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ALL SAINTS CHURCH,
NORTH STREET,
YORK;
TREE-RING ANALYSIS OF TIMBERS FROM
THE WESTERN END OF THE NORTH AISLE ROOF

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SUMMARY

Analysis by dendrochronology of timbers to the western end of the north aisle roof of All Saints Church, York, shows that a number of these were cut as part of a single episode of felling at some point between 1166 at the earliest and 1191 at the latest. It is possible that these timbers represent the remains of a roof to an aisle believed to have been added to an already existing, earlier, church in the later-twelfth century as the population on this bank of the river Ouse grew.

A further timber from the north aisle roof has an estimated felling date in the period 1477–1502. This timber may be part of works undertaken at this time with the repair or completion of the roofs and ceilings to the aisles and chancel.

A final sample has an estimated felling date in the period 1675–1700 and may represent a phase of repair or renovation of the north aisle roof.

Four further samples remain ungrouped and undated.

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Introduction

The first reference to a church of All Saints in North Street, York (SE 600 517 Fig 1a/b) is in 1089, when the patronage of the rectory was granted by a layman, Ralph Paganell, to the Benedictine Priory of the Holy Trinity he had re-founded nearby in Micklegate. That a rectory was established at such an early date indicates that a church existed on the site before the Norman Conquest. This early building was probably a simple rectangular structure, which fitted into the central space between the east end of the present chancel and the western aisle of the nave.

As the population on this bank of the river Ouse expanded at the end of the twelfth century, an aisle was added to the church (though it is believed that the eastern bay of the Chancel might be as early as 1150), this incorporating fragments of Roman gritstone columns found on the site. In the early-thirteenth century the chancel was reconstructed in the Early English style (receiving an internal decorative arcade), and a second aisle was added, with capitals adorned with the distinctive nailhead decoration of the period. In the first half of the fourteenth century, as the urban elite of the city began to build their large houses in the parish, the east end was sumptuously rebuilt. The present east windows with Geometric and Curvilinear tracery of the Decorated period of Gothic architecture were installed and the side aisles were extended east to be level with the east wall of the chancel.

The whole building was the extended westwards (explaining why the present wallplate of the north aisle ends where it does), and the church took on its present form in the late-fourteenth century when the tower and spire were erected, the nave extended, and the arcades reconstructed. It is possible that almost the whole of the old church was demolished, leaving only the easternmost bays standing in order that mass might continue at the altars. The tower, octagon, and 120 foot spire, were the first part of the new work to be constructed, this was underway in 1394 when Richard Byrd gave money in his will to the new fabric. The rest of the building must have been all but complete by about 1410 when work began on glazing the north and south wall.

The modest way the arcades were rebuilt, using old material and with minimum detail, suggests that by the fifteenth century, after the extravagance of the tower and spire, the amount of money available for the work was restricted. In the 1440s the roof was still not complete and although bequests of tiles and lead were made in order that work might proceed 'within a few years' the work was only completed in the 1470s when the lavish ceilings over the chancel and aisles were installed. These were erected during the incumbency of John Gilyot 1467-1472. The hammerbeams of all three ceilings are in the form of angels who hold a variety of objects, including musical instruments and liturgical apparatus.

Sampling

Sampling and analysis of the timbers to the western end of the north aisle roof were requested by Robert Richards, Churwarden, as part of a considerable programme of research and investigation (including archaeological excavation) into the history and development of the church. It was hoped that tree-ring analysis would determine a date for

the timbers here and establish whether the present roof could possibly be that of the original or, if not, at what date it might have been constructed.

In essence the north ailse roof comprises three parts (Fig 2), with solid brick partition between each part. To the eastern end (not quite one half of the whole north aisle) the roof comprises six hammer beam trusses (Fig 3a), the trusses carrying a ridge beam with a single purlin to each pitch of the roof. The western part (again not quite half of the whole) is without principal trusses, the barrel vaulted roof (cealed from below and not visible from within the church, Fig 3b) comprising about 28 coupled common rafter trusses with collars, the rafters (possibly in two sections) falling to wall plates to the north and south walls of the aisle. A number of these timbers show clear evidence, by way of redundant mortices and peg holes, of being reused in their presnt locations. There are in this part of the aisle, however, three slendar cross-beams which appear to tie the aisle walls together, but probably do not act as tiebeams to any of the rafter frames. The remaining portion of the north aisle, the west chapel, comprises a small section at the far west end. Access to this roof not being possible, it is not clear what form this section of roof takes. These disvisions can again be seen in the externally roof lines of the north aisle (Fig 4a/b).

At the time of sampling access was only available to the coupled common rafter frames of the larger western portion of the roof (Fig 5a/b), and with the aim of fulfilling the sampling brief for this project, core samples were obtained from ten different timbers here. Each sample was given the code YRK-N (for York – site 'N'), and numbered 01–10. Details of the samples are given in Table 1, including the timber sampled and its location (the frames being numbered from east to west), the total number of rings each sample has, and how many of these, if any, are sapwood rings. The individual date span of each dated sample is also given. Although there were other timbers potentially available for sampling in this part of the aisle, the three slender cross beams for example, these all appeared to have insufficient rings for dating and were not sampled.

The Nottingham Tree-ring Dating Laboratory would like to take this opportunity to thank the Church Warden for All Saints Church, Dr Robert Richards, not only for his enthusiastic support for this programme of research, for arranging this programme of analysis, and for going to considerable lengths to arrange access to the roof, but also for generously funding this programme of analysis out of his personal pocket.

Tree-ring dating

Tree-ring dating relies on a few simple, but quite fundamental, principles. Firstly, as is commonly known, trees (particularly oak trees, the timber most commonly used in building construction until the introduction of pine from the late eighteenth century onwards) grow by adding one, and only one, growth-ring to their circumference each, and every, year. Each new annual growth-ring is added to the outside of the previous year's growth just below the bark. The width of this annual growth-ring is largely, though not exclusively, determined by the weather conditions during the growth period (roughly March–September). In general, good conditions produce wider rings and poor conditions produce narrower rings. Thus, over the lifetime of a tree, the annual growth-rings display a climatically influenced pattern. Furthermore, and importantly, all trees growing in the same area at the same time will be

influenced by the same growing conditions and the annual growth-rings of all of them will respond in a similar, though not identical, way (Fig 6).

Secondly, because the weather over a certain number of consecutive years (the statistically reliable minimum calculated as being 54 years) is unique, so too is the growth-ring pattern of the tree. The pattern of a shorter period of growth, 20, 30**,** or even 40 consecutive years, might conceivably be repeated two or even three times in the last one thousand years, and is considered less reliable. A short pattern might also be repeated at different time periods in different parts of the country because of differences in regional micro-climates. It is less likely, however, that such problems would occur with the pattern of a longer period of growth, that is, anything in excess of 45 years or so. In essence, a short period of growth, anything less than 45 rings, is not reliable, and the longer the period of time under comparison the better.

Tree-ring dating relies on obtaining the growth pattern of trees from sample timbers of unknown date by measuring the width of the annual growth-rings. This is done to a tolerance of 1/100 of a millimeter. The growth patterns of these samples of unknown date are then compared with a series of reference patterns or chronologies, the date of each ring of which is known. When the growth-ring sequence of a sample 'cross-matches' repeatedly at the same date span against a series of different reference chronologies the sample can be said to be dated. The degree of cross-matching, that is the measure of similarity between sample and reference, is denoted by a '*t*-value'; the higher the value the greater the similarity. The greater the similarity the greater is the probability that the patterns of samples and references have been produced by growing under the same conditions *at the same time*. The statistically accepted fully reliable minimum *t*-value is 3.5.

However, rather than attempt to date each sample individually it is usual to first compare all the samples from a single building, or phase of a building, with one another, and attempt to cross-match each one with all the others from the same phase or building. When samples from the same phase do cross-match with each other they are combined at their matching positions to form what is known as a 'site chronology'. As with any set of data, this has the effect of reducing the anomalies of any one individual (brought about in the case of tree-rings by some non-climatic influence) and enhances the overall climatic signal. As stated above, it is the climate that gives the growth pattern its distinctive pattern. The greater the number of samples in a site chronology the greater is the climatic signal of the group and the weaker is the non-climatic input of any one individual.

Furthermore, combining samples in this way to make a site chronology usually has the effect of increasing the time-span that is under comparison. As also mentioned above, the longer the period of growth under consideration, the greater the certainty of the cross-match. Any site chronology with less than about 55 rings is generally too short for reliable dating.

Having obtained a date for the site chronology as a whole, the date spans of the constituent individual samples can then be found, and from this the felling date of the trees represented may be calculated. Where a sample retains complete sapwood, that is, it has the last or outermost ring produced by the tree before it was cut, the last measured ring date is the felling date of the tree.

Where the sapwood is not complete it is necessary to estimate the likely felling date of the tree. Such an estimate can be made with a high degree of reliability because oak trees generally have between 15 to 40 sapwood rings. For example, if a sample with, say, 12 sapwood rings has a last sapwood ring date of 1400 (and therefore a heartwood/sapwood boundary ring date of 1388), it is 95% certain that the tree represented was felled sometime between 1403 (1400+3 sapwood rings (12+3=15)) and 1428 (1400+28 sapwood rings (12+28=40)).

Analysis

Each of the 10 samples obtained from the roof timbers of the west end of the north aisle was prepared by sanding and polishing, and, although some of them having relatively low numbers of annual rings, the widths of their annual growth rings were measured. The data of these measurements were then compared with each other as described in the notes above. By this process a single group comprising four samples, could be formed, the samples cross-matching with each other as shown in the bar diagram, Figure 7.

The four cross-matching samples were combined at their indicated off-set to form YRKNSQ01, a site chronology with an overall length of 197 rings. This site chronology was then satisfactorily dated by repeated and consistent comparison with a large number of relevant reference chronologies for oak as spanning the years 960 to 1156. The evidence for this dating is given in the *t*-values of Table 2.

Site chronology YRKNSQ01 was compared with the six remaining ungrouped samples, but there was no further satisfactory cross-matching. The remaining six ungrouped sample were then compared individually with the full body of reference material, this indicating cross-matches and dates for two further samples, YRK-N03, with a last measured ting date of 1660, and YRK-N09, with a last measured ring date of 1462. The evidence for this dating is given in the t-values of Tables 3 and 4.

Interpretation

Site chronology YRKNSQ01

None of the four samples in site chronology YRKNSQ01 retain complete sapwood (the last ring produced by the tree immediately before it was cut down), and it is thus not possible to say precisely when any of the trees were felled. Two of the samples do, however, retain the heartwood/sapwood boundary (denoted by h/s in Table 1 and the bar diagram), this meaning that only the sapwood rings are missing. Given that the number of sapwood rings on oak trees generally lie within known limits (the 95% probability interval being 15–40 sapwood rings), it is possible to calculate the likely felling date of the timbers with a high degree of reliability. In this instance, furthermore, given that the relative position and the date of the heartwood/sapwood boundary on the two samples is very similar, it is likely that the trees represented were all cut at the same time as each other in a single episode of felling.

The average date of the heartwood/sapwood boundary on the two samples that retain it (YRK-N01 and N10) is 1151. Adding to this date the likely minimum and maximum number of sapwood rings (15–40) would give the timbers an estimated felling date in the range 1166–91. The two other samples of this group (YRK-N04 and N06) do not retain complete sapwood, and thus, strictly speaking, it is not possible to determine the felling date of the trees with reliable precision. However, the high degree of cross-matching between these two samples and samples YRK-N01 and N10, would suggest that the trees represented were growing close to each other in the same copse or stand of woodland. This makes it more likely that all four trees represent a single extraction of timber, it being unlikely that trees, originally growing so close together, but felled at very different times, would come to be used in the same building.

Sample YRK-N03

Sample YRK-N03 also retains only the heartwood/sapwood boundary. Given that on this sample the heartwood/sapwood boundary is dated to 1660, and making an allowance of 15–40 for the likely minimum/maximum number of missing sapwood ring, would give the tree represented by this sample an estimated felling date in the range 1675–1700.

Sample YRK-N09

Likewise sample YRK-N09 has only the heartwood/sapwood boundary. Given that on this sample the heartwood/sapwood boundary is dated to 1462, and again making an allowance of 15–40 for the likely minimum/maximum number of missing sapwood ring, would give the tree represented by this sample an estimated felling date in the range 1477–1502.

Undated samples

Four samples, YRK-N02, N05, N07, and N08 remain ungrouped and undated. There is no clear reason for this, all four samples having at least just sufficient rings for reliable analysis (and sample N08 actually being quite long), and none of them show any problems with their rings, such as stress or distortion, that might cause difficulties with dating. The phenomenon of undated longer samples is common feature in every programme of tree ring analysis, and indeed it is quite rare for every measured sample to be dated. One theory for this is that, while the majority of timbers have been sourced from one location (even if the one location covers a wide general area), the undated samples represent timbers each sourced from different woodland locations, this being still more likely where a roof has been constructed from reused timbers. This has the effect of making them ‘singletons’, which, though these too can sometimes be cross-matched (as samples YRK-N03 and N09), are more difficult to date than groups of well-replicated samples. Another possibility is that the undated timbers are derived from trees which, though not showing any signs of disturbance, have been affected to a greater degree than the dated timbers by some non-climatic influence.

Conclusion

Tree-ring analysis of timbers to the roof of the western part of the north aisle shows that a small number of these beams have been derived from trees which were felled at some point between 1166 at the earliest and to 1191 at the latest. As such, these are a remarkably early collection of beams, and, although timbers having twelfth century, or earlier, felling dates are not altogether unknown in tree-ring studies, they represent a very rare example, there probably being only a handful of other buildings in the country with timbers dating from this time. Given the dates of these timbers it certainly seems possible that they were originally felled for a roof of an aisle which is believed to have been added to an existing church in the later twelfth century as the population of the area increased.

It seems likely that this aisle was re modelled or renovated some time, it being given a new plinth and the lancet windows being replaced with the current, larger, early-fifteenth century, windows with new stained glass. Some time later, repairs or alterations were made to the roof. This re-roofing, probably completed in the 1470s, retained and re-used a number of the earlier, late-twelfth century, timbers. It would appear likely that this roof required further repair in the later-seventeenth century.

It may be of interest to note the date at which at least one of the trees might have started growing, and the age it had reached when felled. As may be seen from Table 1 and the bar diagram Figure 7, the first, or earliest, extant ring on any sample, YRK-N06, is dated to 960. This ring, however, is not the centre ring of the tree (ie, its first growth ring) but is, roughly estimated, 20 or even 30 years from it (see Fig 8). If this estimate is correct, this would suggest that the tree represented by the sample began growing (in round terms) about 930–940. Samples with rings from such an early date, while not unknown to tree-ring studies, are not particularly common, with some other examples of early rings, as it happens, being found on a few timbers from the Chapter House roof at York Minster.

Given that the tree is one of a group estimated to have been cut in 1166–91, if it had begun growing in 930, it could have reached about 250–260 years of age when felled, again a fairly uncommon figure in tree-ring analysis.

It may also be of interest to note the cross-matching between site sequence YRKNSQ01 and the various reference chronologies used to date it, as listed in Table 2. Given that the highest *t*-values, ie, the greatest degrees of similarity, are found with reference chronologies made up of material from Lincoln Cathedral and Ely Cathedral, this would suggest the trees used at all three sites may have originally been growing in the same general area. While the woodland sources of the trees used at Lincoln and Ely are themselves not reliably known, there is some intimation, from both documentary sources, and from tree-ring analysis, that this might have been Sherwood Forest.

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Table 1: Details of tree-ring samples from the north aisle roof, All Saints Church, North Street, York

Sample number	Sample location	Total rings	Sapwood rings*	First measured ring date (AD)	Heart/sap boundary (AD)	Last measured ring date (AD)
YRK-N01	South rafter, frame 1	159	h/s	987	1145	1145
YRK-N02	South rafter, frame 4	47	h/s	------	------	------
YRK-N03	North rafter, frame 5	152	h/s	1509	1660	1660
YRK-N04	North rafter, frame 6	134	no h/s	967	------	1100
YRK-N05	South rafter, frame 6	59	h/s	------	------	------
YRK-N06	South rafter, frame 7	123	no h/s	960	------	1082
YRK-N07	North rafter, frame 10	50	h/s	------	------	------
YRK-N08	South rafter, frame 10	122	h/s	------	------	------
YRK-N09	South rafter, frame 11	50	h/s	1413	1462	1462
YRK-N10	Collar, frame 17	116	h/s	1041	1156	1156

h/s = heartwood/sapwood boundary, i.e., only the sapwood rings are missing

Table 2: Results of the cross-matching of site chronology YRKNSQ01 and the reference chronologies when the first ring date is 960 and the last ring date is 1156		
Reference chronology	*t*-value	
St Hugh's' Choir, Lincoln Cathedral, Lincoln	10.1	(Laxton and Litton 1988)
Angel Choir, Lincoln Cathedral, Lincoln	9.6	(Laxton and Litton 1988)
Ely Cathedral, Cambs	9.4	(Howard *et al* 1995)
Hemmington Bridges, Hemmington, Leics	7.0	(Howard *et al* 1988)
Transept roof, Lincoln Cathedral, Lincoln	6.5	(Laxton and Litton 1988)
Chapter House, York Minster, York	6.5	(Howard *et al* 1998 unpubl)
All Hallow's Church, Kirkburton, W Yorks	6.4	(Arnold and Howard 2007)
England Master Chronology	6.2	(Baillie and Pilcher 1982 unpubl)

Table 3: Results of the cross-matching of site chronology YRK-N03 and the reference chronologies when the first ring date is 1509 and the last ring date is 1660		
Reference chronology	*t*-value	
Manor House, Alford, Lincs	7.2	(Arnold *et al* 2003)
Stoneleigh Abbey, Stoneleigh, Warwicks	6.7	(Howard *et al* 2000)
Church Pews, Staunton Harold, Leics	5.8	(Howard *et al* 1996a)
Church of St Nicholas, Bringhurst, Leics	5.6	(Arnold *et al* 2005)
Bentley Hall, Hungry Bently, Derbys	5.4	(Arnold and Howard 2009a)
101 Meeting Street, Quorn, Leics	5.3	(Arnold *et al* 2008 unpubl)
Church Farm House, Ockbrook, Derbys	5.1	(Arnold and Howard 2009b)
Staircase House, Stockport, Cheshire	5.1	(Howard *et al* 2003)

Table 4: Results of the cross-matching of site chronology YRK-N09 and the reference chronologies when the first ring date is 1413 and the last ring date is 1462		
Reference chronology	*t*-value	
Ughill Manor, Bradfield, S Yorks	7.6	(Howard *et al* 1994)
Hall Broom Farm, Dungworth, Derbys	5.9	(Howard *et al* 1993)
Cromford Bridge House, Cromford, Derbys	5.0	(Arnold and Howard 2007 unpubl)
Anne of Cleeve's House, Melton Mowbry, Leics	4.9	(Howard *et al* 1997)
Seaton Holme, Easington, Co Durham	4.8	(Arnold *et al* 2008)
St Nicholas' Church, Stanford upon Avon, Northants	4.8	(Howard *et al* 1996b)
Hardwick Old Hall, Doe Lea, Derbys	4.7	(Howard *et al* 2002)
White Hart Yard, Newcastle Upon Tyne	4.7	(Arnold *et al* 2005)

Site chronology YRKNSQ01 (Table 2) is a composite of the data of the relevant cross-matching samples as seen in the bar diagram Figure 7. This composite data produces an 'average' tree-ring pattern, where the overall climatic signal of the growth is enhanced, and the possible erratic variations of any one individual sample are reduced. This 'average' site chronology is then compared with several hundred reference patterns covering every part of Britain for all time periods, cross-matching with a number of these only at the time span indicated, the Table giving only a small selection of the very best matches as represented by '*t*-values' (ie, degrees of similarity). It may be noticed from this Table that the resultant *t*-values are well in excess of the *t*=3.5 value usually taken as the minimum acceptable level for satisfactory dating. These values, along with the many other slightly lower, unlisted, cross-matches, indicate a very firm and reliable date for the timbers

Samples YRK-N03 and N09 have been compared individually with the reference patterns, cross-matching only at the dates shown (Tables 3 and 4).

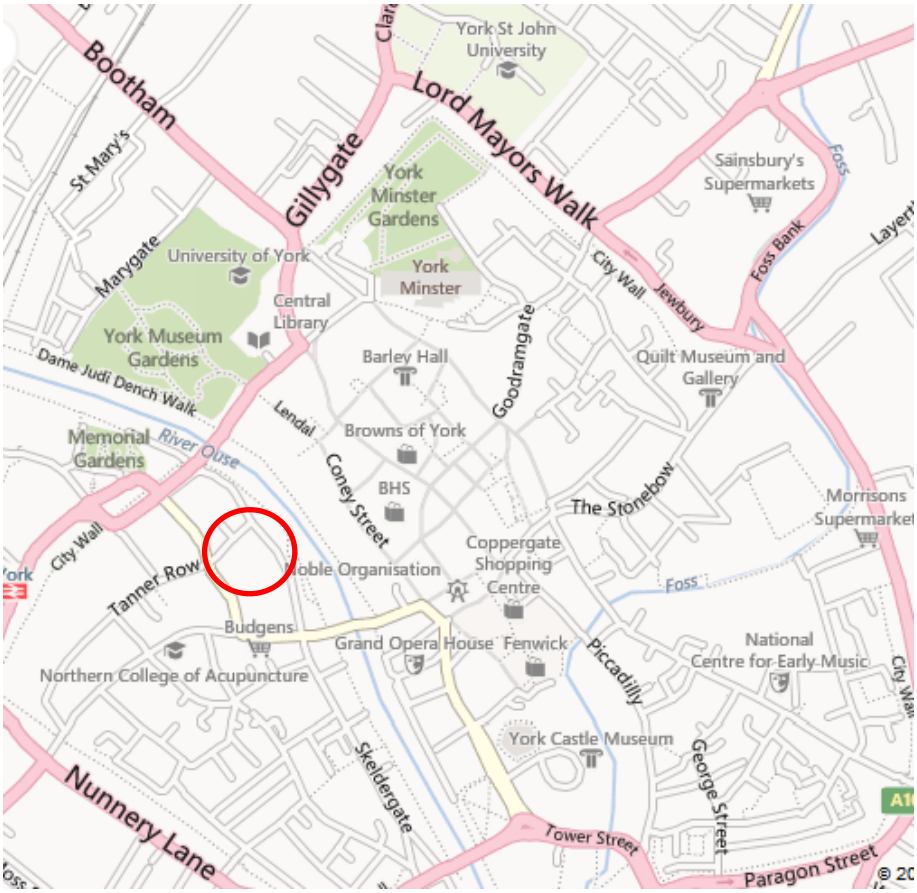


Figure 1a/b: Maps to show location of York (top) and All Saints' Church (bottom)

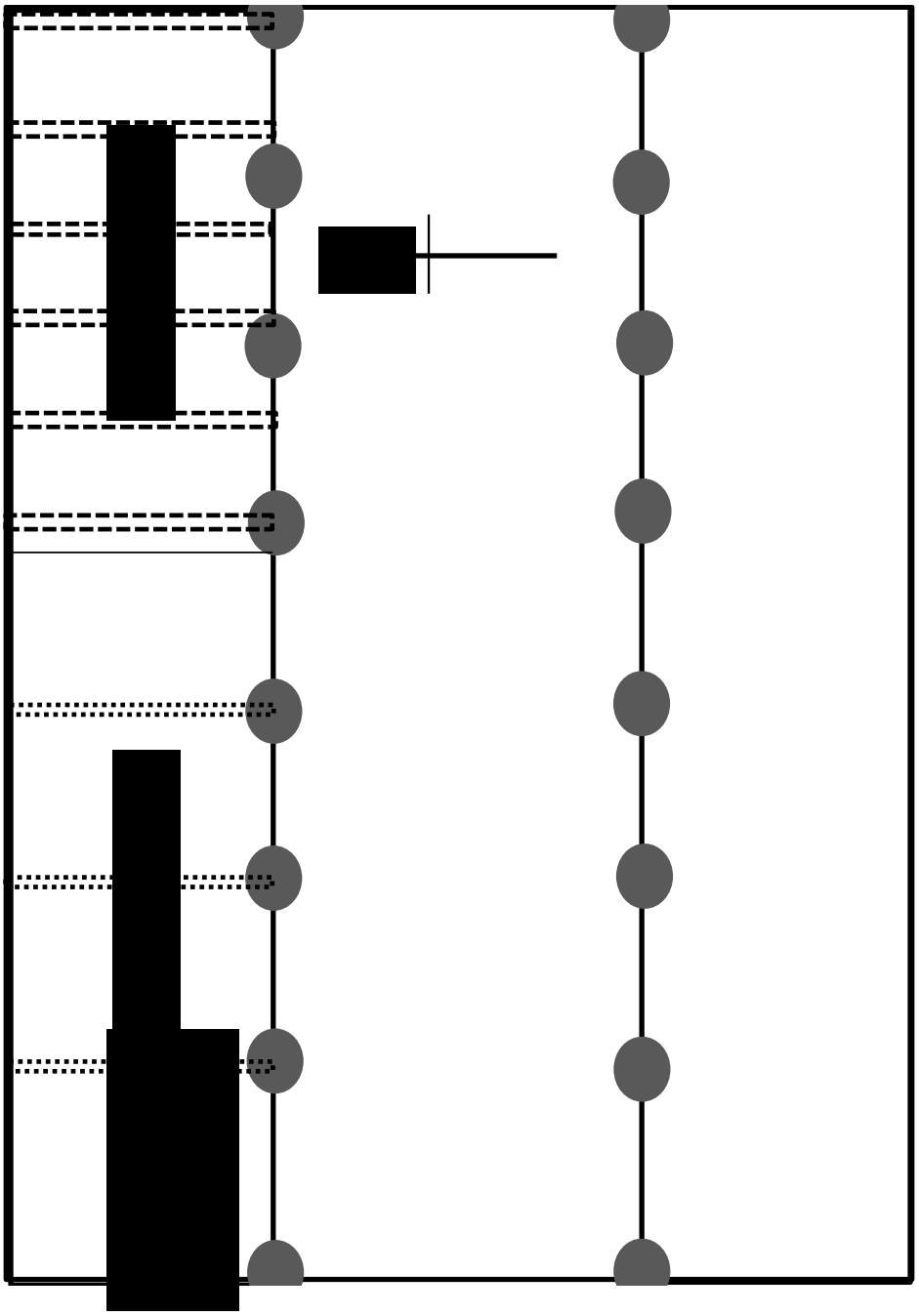


Figure 2: Highly simplified ground floor plan of All Saints Church to show position and arrangement of the north aisle roofs

Figure 3a/b: Internal views of the north aisle looking west to east (top) and east to west (bottom). It is above this latter area that the samples analysed here have been obtained

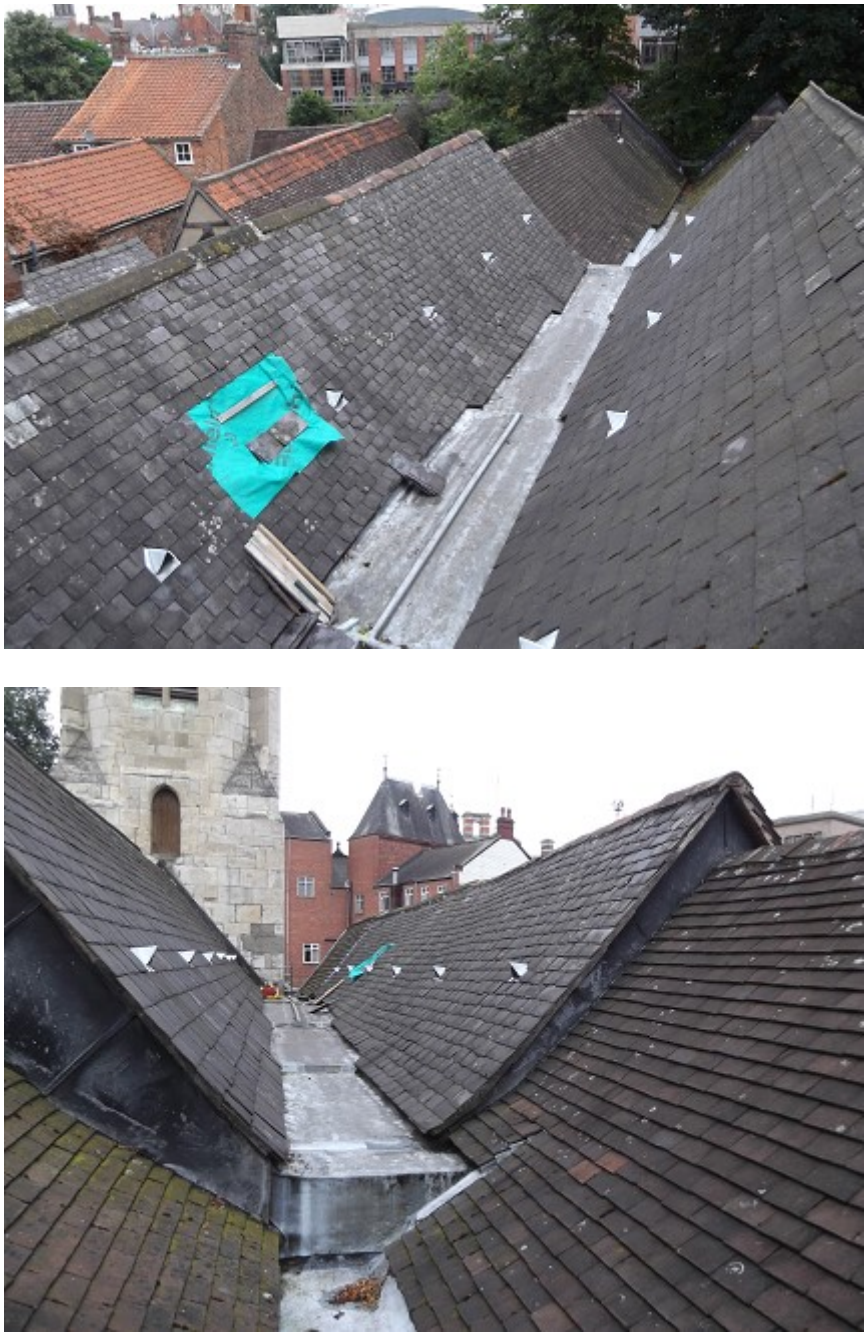


Figure 4a/b: Views of the north aisle roofscape looking west to east (top) and east to west (bottom)

Figure 5a/b: Views of the roof trusses to the west end of the north aisle looking west to east (top) and east to west (bottom)

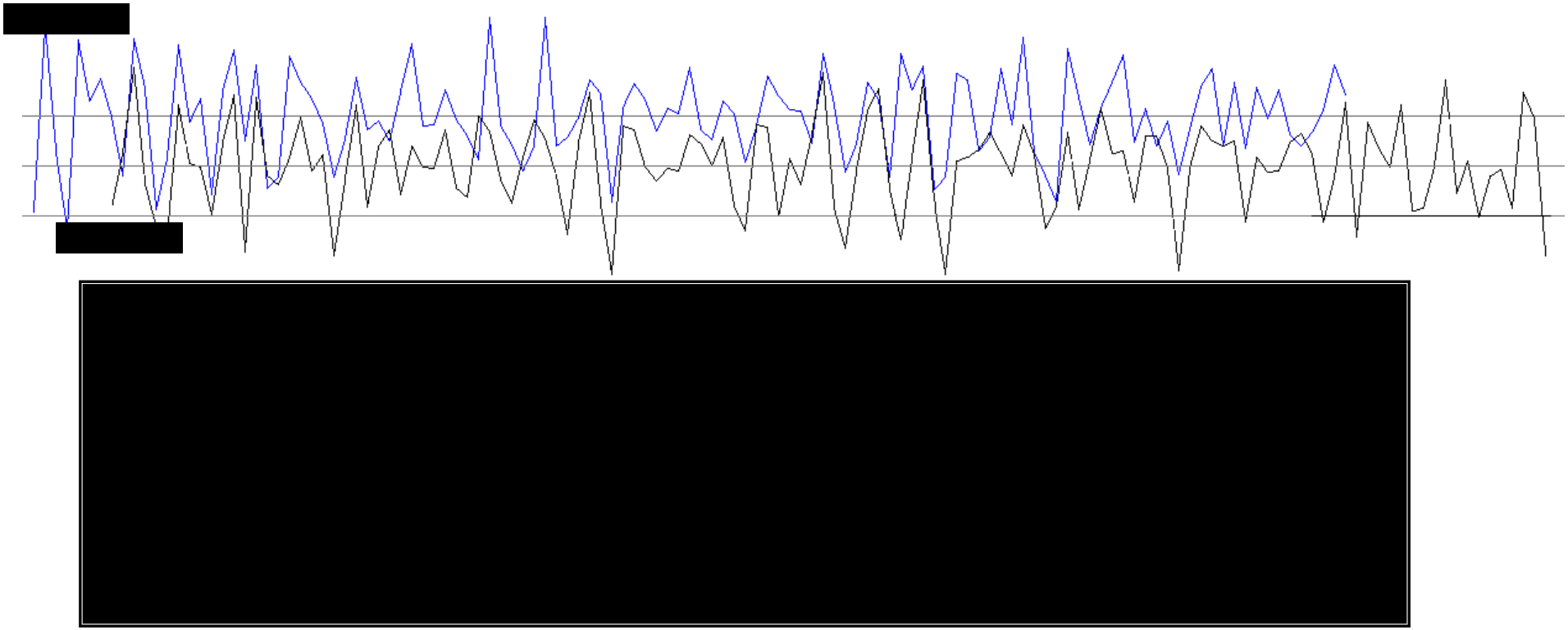
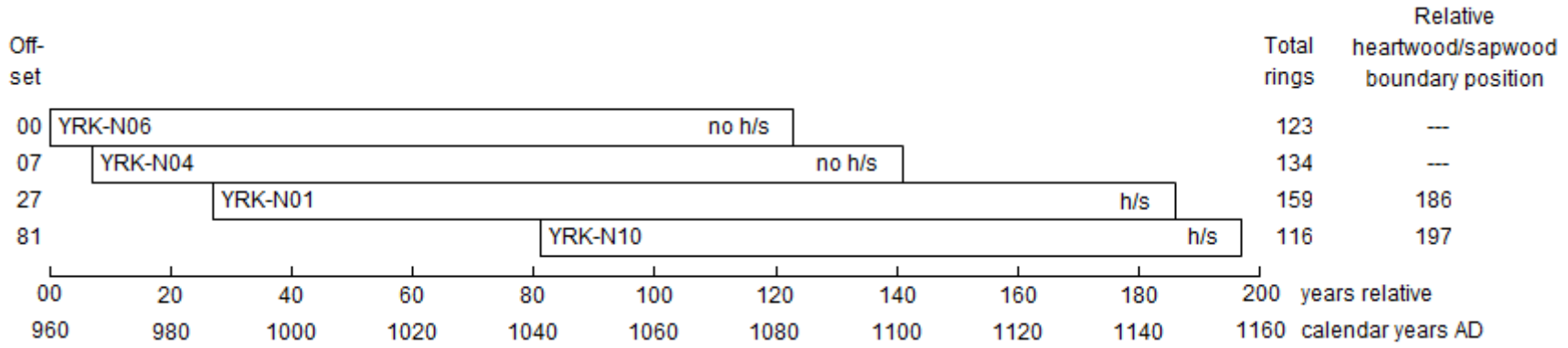


Figure 6: Graphic representation of the cross-matching of two samples, YRK-N04 and N06

When cross-matched at the correct positions, as here, the variations in the rings of these two samples correspond with a high degree of similarity. As the ring widths of one sample increase (represented by peaks in the graph), or decrease (represented by troughs), so too do the annual ring widths of the second sample. This similarity in growth pattern is a result of the two trees represented having grown in the same area *at the same time.* The growth ring pattern of two samples from trees grown at different times would never correspond so well.



blank bars = heartwood rings
h/s = heartwood/sapwood boundary, i.e., only the sapwood rings are missing

Figure 7: Bar diagram of the samples in site chronology YRKNSQ01

The four samples of this group are shown here in the form of a bar diagram at positions where the ring variations of each sample cross-match with each other. This similarity is produced by the trees represented sharing periods of growth in common (i.e., where the bars overlap). The samples are combined at these offsets to form a 'site chronology', YRKNSQ01, having an overall combined length of 233 rings. This site chronology is then compared with a large database of reference chronologies for all time periods for all parts of England, cross-matching only with a date span of 960 (the date of the earliest ring on any individual sample, YRK-N06) to 1156 (the date of the latest ring on any individual sample, YRK-N10) (see Table 2).

None of the samples retain complete sapwood and it is thus not possible to say with reliable precision when any of the trees were felled. Two of the samples (YRK-N01 and N10) do, though, retain the heartwood/sapwood boundary (h/s), meaning that only the sapwood rings are missing. By taking the average date of this boundary (here 1151) and adding to this the minimum/maximum number of sapwood rings the trees are likely to have had (15/40), it can be calculated that the timbers have an estimated felling date of sometime between 1166 at the earliest and 1191 at the latest. The two other samples of this group (YRK-N04 and N06) are missing not only all their sapwood rings, but an unknown number of heartwood rings as well and their felling date cannot be estimated. It is *possible* that the trees these samples represent were felled at the same time as the trees represented by YRK-N01 and N10, but it is equally possible that they were felled at different times.

Figure 8: Estimating the start of growth of the tree represented by sample YRK-N06