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TREE-RING ANALYSIS OF OAK TIMBERS FROM PETERBOROUGH CATHEDRAL, PETERBOROUGH, CAMBRIDGESHIRE: BOARDS FROM THE PAINTED NAVE CEILING

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Summary

Dendrochronological analysis was carried out on nine in situ oak boards from bay 1 of the painted nave ceiling at Peterborough Cathedral. The ring sequences from seven of these boards matched and dated to produce a tree-ting chronology spanning the period AD 972-1214. These were all probably felled and initially used in the mid-thirteenth century or later. The oak boards were derived from imported timbers, probably from northern Germany, and 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, during the early-fourteenth century to around AD 1650, and are thus a valuable addition to the growing body of information concerning the evolution of the timber trade.

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TREE-RING ANALYSIS OF OAK TIMBERS FROM PETERBOROUGH CATHEDRAL, PETERBOROUGH, CAMBRIDGESHIRE: BOARDS FROM THE PAINTED NAVE CEILING - *PHASE 1*

Introduction

This document is a technical archive report on the dendrochronological analysis of boards from bay 1, the most easterly, of the painted nave ceiling, Peterborough Cathedral, Peterborough (TL194987). It is the first of series of interim reports that will summarise the dendrochronological results from each separate phase of the analysis as the restoration project proceeds. The final publication will draw together the information from the interim reports into a more comprehensive dendrochronological record presenting the overall conclusions. It is beyond the dendrochronological brief to describe the ceiling in detail or to undertake the production of detailed drawings. As part of a multidisciplinary study of the ceiling, elements of this report may be combined with detailed descriptions, drawings, and other technical reports to form a comprehensive publication on the ceiling. The conclusions presented here may therefore have to be modified in the light of subsequent work.

Peterborough Cathedral lies in the centre of Peterborough, and is now in the unitary authority of the City of Peterborough, though traditionally in the Soke of Peterborough, part of Northamptonshire (Fig 1). A Benedictine Abbey was established on the site *c* AD 960. The present cathedral, built between *c* AD 1118 and *c* AD 1238 (Higham 1990), is one of the finest surviving and most complete twelfth- and thirteenth-century structures in England. One of its most notable features is the nave ceiling (Fig 2) which consists of a unique series of painted panels. The pattern of boards allows the ceiling to be divided into ten bays, with ten large diamonds, one per bay, encompassing four smaller ones (Fig 3). This painted wooden ceiling is the largest surviving medieval example of its type in Europe. Its presence however is fortuitous as it reflects the failure in the late-twelfth or early-thirteenth centuries to provide the church with rib vaulting in the nave when it became clear that the structure would be unable to bear the weight of stone vaulting throughout. The date proposed for the painting of the ceiling is thirteenth century and probably during the period *c* AD 1220-40 (Binski pers comm; Mackreth pes comm).

The nave ceiling painted panels are the subject of a 3-4 year conservation programme partially funded by English Heritage. As part of this two separate, though clearly linked, dendrochronology projects have been commissioned at the request of David Heath, English Heritage Cathedral Architect. The first project, now completed, was the analysis of the relic nave roof above the ceiling boards, including the joists to which the boards are attached, and the related roof of the north-west portico. The results of this confirm the interpretation, based on documentary and structural evidence, of the construction sequence of the nave and north-west portico (Tyers 1999a). The second of these projects, and the subject of this report, is the analysis of the painted boards. The purpose of this analysis is to provide dating evidence for the insertion of the primary oak ceiling boards and, through a comprehensive sampling strategy, to detect any variation in date along the length of the nave. This should confirm or refute the previously accepted dating evidence from documentary sources and other specialist information. In addition it was hoped to determine whether the boards were of local provenance like the structural timbers examined by Tyers (1999a) or whether they may represent a group of early imported planking.

Methodology

Professional practice at the Sheffield Dendrochronology Laboratory is described in English Heritage (1998). The following summarises relevant methodological details used for the dendrochronological analysis of the nave ceiling boards.

Prior to sampling an assessment survey was undertaken to determine whether the original oak boards were suitable for analysis, how this could be undertaken *in situ*, and to allow a suitable sampling strategy to be formulated. Oak (*Quercus* spp.) is currently the only species used for routine dating purposes in the British Isles, although research on other species is being undertaken (eg Tyers 1997a; Groves 1997). Timbers with less than 50 annual growth rings are generally considered unsuitable for analysis as their ring patterns may not be unique (Hillam *et al* 1987). Thus oak timbers are generally sought which have at least 50 rings and if possible either bark/bark edge or some sapwood surviving (see below).

In standing buildings samples are generally removed from selected timbers in the form of either cross-sectional slices or cores. Alternatively if the removal of samples is inappropriate, *in situ* measurement, high resolution photography, or taking an imprint of the wood structure can, in instances where the end-grain is visible, accessible and cleaned sufficiently to reveal the ring sequence clearly, replace the need for the physical removal of a sample. The usual procedure with boards or panel paintings, where sampling is unacceptable, is for the analysis to be undertaken in the laboratory by carefully cleaning up the cross-sectional surface and mounting the intact board in a protective cradle attached to the travelling stage. However the boards in the nave ceiling were to remain *in situ*. The cross-sectional surface of some of the boards were certainly accessible, so a series of minimal intervention techniques were considered. The decision was made to initially attempt the most straight forward technique which, incidentally, was the cheapest but had not previously be used in Britain. The cross-sectional surface of each selected board was prepared by a combination of sanding, use of a surgical blade, compressed air, and soft brushes. The ring sequence was obtained by taking a series of overlapping imprints of the wood structure using 'FIMO' (Leuschner and Leuschner 1996).

The 'FIMO' moulds were heat-hardened to ensure permanence. Any moulds which failed to contain the minimum number of rings or have unclear ring sequences were rejected. The sequence of growth rings in the samples selected for dating purposes were measured to an accuracy of 0.01mm using a purpose built travelling stage attached to a PC Windows-based measuring system (Tyers 1997b). The ring sequences were plotted onto semi-logarithmic graph paper to enable visual comparisons to be made between them. In addition cross-correlation algorithms (Baillie and Pilcher 1973; Munro 1984) were employed to search for positions where the ring sequences were highly correlated. The Student's *t* test is then used as a significance test on the correlation coefficient and those quoted below are derived from the original CROS algorithm (Baillie and Pilcher 1973). A *t* value of 3.5 or over is usually indicative of a good match (Baillie 1982, 82-5), provided that high *t* values are obtained at the same relative or absolute position with a range of independent sequences and that the visual match is satisfactory.

The ring sequences from each series of imprints from a single board were compared to ensure that they crossmatched and then were combined to form the individual board sequences. Dating is usually achieved by cross-correlating, or crossmatching, ring sequences within a phase or structure and combining the matching patterns to form a phase or site master curve. This master curve and any remaining unmatched ring sequences are then tested against a range of reference chronologies, using the same matching criteria as above. The position at which all the criteria are met provides the calendar dates for the ring sequences. A master curve is used for absolute dating purposes whenever possible as it enhances the common climatic signal and reduces the background 'noise' resulting from the local growth conditions of individual trees.

During the crossmatching stage an additional important element of tree-ring analysis is the identification of 'same-tree' timber groups. The identification of 'same-tree' groups is based on very high levels of similarity in year to year variation, longer term growth trends, and anatomical anomalies. Such information should ideally be used to support possible 'same-tree' groups identified from similarities in the patterns of knots/branches during detailed recording of timbers for technological and woodland characterisation studies. Timbers originally derived from the same parent log generally have *t* values of greater than 10.0, though lower *t* values do not necessarily exclude the possibility. It is a balance of the range of information available that provides the 'same-tree' link.

The crossdating process provides precise calendar dates only for the rings present in the timber. The nature of the final ring in the sequence determines whether the date of this ring also represents the year the timber was felled. Oak consists of inner inert heartwood and an outer band of active sapwood. If the sample ends in the heartwood of the original tree, a *terminus post quem* for the felling of the tree is indicated by the date of the last ring plus the addition of the minimum expected number of sapwood accessible but badly eroded were rejected as these would not provide a suitable surface for the 'FIMO' imprints without the removal of significant quantities of wood. Sapwood was noticeable by its absence and none of the primary oak boards, sampled or not, showed any evidence for the presence of sapwood. The absence of sapwood on the boards is typical of panelling and panel paintings because its more friable nature makes it inappropriate for such purposes. It would cause severe problems where panels were jointed together and severe damage to a painting where the sapwood rotted and was lost. Although the lack of sapwood on the nave ceiling boards would reduce the precision of the dendrochronological interpretation, the information obtained from the analysis was nevertheless considered to be of value to the overall project.

Details of the nine boards selected as suitable for sampling are presented in Table 1 and Figure 5. During the initial sampling it was found that it was more effective to take a series of overlapping imprints from each board. A total of 45 imprints were taken from the nine boards. The number of imprints taken from each board was variable according to board specific problems, such as particularly awkward access, surface degradation, and presence of bands of very narrow rings. Duplicate sets of imprints were taken from each board in order to minimise any difficulties during measurement but also as access would not be possible following the removal of the phase 1 scaffolding. Notes were made for each sampled board to indicate inaccessible sections, including length and rough ring counts, so that an allowance could be made for these unmeasured rings.

Eighteen imprints were rejected as the ring sequence was not sufficiently clear for reliable measurement. Noticeably this rejection rate decreased markedly as sampling proceeded. The remaining 27 imprints representing nine boards were measured and initially analysed in single board groups. Within each board group those ring sequences which crossmatched were combined to produce an individual board sequence, though board **37-I-c** is represented by an inner and an outer section which cannot be linked due to a break in the board (Fig 6; Tables 2a-j). The individual board sequences were then compared and seven were found to match (Fig 7; Table 3). These were combined to form a 243-year master curve, PCNC-1. The data for this master curve is not presented as it is an interim site master curve that will only be finalised when the analysis has been completed on the samples derived from the full extent of the nave ceiling.

PCNC-1 and the unmatched ring sequences from boards **37-I-b** and **38-IV-w** and the short inner section of **37-I-c** were tested against an extensive range of dated reference chronologies from the British Isles and elsewhere in Europe. These comprise data-sets dating on average from AD400 to the present and ranging between Russia and Ireland on an east-west axis and Norway and southern France on a north-south axis. PCNC-1 was dated to the period AD 972-1214 against chronologies derived from material of northern central European origin (Table 4). No reliable results could be obtained for rings which may be missing. This is the date after which the timber was felled but the actual felling date may be many decades later depending on the number of outer rings removed during timber conversion. Where some of the outer sapwood or the heartwood/sapwood boundary survives on the sample, a felling date range can be calculated using the maximum and minimum number of sapwood rings likely to have been present. Alternatively, if bark-edge survives, then a felling date can be directly obtained from the date of the last surviving ring. In some instances it may be possible to determine the season of felling according to whether the ring immediately below the bark is complete or incomplete. However the onset of growth can vary within and between trees and this, combined with the natural variation in actual ring width, means that the determination of felling season must be treated cautiously. The sapwood estimate applied must be appropriate to the source of the timber as there is a geographical variation in the number of sapwood rings present which increases from east to west across north-west Europe (Baillie *et al* 1985; Hillam *et al* 1987; Wazny and Eckstein 1991).

The dates obtained by the technique do not by themselves necessarily indicate the date of the structure from which they are derived. Evidence indicates that seasoning of timber for structural purposes was a fairly rare occurrence until relatively recent times and medieval timber was generally felled as required and used whilst green (eg Rackham 1990; Charles and Charles 1995). Physical evidence for the rapid use of trees is widespread in buildings as many show clear evidence of warping or splitting after having undergone conversion. However it is necessary to incorporate other specialist evidence concerning the reuse of timbers and the repairs or modifications of structures, as well as factors such as stockpiling, seasoning, and transport, before the dendrochronological dates given here can be reliably interpreted as reflecting the construction date of phases within the structure.

Results

The nomenclature and numbering scheme of Donald Mackreth, Cathedral Archaeologist, and the Perry Lithgow Partnership are followed throughout this report. The term sampling is usually used to imply the physical removal of a section of wood, however in this study it refers to the taking of imprints.

The initial site visit in March AD 1998 ascertained that the primary phase oak boarding accessible from the temporary scaffolding below the ceiling was suitable for dendrochronological analysis. This visit also allowed evaluation of the site specific difficulties in obtaining the ring sequences and enabled informed decisions to be made on the techniques that could be used. In April a detailed assessment of the boards in bay 1, panels 36/I to 39/IV (Fig 4), was undertaken and some initial sampling carried out in order to assess the success of the 'FIMO' technique. As the technique was clearly successful further sampling in this section was carried out in May. The majority of boards contained sufficient rings for analysis but the determining factor in board selection was simply whether the cross-sectional surface at the end of the board was accessible. Cross-sections which were boards **37-I-b** or **38-IV-w** so these remain undated. A tentative match was identified for the short inner section of **37-I-c** but further statistical support is required before this can be accepted. This support may be forthcoming as the analysis proceeds and the site master chronology is strengthened by the inclusion of additional samples.

Interpretation

The sapwood estimate applicable is 8-38 at 95% confidence limits (Hillam *et al* 1987). The lowest minimum expected number of sapwood rings is 8 and, in the absence of sapwood, it is this value that has been used to produce a *terminus post quem* for felling for each board (Fig 7). If there are unmeasured outer rings on a board then these are taken into account when calculating the *terminus post quem* for felling. The quality of the intra-site crossmatching, as well as the visual characteristics, suggests that these boards form a single contemporaneous group. The outermost measured ring of the board group dates to AD 1214. This is on board **37-IV-h** but there are an additional six unmeasured outer rings. Consequently the boards were all therefore probably felled and primarily used after AD 1228.

Discussion

This is an interim report and it is therefore intended that the following discussion raises a number of issues that will be placed in context and considered in more detail when the analysis has been extended to incorporate boards from the full length of the nave ceiling.

At present only seven boards have been dated from the nave ceiling and, in the absence of sapwood, the strict dendrochronological interpretation is that they were felled and used after AD 1228. As the dendrochronological program progresses it may be possible to improve the current interpretation and produce a felling date range instead of just a *terminus post quem* for felling. In order to achieve this it is clearly a priority to locate some boards with traces of sapwood or the heartwood-sapwood boundary. However if the boards visible in this first phase of work are representative then this may not be achieved. If no sapwood can be found then, as long as the analysed assemblage is sufficiently large, it may still be possible to estimate a felling date range by taking into account other factors, such as the variation in end dates, as was accomplished at Bowhill (Groves forthcoming). The relationship of the felling date to the initial use of the boards relies on evidence from previous studies of panels and panel paintings of known date. Previous studies of panels and panel paintings of known date imply that very little heartwood would be removed during the manufacture of the panel from the raw timber and the period of time taken for transport, storage, and manufacture, either prior to or after importation, appears to be minimal (eg Fletcher 1980; Lavier and Lambert 1996; Tyers 1998a). Consequently the date of use of the boards is likely to be within the same period as the felling date range, with the slight possibility that, if the boards had the maximum expected number of sapwood rings, the usage date could be a few years after the latest possible felling year.

The degree of similarity, as indicated by *t* values, of the ring sequences from the individual boards is good and implies that the trees used to produce the boards were derived from a single common woodland (Table 3). It is hoped that this assumption will be substantiated as more boards are analysed. The site master chronology PCNC-1 has been dated against reference chronologies from northern central Europe, rather than with chronologies from further west in the British Isles or France (Table 4). PCNC-1 matches particularly well with chronologies from northern Germany and Denmark which suggests that the source of the timber is likely to be within this region.

Documentary sources indicate that timber was deliberately exported through organised routes as early as the thirteenth century (Simpson pers comm). Timber, in the form of oak planking, was extensively exported from the eastern Baltic region primarily through the German Hanse from the early-fourteenth century until around AD 1650. Extensive documentary evidence in customs accounts (Dollinger 1970; Fedorowicz 1980; Clarke 1992), buildings accounts (Salzman 1952, 206), and the detailed records from the Danish Books of the Sound Dues (eg Bonde *et al* 1997) indicates its importance as a raw material. The advances in dendrochronology over the last decade have seen the development and exchange of the large network of oak chronologies covering northern Europe. This has allowed oak timbers exported significant distances away from their source region to be dated and has had the added bonus of identifying the geographical region from which they were derived (Bonde and Jensen 1995; Bonde *et al* 1997). This increasingly large body of data is currently dominated by groups of timbers imported into various parts of north-west Europe, probably from the eastern Baltic region (Baillie 1984; Wazny 1990; Bonde *et al* 1997). In Britain dendrochronology has identified eastern Baltic boards used for panel paintings, coffins, boat planking, barrel staves, wall and ceiling panelling, doors, altars, and decorative screens. Documentary evidence indicates its importation all down the eastern seaboard of both England and Scotland, and round the south and west coast of England as far as Bristol (Simpson pers comm). Dendrochronological evidence has demonstrated the presence of such eastern Baltic imports at various locations in England and Scotland, ranging from east coast ports as far north as Aberdeen, locations further inland, and as far west as Exeter (Groves forthcoming; Howard *et al* 1995; Lewis 1995; Mills and Crone 1998; Tyers 1991; 1998a).

The Peterborough nave ceiling boards are however clearly earlier than this period of major export and also appear to be derived from a source lying somewhere between the eastern Baltic region and England. Timbers ranging in date from the mid-eighth century to the late-seventeenth century, thought to be from this more westerly source, have been previously identified dendrochronologically but form a much smaller body of data than that of eastern Baltic imports. These timbers tend to be in the form of barrel staves, either in their primary form or reused in waterfronts or wells, or occasionally panel paintings. However, assuming that the few nave ceiling boards analysed so far are representative, then no large deliberately imported assemblage has until now been identified as early as the thirteenth century. The analysis of the Peterborough Cathedral nave ceiling boards therefore raises fundamental issues concerning the pre-Hansa timber trade and the source of the timber prior to the extensive exploitation of woodlands in the eastern Baltic region.

The visual characteristics of the nave ceiling boards indicate that they were derived from slow-grown, long-lived, straight-grained trees. These trees grew in a closed high-canopy environment and were around 300 years old when felled. They are thus very similar in character to the material imported from the eastern Baltic between the fourteenth and mid-seventeenth centuries (Fig 8). However they are also very similar in character to the structural timbers above the ceiling, the majority of which were felled and used in the late-twelfth century, which were derived from local woodland sources (Fig 8; Tyers 1999). The use of imported boards in the ceiling, probably less than 50 years after the use of locally grown timbers for the structural elements of the roof, may indicate that such high-quality timber was no longer available locally, or that cheap imports had become available during the intervening period, or even that the use of imported timber was perhaps seen as prestigious.

Conclusion

The phase 1 analysis has been successful on a number of fronts. The use of FIMO had not previously been attempted in this country but has clearly proven to be a reliable method for 'sampling' the nave ceiling boards. This technique will certainly be used in the subsequent phases of analysis of the oak boards as the conservation programme progresses westwards along the nave ceiling.

The dating evidence provided currently suggests a construction date of mid-thirteenth century or later for the painted ceiling but it is hoped that it will be possible to refine this interpretation as the analysis progresses and incorporates more samples. At present the date of *circa* AD 1220-40 proposed by both Binski (pers comm) and Mackreth (pers comm) compares favourably with the dendrochronological evidence. The identification of a potentially large assemblage of deliberately imported timbers in the mid-thirteenth century is exciting, as is the suggestion that they are of north German origin rather than from further east like the bulk of the dendrochronologically proven imported material.

Acknowledgements

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Figure 1: Map showing the general location of Peterborough Cathedral, Peterborough, based upon the Ordnance Survey 1:50000 map with permission of The Controller of Her Majesty's Stationary Office, ©Crown Copyright

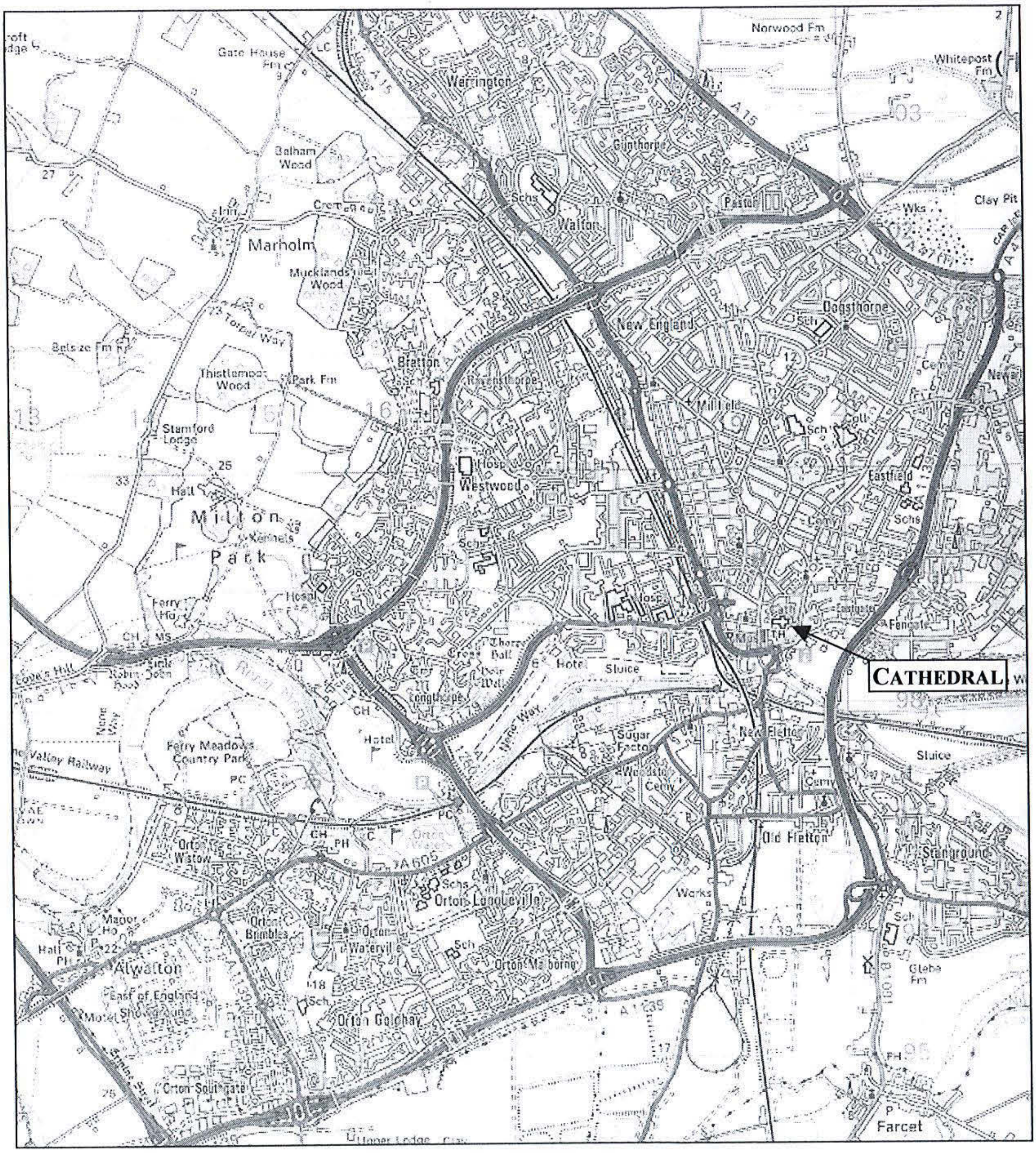


Figure 2: Plan of the cathedral showing the nave

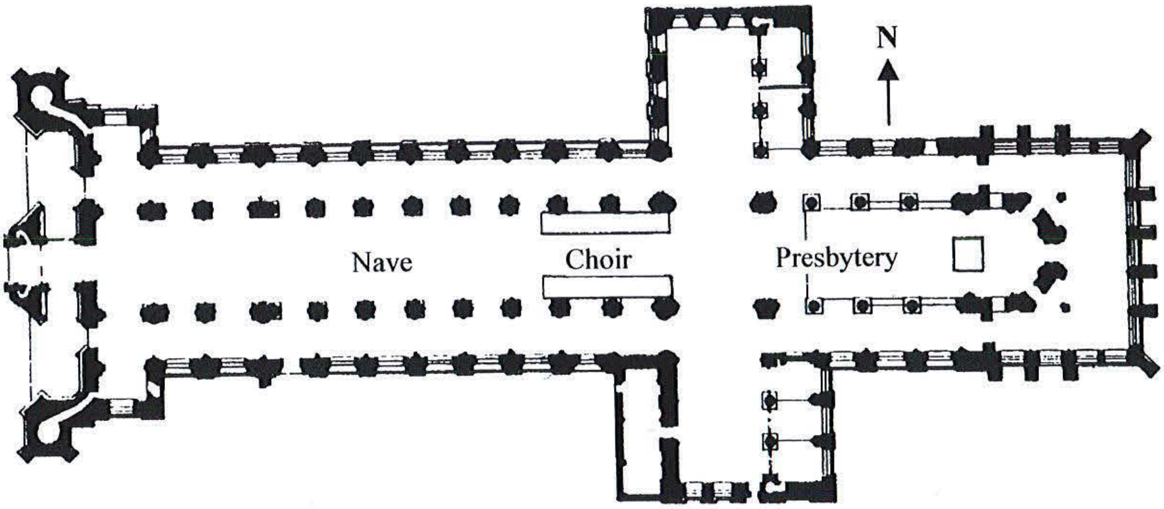


Figure 3: Plan of the ceiling from above showing the original trusses, bay divisions, and the diamond layout of the painted panels (after Bush 1997; Tyers 1999a)

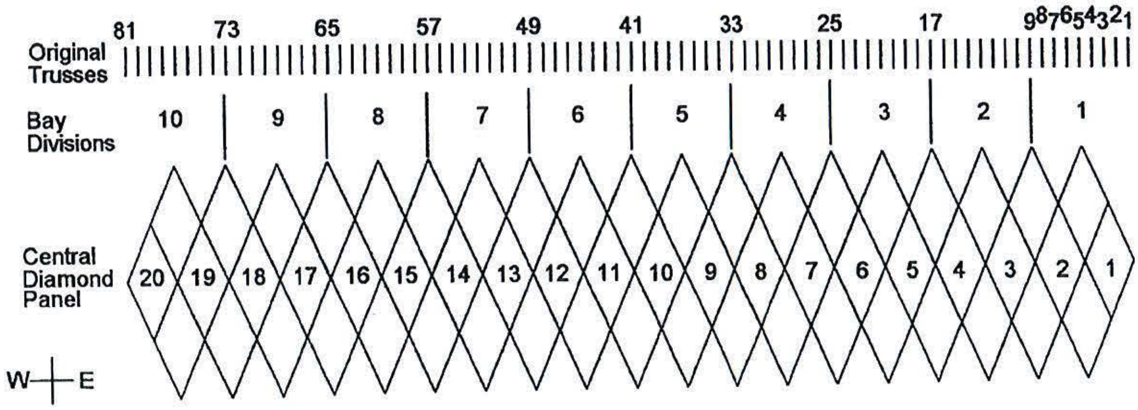


Figure 4: Plan of the ceiling from below highlighting the bay divisions and the location of panels 36/I to 39/IV

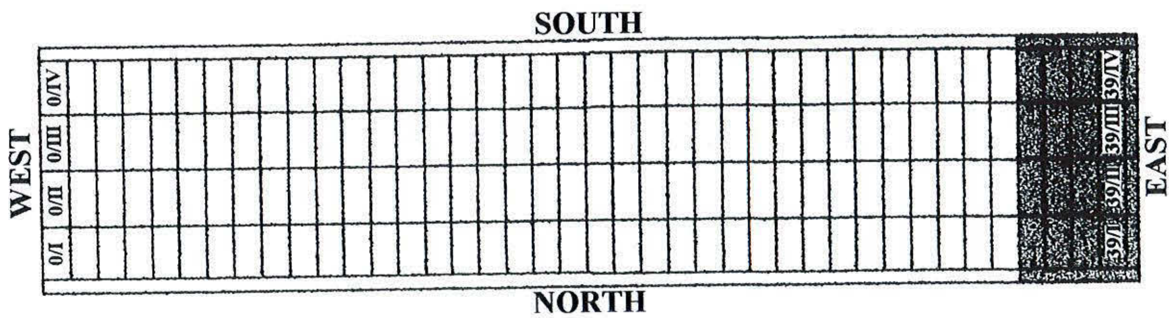


Figure 5: Plan from below showing panels 36/I - 39/IV and the location of the sampled boards
• dated; • undated

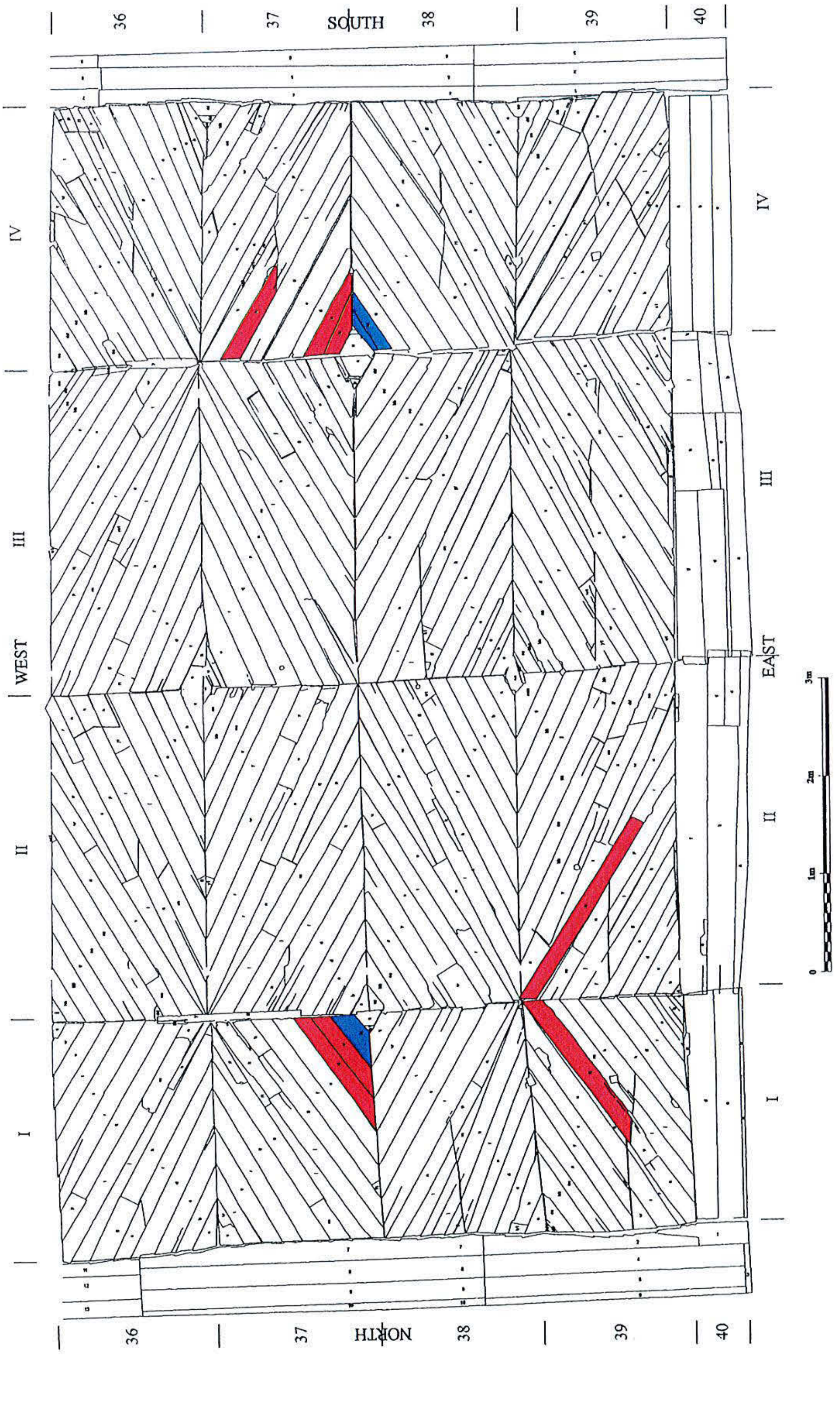


Figure 6: Bar diagram showing the relative positions of the matched ring sequences from the individual imprints of each board. All groups are aligned to start at relative year 1

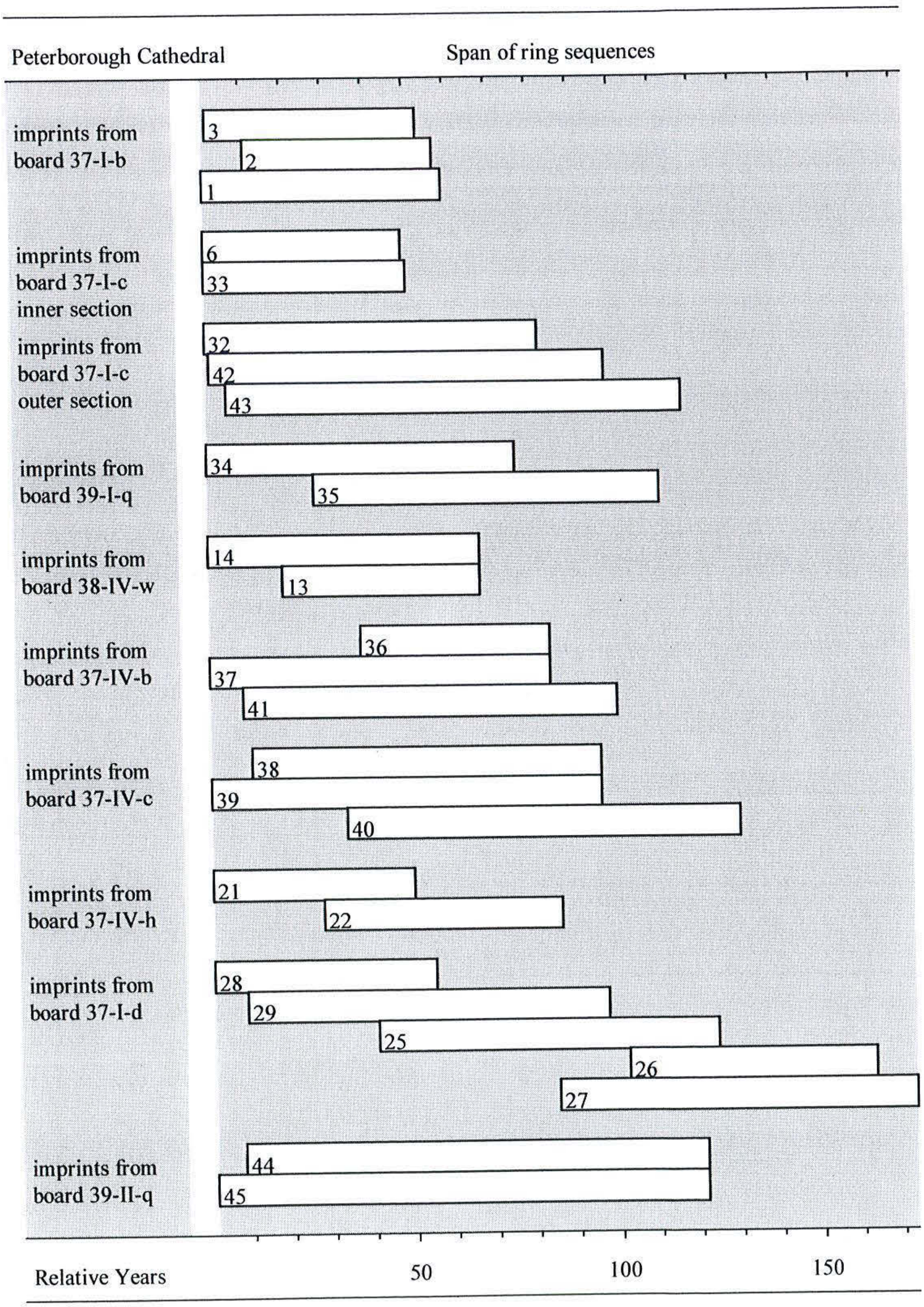
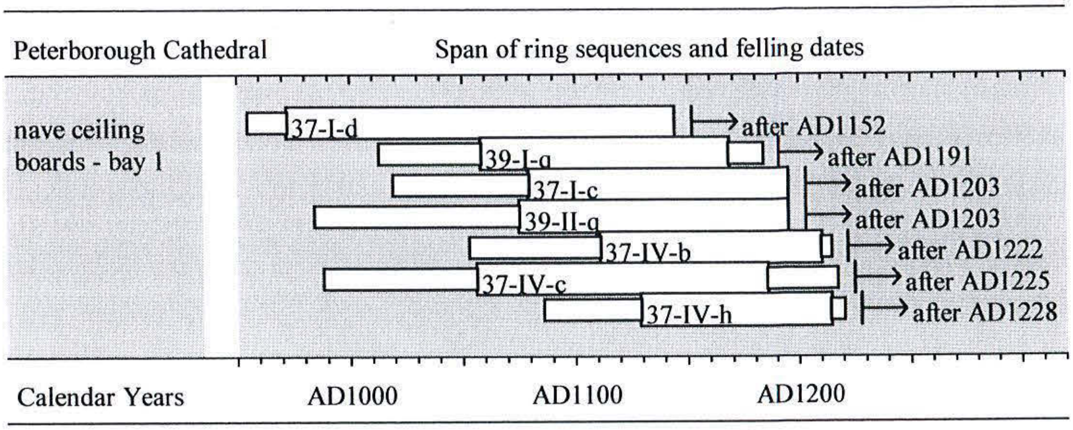


Figure 7: Bar diagram showing the relative positions of the dated board ring sequences and their associated felling dates.



KEY for Figures 6 and 7

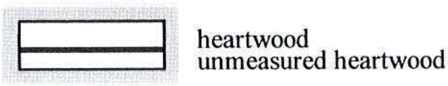


Figure 8: Diagram comparing the ring sequence length and average growth rates of the imported Peterborough nave ceiling boards (?mid thirteenth-century), the native Peterborough nave and north-west portico roof timbers (late twelfth/mid thirteenth-century), and the imported Bowhill ceiling boards and sub-ribs (late fifteenth/early sixteenth-century). Ring sequence lengths are, in the absence of pith and bark, an underestimate of tree age. The average growth rates tend to be an over estimate as it is the narrower outermost rings that tend to be unmeasurable. The shorter ring sequence lengths in the Bowhill ceiling board group are usually from boards which appear to be sections of originally wider, but now broken, boards

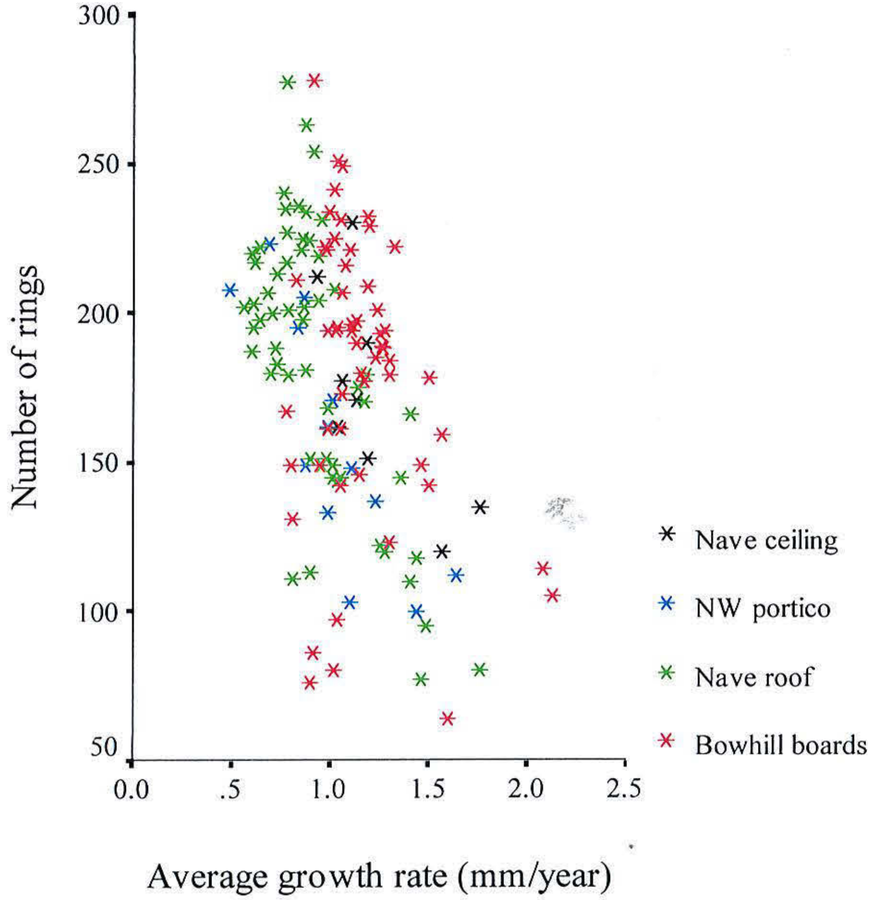


Table 1: Details of the boards from the nave ceiling, Peterborough Cathedral, sampled for dendrochronological analysis

Board – panel identification number and board identification letter
Number of rings - total number of measured
nn+ or +*nn* – number of unmeasured rings
AGR - average growth rate in millimetres per year
cross-section dimensions - maximum dimensions of the cross-section in millimetres

Board	Total number of rings	AGR	Cross-section dimensions	Date of measured ring sequence	Comment
37-I-b	59 +*61*	1.57	230 x 10	-	imprints 1-3
37-I-c	*60*+ 117	1.06	210 x 10	AD 1079-1195	imprints 4-8, 30-33, 42, and 43
39-I-q	*45*+ 111 +*15*	1.13	200 x 10	AD 1058-1168	imprints 9-12, 34, and 35
38-IV-w	*29*+ 67 +*55*	1.19	175 x 10	-	imprints 13 and 14
37-IV-b	*58*+ 100 +*4*	1.04	170 x 10	AD 1111-1210	imprints 15, 16, 23, 36, 37, and 41
37-IV-c	*68*+ 130 +*32*	1.11	215 x 10	AD 1056-1185	imprints 17-20, 24, and 38-40
37-IV-h	*43*+ 86 +*6*	1.76	235 x 10	AD 1129-1214	imprints 21 and 22
37-I-d	*17*+ 173	1.18	225 x 10	AD 972-1144	imprints 25-29
39-II-q	*91*+ 121	0.93	205 x 10	AD 1075-1195	imprints 44 and 45

Table 2a: Matrix showing the *t* values obtained between the measured imprint ring sequences from board **37-I-b**

Imprint	2	3
1	12.24	20.50
2		14.27

Table 2b: Matrix showing the *t* values obtained between the measured imprint ring sequences from the inner section of board **37-I-c**

Imprint	33
6	14.31

Table 2c: Matrix showing the *t* values obtained between the measured imprint ring sequences from the outer section of board **37-I-c**

Imprint	42	43
32	9.16	10.59
42		18.47

Table 2d: Matrix showing the *t* values obtained between the measured imprint ring sequences from board **39-I-q**

Imprint	35
34	19.94

Table 2e: Matrix showing the *t* values obtained between the measured imprint ring sequences from board **38-IV-w**

Imprint	14
13	12.41

Table 2f: Matrix showing the *t* values obtained between the measured imprint ring sequences from board **37-IV-b**

Imprint	37	41
36	12.10	12.46
37		14.31

Table 2g: Matrix showing the *t* values obtained between the measured imprint ring sequences from board **37-IV-c**

Imprint	39	40
38	28.81	31.90
39		37.03

Table 2h: Matrix showing the *t* values obtained between the measured imprint ring sequences from board **37-IV-h**

Imprint	22
21	12.62

Table 2i: Matrix showing the *t* values obtained between the measured imprint ring sequences from board **37-I-d.** \ - overlap is less than 15 years

Imprint	26	27	28	29
25	7.54	14.01	5.73	13.22
26		17.48	\	\
27			\	\
28				14.69

Table 2j: Matrix showing the *t* values obtained between the measured imprint ring sequences from board **39-II-q**

Imprint	45
44	29.83

Table 3: Matrix showing the *t* values obtained between the matching board ring sequences

- = t-values less than 3.00

Board	39-I-q	37-IV-b	37-IV-c	37-IV-h	37-I-d	39-II-q
37-I-c	8.89	5.57	6.78	3.37	3.50	7.39
39-I-q		4.43	7.19	-	-	7.94
37-IV-b			6.17	4.78	4.61	6.23
37-IV-c				3.58	6.27	7.95
37-IV-h					-	3.47
37-I-d						-

Table 4: Dating the interim site master chronology, PCNC-1. Results of comparisons between some relevant reference chronologies and PCNC-1 at AD 972-1214 inclusive. Some *t* values less than 3.0 are given to demonstrate why it is thought that the nave ceiling boards are imported from northern Germany/Denmark

Region/Group	Reference chronology	*t* value
Germany	Lüneburg (Leuschner pers comm)	9.73
	Niedersachsen Nord (Leuschner pers comm)	9.99
	Niedersachsen Kuestenraum (Leuschner pers comm)	5.93
	Schleswig-Holstein (Eckstein *et al* 1970)	7.88
	South (Becker 1981)	6.58
	Trier region (Hollstein 1980)	7.38
	Weserbergland (Delorme 1972)	7.20
Denmark	Svendborg (Bonde pers comm)	7.49
	West (Bonde pers comm)	7.25
Netherlands	Dordrecht (Jansma 1995)	3.45
	Maastricht (Jansma 1995)	5.79
Poland	East Pomerania (Wazny 1990)	3.73
	Southern Vistula (Krapiec pers comm 1995)	3.37
Sweden	Lund (Bartholin pers comm 1995)	1.89
	West (Brathen pers comm 1983)	1.07
	Mellansverige (Bartholin pers comm)	2.31
France	Paris Basin (Lambert, Lavier, and Bernard pers comm 1994)	1.24
	East (Lambert, Lavier, and Bernard pers comm 1994)	2.95
	West (Lambert, Lavier, and Dourcerain pers comm 1994)	0.81
	Burgundy (Lambert and Lavier pers comm 1994)	2.67
Ireland	Dublin (Baillie 1977a)	2.95
Scotland	South central (Baillie 1977b)	1.32
England	East Midlands 1988 (Laxton and Litton 1988)	3.79
	East Anglia (Tyers, Hillam, and Groves unpubl)	2.29
	South East (Tyers, Hillam, and Groves unpubl)	1.89
	Yorkshire (Tyers, Hillam, and Groves unpubl)	3.09
	North West (Tyers, Hillam, and Groves unpubl)	1.70
	Peterborough Cathedral nave roof (Tyers 1999a)	4.13
Imported	Hull Magistrates Court coffin boards (Tyers 1998b)	4.67
	Millennium Bridge City boards (Tyers 1999b)	3.52
	Fleet Valley - PWB88 C/H (Hibberd 1992)	7.90
	Copper Wreck: boat group (Wazny and Bonde pers comm 1994)	4.05