, as well in the making [of] drying oils, &c.' (1758, Vol. 1, p. 152).

In *A Practical Treatise,* the description of sugar of lead included its synonyms: 'Sacrum. A vulgar and corrupted mode of expressing Saccharum Saturni, or Sugar of Lead' (1795, p. 55), and Tingry included another synonym, 'Sal Saturn]' (1804, p. 87). Bachhoffner explained the derivation of these names by noting that Saturn was the planet associated by alchemists with lead (1837, p. 57). By 1835, Field was using the modem term, 'acetate of lead', but he included its ancient names as well: 'This is the ... *Saturnus Glorificatus* of the alchemist, celebrated for its uses in forming pastes for artificial gems, for drying oils, &c.' (183 5, p. 56).

In *A Practical Treatise* it was noted that as we] I as causing the oils to dry more quickly, sugar of lead 'has the property of rendering oils thicker' (1795, p. 58). Field remarked that unlike other driers such as zinc sulphate, acetate of lead possessed the property of 'gelatinizing' mixtures of oil and varnish (1841, p. 109).

Field stated that acetate of lead could be substituted for litharge in the preparation of a pale drying oil. The advantage of the lead acetate was that it was soluble with less heat and that "Its acid being volatile escapes during solution and bleaches the oil' (1841, p. 367). The use of less heat and the bleaching action presumably ensured a lighter coloured product.

Neil (1833) performed experiments to determine whether sugar of lead and 'copperas' [in this case zinc sulphate see note 16, p. 40] 'combine' with an oil varnish. He found that the two ounces of copperas he used in making the varnish could be filtered out of the mixture after eight months, whereas in another experiment, using two ounces of sugar of lead, only '7 drachms' was available in the filter after eight months (1833, pp. 76-7).

Artists were advised to add sugar of lead to drying oil as well as to raw oil. The former practice was questioned by Martel who remarked, 'The advantage of adding it to oil already rendered drying is not very evident' (1859, p. 45).- However, this application of sugar of lead to an oil already treated with driers may be explained by remarks in an edition of Field:

> Dryers should be added to pigments only at the time of using them, because they exercise their drying property while chemically combining with the oils employed, during which the latter become thick or fatten, and render additional oil and dryer necessary when again used. (1850, p. 133)

Field had cautioned that the presence of too much drier 'is inimical to drying' (1835, p. 56). This may explain the rather puzzling advice given by lbbetson to add 'nearly an equal quantity of sugar of lead' to vermilion since the sugar of lead will prevent the vermilion from becoming hard (1828, p. 15). There was only one other occasion where sugar of lead was used for this purpose (see p. 154); otherwise sources were consistent in recommending sugar of lead as a drier.

Despite numerous recipes which called for sugar of lead as a drier, it is difficult to arrive at the proportions used in its various applications. In most recipes, quantities by weight which amounted to less than half an ounce were rarely given in standard measures. Instead, authors called variously for 'a small amount'; 'enough to cover a sixpence' or to cover 'a shilling'; or an amount 'the size of a bean'. However, in one instance where the original recipe called for an amount 'about the size of a bean', the same recipe using the same ratio of ingredients was found in one of Roberson's recipe books, and the amount of lead acetate specified there was half of an ounce to three ounces of varnish and oil.'

Identifying the amount used is also hampered by frequent instructions to dissolve it first in water. Although some authors did indicate that **it** was to be a saturated solution, this was not common advice. Only one recipe stated the amount of sugar of lead to add to the water: Roberson's White McGuelp recipe (HKI.MS.789-1993) called for the addition of one ounce to one quarter pint of boiling water.

In some gumtion recipes $^{1}/_{8}$ part of lead acetate was called for (e.g. Osborn 1845; Field 1850). lbbetson, the inventor of the medium 'gumtlon', had specified that 'a little more than one third sugar of lead, in *quantity not weight'* be added to ½ oz of gum mastic. He then called for raw linseed oil, but did not specify, the amount, only remarking that after grinding, 'if it should seem too stiff for use, put a little more oil' (1828, p. 16). In the second edition of lbbetson's book where the gumtion recipe first appeared, the amounts of sugar of lead he had mixed with certain pigments were also included. The pigments and sugar of lead were to be ground together in the 'newest raw linseed oil' (1828, p. 15):

Pigments		**Amount of sugar of lead**
Raw Terra de Sienna Burnt Terra de Sienna Yellow ochre Lake White lead Naples yellow Vandyke brown	}	one sixth part
Prussian blue	}	one fourth part (and one fourth part of gum mastic)
Vermilion	}	nearly an equal quantity

In some of the sources published before 1850, the authors provided information on the quality of sugar of lead to use as well as the need to remove acidity or to dry it prior to use. For example, Neil specified that:

> Sugar of lead, when bought for the purpose of adding to varnish as a drier, ought to be that which has been made from white lead, and not that which has been made from litharge, that from white lead being the finest, and in its particles purer and transparent. (1833, p. 55)

Others cautioned that it should be in an alkaline rather than acid state. Field remarked that in using sugar of lead:

> ... if the acid abound, which is does usually in the purer and more crystalline kinds, its power of drying is weakened, and it may have some injurious action upon colours, such as those of ultramarine and lakes. (1850, P. 141)

He recommended that a small amount of litharge be added in medium preparations to counteract the acidity increase its drying property and 'correct its injurious tendency' (1850, p. 141).

Although the reduction of acidity in the sugar of lead was not referred to directly in other sources, it may be taken as implicit in their instructions. For example, in Mérimée's recipe for Flander's varnish he directed that the mixture of mastic varnish, oil and sugar of lead should be poured into pure water, and stirred for some time, 'renewing the water to carry the portion of acetate not combined' (1839, p. 65). In the elaborate instructions for making the artists' medium megilp, which were published in the *Art Union Monthly Journal qf the Arts* (Vol.

X), Thomas Miller specified that 'subacetate of lead' should be used for making the drying oil and '...not ACETATE; this, to some persons may not appear essential, but it is of the utmost importance, and could be shown to be so chemically' (1848, p. 229). According to Ure's dictionary (1840), the subacetate was an alkaline form of sugar of lead.

In 'Llebigs' recipe for drying oil which was copied into one of Roberson's recipe books (HKLMS.788-1993), the following instructions were included for preparing the subacetate of lead prior to using it in the recipe: 'neutral' acetate of lead was to be combined with litharge to result in a 'conversion of the neutral into a tribasic acetate of lead'.

Some authors cautioned that sugar of lead should be dried (e.g. heated slightly or calcined) prior to use. For example, Cawse remarked, '...the sugar of lead, previously to its being used, should always be calcined, as it is less liable to turn black' (1840, pp. 17-18). Neil made no mention of such blackening, but he did remark that sugar of lead 'contains about 14.2 per cent of the water of crystallisation' and that before use it should be reduced to a powder and slowly dried. He also recommended that it be stored in air-tight containers after this treatment (1833, p. 55). Neil felt that the presence of water 'prevents that complete union of the particles of gum, oil, and lead' in the varnish (1833, p. 55). He reported on an experiment with undried sugar of lead and undried copperas (in this case possibly sulphate of zinc, see note 16, p. 40) in a copal varnish (one to one) and observed that small pin-holes formed at the surface upon drying, which he attributed to the fact that the sugar of lead and sulphate of zinc were not dried prior to use (1833, p. 75).

In the second catalogue available from Winsor & Newton (c. 1840), 'sugar of lead' was listed amongst their oil colours. It continued to be listed as such in the catalogues available throughout the century. Reeves also listed sugar of lead with their oil colours from the earliest catalogue available (1852) through to 1892; however, it was no longer listed in their last two catalogues (c. 1896 and c. 1898). Rowney listed Isacrum' from their earliest available catalogue (1845) through to the last seen (1907). In their 1892 catalogue it appeared as 'Sacrum or Sugar of Lead' (1892, p. 17).

The first indication of what the ingredients for this product could have been appeared in Bulkley (1821). He included a 'Receipt for Making the Dryer' which consisted of sacrum (sugar of lead) ground in raw oil with the addition of mastic resin (these were, in fact, directions for making lbbetson's medium 'gumtion', although not identified as such). Bulkley remarked that the 'drier' could be kept in ‚gaily-pots' and instructed, 'Put a little of this to the colours, to assist them in drying. You will likewise find it serviceable in your glazing tints' (1821, P. 54).

Then in Fielding, the ingredients in commercially prepared 'drier' were clearly identified:

> Acetate, or sugar of lead, ground with boiled oil, poppy, nut, or linseed, can scarcely be called a vehicle, being merely used to force the slow-drying colours, such as Vandyke Brown, Blacks, &c., to dry when frosty or cold weather prevents this very necessary operation from proceeding at the same rate with colours of better qualities. This mixture should be ground exceedingly fine, by which its dessicating (sic) properties are greatly increased. It is kept in bladders* at all the colour shops, and known by the name of 'drier' (1839, p. 71) [In his 1846 edition he added: *and metallic tubes (p. 168)]

Field warned his readers against lead acetate, saving that it 'acts injuriously' on some colours (1835, p. 56) and elsewhere he included it in a list of lead compounds which could cause change in 'Light, bright, and tender colours…..' (1835, p. 188). However, Templeton reassured readers that although:

> ... it is imagined by some, that this mixture [sugar of lead and pale drying oil] has a tendency to injure the colours; but if just so much of it is used, as will ensure their drying in moderate time, no injury need be feared... (1846,p.27)

Templeton's view was supported by Eastlake, who associated the damage with excess amounts:

> The use of acetate or sugar of lead is... dangerous, on account of its tendency to re-crystallise, thereby rendering the transparent colours dull; the extreme case of its visible efflorescence can only occur when it is used in unnecessary abundance.
> (1847, Vol. 1, p. 350)

Later in the century, Standage remarked that sugar of lead would darken cadmium yellows, but offered no explanation for this reaction (1892, pp. 62-3).

Aside from the view that it was harmful to pigments, Field also described a problem with sugar of lead in another application:

> The inexperienced ought here to be guarded also from the highly improper practice of some artists, who strew their pictures while wet with the acetate of lead, or use this substance otherwise in its crystalline or granular form, without grinding or solution, which, though it may promote present drying, will ultimately effloresce on the surface of the work, and throw off the colour in sandy spots. (1935. p. 56)

Church, writing some fifty years later, also remarked on the phenomenon of efflorescence which he attributed to the use of lead acetate:

> I have seen one of the results of this commingling of sugar of lead with the medium or the paint in the production of an immense number of small spots in the picture, sometimes appearing through the surface-varnish in the form of a white efflorescence. (1890, p. 94)

Church surmised that this efflorescence could lead to darkening at the surface of the paint:

> This efflorescence consists at first of lead acetate in crystals, but these soon attract carbonic acid from the air and become lead carbonate, which, in its turn, is changed into lead sulphide by the action of sulphuretted hydrogen [hydrogen sulphide]. This tendency of the lead compounds to yield brown or black lead sulphide is, indeed, the great drawback to any use of these substances as dryers. (1890, p. 94)

According to Church, the use of sugar of lead had been widespread: ‘lt was a common practice to employ powdered sugar of lead or a solution of this salt in water to hasten the drying of vehicles and slow-drying pigments which have been ground in oil’ (1890, p. 93)

Field appeared to relate the development of such efflorescence to the use of lead acetate in a crystalline form only and seemed to feel that it would not prove harmful if it were dissolved first in water and used in a dilute solution; for later on he recommended that in damp weather to promote the drying of the colours, the ground of a picture should be sponged with ‘a weak aqueous solution of the acetate or sugar of lead’, prior to painting (1835, p. 57).

Neil had also described a similar efflorescence but did not single out lead acetate in particular, and appeared to be blaming any lead drier:

> Every description of varnish which has lead for driers will always be the harder for them, and when worn for a time, if minutely looked into, it will be found that the air has separated the particles of lead, which will be found upon the polished surface of the varnish like an almost imperceptible white dust, exactly in proportion to the quantity of lead introduced into the varnish in making it. (1833), pp. 61-2)

Eventually, the general advice was to avoid sugar of lead wherever possible and recommendations against its use grew stronger later in the century. By 1890 Scott Taylor was warning:

> The universal employment of White Lead for mixing with other colours renders it of the utmost importance ... that it should at least be free from such a notoriously powerful disintegrator as acetate, or sugar of lead. (1890, p. 40)

Appendix 23

PETERBOROUGH CATHEDRAL NAVE CEILING CONSERVATION PROJECT

Tabulated Inventory of Paint Samples 1997 - 2003

Contents

All Samples from Lozenge Boards (64 + 1 Rep.)

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1997 1/2093	Lozenge Psaltery Player, instrument: *pink/brown colour on wooden support.*	• *yellow earth pigment with siliceous inclusions in a lead white matrix 250pm* • *red iron oxide in lead white matrix 25 pm* • *lead white preparation with sorne calcium sulphate l5 pm* • *trace wood support*	• coating and accretion of dirt on surface 10 p.m *The rough texture of the paint is due to the siliceous inclusions in the yellow iron oxide-rich paint layer, which has been applied over a layer of red iron oxide*
1997 2/2094	Lozenge Psaltery Player, cusped mandorla: *green paint layer.*	• *verdigris combined with a brilliant yellow earth pigment 90pm* • *carbon black (drawing?)* • *lead white preparation with some calcium sulphate 5-80pm* • *trace wood support*	• coating and accretion of dirt on surface 5 pm • analysis by SEM/EDX indicated that the verdigris has a high chlorine content. This analysis also indicated a high Al and Si content in the yellow iron earth pigment, together with traces of Ti and K *Particles of basic verdigris have been combined with yellow iron oxide to produce the yellow/green paint layer*
1997 3/2095	Lozenge Psaltery Player, cusped mandorla: *blue/green over green.*	• Prussian blue in lead white matrix 90 pm • large particles of verdigris (400 x 200 pm) combined with brilliant yellow earth pigment in an oil medium 850 pm • *wood su ort*	• presence of verdigris in oil confirmed by FTIR analysis. This analysis also indicated a partial alteration of verdigris to form a copper chloride (atacamite). *Prussian blue combined with lead white has been applied over the verdigris and yellow iron oxide (mid-green paint layer) below*
1997 4/2096	Lozenge Psaltery Player, edge of instrument: *purple with white line applied in impasto.*	• *lead white 85 pm* • *particle of verdigris (l80 x 160 pm)* • *black and orange/red iron oxide particles in a lead white matrix 100 pm* • *wood support*	• coating and accretion of dirt on surface • analysis by SEM/EDX indicated that the copper green particle in this sample has partially altered to form a copper chloride. The upper portion of the particle has a high Si content with a little Al. SEM/EDX analysis also indicated a low Al and Si content in the yeilow iron earth pigment, together with traces of K. The black pigment articles contain some S, Si, Al & Ca. *The purple appearance has been produced by combining red and yellow iron oxide pigments with carbon black and lead white. A large inclusion of verdigris is also evident in this paint layer. A linear detail in lead white has been applied in impasto over the purple area. Crude retouchings white are also visible.*
1997 5/2097	Lozenge Psaltery Player, cusped mandorla: *glue over inrense red detail.*	• pure vermilion 350 pm þ medium rich white preparation 50 pm	• crust on surface 20 pm • thick dark coating of animal glue on surface (confirmed by FTIR) 330 pm • accretion of dirt 10 m *a layer of pure vermilion with a trace of a creamy white preparation below. On top of the red pigment is a layer of glue 330 um thick. This layer of animal glue, and the accretion of dirt which has accumulated on its surface, is clearly visible in UV light*
1997 6/2098	Lozenge Psaltery Player, cusped mandorla, red decorative motif: *bright lower red.*	• *dispersion sample only. Analysis by PLM indicated the presence of vermilion*	*Examination of a dispersion of Sample 6/2098 confirmed the presence of vermilion.*
1997 7/2099	Lozenge Psaitery Player, left proper cheek: *pale flesh tone.*	• *few tiny particles of vermilion in a lead white matrix with a* • *single large particle of carbon black 65 pm* • *vermilion with a few particles of yellow iron oxide and carbon black in a translucent lead white matrix 20 pm* • *carbon black in a matrix of calcium sulphate, lead white and animal glue 35*	• analysis of animal glue in lowest layer was confirmed by FIIR *The flesh tones were built up by the application of vermilion combined with yellow iron oxide and carbon black over a grey ground. An accretion of surface dirt is clearly visible over the highlight of the flesh which consists of lead white combined with a little vermilion*
1997 8/2100	Lozenge Psaltery Player, hair: *metallic bloom on surface of brown hair.*	• carbon black combined with yellow iron oxide and lead white 35 um • large particles ot' verdigris combined with a brilliant yellow earth pigment 80pm • *wood support (calcium sulphate is present at the interface of the ii ood and aint lavers)*	• dense hlack layer on surt'ace which has a metallic sheen 15 pm • SEM/EDX analysis indicated a high Al and Si content in the yellow iron earth pigment. together with traces of Ti and K. This analysis also indicated that the verdigris has partially altered to form a copper chloride. *showing the dense dark layer incorporating black and red particles which has been applied over the green background of verdigris and yellow iron oxide*

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1997 9/2101	Lozenge Psaltery Player, top of head: *dark line which appears to be beneath 'early green' (S2).*	• *carbon black with brown and yellow iron oxide particles and a single particle of a lead-based yellow, likely to be massicot l20 pm*	• dense black layer which has a metallic sheen 5 pm • SEM/EDX analysis indicated a low Al and Si content in the yellow iron earth pigment, together with traces of K. *A mixture of carbon black, brown and yellow iron oxide pigments, together with a single particle of massicot, were employed for this dark line.*
1997 10/2102	Lozenge St. Paul: *highlight of red drapery which blooms readily on contact with water.*	• carbon black with yellow iron oxide, white and some vermilion from underlying layer 45 gm • *vermilion 20 pm* • *red lead combined with calcium carbonate 35 pm* • *red lead combined with carbon black 45 pm* • *wood su ort*	• some positive staining for sulphate in the upper-most layer – specific translucent particles give a positive result. In addition, analysis by SEM/EDX indicated that ciay-rich particles are present in this layer. This analytical technique was also used to confirm the presence of vermilion (HgS). *It seems likely that the layer of red lead combined with a carbon black pigment, together with the red lead and vermilion layers which overlay it, are original. The rather crude, thick, and now grey-coloured line which is made up of yellow iron oxide combined with carbon black, lead white, calcium sulphate and clay-rich particles is likely to have been added later.*
1997 11/2103	Lozenge St. Paul: *drip of glue rom near to bible.*	• yellow iron oxide 180 pm • lead white 80 gm	• thick layer of animal glue on surface (confirmed by FTIR) 130 pm *showing a layer of a yellow iron oxide pigment with a trace of a lead white ground beneath. On the surface is a thick layer of animal glue which is more clearly visible when the sample is viewed in UV light*
1997 12/2104	Lozenge St. Paul, left proper sleeve, yellow brown drapery: *intense yellow agglomerate in yellow/brown paint layer.*	• intense yellow iron oxide 250 pm • black pigment 60 pm • red iron oxide with lead white 15 pm • yellow iron oxide combined with some calcium carbonate and lead white 90 pm • *wood support*	• accretion of dirt on surface • SEM/EDX analysis indicated that the yellow earth pigment in both layers is rich in Al and Si with a trace of K & S. This method of analysis also indicated that the black layer is rich in Al, Si with traces of S, Ca and Fe. *showing two layers of yellow iron oxide pigment divided by a layer of carbon black. Though the uppermost layer of yellow clearly represents a level of repainting, it is not clear whether the lower yellow paint layer is original or not.*
1997 14/2106	Lozenge St. Paul, cusped mandorla: *turquoise blue which blooms readily in contact with water.*	• Prussian blue combined with lead white 15 pm • Prussian blue combined with lead white 60 pm • lead white preparation 25 pm • wood support	*showing two layers of Prussian blue combined with lead white - the lower containing a higher proportion of lead white. Both of these layers are clearly part of the 19th-century retouching of the scheme,*
1997 15/2107	Lozenge St. Paul, hair, left proper side: *yellow highlight over purple/brown.*	• yellow iron oxide combined with carbon black and lead white 100 pm • lead white 75 pm • *large particles of carbon black combined with red and yellow* • *iron oxides and lead white 300 um*	• SEM/EDX analysis suggested the presence of a trace of S in black particles in the upper layer containing black pigment, while traces of Al, Si and S were present in the black pigment in the lowest layer. *showing large particles of carbon black combined with red and yellow iron oxide pigments applied in a layer 300 microns thick. Over this a lead white ground has been applied, and a layer consisting of lead white combined with carbon black and yellow iron oxide on top. It seems likely that the lead white ground and overlying paint layer represent a phase of repainting.*
1997 16/2108	Lozenge St. Paul, cusped mandorla, inner area: *bright yellow/green with darker green on surface.*	• vermilion in yellow and white matrix 25 pm • dark green combined with brilliant yellow 50 pm • *azurite combined with yellow earth in an organic matrix l75* • *white layer consisting of lead white, calcium sulphate and copper oxalate 20 pm* • *wood support*	• FTIR analysis indicated the presence of copper oxalate, which is likeiy to be a transformation product of the original azurite particles. *A layer of natural azurite combined with a little yellow iron oxide, which almost certainly represents the original layer, is evident at the base of the sample with a layer of verdigris and yellow iron oxide on top. A thin layer of lead white mixed with vermilion and yellow iron oxide lies on the surface of the green layers.*
1997 20/2112	Lozenge St. Peter, above left proper eye: *flesh tone.*	• red lead combined with lead white and some carbon black 50 pm • dirt • *tiny particles of vermilion combined with lead white in an oil medium 85 pm* • *tinted preparation (lead white combined with a little black and red) 45 pm* • *trace wood support*	• accretion of dirt on surface *showing the grey preparation applied to the wood support, over which the flesh tone of vermilion combined with lead white in an oil medium was applied. The crude repainting has been undertaken in red lead combined with lead white.*

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1997 21/2113	Lozenge St. Peter, above right proper eye: *flesh tone consolidated by the Perry Lithgow Partnership, 4.97.*	• lead white combined with a little carbon black 20 pm • dirt • *tiny particles of vermilion in a lead white matrix 50 pm* • *azurite combined with yellow earth in a lead white matrix 60* • *wood support 25*	*showing that an underpainting in pale green was originally employed to model the flesh tones. This underpaint consists of a layer of natural azurite combined with yellow iron oxide and lead white, and was applied in a layer 60 microns thick. Over this was applied the flesh tone of vermilion combined with lead white. A layer of repainting, consisting of lead white combined with a little carbon black, is evident on the surface of the sample*
1997 22/2114	Lozenge St. Peter, left proper knee: *highlight of brilliant red drapery which blooms readily in contact with water.*	• *red lead cdmbined with lead white and some calcium sulphate 65 pm* • *vermilion l00 pm* • *red lead combined with lead white and carbon black (there is a sulphate-rich "-one at the top of this layer) 80 pm* • *red lead combined with carbon black l0*	• a few translucent particles within uppermost red lead and lead white layer give a positive sulphate test. There is also a sulphate-rich zone immediately beneath the vermilion. *showing a layer of red lead combined with a little carbon black and lead white which was applied in preparation for the thick vermilion paint layer. The uppermost layer contains red lead, lead white, and a sulphate-rich component.*
1997 23/2115	Lozenge St. Peter, left proper temple: *flesh tone with what appears to be an earlier consolidant on the surface.*	• *vermilion in a lead white matrix 110 pm* • *azurite combined with a little yellow earth in a lead white matrir 65 pm* • *wood support with some clay-rich material and lead white at the interface of the wood and painr layer.*	• FTIR analysis indicated that the azurite has partially altered to form copper oxalate. • FTIR analysis also confirmed the presence of a proteinaceous material, likeiy to be animal glue, combined with calcium sulphate on the surface of the sample. • lead test positive in matrix of vermilion and in matrix of blue/green layer. The blue particles are decolourised by the acid. • SEM/EDX anaiysis confirmed the presence of vermilion (HgS) in the uppermost paint layer and confirmed Cu in the azurite articles. *A layer of dark green underpainting produced by mixing natural azurite and some yellow iron oxide in a lead white matrix (above)was employed to produce the tonal modelling for the flesh tones of vermilion combined with lead white (top).*
1998 4/2350	Replacement Lozenge (35 IV): *new board with crude painting in red and black.*	• red lead with red iron oxide and carbon black 100 pm • lead white 50 pm • wood support	• thick dark surface accretion *A thick layer of red earth combined with carbon black was applied over a lead white ground on the new support*
1997 24/2116	Lozenge St. Peter, right proper sleeve: *dark-blue lining of sleeve.*	• dark blue layer containing Prussian biue with barytes (barium sulphate) and a little lead white 25 pm • pale blue layer containing Prussian blue in a lead white matrix • 100 pm • *trace carbon black (? drawing)* • *wood with calcium sul hate at the wood/paiont interface*	• SEM/EDX analysis suggested the presence of a trace of S in the upper layer containing black pigment *showing two layers of Prussian blue combined with lead white. The uppermost layer contains a higher proportion of Prussian blue, and both layers are part of a 19th-century phase of repainting.*
1998 1/2347	Lozenge (35 IV), green backy'ound to foliate motif: *later blue~green over green.*	• Prussian blue in lead white matrix 15 pm • verdigris combined »ith a brilliant yellow earth pigment in an oil medium 80 pm • *wood (oak) support*	• thick dark surface accretion • re sample 3/2095 *Prussian blue in a lead white matrix was applied over a layer of verdigris combined with yellow earth in an oil medium.*
1998 2/2348	Lozenge (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 pm • lead white with a few red lead inclusions applied in thick impasto 580 pm þ red iron oxide with a few charcoal black and red lead particles 25 pm þ lead white with a little red lead 50 pm • *red iron oxide with some charcoal black particles 7 pm* • *tmce white round*	• 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 *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.*

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1998 3/2349	Lozenge (36 IV dd) foliate motif: *foliate scroll beneath creamy-white re paint.*	• lead white 40 pm • *lead white with single vennilion particle 150 pm* • *wood (oak) support*	• re sample 27/2119 • differentiation between the two lead white layers is only possible in bright field illumination *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 it's clear that two distinct layers of lead white are present, the lower containing a single particle of vermilion*
1998 7/2353	Lozenge (37 IV b), 'Green Man', mouth, foliate motif: *raised curvilinear detail beneath creamv- white overpaint.*	• lead white 50 pm *þ lead white 100 pm* • *wood support*	• surface accretion and dirt • differentiation behveen the two lead white layers is only possible in bright field illumination *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.*
1998 8/2354	Lozenge (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 pm þ pale pink layer of lead mhite combined ivith red iron oxide and carbon black 45pm • *lead white with some chareoal black 90 pm* • *asurite combined with yellow earth in a lead white matrix 70* • *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.
1998 12/2358	Lozenge (36 III a) flesh tone of Janus: *pink'cream flesh tone above his left eye.*	• *lead white combined with a few particles of vennilion 65 pm* • *asurite combined with yellow earth in a lead white matrix 80* • *wood support*	• surface accretion and dirt • FTIR analysis indicated the presence of lead white in an oil medium *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.*
1999 14	29 III b Lozenge	Nave ceiling painting. Sample taken from a red painted area overlapping a bass-relief underpainting of an earlier scheme. The sample was taken near the harp of the horse.	Black: (similar to sample 44) consists of carbon black with large particles. This black layer was found over a haematite-rich red ochre layer and beneath three other layers from a different scheme (from top): a red layer of red lead and ferric oxide particles over a layer of charcoal black over a yellowish lead and gypsum (probably)-containing layer
1999 15	33 III b Lozenge	Nave ceiling painting. Sample taken from a greenish-grey paint near the wing of the beast. This paint is overlapping an earlier scheme. It seems that the earlier scheme was painted with red paint in this area (from visual evidence).	Bluish-green: Prussian blue Applied over an olive green paint layer consisting of copper-bearing pigments Olive green: this paint layer consists of a copper-bearing pigment It was found over a white lead layer and beneath a bluish-green layer: a mixture of Prussian blue, barytes and white lead
1999 20	33 III cc Lozenge	Nave ceiling painting. Sample taken from the staff of Agnus Dei from an area showing an earlier painted scheme in bass- relief beneath the existing painting.	Black: undiluted charcoal black layer with large charcoal black particles Applied directly of the wooden board and found beneath a white lead layer
1999 22	29/30 III Lozenge	Slide film 27 (nos. 12-9) - Red paint under ceiling bolt. Sample taken 30/6/99. Reason for sample, to find out if it is the original paint layer and what it is. The paint is lean, and appeared to be neither a thick or thin paint layer. The paint appears to be directly applied to the wood with no visible ground.	Orange-red: mixture of red lead, ferric oxide, white lead and barium sulphate Applied over a white lead ground

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1999 28	34 III a Figurative lozenge	Blue/green background paint protected by an original nail head (now missing). This paint is not granular but is surrounded by the 1740's green/blue, granular paint. Information required: pigments; medium; date of underpaint. If this is found to be original paint it would suggest that at least the background was painted before the boards were fixed in place. This might explain the presence of carpenter's and register marks incised in some boards.	Reddish: red ochre with dispersed particles of haematite Green: copper-bearing green with clay minerals The red is applied over the copper-bearing green layer and beneath large corrosion particles caused by the presence of an iron nail
1999 29	33 II c1 Figurative lozenge	Bright copper green underneath a hanging bolt washer. The green paint escaped the 1830s repaint It has a granular texture. NB Helen Howard's 1997 samples 2/2094, 3/2095 from the Psaltery Player lozenge; also, her 1998 sample 1/2347 from a foliate lozenge. Information required: Layer structure; pigments; medium; date of underpaint.	Olive green: copper-bearing pigment mixed with yellow ferric oxide particles Applied in a single layer
1999 33	32 III w Foliate lozenge	Apparent original designs visible in raking light. Information required: Layer structure; pigments; medium; date of underpaint.	Yellowish-white: white lead Applied directly over the wooden board. A thin yellowish layer is applied over the white layer
1999 34	30 IV v Lozenge	Apparent original design of tail and harness of mule visible in raking light. Information required: Layer structure; pigments; medium; date of underpaint.	Black: consists of large charcoal black particles rich in ferric hydroxide and white lead particles Found beneath three layers (from top): a thick granular black layer of black, white lead and ferric oxides and hydroxide particles, over a red lead layer over white lead ground Orange-red: mixture of red lead and ferric oxide ? This reddish layer was applied beneath a composite black layer and over a white lead ground. This phase that seems to be coherent overlays an earlier black layer with large charcoal black particles in a ferric hydroxide matrix.
1999 41	31 II z Lozenge St Peter	Micro-flaking – At present this represents the only example of micro-flaking other than that found on the black of the wave pattern. It would be useful to cross reference the information gathered, to assess the similarities in method and materials in order to try and establish the cause of the flaking.	Dark green glaze: Prussian blue mixed with white lead and barium sulphate Applied over a white lead layer over a yellowish layer rich in lead, silicon, calcium and iron
1999 44	33 III a Figurative lozenge	Sample from rear leg of original Renard underlying the dragon overpaint.	The orange-red lead paint was applied beneath the heamatite-rich ochre and these were found beneath two other paint layers of a later date (from top): a yellowish layer over a pinkish layer of iron oxides and white lead Yellowish-white: lead-rich containing layer The yellowish layer is applied over a pink layer. The latter might be the result of diffusion of ferric oxide particles from a layer underneath that consists of a haematite-rich ochre layer over a red lead layer
1999 55	34 IV b Lozenge	The design is unclear but is on a reused board. It appears to be the only example of this so far. Information required: Layer structure; pigments; medium; date of underpaint.	Red: porous layer consisting of ferric oxide and red lead Found beneath three layers (probably belonging to a single or two other paint phases). From top: a black layer of charcoal black mixed with barytes and ferric oxide and hydroxide particles, over a reddish-orange layer with lead white inclusions over a lead white ground Orange-red: red lead layer with probably ferric oxide dispersed particles The reddish-orange layer was applied beneath a black layer (probably belonging to the same painting scheme), over a white lead ground

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
2000 13	22 II z Lozenge	Head of angel with trumpet – Sample of flesh tone on neck. Information required – Identification of original paint scheme if present in sample.	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. 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.
2000 14	21 II a Lozenge	Head of angel with trumpet – Sample of flesh tone on bridge of nose. Information required – Identification of original paint scheme if present in sample.	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.
2000 15	19 III aa Lozenge	Face and neck of archbishop – Sample of flesh tone on left temple. Information required – Identification of original paint scheme if present in sample.	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
2000 16	19 III aa Lozenge	Face and neck of archbishop – Sample of flesh tone below nostril. Information required – Identification of original paint scheme if present in sample.	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.[1]
2000 21	22 III a Lozenge	Sample from collar of archbishop – fragment of green paint within area of paint loss on collar. Information required – Identification of original paint scheme if present in sample.	Although analysis of the sample has yet to be completed (PLM is required) preliminary analysis appears to show a mixed green, containing a copper green with yellow and orange iron oxides. Barytes has been identified on one area of the sample and this suggests a nineteenth century date for the layer. 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.[2] SEM.EDX also detects arsenic within the mixed green layer. If the layer does date from the nineteenth century, it is possible that the arsenic arises from Emerald green pigment. Although the highly characteristic spherical shapes of emerald green pigment have not been observed under reflected light. Alternatively the arsenic could arise from the inclusion of yellow orpiment (or reddish orange realgar) within the layer. Orpiment, although not common, was in use in European painting from 1300 to 1900[3]. PLM is required to identify the arsenic containing pigment.

[1] 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.
[2] 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.
[3] Fitzhugh, E, 'Orpiment and Realgar', *Artists' Pigments A Handbook of their history and characteristics*, Vol 3, Fitzhugh, E (ed.), National Gallery of Art Washington/Oxford University Press, Oxford, 1997, p. 49.

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
2000 22	21 III a Lozenge	Central lozenge board without 1830s overpaint – Sample through 1740s blue/green paint. Information required – Identification of original paint scheme if present in sample.	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.[4] 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.
2001 1	12 II a Lozenge	Paint under original nail head (now missing) – Blue on edge of missing nail head. Original paint? Information required – Identification of original paint scheme if present.	The sample contains large particles of Prussian blue so cannot be original paint, but rather must represent later paint which was drawn under the nail head whilst wet. The particle characteristics (varying size up to very large and angular) suggest the paint probably dates from the eighteenth century restoration.[5] Interestingly SEM.EDX identified the presence of potassium associated with the blue, this might possibly originate from the saltpeter or alum used in manufacture of the pigment.[6] Lead white and red iron oxide are also present.
2001 2	12 III a Lozenge	Paint under original nail head (now missing) – Flesh tone on neck of King (4). Original paint? Information required – Identification of original paint scheme if present.	The flesh tone paint is a single application of lead white, vermilion, carbon black with a little iron oxide yellow. It appears to be original. This pigment combination has been identified in previous research and attributed to the thirteenth century (Howard 1997).
2001 3	13 III b Lozenge	Paint under original nail head (now missing) – Red on crown of King (4). Original paint? Information required – Identification of original paint scheme if present.	The paint is a single layer of red lead with a little carbon black and possible some calcium carbonate. The paint appearance is consistent with it being original.
2001 4	13 I a Lozenge	Paint under original nail head (now missing) – Red/brown on base of organistrum. Original paint? Information required – Identification of original paint scheme if present.	The upper layer of the sample comprises a thick layer of iron oxide, probably corrosion from the now absent nail head. The thin red layer below contains vermilion. SEM.EDX also detects arsenic in this area, suggestive of the presence of orange-red realgar, The brownish lower layer gives EDX spectra suggestive of vermilion and realgar. Realgar is known to alter to orpiment and white arsenic trioxide.[7]

[4] Welsh, F., 'Particle characteristics of Prussian Blue in an historical oil paint', JAIC 27 (1988): 55- 63.
[5] Welsh, F., 'Particle characteristics of Prussian Blue in an historical oil paint', JAIC 27 (1988): 55- 63.
[6] Berrie, B., 'Prussian Blue', *Artists' Pigments A Handbook of Their History and Characteristics*, Vol. 3, Oxford University Press, Oxford, 1997, p.194.
[7] West Fitzhugh, E., 'Orpiment and realgar', *Artists' Pigments A Handbook of Their History and Characteristics*, Vol. 3, Oxford University Press, Oxford, 1997, p.51.

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
2001 5	13 I c Lozenge	Paint under original nail head (now missing) – Green on drapery of organistrum player. Original paint? Information required – Identification of original paint scheme if present.	The sample shows a single layer containing a mixture of natural azurite with lead white, iron oxide yellow, chalk, orpiment (and possibly realgar). This paint is similar to the bright blue-green seen in previous research.[8] 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. Particles of orpiment appear to be present. Some of the deeper red particles have a microscopic appearance consistent with realgar. Iron oxide and chalk are also present
2001 6	14 III aa Lozenge	Paint under original nail head (now missing) –Brown from background of Logic. Original paint? Information required – Identification of original paint scheme if present.	The sample shows a single layer of red paint applied thinly to the timber substrate. The paint is a mixture of red lead with a little carbon black. Some red iron oxide also appears to be present, although this could result from contamination from the missing nail. The appearance of the paint is consistent with a thirteenth century date.
2001 7	17 II b Lozenge	Paint under original nail head (now missing) –Green from background of Grammar. Original paint? Information required – Identification of original paint scheme if present.	The blue-green paint contains a similar pigment mixture to that found on sample 5 above, with the absence of any arsenic pigment. There appears to be a trace of metal from the absent nail head on the sample surface. Carbon black is also present. Barium sulphate was present: see discussion on following page
2001 8	17 IV b Lozenge	Paint under original nail head (now missing) –Red from background of Rhetoric. Original paint? Information required – Identification of original paint scheme if present.	The sample shows a single layer of red lead. Some of the red lead appears to have converted to lead white.[9] Appearance consistent with the sample being from original paint
2001 27	14 I w Lozenge board	Paint under original nail head (now missing) – Off white paint from neck of the organistrum instrument. Confirmation of original paint? Information required – Identification of original paint scheme if present.	The paint appears to be a single application of lead white, vermilion, carbon black with a little iron oxide yellow. Its appearance is consistent with it being of thirteenth century date. A similar paint mixture has been identified in previous research and attributed to the original decoration (Howard 1997).
2001 28	14 I w Lozenge board	Paint under original nail head (now missing) – Black paint from neck of the organistrum instrument. Confirmation of original paint? Information required – Identification of original paint scheme if present.	The sample reveals a dark paint containing carbon black and a little iron oxide. The paint layer is intermingled at its lower boundary with a white lead paint, which appears to contain a particle of azurite. The appearance of the paint is consistent with a thirteenth century date
2001 29	14 II bb Lozenge board	Paint under original nail head (now missing) – Pink paint from body of the organistrum instrument. Confirmation of original paint? Information required – Identification of original paint scheme if present.	The paint appears to be a single application of lead white, vermilion, carbon black with a little iron oxide yellow. Its appearance is consistent with it being of thirteenth century date. A similar paint mixture has been identified in previous research and attributed to the original decoration (Howard 1997).
2003 1	22 III a Lozenge	Paint under original nail head (now missing) — Flesh tone on neck of Archbishop (1). Identification of original paint scheme if present.	The sample shows a single layer of flesh coloured paint, comprised mainly of lead white with some vermilion and carbon black particles. Its appearance is consistent with it being of thirteenth century date.
2003 2	23 II cc Lozenge	Paint under original nail head (now missing) – Green with red stripe within hair of Archbishop (1). Identification of original paint scheme if present.	The sample clearly shows the blue-green paint superimposed by a layer of deep red pigment. The blue-green layer containing a mixture of natural azurite with lead white and a red pigment, possibly Vermilion. This paint appears very similar to the bright blue-green seen in previous research.10 The upper red layer has a microscopic appearance consistent with iron oxide.

[8] Davies, 2001, *op cit*, sample 21 (3068), Howard, 1997, *op cit*, samples 2108 and 2115.

[9] Pers. Comm. Sharon Cather to author. I am indebted to Ms Cather for describing the conversion of minium to cerussite (basic lead carbonate), then to brown lead (plattnerite), which the Courtauld Institute of Art, Conservation of Wall Paintings Department have come across in various contexts, for example, Canterbury Cathedral, St Gabriel's Chapel c. 1130; Westminster Abbey, Chapter House, c. 1380. This apparent alteration can also be seen on samples 9, 10 and 11 within this report.

[10] Davies, 2001, *op cit*, sample 21 (3068), Howard, 1997, *op cit*, samples 2108 and 2115.

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
2003 3	23 II cc Lozenge	Paint under original nail head (now missing) – Flesh tone with red edge on neck of Archbishop (1). Identification of original paint scheme if present.	The paint comprises two layers, the lower appears to be red lead (minium) and the upper iron oxide. No flesh tone paint is visible on the sample as polished. The paint appearance is consistent with it being of thirteenth century date.
2003 4	22 III a Lozenge	Paint under original nail head (now missing) – Light red from within lower robe drapery of Archbishop (1). Identification of original paint scheme if present.	The paint is a single layer of red lead with a little carbon black and possibly some calcium carbonate. The white could be cerussite arising from the conversion of minium.[11] The paint appearance is consistent with it being of thirteenth century date.
2003 5	22 III a Lozenge	Paint under original nail head (now missing) – Light red from within lower robe drapery of Archbishop (1). Identification of original paint scheme if present.	The paint is a single layer of red lead with a little carbon black and possibly some calcium carbonate. The white could be cerussite arising from the conversion of minium.[12] The paint appearance is consistent with it being original.
2003 6	22 III a Lozenge	Paint under original nail head (now missing) – Dark red from within lower robe drapery of Archbishop (1) (same hole as Sample 5). Identification of original paint scheme if present.	The lower paint layer appears to consist of red lead with some carbon black particles. The upper paint layer has a microscopic appearance consistent with iron oxide. Some white and black particles are present within the iron oxide matrix.
2003 7	23 II cc Lozenge	Paint under original nail head (now missing) – Off white from white edging of drapery of Archbishop (1). Identification of original paint scheme if present.	Sample shows a single layer of off-white paint over a translucent substance directly on the timber surface. The translucent material may be the calcium sulphate combined with a proteinaceous material (probably animal glue) which was identified at the timber/paint interface during previous research.[13]
2003 8	23 II aa Lozenge	Paint under original nail head (now missing) – White paint from mitre of Archbishop (1). Identification of original paint scheme if present.	Single thin layer of white paint, shows no evidence of design. Possibly a significant sample in aiding our understanding of the original production of the ceiling, as it suggests the basic colours were blocked out prior to the ceiling being fixed in place, but the design details added after the nails were inserted. However, it maybe that during later interventions the design details were considerably altered and the sample is simply from an area that was originally plainly painted.
2003 9	21 III e wave	Paint under original protruding nail head – Black from an apparent black line on outer curved edge of board. Identification of original paint scheme if present.	Very limited evidence on sample of carbon black paint.
2003 10	21 I c Lozenge	Paint under original nail head (now missing) – Red paint from within white background of angel with cornetto lozenge. Identification of original paint scheme if present.	The paint is a single layer of red lead with a little carbon black and possibly some calcium carbonate. The white could be cerussite arising from the conversion of minium.[14] The paint appearance is consistent with it being original.
2003 11	18 I ee Lozenge	Paint under original nail head (now missing) – Green paint from within drapery (?)of Grammar lozenge. Identification of original paint scheme if present.	The blue-green layer containing a mixture of natural azurite with lead white and an red/orange pigment, possibly iron oxide. This paint is similar to the bright blue-green seen in previous research.[15]

Calcium sulphate found in 16 samples:

[11] Pers. Comm. Sharon Cather to author. I am indebted to Ms Cather for describing the conversion of minium to cerussite (basic lead carbonate), then to brown lead (plattnerite). The Courtauld Institute of Art, Conservation of Wall Paintings Department have observed this phenomena in various contexts, for example, Canterbury Cathedral, St Gabriel's Chapel c. 1130; Westminster Abbey, Chapter House, c. 1380.
[12] Pers. Comm. Sharon Cather to author, as previous sample.
[13] Howard, 1997, *op cit*.
[14] Pers. Comm. Sharon Cather to author, as previous sample.
[15] Davies, 2001, *op cit*, sample 21 (3068), Howard, 1997, *op cit*, samples 2108 and 2115.

Samples from Base Boards (3)

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1999 9	35 III m Base board, Glue	Nave ceiling painting. Sample was taken from a crystalline glue drip from the ceiling.	
1999 17	29 III base board	Nave ceiling painting. Sample was taken from an area with white blanching over black paint.	Black: consists of large charcoal black particles rich in ferric hydroxide and white lead particles Applied beneath another composite black layer consisting of ferric oxide and hydroxide particles lead white and charcoal black particles Black: consists of charcoal-black particles mixed with white lead and dispersed particles of ferric hydroxide Overlays another composite black layer richer in ferric hydroxide
2000 20	19 III m Base Board	Sample from raised scroll design through 1830s white paint. Information required – Identification of original paint scheme if present in sample.	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 *** Scan image in? The lower layer is composed mainly of lead white but also contains a few carbon black and iron oxide yellow pigment particles.

All Samples from Coloured Bands Boards (6 + 4 rep.)

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1999 10	32 III Replacement board Coloured bands	Nave ceiling painting. Sample taken from a black painted area of a replacement board with no traces of earlier decoration underneath the existing scheme. Sample to be compared with sample 6.	Black: charcoal black mixed with white lead and barium sulphate Applied over a layer of white lead and barium sulphate
1999 11	32 III Replacement board Coloured bands	Nave ceiling painting. Sample taken from a red painted area of a replacement board with no traces of earlier decoration underneath the existing scheme. Sample to be compared with sample 7.	Orange-red: consists of red lead mixed with white lead Applied over a whit lead ground and found beneath an undiluted red lead paint layer.
1999 27	32 II l Coloured Bands	Nave ceiling painting. Sample of red paint from one of three original nail holes in grooves of the coloured bands board. Significance as above. Information required: pigments; medium; date of underpaint.	
1999 35	32 IV m Replacement Coloured bands	(Sample of black) This is a replacement board apparently repainted in the 1740's. Information required: Analysis of pigments may help to identify other 1740's work.	Black: Charcoal black particles Applied over a white lead ground
1999 36	32 IV m Replacement Coloured bands	(Sample of red) This is a replacement board apparently repainted in the 1740's. Information required: Analysis of pigments may help to identify other 1740's work.	Orange-red: red lead Applied over a white lead ground
2000 1	22 III o Coloured bands	Original frieze decoration on oak replacement boards - suspected original Ashlar decoration visible in relief on two repositioned oak ceiling boards. Sample of paint from trefoil design. Information required – Identification of original paint scheme.	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 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.
2000 2	22 III o Coloured bands	Original frieze decoration on oak replacement boards - suspected original Ashlar decoration visible in relief on two repositioned oak ceiling boards. Sample of paint from tendril design. Information required – Identification of original paint scheme.	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
2000 6	21 I o Coloured bands	Paint under original nail head (now missing) – Sample of thin layer of white paint or preparation layer from within a groove. Current theory is that the three grooves were painted red, black, red. Another example of white paint instead of red in a groove has been found on board 19 III g (possibly take sample during next visit?). Information required – Identification of paint/preparatory layer. Compare with similar sample (Kakoulli, 1999 Sample 57).	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.[16] The sample shows only a very thin layer of lead white paint, directly on the timber substrate
2000 7	21 I o Coloured bands	Paint under original nail head (now missing) – Sample of black paint on raised area between grooves. Current theory is that these raised areas were originally unpainted. Information required – Identification of original paint scheme.	The sample shows only a very thin layer of black paint, directly on the timber substrate.
2001 9	11 II j Coloured bands	Paint under original nail head (now missing) – Red paint from outer groove. Control sample for comparison with Samples 10 and 11.	Appearance consistent with the sample being from original paint. Single layer of red lead. Some of the red lead appears to have altered to lead white

[16] 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.

All Samples from Extended Chevron boards (12)

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1997 27/2119	Extended chevron St. Peter, border with extended chevron pattern: *ghost of trefoil patrern beneath chevron design.*	• lead white 80 pm • pale pink layer of vermilion combined with lead white 25 pm • lead white 125 pm • *carbon black (?drawing)* • *wood support*	• consolidant and accretion of surface dirt • pink and white layers appear to have been applied wet on wet • white layers and matrix of pink stains positive for lead *The wood support is clearly visible at the bottom of the cross-section, and over this a layer of lead white has been applied. Approximately 3/5 up this layer of lead white is a trace barely visible in the photograph of vermilion combined with lead white, and it seems likely that this combination was employed for the 'fleur-de-lys' decoration. A second layer of lead white covers the pink rnotif. A similar pink layer is visible in Sample 26/2118*
1998 11/2357	Extended chevron (37 III r): *extensive drips and staining of dark brown material on creamv-white ground.*		• FTIR analysis indicated the presence of shellac
1999 8	35 II g Extended chevron	Nave ceiling painting. Sample taken from the centre of a trefoil shown through a cream-colour painted scheme. The centre of the trefoil shows very grainy texture and microflaking probably suggesting the use of thin metal foil.	Yellowish-white: white lead and barium sulphate 2 layers of white lead mixed with barium sulphate applied directly over the wood
1999 16	28 I p Extended chevron	Nave ceiling painting. Sample taken from a cream-colour area overlapping an earlier scheme with trefoils showing in bass- relief beneath the existing painting.	Black: undiluted charcoal black layer with large charcoal black particles. Found beneath two layer of white lead. Yellowish-white: white lead Overlaying a layer with large charcoal black particles
1999 39	33 II u Extended chevron	To identify original colour/decorative surface of various trefoils. HH found carbon black & thought it may be drawing – could it be the intended colour/appearance? If the new samples are taken from the central areas of the trefoils and are found to contain carbon black, it seems unlikely that the drawing would have continued into these areas: drawing lines are usually limited to the perimeters. In the same HH sample 27/2119 she also noted that the pinkish layer extended over both the trefoil and the background. It is surely unlikely that the trefoil design would only be delineated by the slight relief. Could the pink layer be from a later date e.g. 1740, when the original decorative scheme of trefoils was painted out and replaced with the simpler extended chevron design – which would be considerably easier and quicker (cheaper) to repaint? It would be useful if one of these samples (or another area) could be large enough to extend over an edge of a raised design. This may show how the different layers interface/overlay.	Grey: white lead with dispersed particles of charcoal black Applied directly over the wooden board and is found beneath a yellowish thin layer Yellowish-white: white lead Overlays a probably earlier scheme of white lead and charcoal black (mixed).
1999 48	31 III p Extended Chevron	4.4 Thin black glaze - There appears to be a thin shiny black glaze on some original boards with wave and extended chevron pattern. The application of this glaze is not uniform with areas being missed. The coating is soluble in acetone, behaving like a glaze. Where the glaze has not been applied to the underlying black surface, this surface is relatively matt. Another surface quality is encountered in these areas, it has a bloom/milky quality to it and would appear to be an altered version of the glaze. This bloom/milky quality tends to be found on the side of the board next to the board which overlaps it.	Black coating

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1999 54	35 II g Extended Chevron	Surface staining, brown drips. Information required: Are these likely to be deposits from the wood mobilised by water infiltration or chemical treatment residues?	
2000 5	24 IV r Extended chevron	Paint on original nail heads – Sample taken from original non-corroded nail head (overpainted in 1740s and 1830s with white lead background paint). Information required - To establish whether nail heads within areas of unpainted background were originally painted to match the colour of the surrounding timber.	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.
2000 17	18 II r Extended Chevron	Sample of raised trefoil design showing as black through the 1830s white background paint. Information required – Identification of original paint scheme if present in sample.	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.
2001 12	14 III k Extended Chevron	Paint from small impasto circle/dot on 'body' of original trefoil. Similar embellishments found previously on some trefoil 'heads in Bays 2 and 3. Information required – Original paint? Identification of impasto paint and stratigraphy of paint layers.	The sample shows lead white with a little calcium carbonate, over a thin carbon black layer, possibly representative of underdrawing. Identical layers have been observed in similar locations without a raised dot.[17]
2001 13	15 I q Extended Chevron	Paint from small impasto circle/dot on 'body' of original trefoil. Similar embellishments found previously on some trefoil 'heads in Bays 2 and 3. Information required – Original paint? Identification of impasto paint and stratigraphy of paint layers.	The sample reveals two layers of lead white with a little calcium carbonate, over a thin carbon black layer, mixed with a thick translucent layer. The translucent layer contains no pigmentation, it stains weakly for protein and is probably an animal glue, which may arise from later intervention. The presence of two white layers is clearly revealed in the SEM.EDX backscattered shown on the following page. Similar layers have been observed in similar locations without a raised dot. Further sampling may elucidate this query
2001 14	14 III t Extended Chevron	Paint from small impasto circle/dot on 'body' of original trefoil. Similar embellishments found previously on some trefoil 'heads in Bays 2 and 3. Information required – Original paint? Identification of impasto paint and stratigraphy of paint layers.	The sample shows lead white with a little calcium carbonate, over a thin carbon black layer. Similar layers have been observed in similar locations without a raised dot. Further sampling may elucidate this query.

[17] Davies, 2001, sample 17 (3064) from 18 II r extended chevron, where a raised trefoil design is just visible showing as black through the 1830s white background paint.

All Samples from Grey Chevron Boards (10 + 4 Rep.)

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1997 28/2120	Grey Chevron St. Peter, chevron border: *impasto decoration benearh grey paint.*	• grey layer ot carbon black combined with lead white and some red. yellow and brown iron oxide particles 430 pm • lead white combined with a little carbon black 800 pm	• accretion of surface dirt and consolidant which has penetrated into the upper portion of the paint layer. FTIR analysis indicated that this material is likely to be shellac. *showing the lead white layer which was applied in impasto, and the overlying grey paint layer. When viewed in UV light, as shown in* ***Plate 64*** *(top) the upper portion of this grey layer fluoresces. Analysis of this portion of the sample by FTIR indicated that shellac may be present.*
1997 29/2121	Grey Chevron St. Peter, border with extended chevron pattern: *'rusry' brown stain on creamv/white aint.*	• lead white with a few dark inclusions and a few particles of red dark coating 15 p.m lead 250 pm	• dark coating 15 um *taken from a brown 'stain' on the extended chevron pattern border surrounding St. Peter, shown at 1200x magnification. The brown appearance of the surface is clearly due to a coating which has penetrated into the lead white paint layer.*
1998 5/2351	Grey chevron (36 III w): *black with bloom and exlensive craquelure.*	• large charcoal black particles combined with yellow iron oxide and lead white 300 pm • wood support	*A thick layer of charcoal black combined with yellow earth and lead white was applied directly to the wood support.*
1999 37	30 III x Grey chevron	(Sample of black/brown) Possible original paint – black and white (possible red traces?) lines under a lost original nail head. The paint appears to follow the groove lines, perhaps indicating the original decorative scheme.	Black: charcoal black Applied directly over the wooden board
1999 38	30 III x Grey chevron	(Sample of white) Possible original paint – black and white (possible red traces?) lines under a lost original nail head. The paint appears to follow the groove lines, perhaps indicating the original decorative scheme.	
1999 47	29 IV s Grey Chevron	4.3 Thick resinous coating - Visually this coating appears to be a thick layer associated with the white patchy MBG. It is possible to remove the white patches very easily with acetone; in fact the swab only has to touch white patchy areas for it to be removed. The material removed by the action of the swab is yellow. Analysis by Brian Ridout states that the white patchy MBG is a crystalline deposit associated with the paint and not MBG. It is found on baseboards and grey chevron. It is possible that the sample 25/2117 Howard (1997) from 31 III v shows the white crystalline deposit in cross section; although Howard makes no mention of crystalline characteristics, but says 'pale white layer on the surface 10 µm [consolidant as yet unidentified]. Inner portion of this stains positive for lead, as does ground'. This would appear to back up Ridout's comment that the deposit is associated with the paint. This hypothesis assumes that Howard's sample is of the white crystalline deposit. Continued application of acetone draws or dissolves brown deposits. This could be a thick paint layer as indicated in Howard's samples (1997) 17/2109 'brown and yellow oxide particles combined with brilliant yellow and black 150 µm' and 25/2117 'dense dark layer with black, brown and yellow inclusions 750 µm'.	"*Thick resinous coating*": of large charcoal black particles rich in ferric hydroxide and white lead particles Applied beneath another black layer of …..resinous? "*Thick resinous coating*": Overlays a composite black pigment with large charcoal black particles, ferric hydroxide and white lead inclusions
1999 57	28.IV o Grey chevron	Nave ceiling painting. Sample of white (?) paint from original nail hole in grooves of the grey chevron board. Significance as above. Information required: pigments; medium; date of underpaint.	*Black:* consists of charcoal black particles mixed with white lead and dispersed ferric hydroxide particles

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
2000 9	27 II s Replacement grey chevron	Red paint from frieze decoration underpaint on replacement softwood ceiling boards – Limited number of these boards in Bays 4, 5 and 6. They may not exist further west on the ceiling. Recent analysis of a sample obtained in 1999 from such a board in Bay 3 identified barytes in the white background underpaint. This suggests the frieze decoration underpaint dates from the 1840s intervention. As this finding goes against our current theory that these softwood boards were 1740s Ashlar boards re-used as ceiling board replacements in the 1830s, further confirmation is required. Barytes was not present in samples from similar boards analysed last year (Kakoulli, 1999, Samples 1 and 2). I noticed that the frieze decoration on the board sampled this year had been overpainted in white before the grey chevron decoration was applied. Could the barytes have been in a similar layer? Information required – Identification of paint layers. Comparison with paint samples mentioned above and with previous samples taken from the 1830s frieze boards to identify similarities.	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.
2000 10	27 II s Replacement grey chevron	Black paint from frieze decoration underpaint on replacement softwood ceiling boards - Information required – As Sample 9	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
2000 11	22 III j Replacement grey chevron	Paint on nail head – As an aid to identification of 1740s nails. Sample from an added nail head in a (positively identified) 1740s softwood replacement board. If sample includes 1740s paint layer the nail must be from that intervention. . Information required – Identification of layer structure. (Should we have taken a paint sample from the board for comparison?)	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.
2000 12	23 I r Replacement grey chevron	Paint on suspected 1740s softwood replacement board – The board appears, from the thickness of the paint layer(s) to be a 1740s replacement. Sample to confirm presence of underlying 1740s paint layer. Information required – Identification of layer structure	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.[18]
2000 18	19 III t Grey Chevron	Possible original paint under original nail head (now missing) – Sample of white paint from within the inner of three grooves. Information required – Identification of original paint scheme if present in sample.	The sample shows a single thin layer of lead white with a tiny amount of carbon black. Calcium was detected by SEM.EDX towards the lower boundary of the paint layer
2001 10	11 I s grey chevron	Paint under original nail head (now missing) – Red paint from middle groove. Very few instances of red paint found in middle grooves. Confirmation of original paint? Information required – Identification of original paint scheme if present.	The surface grey paint layer comprises lead white with calcium carbonate, the colouring pigments appear to be iron oxide, carbon black and an organic brown. The second white layer is also lead white with calcium carbonate, pigmented with a little iron oxide and carbon black. The orange-brown layer appears to consist of iron oxide, some red lead and carbon black in particles ranging from medium to very large. The carbon particles have a smooth even surface. The primary paint layer is red lead, with some white lead inclusions. The red lead paint appears to be consistent with a thirteenth century date.

[18] 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.

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
2001 11	11 I f grey chevron	Paint under original nail head (now missing) – Red paint from middle groove. Very few instances of red paint found in middle grooves. Confirmation of original paint? Information required – Identification of original paint scheme if present.	Appearance consistent with it being original paint, single layer of red lead applied directly to the timber surface.

All Samples from Stepped Chevron Boards (18 + 5 Rep.)

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1997 17/2109	Stepped chevron St. Paul, stepped 'battlement' border around figure: *brown/blacl'.*	• brown and yellow iron oxide particles combined with briiliant yellow and black 150 pm • large carbon black particles comhined with yellow iron oxide and lead white 80 pm • lead whi(e 45 pm	• pale layer ot coating or consolidant on surface 5 pm • a few particles in the uppermost paint layer stain positive t'or lead. as does the white ground. SEM/EDX analysis suggested the presence of a trace of S in black pigment particles in the upper paint layer, and indicated that calcium sulphate is also present in this layer. *showing a thick layer of dark repainting and, beneath, a layer of carbon black combined with yellow iron oxides and lead white. On the uppermost surface of the sample is a thin coating (or layer of consolidant) which produces a 'metallic sheen'*
1997 18/2110	Replacement Stepped Chevron St. Paul, 19th-century replacement board with stepped 'battlement' border pattern: *metallic rev over cream.*	• brown and yellow iron oxide particles combined with brilliant yellow, barytes and black 45 pm • lead white 75 pm • pine support (replacement board)	• coating, as yet unidentified, and accretion of dirt on surface 5 pm • SEM/EDX analysis indicated the presence of barytes (barium sulphate) in the paint layer. *showing the lead white preparatory layer, and dark brown paint layer which consists of a mixture of brown and yellow iron oxide pigments combined with barytes and carbon black. The silvery sheen on the surface of the paint layer is due to a pale coating which has not yet been identified.*
1999 1	30 II w Replacement Stepped chevron	Nave ceiling painting. Area decorated with stepped chevron pattern overlapping an earlier scheme with black and red decoration. Sample taken from the black decoration of the earlier scheme.	Black: charcoal black particles Applied over a white lead ground and beneath another scheme of painting (of phase III?)
1999 2	30 II w Replacement Stepped chevron	Nave ceiling painting. Area decorated with stepped chevron pattern overlapping an earlier scheme with black and red decoration. Sample taken from the red decoration of the earlier scheme.	Red: haematite rich red ochre Applied over a white lead ground and beneath another scheme of painting (of phase III?)
1999 30 (within) 31 (outer) 32 (outline)	33 III y Stepped chevron	The linear design is out of phase with the visible paint. Is this evidence of the original scheme or a corrected mistake? Information required: a sweep across the line and background on either side of the line to determine whether the line is original; whether there is surviving original background paint; whether the raised line is due to impasto underpaint alone or the sinking back of the wood surface either side of the line.	Yellowish-white: white lead Applied directly over the wooden board. A thin yellowish layer is applied over the white layer
1999 52	34 III e Replacement Stepped Chevron	4.8 Black coating, resinous medium where it is in impasto - To date this has only been found on replacement boards dating from the last restoration. It overlies the black/purple. As mentioned in the heading the coating looks resinous where it has been applied in impasto, elsewhere it is matt.	Black: consists of large charcoal black particles rich in ferric hydroxide and white lead particles Applied beneath another black layer consisting of fine charcoal black particles with dispersed yellow, brown and reddish particles
1999 53	35 IV e Replacement Stepped Chevron	4.9 The black on the 1880's boards - The black found on the 1880's boards is more of a dark slate grey. It seems to only be found on these boards.	*"Black on 1830's boards":* consists of charcoal black particles mixed with white lead and barium sulphate dispersed ferric oxide and hydroxide particles Applied over a white lead ground

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
2000 8	20 II f stepped chevron	Original paint on raised linear original design – To date we do not have a sample of original paint from original linear stepped chevron design. Current theory is that it was probably black. Information required – Identification of original paint scheme.	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
2000 19	20 II f Stepped Chevron	Sample from raised linear design through white background paint. Information required – Identification of original paint scheme if present in sample.	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
2001 15	9 I f Stepped Chevron	Original linear stepped chevron decoration visible in relief under C18th/19th paint. Sample through white. Information required – Identification of original paint scheme if present in sample.	The sample appears to show two layers of lead white. The upper layer being fairly thinly applied. The lower, thicker white contains a very few coloured particles, probably vermilion and carbon black. A translucent organic substance appears to be present at the paint timber interface
2001 16	9 I f Stepped Chevron	Original linear stepped chevron decoration visible in relief under C18th/19th paint. Sample through black. Information required – Identification of original paint scheme if present in sample.	The sample shows brown on white on coarse orange-brown paint directly on the timber substrate. Microscopy suggests the paint dates from the eighteenth and nineteenth centuries, with any earlier paint absent from this specific location. The characteristic chunky orange-brown paint is present overlying apparently thirteenth century paint on sample 10 and it has therefore been tentatively assigned to the 1740s phase.
2001 17	9 I f Stepped Chevron	Original linear stepped chevron decoration visible in relief under C18th/19th paint. Sample through white. Information required – Identification of original paint scheme if present in sample.	The sample appears to show only off-white paint. Under reflected light it is just possible to discern two off-white paint layers, the upper one being thinly applied. Noticeable at the base of the sample is a beige layer, probably with an animal glue medium.[19]
2001 18	9 I f Stepped Chevron	Original linear stepped chevron decoration visible in relief under C18th/19th paint. Sample through black. Information required – Identification of original paint scheme if present in sample.	The upper layers of the sample appear to date from the 1830s. The brown is comprised of umber, natural iron oxide, calcium and barium sulphate. The upper white layer is lead white and calcium carbonate. The lower again lead white and calcium carbonate. The characteristic coarse orange-brown is identical to that observed on previous samples. The lowest white layer is basic lead carbonate and may date from the thirteenth century. The beige layer visible at the base of the sample appears to be calcium sulphate in an animal glue binder
2001 19	9 I f Stepped Chevron	Original linear stepped chevron decoration visible in relief under C18th/19th paint. Sample through white. Information required – Identification of original paint scheme if present in sample.	The sample appears to show two layers of lead white. The upper layer being fairly thinly applied. The lower, thicker white contains a few coloured particles, probably vermilion and carbon black. The beige layer visible at the base of the sample appears to be calcium sulphate in a glue binder.
2001 20	12 III e Stepped Chevron	Original linear stepped chevron decoration visible in relief under C18th/19th paint. Sample through white. Information required – Identification of original paint scheme if present in sample.	The presence of two distinct white layers can be seen on this sample under dark and bright field reflected light and even more clearly on a EDX backscattered image. Both layers consist primarily of basic lead carbonate with small amounts of extender and coloured pigments. Interestingly the lower layer contains a small copper blue particle, possibly natural azurite, which would seem to associate that paint layer with the thirteenth century paintwork
2001 21	12 III e Stepped Chevron	Original linear stepped chevron decoration visible in relief under C18th/19th paint. Sample through black. Information required – Identification of original paint scheme if present in sample.	This sample has a very similar appearance to sample 18 discussed above. The brown is comprised of umber, natural iron oxide, calcium and barium sulphate. The characteristic coarse orange-brown is identical to that observed on previous samples. The lowest white layer is basic lead carbonate and may date from the thirteenth century. The beige layer visible at the base of the sample appears to be calcium sulphate in an animal glue binder
2001 22	12 III e Stepped Chevron	Original linear stepped chevron decoration visible in relief under C18th/19th paint. Sample through white. Information required – Identification of original paint scheme if present in sample.	The sample shows a lead white paint applied over the characteristic orange-brown discussed above. The lower white lead layer may be dated to the thirteenth century

[19] The layer stains weakly positive for protein.

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
2001 23	17 IV g Stepped Chevron	Paint under original nail head (now missing) – White paint from raised linear stepped chevron decoration. Confirmation of original paint? Information required – Identification of original paint scheme if present.	The sample shows a very thinly applied white lead layer directly on the timber substrate. It has not been overpainted. Its microscopic appearance is consistent with it being of thirteenth century date
2001 24	17 IV g Stepped Chevron	Paint under original nail head (now missing) – Black paint from background(?) area adjacent to raised linear stepped chevron decoration. Confirmation of original paint? Information required – Identification of original paint scheme if present.	The sample appears to show unpainted timber. Surface deposits appear to be accretions of dust and debris, rather than a deliberately applied paint finish.
2001 25	15 I f Stepped Chevron	Paint under original nail head (now missing) – White paint from raised linear stepped chevron decoration. Confirmation of original paint? Information required – Identification of original paint scheme if present.	The sample shows a thinly applied white lead layer directly on the timber substrate. It has not been overpainted. Its appearance may be consistent with a thirteenth century date
2001 26	15 I f Stepped Chevron	Paint under original nail head (now missing) – Black paint from background(?) area adjacent to raised linear stepped chevron decoration. Confirmation of original paint? Information required – Identification of original paint scheme if present.	The sample appears to show unpainted timber. Surface deposits appear to be accretions of dust and debris, rather than a deliberately applied paint finish. It has not been overpainted. However, iron corrosion products, probably from the now absent nail head are present on its surface

All Samples from Wave Pattern Boards (9 + 1Rep.)

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1997 19/2111	Wave St. Paul, chevron border: *opaque rich black.*	• shiny black pigment particles 15 pm • lead white 7 pm • dense black combined with lead white 65 pm • lead white 45 pm • wood support	• SEM/EDX analysis suggested the presence of a trace of S, Cl and Ti in black pigment particles from the uppermost layer. *showing the wood support which has been prepared with a lead white ground and, over this, a dense layer of carbon black combined with lead white. A second lead white ground has been applied over the lower black layer. The uppermost layer of the sample consists of highly reflective black particles*
1997 26/2118	Wave St. Peter, border with chevron pattern: *broivn stain at edge of border.*	• lead white 50 pm • pale pink layer ot vermilion combined with lead ivhite *35* pm • lead white 100 pm • wood su ort	• consolidant and accretion of surface dirt • pink and white layers appear to have been applied wet on wet *showing the wood support over which a layer of lead white is evident. A trace of vermilion is apparent towards the upper part of this thick white layer which compares closely to that found in Sample 27. A thick accretion of surface dirt is visible at the top of the sample.*
1998 9/2355	Wave (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 bire&ingent. The refractive indices of one are greater than 1.58, while the refracuve indices of the other are less than 1.58. • SEM/EDX indicated the presence of sodium sulphate (Na, S & 0), a little Pb was also present in one of the spectra. • XRD provided a clear and strong pattera for • ammonium lead sulphate (NE4)> Pb (SO~Q and a little sodium sul hate) *Instrumental analysis of the salts in a sample taken from this area confirmed the presence of ammonium lead sulphate and sodium sulphate.*
1999 18	28 III e Wave	Nave ceiling painting. Sample was taken from a cream-colour paint overlapping an earlier scheme with wavy decoration showing in bass-relief beneath the existing painting.	Yellowish-white: white lead and barium sulphate 2 layers of white lead and barium sulphate applied over a red lead layer belonging to an earlier phase
1999 21	35 I Wave	Nave ceiling painting. Sample taken from an area affected with white efflorescence.	

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1999 45	31 III d Wave pattern	4.2 Deep matt black (a) **-** This is found on wave pattern boards and associated with micro flaking. Visually this appears to be a single layer of paint without a ground. The paint layer is not thick, but it is saturated enough to produce a deep velvety layer of paint. Further thoughts on this combined with the sample 19/2111 from the black of the wave pattern indicate that this black is a combination of two blacks. See section 5, 'two wave patterns'. The first black, which may be prone to micro flaking, would appear to be a 'dense black combined with lead white 65µm' applied over the first layer, presumably the ground 'lead white 45 µm'. Over this is a 'lead white 7 µm' followed by the later black 'shiny black pigment particles 15 µm'. The 'shiny black pigment particles 15 µm may relate to the observations in section 8 'Paint damage' where possible crystalline faces are noted.	"Deep matt black": milky thin layer rich in lead overlaying a black layer consisting of charcoal black particles mixed with lead white Applied over a white lead ground
1999 46	32 I u Wave	4.2 Deep matt black (b) - This paint would seem to be identical to that in 4.2 (a) above. The only difference noticed so far is that it is not associated with micro flaking. It might be that this is found where the first black layer has remained well secured to the white ground, and where the white ground has remained well secured to the wood.	
1999 51	32 III c Replacement Wave	4.7 Velvety/black - This appears thicker than the black/black (4.6), but otherwise could be the same as 4.6. Only found on replacement boards. Paint edges can have a shiny edge.	"Velvety/black": milky layer applied over a black lustrous layer of black fine particles Applied over a ground consisting of white lead and barium sulphate (barytes)
1999 56	34 II e Wave	Scroll underpaint – edge of raised design, across white background and black repaint.	
2000 4	22 I r wave	Linear wave pattern in red with scrolled ends – Red paint visible under edge of black wave pattern. Sample taken to confirm Kakoulli's findings in 1999 (Sample 18). Information required – Identification of original paint scheme.	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.[20] 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.

[20] 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.

All Samples from Dogtooth/Bun Boards (4 + 2 Rep.)

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1998 6/2352	Dogtooth (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 broem iron oxide particles 280pm • lead white 40 pm • lead white 120 • *wood suppo rt*	• re sample 28/2120 • differentiation between the two lead white layers is only possible in bright field illumination *Here a layer of carbon black combined with lead white and red, yellow and brown earth particles was applied over a lead white ground.*
1999 19	28 I d/e Bun	Nave ceiling painting. Sample was taken from a cream-colour paint overlapping an earlier scheme showing in bass-relief beneath the existing painting (bun decoration).	Black: undiluted very thin charcoal black layer with large charcoal black particles Applied directly of the wooden board and found beneath a white lead layer
1999 40	34 I d Dogtooth/Bun	A shape (possibly a malformed bun),visible in relief. This is the only sign of visible underpaint on this board.	Yellowish-white: white lead Applied directly over the wooden board.
1999 49	30 IV d Replacement Dogtooth	4.5 Black/purple - This is only found on replacement boards. On the 1830's boards it would appear to be the only black, on the 1740's boards it can be found over an earlier black. It would therefore appear to be an 1830's black. Small areas of impasto in the paint can be shiny, i.e. the edges of brush marks. The dating used here follows the suppositions made in section 10. These are suppositions only.	*Black/purple":* consists of charcoal black particles mixed with white lead and dispersed ferric oxide and hydroxide particles
1999 50	31 IV m Replacement Bun pattern	4.6 Black/black - Like the previous category, 4.5, this is only found on replacement boards. It could be related to observations in sections 4.2 (a) & (b). It is found over underpaint which is thought to date from the 1740's. There are irregularities of sheen on the paint surface (matt, shiny, bloom/milky) again similar to section 4.2.	"Black/black": milky layer applied over a black lustrous layer of black fine particles Applied over a yellowish layer consisting of white lead and barium sulphate (barytes), over a white lead ground
2000 3	22 IV e dogs-tooth	Sample from an exposed area of seemingly original linear dogstooth pattern (white). This is a significant find and has been sampled for positive identification of the paint. The sample may also further out knowledge of any original preparatory layer.	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.

All Samples from Key Pattern Boards (7)

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1997 13/2105	Key St. Paul, 1st order of border pattern around figure: *white with black key pattern.*	• lead white 25 pm • large particles of carbon black combined with yellow iron oxide and lead white 125 pm • lead white 260 pm • wood support	*showing the lead white ground layer penetrating into the wood support, over which is a layer of carbon black combined with yellow iron oxide particles. Another lead white ground covers this black paint layer but the uppermost layer of black repainting is not present in the sample.*
1997 25/21I7	Key St. Peter, border with key pattern: *shiny black paint with white bloom on surface.*	• dense dark layer with hlack. brown and yellow inclusions 750 Pm • carbon black. yellow and brown particles >5 pm • lead white I 5 m	• pale white layer on the surface 10 pm (? consoiidant as yet unidentified). Inner portion of this layer stains positive for lead. as does ground. *showing a thick dark layer of black, brown and yellow inclusions which has been applied directly over a layer containing yellow iron oxide, carbon black and lead white on a lead white ground. The metallic sheen on the surface of the paint layer, evident in plate 56, is due to the unidentified surface coating, which remains on the surface of the sample.*
1999 12	28 III c Key	Nave ceiling painting. Sample was taken from the painted decoration of an earlier scheme showing in bass-relief through the key decoration of the existing painting. It was taken from a grooved area.	
1999 13	28 III c Key	Nave ceiling painting. Sample was taken from the painted decoration of an earlier scheme showing in bass-relief through the key decoration of the existing painting. It was taken from a flat area adjacent to a grooved area (see sample 12).	Black: consists of large charcoal black particles rich in ferric hydroxide and white lead particles Applied beneath another composite black layer consisting of ferric oxide and hydroxide particles lead white and charcoal black particles Black: consists of ferric oxide and hydroxide particles lead white and charcoal black particles Overlays a another black layer consisting of charcoal black particles mixed with yellow ferric hydroxide and white lead (belonging to an earlier phase)
1999 26	32 1 e Key Pattern	(Photo F5 35) **-** Nave ceiling painting. Sample of red paint from groove in a key pattern board. The paint had been protected by an original nail head (now missing). This important find would suggest that: (a) This paint survives from the original C13th scheme. (b) The original painted design on the key pattern boards – and possibly all grooved boards – was similar to the coloured bands boards. (c) Being under an original nail the design would have been painted before the board was fixed in place. Information required: pigments; medium; date of underpaint.	Orange-red: red lead mixed with white lead Applied directly over the wooden board
2001 30	8 III c Key	Paint under 1830s hanging bolt (temporarily removed during treatment) – Black on raised area between outer groove and outer edge of board. Current theory is that these raised areas were originally unpainted. Information required– Identification of original paint scheme if present.	Sample shows a thinly applied carbon black layer over white lead paint directly on the board. No evidence useful for specifically dating the paint layers has been noted on the sample.
2001 31	12 II d Key	Paint under original nail head (now missing) – Black paint from raised area between outer and middle groove. Current theory is that these raised areas were originally unpainted. Information required– Identification of original paint scheme if present.	The sample appears to show unpainted timber. Surface deposits appear to be accretions of dust and debris, rather than a deliberately applied paint finish

All Samples from Softwood Replacement Ceiling Boards (18)

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1997 18/2110	Replacement Stepped Chevron 19th-century replacement board with stepped 'battlement' border pattern: *metallic rev over cream.*	• brown and yellow iron oxide particles combined with brilliant yellow, barytes and black 45 pm • lead white 75 pm • pine support (replacement board)	• coating, as yet unidentified, and accretion of dirt on surface 5 pm • SEM/EDX analysis indicated the presence of barytes (barium sulphate) in the paint layer. *showing the lead white preparatory layer, and dark brown paint layer which consists of a mixture of brown and yellow iron oxide pigments combined with barytes and carbon black. The silvery sheen on the surface of the paint layer is due to a pale coating which has not yet been identified.*
1998 4/2350	Replacement (lozenge) (35 IV): *new board with crude painting in red and black.*	• red lead with red iron oxide and carbon black 100 pm • lead white 50 pm • wood support	• thick dark surface accretion *A thick layer of red earth combined with carbon black was applied over a lead white ground on the new support*
1999 1	30 II w Replacement Stepped chevron	Nave ceiling painting. Area decorated with stepped chevron pattern overlapping an earlier scheme with black and red decoration. Sample taken from the black decoration of the earlier scheme.	Black: charcoal black particles Applied over a white lead ground and beneath another scheme of painting (of phase III?)
1999 2	30 II w Replacement Stepped chevron	Nave ceiling painting. Area decorated with stepped chevron pattern overlapping an earlier scheme with black and red decoration. Sample taken from the red decoration of the earlier scheme.	Red: haematite rich red ochre Applied over a white lead ground and beneath another scheme of painting (of phase III?)
1999 10	32 III Replacement board Coloured bands	Nave ceiling painting. Sample taken from a black painted area of a replacement board with no traces of earlier decoration underneath the existing scheme. Sample to be compared with sample 6.	Black: charcoal black mixed with white lead and barium sulphate Applied over a layer of white lead and barium sulphate
1999 11	32 III Replacement board Coloured bands	Nave ceiling painting. Sample taken from a red painted area of a replacement board with no traces of earlier decoration underneath the existing scheme. Sample to be compared with sample 7.	Orange-red: consists of red lead mixed with white lead Applied over a whit lead ground and found beneath an undiluted red lead paint layer.
1999 23/24/25	32 III s Patch	Board (removed for investigation) - A sample of both layers of hessian. This small piece of softwood board has been used to pack the vertical gap between two boards. Does the earlier hessian and adhesive date from the 1740s or 1830s restoration rather than 1924 when the reverse of all ceiling boards were covered? The earliest layer is covered in a thick layer of dirt suggesting it was in place for a considerable time before the 1926 hessian was applied overall. Information required: identification of the glues.	Yellowish-white: white lead Applied directly over the wood
1999 35	32 IV m Replacement Coloured bands	(Sample of black) This is a replacement board apparently repainted in the 1740's. Information required: Analysis of pigments may help to identify other 1740's work.	Black: Charcoal black particles Applied over a white lead ground
1999 36	32 IV m Replacement Coloured bands	(Sample of red) This is a replacement board apparently repainted in the 1740's. Information required: Analysis of pigments may help to identify other 1740's work.	Orange-red: red lead Applied over a white lead ground
1999 49	30 IV d Replacement Dogtooth	4.5 Black/purple - This is only found on replacement boards. On the 1830's boards it would appear to be the only black, on the 1740's boards it can be found over an earlier black. It would therefore appear to be an 1830's black. Small areas of impasto in the paint can be shiny, i.e. the edges of brush marks. The dating used here follows the suppositions made in section 10. These are suppositions only.	*Black/purple":* consists of charcoal black particles mixed with white lead and dispersed ferric oxide and hydroxide particles

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1999 50	31 IV m Replacement Bun pattern	4.6 Black/black - Like the previous category, 4.5, this is only found on replacement boards. It could be related to observations in sections 4.2 (a) & (b). It is found over underpaint which is thought to date from the 1740's. There are irregularities of sheen on the paint surface (matt, shiny, bloom/milky) again similar to section 4.2.	"Black/black": milky layer applied over a black lustrous layer of black fine particles Applied over a yellowish layer consisting of white lead and barium sulphate (barytes), over a white lead ground
1999 51	32 III c Replacement Wave	4.7 Velvety/black - This appears thicker than the black/black (4.6), but otherwise could be the same as 4.6. Only found on replacement boards. Paint edges can have a shiny edge.	"Velvety/black": milky layer applied over a black lustrous layer of black fine particles Applied over a ground consisting of white lead and barium sulphate (barytes)
1999 52	34 III e Replacement Stepped Chevron	4.8 Black coating, resinous medium where it is in impasto - To date this has only been found on replacement boards dating from the last restoration. It overlies the black/purple. As mentioned in the heading the coating looks resinous where it has been applied in impasto, elsewhere it is matt.	Black: consists of large charcoal black particles rich in ferric hydroxide and white lead particles Applied beneath another black layer consisting of fine charcoal black particles with dispersed yellow, brown and reddish particles
1999 53	35 IV e Replacement Stepped Chevron	4.9 The black on the 1830's boards - The black found on the 1880's boards is more of a dark slate grey. It seems to only be found on these boards.	*"Black on 1830's boards":* consists of charcoal black particles mixed with white lead and barium sulphate dispersed ferric oxide and hydroxide particles Applied over a white lead ground
2000 9	27 II s Replacement grey chevron	Red paint from frieze decoration underpaint on replacement softwood ceiling boards – Limited number of these boards in Bays 4, 5 and 6. They may not exist further west on the ceiling. Recent analysis of a sample obtained in 1999 from such a board in Bay 3 identified barytes in the white background underpaint. This suggests the frieze decoration underpaint dates from the 1840s intervention. As this finding goes against our current theory that these softwood boards were 1740s Ashlar boards re-used as ceiling board replacements in the 1830s, further confirmation is required. Barytes was not present in samples from similar boards analysed last year (Kakoulli, 1999, Samples 1 and 2). I noticed that the frieze decoration on the board sampled this year had been overpainted in white before the grey chevron decoration was applied. Could the barytes have been in a similar layer? Information required – Identification of paint layers. Comparison with paint samples mentioned above and with previous samples taken from the 1830s frieze boards to identify similarities.	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.
2000 10	27 II s Replacement grey chevron	Black paint from frieze decoration underpaint on replacement softwood ceiling boards - Information required – As Sample 9	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
2000 11	22 III j grey chevron	Paint on nail head – As an aid to identification of 1740s nails. Sample from an added nail head in a (positively identified) 1740s softwood replacement board. If sample includes 1740s paint layer the nail must be from that intervention. . Information required – Identification of layer structure. (Should we have taken a paint sample from the board for comparison?)	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.

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
2000 12	23 l r Replacement grey chevron	Paint on suspected 1740s softwood replacement board – The board appears, from the thickness of the paint layer(s) to be a 1740s replacement. Sample to confirm presence of underlying 1740s paint layer. Information required – Identification of layer structure	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.[21]

All Samples from 1830s Softwood Ashlar Boards (8)

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1998 10/2356	Frieze 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 pm • lead white 125 pm þ pale pink layer of lead mhite combined with red iron oxide, carbon black and red lead 45 pm • lead white applied in two layers (iotal thickness 70 pm)	• sample re 8/2354 • Hg & S (vermilion) confirmed by SEM/EDX in the uppermost red layer *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.*
1999 3	34-35 Frieze	Frieze on south wall. Sample taken from the black decoration. Underneath this scheme of painting there is evidence of an earlier painting (showing in bass-relief).	Red-orange: (similar to samples 7, 11, 42) consists of red and white lead Applied over a white lead ground and found underneath two layers of paint (from top): a black layer consisting of carbon black particles mixed with white lead and barytes and ferric oxide and hydroxide particles over a white lead ground
1999 4	34-35 Frieze	Frieze on south wall. The cream-colour paint sample was taken from the background of the floral decoration. Underneath this scheme of painting there is evidence of an earlier painting (showing in bass-relief).	Black: the black consists of carbon black particles in a white lead matrix and mixed with dispersed particles of ferric oxide and hydroxide Pink: consists of red lead in white lead matrix. Applied over a white lead ground
1999 5	34-35 Frieze	Frieze on south wall. Sample taken from the red floral decoration. Underneath this scheme of painting there is evidence of an earlier painting (showing in bass-relief).	Red: haematite-rich red ochre Applied over a white lead ground
1999 6	32-33 Frieze	Frieze on south wall. Sample taken from a black paint (with resinous appearance) of a replacement board (with no evidence of earlier painted scheme below the existing painting).	Black: mixture of carbon black, red ferric oxide and yellow ferric hydroxide particles, white lead and copper green particles (?) No evidence of any substrate on the sample examined
1999 7	32-33 Frieze	Frieze on south wall. Sample taken from a terracotta-red paint of a replacement board (with no evidence of earlier painted scheme below the existing painting).	Orange-red: (similar to samples 3, 11, 42) consists of red lead Applied over a white lead ground ?

[21] 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.

Year Sample	Location & Description	Original & Later Polychromy	Additional materials & Comments
1999 42	34/35 I Frieze Boards (north)	Evidence of underpainting. Top layer green	Pink: red lead in a white lead ground The pink layer was found as the intermediate layer between a reddish layer and a white lead ground. This phase of painting is found beneath a bluish-green layer over a white lead ground. Reddish: red lead A reddish layer was applied over a pink layer over two layers of white lead. This phase of painting is found beneath a bluish-green layer over a white lead ground. Bluish-green: consists of probably Prussian blue (or similar – check) mixed with white lead and barium sulphate This layer was applied over a white lead ground, overlaying another painting phase of a red paint over pink over two layers of white lead ground
1999 43	30/31 I Frieze Boards (north)	Green background with stain over.	Yellowish-white: white lead and barium sulphate

All Samples from Joists Above Ceiling (3)

2002 32	Ceiling structure above Joist 1 east side	Painted decoration found on a 2m section of the easternmost ceiling joist – Black paint from pattern of circles and triangles Information required – Identification of materials and technique and comparison with paint on ceiling boards.	The sample shows a simple layer structure, with an off white ground and a relatively thin upper dark paint layer. The white ground is composed largely of lead white, with a few iron oxide articles and some carbon black. The black layer contains a carbon black pigment together with some iron oxide - an orange iron oxide particle is visible on the cross-section photomicrograph. Calcium is also present in the black paint. No phosphorous was detected by SEM.EDX therefore the possibility of the black being Bone black pigment has been ruled out. The calcium presumably originates from an inert calcium based filler - occasional transparent white particles are visible.
2002 33	Ceiling structure above Joist 1 east side	Painted decoration found on a 2m section of the easternmost ceiling joist – Red paint from pattern of circles and triangles. Information required – Identification of materials and technique and comparison with paint on ceiling boards.	This sample shows the off-white ground layer. No surface paint layer is present on the sample. No SEM.EDX was undertaken on this sample.
2002 34	Ceiling structure above Joist 1 east side	Painted decoration found on a 2m section of the easternmost ceiling joist – White paint from pattern of circles and triangles. Information required – Identification of materials and technique and comparison with paint on ceiling boards.	The sample shows the timber substrate, white ground and upper red paint layer. The off-white lead white ground contains a few transparent white calcium containing particles as well as a very few black and brown pigment particles. The red paint layer also contains transparent particles, also calcium based. The red layer has a microscopic appearance consistent with an iron oxide red pigment. The red layer produces SEM.EDX spectra with peaks for lead, iron and calcium. The lead present is attributed to the underlying white lead ground.