Research Report Series 23/2023

Priests' Room and Annex, Church of St Mary, North Bar Within, Beverley, East Riding of Yorkshire

Radiocarbon wiggle-matching of oak timbers

Alison Arnold, Robert Howard, Cathy Tyers, Michael Dee, Sanne Palstra and Peter Marshall

Scientific Dating

Priests' Room and Annex, Church of St Mary, North Bar Within, Beverley, East Riding of Yorkshire

Radiocarbon wiggle-matching of oak timbers

Alison Arnold, Robert Howard, Cathy Tyers, Michael Dee, Sanne Palstra and Peter Marshall

2023

NGR: TA 03150 39805

Print: ISSN 2398-3841
Online: ISSN 2059-4453

Summary

Independent validation of tentative tree-ring dating for a previously undated site chronology, BEVFSQ04, from the Church of St Mary, Beverley, East Riding of Yorkshire, has been obtained by radiocarbon wiggle-matching and it can now be considered as a radiocarbon-supported dendrochronological date, that spans AD 1608–1731$_{DR}$. Radiocarbon wiggle matching for a second undated site, BEVFSQ02, however, does not allow confirmation of the date suggested by the ring-width dendrochronology. Scientific dating evidence for the dated timbers from the Annex and Priests' Rooms illustrates the complex structural history of these two components of the Church of St Mary.

Contributors

Alison Arnold, Robert Howard, Cathy Tyers, Michael Dee, Sanne Palstra, and Peter Marshall.

Acknowledgements

We would like to thank David Cook of the Yorkshire Vernacular Buildings Study Group for facilitating access and the Church for allowing sampling to be undertaken.

The front cover image [WSA01/01/03001], taken in AD 1937, shows a view of the interior of the Priests' room at St Mary's Church, showing the variety of items, including a set of eighteenth-century stocks, stored there. © Historic England Archive.

Archive location

Historic England, The Engine House, Fire Fly Avenue, Swindon, SN2 2EH

Date of research

Dendrochronological sampling was undertaken on the 31 March 2015 and the radiocarbon dating programme was undertaken from 2021–2023.

Contact details

Historic England. Cannon Bridge House, 25 Dowgate Hill, London EC4R 2YA. 020 7973 3700. customers@HistoricEngland.org.uk

Contents

Illustrations

Tables

Introduction

The *Early Fabric in Historic Towns: Voluntary Group Projects*, funded by Historic England, have been developed in the recognition and acknowledgement of the excellent work being undertaken by local vernacular groups in the study of local architectural trends and fabrics. The project's intention is to encourage this type of study through the provision of support and to facilitate training of more people in building analysis and recording. The local projects were coordinated by Rebecca Lane (Historic England South West Region: Senior Architectural Investigator).

Early Fabric in Beverley Project

Whilst there is a corpus of research on form and age of the town of Beverley, it does not cover detailed examination of early fabric or aspects of typology, with analysis and interpretation of existing buildings until now not having benefited from dendrochronology, with the exception of some limited work on the Minster.

Initially, 13 properties were identified that were thought to be key to understanding the town's architectural development for a programme of comprehensive investigation. These properties were assessed for their suitability for tree-ring dating and those found to contain timbers potentially suitable for analysis were sampled. As the project progressed and some of the original buildings identified were rejected as unsuitable for tree-ring dating, further candidates for tree-ring analysis were assessed and sampled if appropriate.

It was hoped that successful dating of these buildings would extend the knowledge of early fabric and selected buildings in the historic town of Beverley in support of Historic England's responsibility to identify and understand the urban vernacular and historic environment of a market town. The reports produced on the buildings recorded as part of this project by the Yorkshire Vernacular Buildings Study Group, led by David Cook, will be held in the YVBSG archive and will be available through their website (www.yvbsg.org.uk), whilst a summary of the project is presented in Vernacular Architecture (Cook and Neave 2018).

Church of St Mary

The Grade I listed parish Church of St Mary (List Entry Number 1162693), located on the east side of North Bar Within, Beverley (Fig 1) is believed to have its origins in the twelfth century, although the majority of the present building dates to the fourteenth and fifteenth centuries. The tower was rebuilt after it collapsed in AD 1520, when work was also undertaken on the nave. Other restorations were carried out in the nineteenth century. In *c* AD 1330 a chapel and sacristy were built on the north side of the chancel (Pevsner 1995), above this are the two rooms under investigation, the Priests' Room and Annex.

The roof over the Priests' Room, the larger of the two rooms, is a monopitch sloping down to the north, although evidence from the east gable suggests it must originally have been a ridged roof. The extant roof has four main beams (the westernmost one is modern), with common rafters running between them and a central longitudinal beam. At least two of the timbers of this roof, the south wallplate and the longitudinal beam, display signs of reuse. It is thought likely that the roof was lowered and flattened when the clerestory was added to the choir in *c* AD 1420.

The roof over the Annex consists of three main beams between which run common rafters. There are six longitudinal beams acting as purlins.

Tree-ring analysis

Sampling and original tree-ring analysis

Twenty core samples from oak (*Quercus* sp.) timbers of the roofs of the Priests' Room and Annex were obtained in 2015 (Arnold *et al* 2020a, figs 7–9; Table 1). Sample BEV-F08, taken from a rafter, had too few rings for secure dating and so was rejected prior to measurement. Following ring-width measurement of the remaining 19 samples they were compared with each other by the Litton/Zainodin grouping programme (Litton and Zainodin 1991; Laxton *et al* 1988), resulting in 10 samples matching to form four groups Arnold *et al* 2020, figs 10-13)

Two samples, both from the Annex roof, matched each other with a *t*-value of 5.4 and were combined at the relevant offset positions to form BEVFSQ01, a site sequence of 143 rings (Arnold *et al* 2020a, fig 10). This site sequence was compared against a series of relevant reference chronologies for oak where it was matched at a first-ring date of AD 1191 and a last-measured ring date of AD 1333. One of these, BEV-F13, has a heartwood/sapwood boundary ring date of AD 1320. Applying the probability distribution of the expected number of sapwood rings in ancient oak timbers from England (Arnold *et al* 2019a, fig 9) would give this timber an estimated felling date in the range AD 1329–1362 (95% probability; Fig 2) probably AD 1333–1348 (68% probability).

The second dated sample, BEV-F14, does not have the heartwood/sapwood boundary ring and so an estimated felling date cannot be calculated for the timber represented, although with a last measured heartwood ring date of AD 1333 it could be contemporary with the other timber.

Four samples, two from the Annex and two from the Priests' Room, matched (minimum *t*-value of 4.6) to form a second site sequence (BEVFSQ02) of 168 rings (Arnold *et al* 2020a, Fig 3), two further Priests' Room samples matched at *t* = 5.7 and were combined to form BEVFSQ03, a site sequence of 84 rings (Arnold *et al* 2020a, fig 12), and finally two of the Annex samples matched at *t* = 8.6 to form BEVFSQ04, a site sequence of 124 rings (Arnold *et al* 2020a, Fig 4). Attempts to date these three site sequences and the remaining ungrouped samples were unsuccessful when the analysis was originally reported.

Revised tree-ring analysis

Following completion of the tree-ring analysis of all the building's sampled as part of the *Early Fabric in Beverley Project* further attempts to date the undated site sequences from the Priests' Room and Annex was undertaken. Comparison of the three undated site sequences with the extensive corpus of reference chronologies for oak once again failed to identify a conclusive cross-dating position, however, some low but consistent correlations were noted against a number of reference chronologies for BEVFSQ02 when it spans AD 1226–1393 (Table 2) and BEVFSQ04 when it spans AD 1608–1731 (Table 3).

Radiocarbon dating

In order to provide independent validation of the calendar dating for BEVFSQ02 and BEVFSQ04 suggested by the revised tree-ring analysis, the longest tree-ring sequence, BEV-F01, from site sequence BEVFSQ02 (Fig 3) and BEV-F19, from site sequence BEVFSQ04 (Fig 4) were selected for radiocarbon dating and wiggle-matching. BEV-F01 has 149 rings including 13 sapwood rings and comprises relative years 20–168 of BEVFSQ02 that potentially spans AD 1245–1393. BEV-F19 has 100 rings (all heartwood) and comprises relative years 1–100 of BEVFSQ04 that potentially spans AD 1608–1707.

Radiocarbon dating is based on the radioactive decay of ^{14}C, which trees absorb from the atmosphere during photosynthesis and store in their growth-rings. The radiocarbon from each year is stored in a separate annual ring. Once a ring has formed, no more ^{14}C is added to it, and so the proportion of ^{14}C versus other carbon isotopes reduces in the ring through time as the radiocarbon decays. Radiocarbon ages, like those in Tables 4–5, measure the proportion of ^{14}C in a sample and are expressed in radiocarbon years BP (before present, 'present' being a constant, conventional date of AD 1950).

Radiocarbon measurements have been obtained from eight single annual tree-rings from timber BEV-F01 (Table 4) and three from timber BEV-F19 (Table 5). Dissection was undertaken by Alison Arnold and Robert Howard at the Nottingham Tree-Ring Dating Laboratory. Prior to sub-sampling, the core was checked against the tree-ring width data. Then each annual growth ring was split from the rest of the tree-ring sample using a chisel or scalpel blade. Each radiocarbon sample consisted of a complete annual growth ring, including both earlywood and latewood. Each annual ring was then weighed and placed in a labelled bag. Rings not selected for radiocarbon dating as part of this study have been archived by Historic England.

Radiocarbon dating was undertaken by the Centre for Isotope Research, University of Groningen, the Netherlands in 2021. Each ring was converted to α-cellulose using an intensified aqueous pretreatment (Dee *et al* 2020) and combusted in an elemental analyser (IsotopeCube NCS), coupled to an Isotope Ratio Mass Spectrometer (Isoprime 100). The resultant CO_2 was graphitised by hydrogen reduction in the presence of an iron catalyst (Wijma *et al* 1996; Aerts-Bijma *et al* 1997). The graphite was then pressed into aluminium cathodes and dated by AMS (Synal *et al* 2007; Salehpour *et al* 2016). Data reduction was undertaken as described by Wacker *et al* (2010).

The Centre for Isotope Research maintains a continual programme of quality assurance procedures (Aerts-Bijma *et al* 2021), in addition to participation in international intercomparison exercises (Scott *et al* 2017; Wacker *et al* 2020). These tests demonstrate the reproducibility and accuracy of these measurements.

The results are conventional radiocarbon ages, corrected for fractionation using $\delta^{13}C$ values measured by Accelerator Mass Spectrometry (Stuiver and Polach 1977; Tables 4–5). The quoted $\delta^{13}C$ values were measured by Isotope Ratio Mass Spectrometry, and more accurately reflect the natural isotopic composition of the sampled wood.

Wiggle-matching

Radiocarbon ages are not the same as calendar dates because the concentration of ^{14}C in the atmosphere has fluctuated over time. A radiocarbon measurement has thus to be calibrated against an independent scale to arrive at the corresponding calendar date. That independent scale is the IntCal20 calibration curve (Reimer *et al* 2020). For the period covered by this study, this is constructed from radiocarbon measurements on tree-ring samples dated absolutely by dendrochronology. The probability distributions of the calibrated radiocarbon dates from BEVFSQ02 and BEVFSQ04, derived from the probability method (Stuiver and Reimer 1993), are shown in outline in Figures 5–6.

Wiggle-matching is the process of matching a series of calibrated radiocarbon dates which are separated by a known number of years to the shape of the radiocarbon calibration curve. At its simplest, this can be done visually, although statistical methods are usually employed. Floating tree-ring sequences are particularly suited to this approach as the calendar age separation of tree-rings submitted for dating is known precisely by counting the rings in the timber. A review of the method is presented by Galimberti *et al* (2004).

The approach to wiggle-matching adopted here employs Bayesian chronological modelling to combine the relative dating information provided by the tree-ring analysis with the calibrated radiocarbon dates (Christen and Litton 1995). It has been implemented using the program OxCal v4.4 (http://c14.arch.ox.ac.uk/oxcal.html; Bronk Ramsey *et al* 2001; Bronk Ramsey 2009). The modelled dates are shown in black in Figures 5–6 and quoted in italics in the text. The Acomb statistic shows how closely the assemblage of calibrated radiocarbon dates as a whole agree with the relative dating provided by the tree-ring analysis that has been incorporated in the model; an acceptable threshold is reached when it is equal to or greater than An (a value based on the number of dates in the model). The A statistic shows how closely an individual calibrated radiocarbon date agrees its position in the sequence (most values in a model should be equal to or greater than 60).

Figures 5 illustrates the chronological model for BEVFSQ02. This model incorporates the gaps between each dated annual ring known from tree-ring counting (eg that the carbon in ring 100 of the measured tree-ring series (GrM-26078) was laid down 31 years before the carbon in ring 131 of the series (GrM-26079), with the radiocarbon measurements (Table 4) calibrated using the internationally agreed radiocarbon calibration data for the northern hemisphere, IntCal20 (Reimer *et al* 2020).

The model has good overall agreement (Acomb: 73.3, An: 25.0, n: 8; Fig 5), with only one radiocarbon date having poor individual agreement (A < 60): GrM-26078 (A:35). It suggests that the final ring of BEVFSQ02 formed in *cal AD 1412–1421* (*95% probability*; *ring 168* (*AD 1393*); Fig 5), probably in *cal AD 1414–1419* (*68% probability*).

Clearly in this instance the radiocarbon wiggle match for BEVFSQ02 does not allow confirmation of the date suggested by the ring-width dendrochronology.

Figure 6 illustrates the chronological model for BEVFSQ04. This model incorporates the gaps between each dated annual ring known from tree-ring counting (eg that the carbon in ring 23 of the measured tree-ring series (GrM-26066) was laid down 14 years before the carbon in ring 37 of the series (GrM-26067), with the radiocarbon measurements (Table 5) calibrated using the internationally agreed radiocarbon calibration data for the northern hemisphere, IntCal20 (Reimer *et al* 2020).

The model has good overall agreement (Acomb: 113.1, An: 40.8, n: 3; Fig 6), with all three radiocarbon dates having good individual agreement (A > 60). It suggests that the final ring of BEVFSQ04 formed in *cal AD 1721–1737* (*95% probability*; *ring 112 (AD 1731)*; Fig 6), probably in *cal AD 1726–1733* (*68% probability*), compatible with the last measured ring being formed in AD 1731 (Table 3). When the last ring of the wiggle-match is constrained to be AD 1731, the model has good overall agreement (Acomb: 120.0, An: 35.4, n: 4; Fig 7), with all three radiocarbon dates having good individual agreement (A > 60). This allows confirmation of the ring-width dendrochronology and it to be considered as a radiocarbon-supported dendrochronological date, that spans AD 1608–1731$_{DR}$ (Table 3), with the final ring of BEVFSQ04 having been formed in AD1731$_{DR}$. The superscript $_{DR}$ indicates that this is not a date determined independently by ring-width dendrochronology, and that the master sequence, BEVFSQ04, should not be utilised as a ring-width master sequence for dating other sites.

Discussion of wiggle-matching results

It is possible, although unlikely, that the timbers in site chronology BEVFSQ02 have the same felling date (Fig 3). This is because the relative positions of the heartwood/sapwood boundaries have wide limits, with a difference of 34 years between sample BEV-F17 (ring

199) and samples BEV-F01/BEV-F06 (ring 155). The provenance of the samples also varies, with both the Priests' Room and Annex being represented.

Indeed, it appears more likely that two phases of felling are represented by this site chronology. Sample BEV-F17 may represent one phase of felling and samples BEV-F01 and BEV-F06 which also have identical relative heartwood/sapwood boundary positions, may represent a different later phase of felling.

The last heartwood ring date of the single sample from the first phase of felling, BEV-F17 is *cal AD 1363–1372* (*95% probability*), probably *cal AD 1365–1370* (*68% probability*). Applying the probability distribution of the expected number of sapwood rings in ancient oak timbers from England (Arnold *et al* 2019, fig 9) would give this timber an estimated felling date in the range *cal AD 1375–1409* (*95% probability*; Fig 8) probably *cal AD 1379–1396* (*68% probability*).

Neither of the timbers from the Priest's room, BEV-F01 and BEV-06, has complete sapwood (Fig 3; Table 1) but both retain the heartwood/sapwood transition and BEV-F01 also retains 13 rings of sapwood. We can estimate the felling dates of these timbers by adding the probability distribution of the expected number of sapwood rings in ancient oak timbers from England (Arnold *et al* 2019a, fig 9) to the estimated dates of the last rings of the respective timbers. For BEV-F01 we apply this probability distribution truncated to allow for the surviving sapwood rings (Bayliss and Tyers 2004, 960–1). These distributions are shown in outline in Figure 9.

Given the relative date of the heartwood/sapwood boundaries of BEV-F01 and BEV-06 is identical, this suggests that these timbers were derived from trees cut down as part of a single episode of felling. The date of this felling episode can be estimated by combining the probability distributions for the felling of each timber. This model also has good overall agreement (Acomb: 129.2, An: 50.0, n: 2; Fig 9), with each prior distribution having good individual agreement. This analysis suggests these two timbers from the Priest's room were felled in *cal AD 1415–1436* (*95% probability*; *BEVFSQ02 felling*; Fig 9), probably in *cal AD 1418–1428* (*68% probability*).

The other sample BEV-F18, in site sequence BEVFSQ02 does not have the heartwood/sapwood boundary ring and an estimated felling date cannot be calculated for the timber represented, except to say that with a last measured heartwood ring date of *cal AD 1395–1404* (*95% probability*) it could be contemporary with BEV-F01 and BEV-06.

Neither of the two samples in sequence BEVFSQ04 have complete sapwood (Fig 3; Table 1), but one, BEV-F20 has 12 sapwood rings. We can thus estimate its felling date by adding the probability distribution of the expected number of sapwood rings in ancient oak timbers from England (Arnold *et al* 2019a, fig 9), truncated to allow for the surviving sapwood rings (Bayliss and Tyers 2004, 960–1) to the date of its last ring, AD 1731$_{DR}$. This suggest that timber BEV-F20 was felled in AD 1731$_{DR}$–1756$_{DR}$ (95% probability; BEV-F20 felling; Fig 10), probably in AD 1732 $_{DR}$–1743 $_{DR}$ (68% probability).

The second dated sample, BEV-F19, does not have the heartwood/sapwood boundary ring and so an estimated felling date cannot be calculated for the timber represented, except to say that with a last measured heartwood ring date of AD 1707$_{DR}$ both common rafters from BEVFSQ04 could have been felled at the same time.

Discussion

Two main beams of the Annex have previously been successfully dated by dendrochronology (Arnold *et al* 2020a), with one timber, BEV-F13, having an estimated felling date in the range AD 1329–1362 (95% probability; Fig 2), probably AD 1333–1348 (68% probability). The other, BEV-F14, with a last measured heartwood ring date of AD 1333 could have been felled at the same time. Radiocarbon wiggle matching has now dated a further four timbers, all common rafters, from the Annex. Two of these, BEV-F17 and BEV-F18, were probably felled in the late fourteenth–very early fifteenth centuries and the others, BEV-F19 and BEV-F20, in the eighteenth century.

It is thus plausible to suggest construction of the Annex roof occurred in the mid-fourteenth century, making this roof slightly later than previously thought, though clearly this suggestion is based on the dating of only two timbers.

One of the previously undated site sequences (BEVFSQ02) contains samples from both the Annex and the Priests' Room roofs. By looking at the relative heartwood/sapwood boundary ring positions of the four samples represented (Fig 2) it is possible to say that one of the Annex roof timbers (BEV-F17), taken from a common rafter, was felled several decades earlier than the two Priests' Room timbers, a main beam and the central longitudinal beam. The other Annex roof timber (BEV-F18), another common rafter, is potentially broadly contemporary with the two Priests' Room samples. From this, it is thought likely that the earlier common rafter (BEV-F17) was reused from a previous structure and that the construction of the Priests' Room and Annex roofs are contemporary, in support of the documentary sources. Evidence of reuse was noted elsewhere within the roofs during the survey undertaken by the Yorkshire Vernacular Buildings Study Group (YVBSG 2016).

The other previously undated site sequence contains samples from the Annex roof (BEVFSQ04; Fig 3), both from common rafters. It is thought likely that the two timbers represented were felled at the same time as each other probably in the mid-eighteenth century.

A summary of the scientific dating evidence for the dated timbers from the Annex and Priests' Rooms (Fig 11) illustrates the complex structural history of the two components of the Church of St Mary.

References

Aerts-Bijma, A T, Paul, D, Dee, M W, Palstra, S W L, and Meijer, H A J, 2021 An independent assessment of uncertainty for radiocarbon analysis with the new generation high-yield Accelerator Mass Spectrometers, *Radiocarbon,* **63**, 1–22. https://doi:10.1017/RDC.2020.101

Aerts-Bijma, A T, Meijer, H, and van der Plicht, J, 1997 AMS sample handling in Groningen, *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, **123**, 221–5. https://doi.org/10.1016/S0168-583X(96)00672-6)

Arnold, A J, Howard, R E, Laxton, R R, and Litton, C D, 2002 *The Urban Development of Newark-on-Trent: A Dendrochronological Approach*, Centre for Archaeol Rep **95/2002.** https://historicengland.org.uk/research/results/reports/95-2002

Arnold, A J, Howard, R E, and Litton, C D, 2006 *Tree-ring analysis of samples from Middleton Hall, Middleton, Warwickshire*, English Heritage Res Dep Rep Ser, **13/2006**. https://historicengland.org.uk/research/results/reports/13-2006

Arnold, A J, and Howard, R E, 2007a *Leicester's Gatehouse, Kenilworth Castle, Kenilworth, Warwickshire; Tree-ring Analysis of Timbers*, Centre for Archaeol Rep, **8/2007**. https://historicengland.org.uk/research/results/reports/8-2007

Arnold, A J, and Howard, R E, 2007b *Trerithick House, Polyphant, Cornwall, Tree-ring Analysis of Timbers*, EH Res Dep Rep Ser, **94/2007**. https://historicengland.org.uk/research/results/reports/94-2007

Arnold, A J, Howard, R E, and Litton, C D, 2008a Nottingham Tree-ring Dating Laboratory: additional dendrochronology dates, No.20, *Vernacular Architect*, **39**, 107–11. https://doi.org/10.1179/174962908X365091

Arnold, A and Howard, R, 2010 *St Firmin Church, Thurlby, Lincolnshire: Tree-ring Analysis of Timbers of the Bellframe and Tower*, Res Dep Rep Ser **72/2010**. https://historicengland.org.uk/research/results/reports/48-2008

Arnold, A J and Howard, R E, 2012 Dates from the Nottingham Tree-Ring Dating Laboratory, *Vernacular Architect*, **43**, 94. https://doi.org/10.1179/0305547712Z.0000000009

Arnold, A J and Howard, R E, 2014 Dates from the Nottingham Tree-Ring Dating Laboratory, *Vernacular Architect*, **45**, 109. https://doi.org/10.1179/0305547714Z.00000000029

Arnold, A J, Howard, R E, and Tyers, C, 2016 *Brampton Manor Barn, Chesterfield, Derbyshire: Tree-ring Analysis of Timbers*, English Heritage Res Rep Ser, **59/2016**. https://historicengland.org.uk/research/results/reports/59-2016

Arnold, A J, Howard, R E, and Dawson, G, 2016 Dates from the Nottingham Tree-ring Dating Laboratory: Nottinghamshire bellframes, *Vernacular Architect*, **47**, 85. https://doi.org/10.1080/03055477.2016.1234300

Arnold, A, Howard, R, Tyers, C, Tyers, I, Bayliss, A, Bollhalder, S, Hajdas, I, and Wacker, L, 2019a *Auckland Castle, Bishop Auckland, County Durham, Tree-ring Analysis and Radiocarbon Wiggle-matching of* ex situ *Oak Timbers from the West Mural Tower*, Hist Engl Res Rep Ser, **77/2019**. https://doi.org/10.5284/1082566

Arnold, A, Howard, R, Tyers, C, Bronk Ramsey, B, Dunbar, E, and Marshall, P, 2019b*The Guildhall, Register Square, Beverley, East Yorkshire. Tree-Ring and Radiocarbon Analysis of Oak Timbers*, HE res Rep, **84/2019**. https://historicengland.org.uk/research/results/reports/84-2019

Arnold, A, Howard, R and Tyers, C, 2020a *Priests' Room & Annex, Church of St Mary, North Bar Within, Beverley: Tree-ring analysis of oak timbers*, Hist Engl Res Rep Ser **221/2020**. https://historicengland.org.uk/research/results/reports/221-2020

Arnold, A J, Howard, R E, and Tyers, C, 2020b *St Marys Court, 49–52 North Bar Within, Beverley, East Riding of Yorkshire: Tree-ring Analysis of Timbers*, Historic England Res Rep Ser, **219/2020**. https://historicengland.org.uk/research/results/reports/219-2020

Arnold, A, Howard, R, and Tyers, C, 2020c *Choir Roof, The Minster, Beverley, East Riding of Yorkshire: Tree-Ring Analysis of Timbers*, HE Res Rep, **220/2020**. https://historicengland.org.uk/research/results/reports/220-2020

Arnold, A J, and Howard, R E, 2020 unpubl The Former Robin Hood Hotel, Beaumont Street, Newark on Trent, Nottinghamshire, unpublished computer file *NWKVSQ01*, NTRDL

Bayliss, A, and Tyers, I, 2004 Interpreting radiocarbon dates using evidence from tree rings, *Radiocarbon*, **46**, 957–64. https://doi.org/10.1017/S0033822200036018

Bridge, M C, 2000 *Tree-ring analysis of timbers from St Andrew's Church, Ford, West Sussex*, Anc Mon Lab Rep, **27/2000.** https://historicengland.org.uk/research/results/reports/27-2000

Bridge, M, 2009 *All Saints Church, Sancton, Near Market Weighton, East Yorkshire Tree-ring Analysis of Timbers from the belfry floor and bellframe*, English Heritage Res Dep Rep Ser, **82/2009**. https://historicengland.org.uk/research/results/reports/82-2009

Bronk Ramsey, C, 2009 Bayesian analysis of radiocarbon dates, *Radiocarbon*, 51, 37–60. https://doi.org/10.1017/S0033822200033865

Bronk Ramsey, C, van der Plicht, J, and Weninger, B, 2001 'Wiggle matching' radiocarbon dates, *Radiocarbon*, **43**, 381–9. https://doi.org/10.1017/S0033822200038248

Christen, J A, and Litton, C D, 1995 A Bayesian approach to wiggle-matching, *J Archaeol Sci*, **22**, 719–25. https://doi.org/10.1016/0168-583X(95)01420-9

Cook, D and Neave, S, 2018 Early fabric in historic towns: The Beverley Project, *Vernacular Architect*, **49**, 58–78. https://doi.org/10.1080/03055477.2018.1524423

Dee, M W, Palstra, S W L, Aerts-Bijma, A T, Bleeker, M O, de Bruin, S, Ghebru, F, Jansen, H G, Kuitems, M, Paul, D, Richie, R R, Spriensma, J J, Scifo, A, von Zonneveld, D, Verstappen-Dumoulin, B M A A, Wietzes-Land, P, and Meijer, H A J, 2020 Radiocarbon dating at Groningen: new and updated chemical pretreatment procedures, *Radiocarbon*, **62**, 63–74. https://doi.org/10.1017/RDC.2019.101

Galimberti, M, Bronk Ramsey, C, and Manning, S, 2004 Wiggle-match dating of tree-ring sequences, *Radiocarbon*, **46**, 917–24. https://doi.org/10.1017/S0033822200035967

Howard, R E, Laxton, R R, Litton, C D, and Simpson, W G, 1985 Tree-ring Dates for some East Midlands Buildings: 3, Table 1, no.3, *Transaction of the Thoroton Society of Nottinghamshire*, **89**, 30–36

Howard, R E, Laxton, R R, and Litton, C D, Nottingham University Tree-ring Dating Laboratory, Hook R, Thornes, R, Royal Commission on the Historical Monuments of England, 1992 List 47 no 9 - Nottingham University Tree-Ring Dating Laboratory: truncated principal trusses project, *Vernacular Architect*, **23**, 59–6. https://doi.org/10.1179/vea.1992.23.1.44

Howard, R E, 2004 unpubl Sandiacre Tithe Barn, Derbys, unpublished computer file *STBASQ01 / 02*, NUTRDL

Laxon, R R, Litton, C D, and Zainodin, H J, 1988 An objective method for forming a master ring-width sequence, *PACT*, **22**, 25–35.

Litton, C D, and Zainodin, H J, 1991 Statistical models of dendrochronology, *Journal of Archaeological Science*, **18**, 29–40. https://doi.org/10.1016/0305-4403(91)90036-O

Miles, D H, 1995 List 64 — Tree-ring dates, *Vernacular Architect*, **26**, 60–62 Part I (HBMC list). https://doi.org/10.1179/vea.1995.26.1.47

Pevsner, N, 1995 *Yorkshire: York and the East Riding* (Pevsner Architectural Guides: Buildings of England), London

Reimer, P J, Austin, W E N, Bard, E, Bayliss, A, Blackwell, P, Bronk Ramsey, C, Butzin, M, Cheng, H, Edwards, R L, Friedrich, M, Grootes, P M, Guilderson, T P, Hajdas, I, Heaton, T J, Hogg, A G, Hughen, K A, Kromer, B, Manning, S W, Muscheler, R, Palmer, J G, Pearson, C, van der Plicht, J, Reimer, R W, Richards, D A, Scott, E M, Southon, J R, Turney, C S M, Wacker, L, Adolphi, F, Büntgen, U, Capano, M, Fahrni, S, Fogtmann-Schultz, A, Friedrich, R, Kudsk, S, Miyake, F, Olsen, J, Reinig, F, Sakamoto, M, Sookdeo, A, and Talamo, S, 2020 The IntCal20 Northern Hemispheric radiocarbon calibration curve (0–55 kcal BP), *Radiocarbon*, **62,** 725–57. https://doi:10.1017/RDC.2020.41

Salehpour, M, Håkansson, K, Possnert, G, Wacker, L, and Synal, H-A, 2016 Performance report for the low energy compact accelerator mass spectrometer at Uppsala University, *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, **371**, 360−4. https://doi.org/10.1016/j.nimb.2015.10.034

Scott, E M, Naysmith, P, and Cook, G T, 2017 Should archaeologists care about 14C intercomparisons? Why? A summary report on SIRI, *Radiocarbon*, **59**, 1589–96. https://doi.org/10.1017/RDC.2017.12

Stuiver, M, and Polach, H A, 1977 Reporting of ^{14}C data, *Radiocarbon*, **19**, 355–63. https://doi.org/10.1017/S0033822200003672

Stuiver, M, and Reimer, P J, 1993 Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program, *Radiocarbon*, **35**, 215–30. https://doi.org/10.1017/S0033822200013904

Synal, H A, Stocker, M, and Suter, M, 2007 MICADAS: a new compact radiocarbon AMS system, *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, **259**, 7–13. https://doi.org/10.1016/j.nimb.2007.01.138

Wacker, L, Christl, M, and Synal, H A, 2010 Bats: A new tool for AMS data reduction, *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, **268**, 976–9. https://doi.org/10.1016/j.nimb.2009.10.078

Wacker, L, Scott, E M, Bayliss, A, Brown, D, Bard, E, Bollhalder, S, Friedrich, M, Capano, M, Cherkinsky, A, Chivall, D, Culleton, B J, Dee, M W, Friedrich, R, Hodgins, G W L, Hogg, A, Kennett, D J, Knowles, T D J, Kuitems, M, Lange, T E, Miyake, F, Nadeau, M-J, Nakamura, T, Naysmith, J P, Olsen, J, Omori, T, Petchey, F, Philippsen, B, Ramsey, C B, Prasad, G V R, Seiler, M, Southon, J, Staff, R, Tuna, T, 2020 Findings from an in-depth annual tree ring radiocarbon intercomparison, *Radiocarbon*, **62,** 873–82. https://doi:10.1017/RDC.2020.49

Wijma, S, Aerts, A T, van der Plicht, J, and Zondervan, A, 1996 The Groningen AMS facility, *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, **113**, 465–9. https://doi.org/10.1016/0168-583X(95)01420-9

YVBSG, 2016 *St Mary's Church, Beverley. Priests' Room and Annex*, unpubl rep

Table 1: Details of the samples taken from the Priests' Room and Annex, Church of St Mary, North Bar Within, Beverley

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date (AD)/*cal AD*	Last heartwood ring date (AD)/*cal AD*	Last measured ring date (AD)/*cal AD*
Priests' Room						
BEV-F01	Main beam 1	149	13	*1264–1273*	*1399–1408*	*1412–1421*
BEV-F02	Main beam 2	111	--	----	----	----
BEV-F03	Main beam 3	60	h/s	----	----	----
BEV-F04	South wallplate, bay 2	82	h/s	----	----	----
BEV-F05	Central longitudinal beam, bay 3	78	near h/s	----	----	----
BEV-F06	Central longitudinal beam, bay 4	144	h/s	*1256–1265*	*1399–1408*	*1399–1408*
BEV-F07	North rafter 3, bay 1	84	h/s	----	----	----
BEV-F08	North rafter 1, bay 2	NM	--	----	----	----
BEV-F09	North rafter 2, bay 2	73	--	----	----	----
BEV-F10	North rafter 3, bay 2	65	h/s	----	----	----
BEV-F11	South rafter 3, bay 2	58	--	----	----	----
BEV-F12	South rafter 2, bay 4	66	--	----	----	----
Annex						
BEV-F13	Beam 2	130	h/s	1191	1320	1320
BEV-F14	Beam 3	129	--	1205	----	1333
BEV-F15	Central longitudinal beam, bay 1–2	65	h/s	----	----	----
BEV-F16	Central block, bay 2	70	h/s	----	----	----
BEV-F17	West common rafter 2, bay 1	119	h/s	*1245–1254*	*1363–1372*	*1363–1372*
BEV-F18	East common rafter 1 (lower), bay 2	100	--	*1296–1305*	----	*1395–1404*

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date (AD)/*cal AD*	Last heartwood ring date (AD)/*cal AD*	Last measured ring date (AD)/*cal AD*
BEV-F19	East common rafter 1 (upper), bay 2	100	--	1608_{DR}	----	1707_{DR}
BEV-F20	East common rafter 2 (upper), bay 2	95	12	1637_{DR}	1719_{DR}	1731_{DR}

Table 2: Results of the cross-matching of site sequence BEVFSQ02 and the reference chronologies when the first-ring date is AD 1226 and the last-measured ring date is AD 1393

Site reference	*t* – value	Span of chronology	Reference
The Guildhall, Boston, Lincolnshire	7.2	1244–1380	Arnold *et al* 2008
15 Flemingate/The Guildhall, Beverley, Yorkshire	5.6	1245-1441	Arnold *et al* 2019b
St Andrew’s Church, Ford, West Sussex	5.0	1286–1511	Bridge 2000
St Mary’s Court, Beverley, Yorkshire	4.8	1173–1336	Arnold *et al* 2020b
Sandiacre Tithe Barn, Derbyshire	4.5	1147–1332	Howard 2004
Merchant Taylors’ Hall, York, Yorkshire	4.4	1240–1413	Howard *et al* 1992
Glenfield Well, Glenfield, Leicestershire	4.3	1182–1393	Howard *et al* 1985
64–72 Goodramgate, York, Yorkshire	4.2	1079–1315	Arnold and Howard 2012
Leicester’s Gatehouse, Kenilworth Castle, Leicestershire	4.1	1282–1374	Arnold and Howard 2007a
Charlton Court Barn, Steyning, West Sussex	4.0	1230–1405	Miles 1995
32 Goodramgate, York, Yorkshire	4.0	992–1298	Arnold and Howard 2012

Table 3: Results of the cross-matching of site sequence BEVFSQ04 and the reference chronologies when the first-ring date is AD 1608 and the last-measured ring date is AD 1731

Site reference	*t* – value	Span of chronology	Reference
Beverley Minster (Choir roof), East Riding of Yorkshire	5.2	1573–1736	Arnold *et al* 2020c
Robin Hood Hotel, Newark, Nottinghamshire	4.9	1616–1738	Arnold and Howard 2020
All Saints Church, Sancton, East Yorkshire	4.8	1620–1719	Bridge 2009
Potterdike House, Newark, Nottinghamshire	4.8	1603–1740	Arnold *et al* 2002
Stone House Prebend, Derbyshire	4.7	1640–1761	Arnold and Howard 2014
Church Farm, Hayton, Nottinghamshire	4.6	1622–1721	Arnold *et al* 2008
St Firmin Church, Thurlby, Lincolnshire	4.5	1599–1792	Arnold and Howard 2010
Middleton Hall, Warwickshire	4.5	1593–1718	Arnold *et al* 2006
Brampton Manor Barn, Chesterfield	4.5	1661–1740	Arnold *et al* 2016
Church of St Swithin (bellframe), Kirklington, Nottinghamshire	4.5	1567–1757	Arnold and Howard 2020
Trerithick House, Polyphant, Cornwall	4.4	1503–1673	Arnold and Howard 2007b

Table 4: Radiocarbon measurements and associated $\delta^{13}C$ values from oak sample BEV-F01 (BEVFSQ02)

Laboratory Number	Sample	Radiocarbon Age (BP)	$\delta^{13}C_{IRMS}$ (‰)
GrM-26070	BEV-F01, ring 33 (*Quercus* sp., heartwood)	656±17	−24.4±0.15
GrM-26071	BEV-F01, ring 34 (*Quercus* sp., heartwood)	672±17	−24.8±0.15
GrM-26072	BEV-F01, ring 35 (*Quercus* sp., heartwood)	670±17	−24.6±0.15
GrM-26073	BEV-F01, ring 36 (*Quercus* sp., heartwood)	648±17	−25.5±0.15
GrM-26074	BEV-F01, ring 37 (*Quercus* sp., heartwood)	644±15	−24.5±0.15
GrM-26077	BEV-F01, ring 38 (*Quercus* sp., heartwood)	613±17	−24.0±0.15
GrM-26078	BEV-F01, ring 100 (*Quercus* sp., heartwood)	680±17	−24.7±0.15
GrM-26079	BEV-F01, ring 131 (*Quercus* sp., heartwood)	591±17	−24.0±0.15

Table 5: Radiocarbon measurements and associated $\delta^{13}C$ values from oak sample BEV-F19 (BEVFSQ04)

Laboratory Number	Sample	Radiocarbon Age (BP)	$\delta^{13}C_{IRMS}$ (‰)
GrM-26066	BEV-F19, ring 23 (*Quercus* sp., heartwood)	339±17	−24.8±0.15
GrM-26067	BEV-F19, ring 37 (*Quercus* sp., heartwood)	289±17	−24.5±0.15
GrM-26068	BEV-F19, ring 57 (*Quercus* sp., heartwood)	200±17	−23.9±0.15

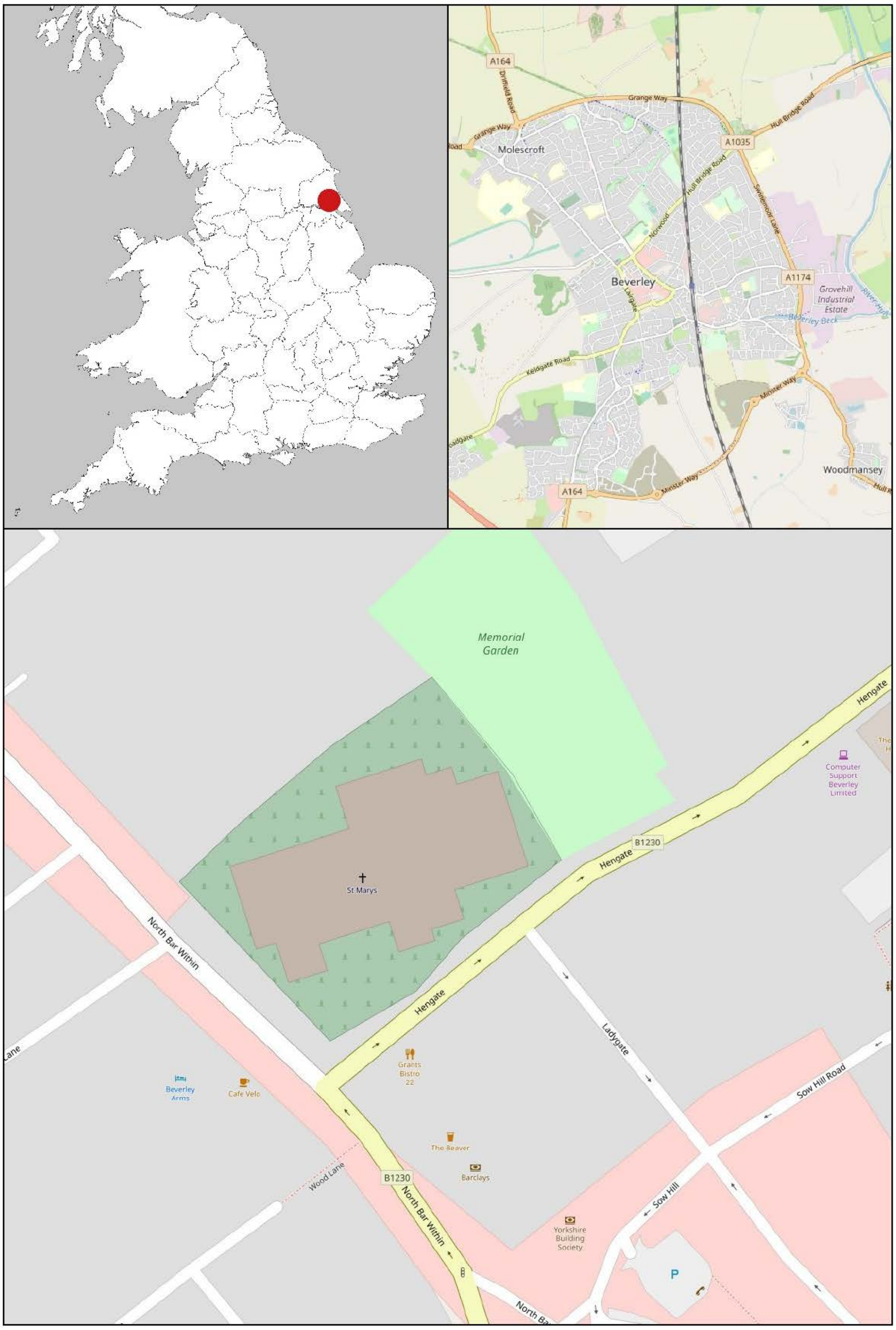

Figure 1: Maps to show the location of Beverley (red dot), and Church of St Mary. Scale: top right 1:25000; bottom 1:2000.

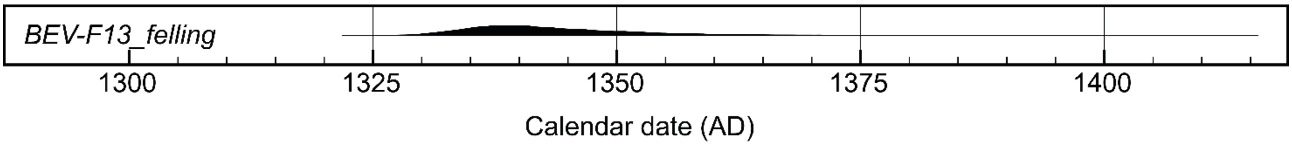

Figure 2: Probability distribution of the felling date for timber BEV-F13

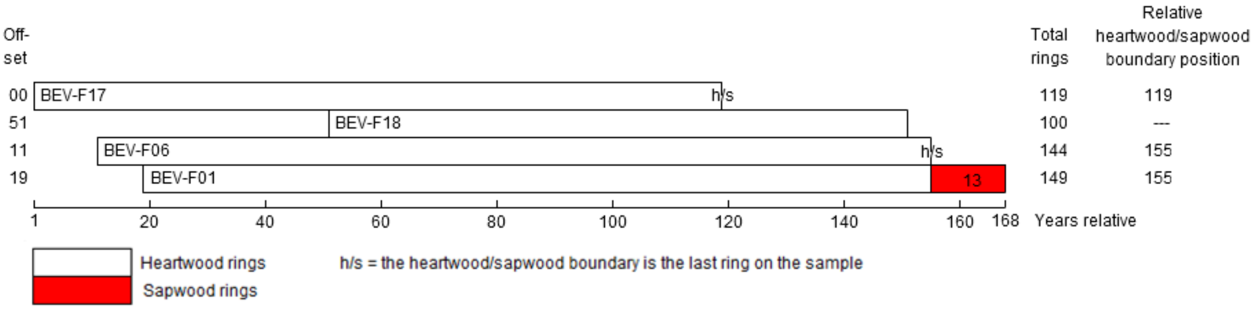

Figure 3: Bar diagram of samples in undated site sequence BEVFSQ02

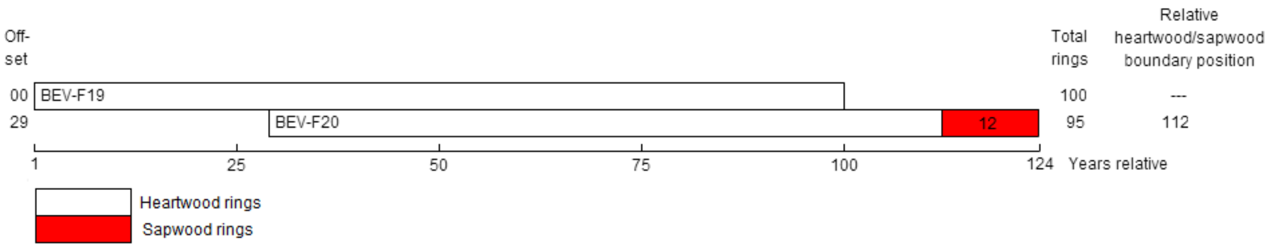

Figure 4: Bar diagram of samples in undated site sequence BEVFSQ04

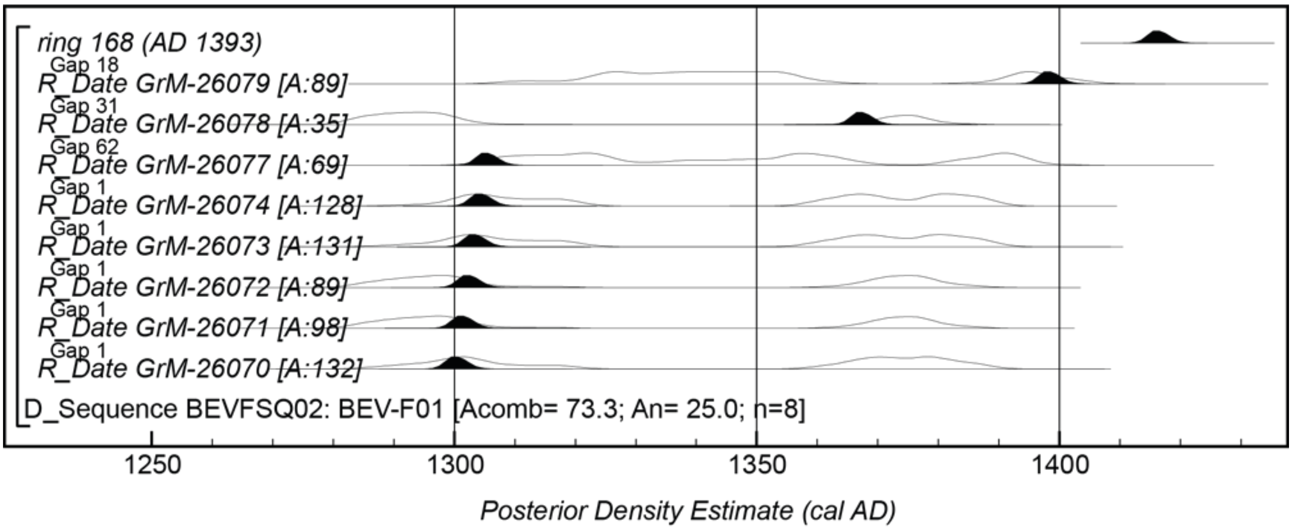

Figure 5: Probability distributions of dates from the undated site sequence BEVFSQ02. Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the simple radiocarbon calibration, and a solid one, based on the wiggle-match sequence. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly

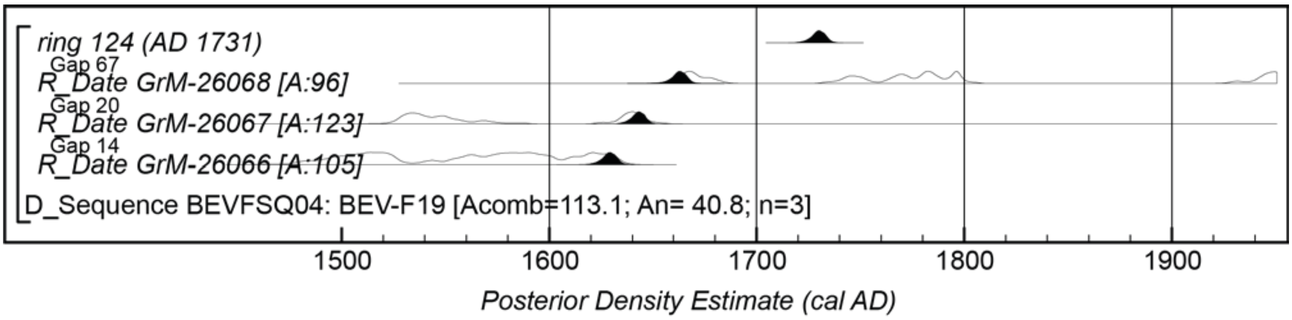

Figure 6: Probability distributions of dates from the undated site sequence BEVFSQ04. The format is identical to Figure 5

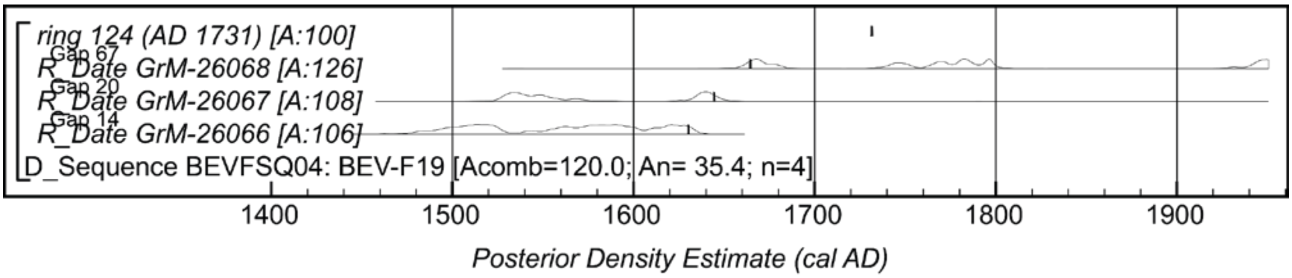

Figure 7: Probability distributions of dates from the undated site sequence BEVFSQ04, including the tree-ring date of AD 1731 for ring 124. The format is identical to Figure 5

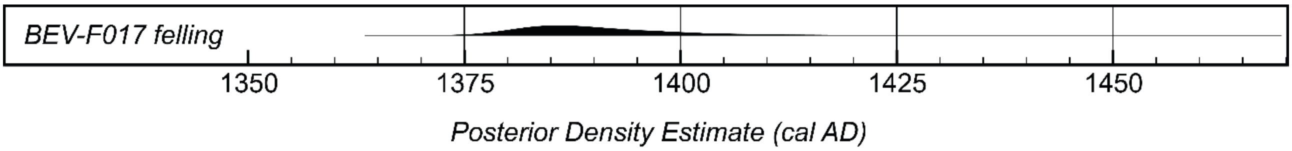

Figure 8: Probability distribution of the felling date for timber BEV-F17

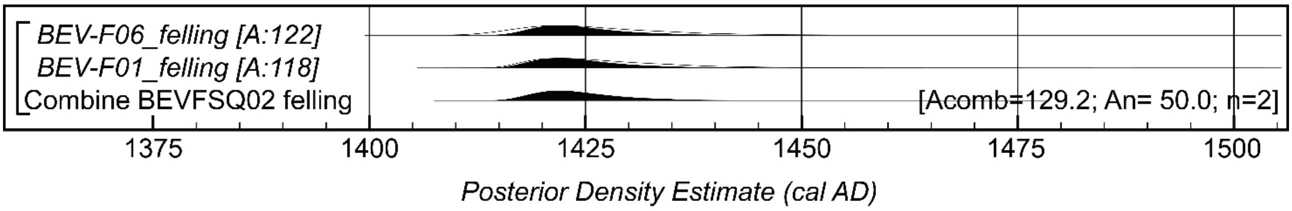

Figure 9: Combined probability distribution estimating the felling date of the timbers in site master sequence BEVFSQ02, if they are interpreted as representing a single felling event

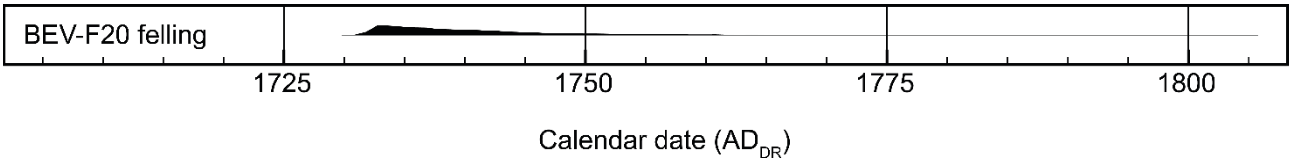

Figure 10: Probability distribution of the felling date for timber BEV-F20

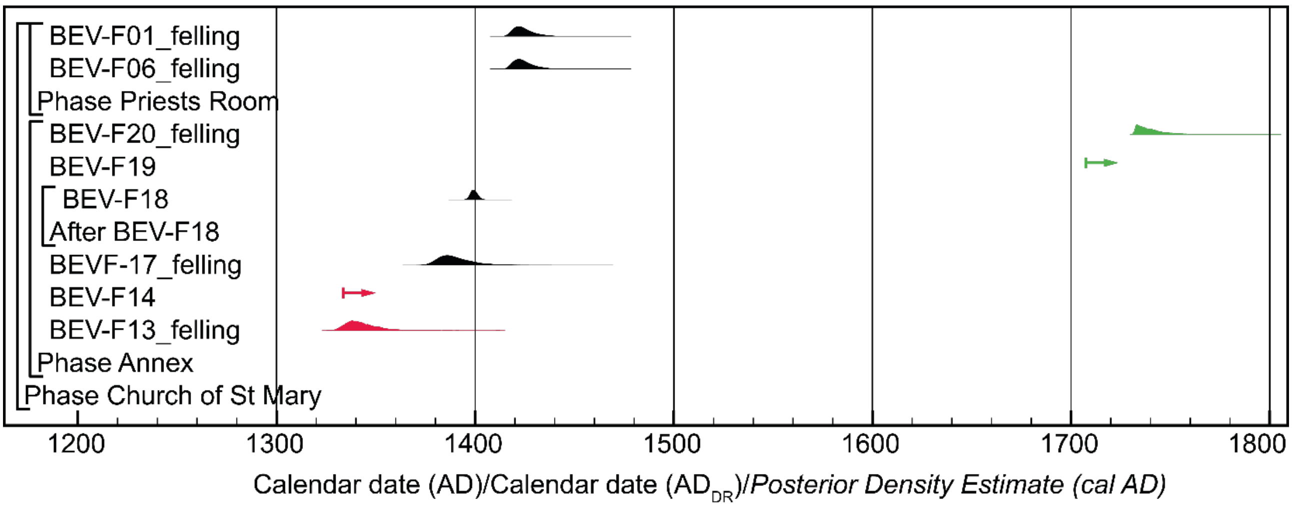

Figure 11: Summary of the scientific dating evidence from the Church of St Mary: red = ring-width dendrochronology, green= radiocarbon supported ring-width dendrochronology, black = radiocarbon dating. Arrows represent *termini post quo* dates

Historic England's Research Reports

We are the public body that helps people care for, enjoy and celebrate England's historic environment.

We carry out and fund applied research to support the protection and management of the historic environment. Our research programme is wide-ranging and both national and local in scope, with projects that highlight new discoveries and provide greater understanding, appreciation and enjoyment of our historic places.

More information on our research strategy and agenda is available at HistoricEngland.org.uk/research/agenda.

The Research Report Series replaces the former Centre for Archaeology Reports Series, the Archaeological Investigation Report Series, the Architectural Investigation Report Series, and the Research Department Report Series.

All reports are available at HistoricEngland.org.uk/research/results/reports. There are over 7,000 reports going back over 50 years. You can find out more about the scope of the Series here: HistoricEngland.org.uk/research/results/about-the-research-reports-database

Keep in touch with our research through our digital magazine *Historic England Research* HistoricEngland.org.uk/whats-new/research

ISSN 2398-3841 (Print)
ISSN 2059-4453 (Online)