RESEARCH REPORT SERIES no. 64-2014

MANOR FARM BARN, KINGSTON DEVERILL, WILTSHIRE
TREE-RING ANALYSIS OF TIMBERS

SCIENTIFIC DATING REPORT

Cathy Tyers, Matt Hurford, and Martin Bridge
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MANOR FARM BARN,
KINGSTON DEVERILL,
WILTSHIRE

TREE-RING ANALYSIS OF TIMBERS

Cathy Tyers, Matt Hurford, and Martin Bridge

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SUMMARY
Dendrochronological analysis was undertaken on 16 samples from the barn at Manor Farm. This resulted in the production of two site sequences, KDMBSQ01 and KDMBSQ02. The former comprises eight samples with an overall length of 150 rings and the latter two samples with an overall length of 81 rings. Site sequence KDMBSQ01 is dated as spanning the years AD 1260–1409. Site sequence KDMBSQ02 is undated. A single sample, KDM-B09, with an overall length of 113 rings is dated as spanning the years AD 1371–1483. Five samples remain ungrouped and undated.

The results indicate that the timbers used in the primary construction of the barn were probably all felled in the last few years of the first decade of the fifteenth century. A single dated arcade post from the southernmost truss indicates that the building underwent repairs or modifications just under a century later, in the last few years of the fifteenth century or, the first few years of the sixteenth century.

CONTRIBUTORS
Cathy Tyers, Matt Hurford, and Martin Bridge

ACKNOWLEDGEMENTS
The laboratories would like to thank Mr Stratton for giving permission to undertake the work. Thanks are also due to Avis Lloyd for arranging access and for supplying additional background material on the building. The drawings were provided by Nigel Fradgley of English Heritage. The dendrochronological work was funded by the English Heritage Scientific Dating Team and coordinated by Peter Marshall.

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INTRODUCTION

In 2009 the Wiltshire Buildings Record (WBR) successfully obtained support through the English Heritage Historic Environment Enabling Programme for their project ‘Wiltshire cruck buildings and other archaic roof types’. The detailed aims and objectives of the project are set out in the Project Design (Lloyd 2009). The overall aim was to establish a typological chronology of archaic roof types and hence elucidate the development of carpentry techniques in the county. This would then facilitate detailed comparison with other counties allowing Wiltshire to be placed in a regional context. Investigation of these late medieval buildings (c AD 1200 – c AD 1550) combined building survey, historical research, and dendrochronological analysis.

A series of 25 buildings identified by the WBR as having the potential to contribute to the aims and objectives of the project was assessed for dendrochronological suitability during 2009. In order to maximise the potential for dating, these detailed dendrochronological assessments and the WBR assessments of the significance of each building informed the final selection of buildings subsequently subjected to detailed study.

A single final Project Report produced by Lloyd (2012) summarises the overall results. However each building included in the project has an associated individual report produced by the WBR, whilst the primary archive of the dendrochronological analysis is the English Heritage Research Report Series.

A brief introduction to dendrochronology can be found in the Appendix. However further details can be found in the guidelines published by English Heritage (1998), which are also available on the English Heritage website (http://www.english-heritage.org.uk/publications/dendrochronology-guidelines/).

Manor Farm barn

Manor Farm is located on the south-east fringe of the village of Kingston Deverill to the south of the River Wylye and north of the B3095 (Fig 1). The Grade II* listed barn is situated in the western part of the farmyard and is on a broadly north-south axis (Fig 2). Stylistically the barn is thought to date to the early fifteenth century.

The following information is from the WBR report (2012) and the Listed Building Entry. The barn is approximately 28 metres long by 9 metres wide and comprises seven bays. Although the barn is clad in later wooden horizontal boards much of the original timber-framing survives (Figs 3, 4, and 5). The extant porch, or cart entrance, located on the east elevation is a later replacement of the original medieval entrance, probably of early eighteenth-century date and is itself flanked by nineteenth-century lean-to structures. The opposing west entrance is now blocked. The barn incorporates both base cruck trusses and post-and-aisle trusses, whilst the end bays were formerly partially hipped. The
consistency of the carpentry details throughout the main barn indicates that it was the product of a single phase of construction.

Trusses 4 and 5 are base crucks (Figs 4 and 6). On the east side of the barn, the feet of the cruck blades rest on chalk padstones, whilst on the west side they are embedded in the stone plinth. The blades rise to a wall plate and slightly cambered tiebeams. Arch braces rise from springings formed from the timber of the blades. There is a ridge purlin and a single row of purlins, and originally there were two tiers of windbraces, as there were throughout the barn.

Trusses 2, 3, 6, and 7 are post-and-aisle trusses. The arcade posts are set on padstones and are slightly jowled. Curved braces rise from the arcade posts to the tiebeam. Above this the arrangement of principals, purlins, collar, and ridge purlin are broadly the same as the base cruck trusses. An unusual feature of these trusses is that they utilise cruck timbers that rise from the aisle plinth to the arcade plate. These timbers have empty mortices which formerly housed a mid-rail that is no longer extant. Trusses 1 and 8 at either end of the barn are of similar construction but the tiebeams receive the hip timbers.

SAMPLING

Dendrochronological sampling and analysis of oak (*Quercus* spp) timbers associated with the barn at Manor Farm was commissioned by English Heritage. It was hoped to provide independent dating evidence for the initial construction of the barn and hence inform the overall objectives of the ‘Wiltshire cruck buildings and other archaic roof types’ project. The dendrochronological study also formed a key component of the English Heritage-funded training programme for the second author, although the reporting was not completed within the duration of the training programme.

Sampling, undertaken by trainee Matt Hurford and supervised by Martin Bridge, was restricted to tiebeam level or below, due to safety issues. The sampling undertaken encompassed as wide a range of elements at this lower level as possible, whilst focussing on those timbers with the best dendrochronological potential. Timbers rejected as containing too few growth rings for reliable analysis included three of the four cruck blades, which were noticeable for their extremely fast-grown nature with only the most promising one of these being sampled. During sampling it was also noted that many of the timbers above tiebeam level were of either borderline suitability or clearly unsuitable for reliable analysis.

A total of 16 oak timbers associated with the medieval timber-framing of the barn were sampled by coring. Each sample was given the code KDM-B (for Kingston Deverill, Manor Barn) and numbered 01–16. The location of the samples was noted at the time of coring and marked on the drawings provided by Nigel Fradgley, these being reproduced here as Figures 6 to 12. It should be noted that the trusses illustrated in Figures 7–12 are based on only a single representative of each main truss type and hence do not show any
variation within each truss type. Further details relating to the samples can be found in Table 1. In this table the timbers have been located and numbered following the scheme on the drawings provided.

ANALYSIS AND RESULTS

Each of the 16 samples obtained was prepared by sanding and polishing. The measurement and analysis was undertaken using a combination of software written by Tyers (2004a) and the Litton/Zainodin grouping procedure (see Appendix). Tyers (2004a) facilitates cross-matching and dating through a process of qualified statistical comparison and visual comparison. It uses a variant of the Belfast CROS programme (Baillie and Pilcher 1973).

The analysis resulted in two groups being formed, the samples of each group cross-matching with each other as shown in Tables 2 and 3 and Figures 13 and 14. The individual series in each group were combined to produce two site chronologies, KDMBSQ01 and KDMBSQ02. Both site chronologies were compared to an extensive range of reference chronologies for oak, this indicating repeated cross-matching for KDMBSQ01 when the date of its first ring is AD 1260 and the date of its last ring is AD 1409 (Table 4). No conclusive cross-matching was identified for KDMBSQ02, so this chronology remains undated.

The two site chronologies were compared with the remaining six ungrouped samples but there was no further satisfactory cross-matching. Each of these ungrouped samples was then compared individually with the reference chronologies, this indicating repeated cross-matching for KDM-B09 when it spanned AD 1371–1483 (Table 5).

The analysis can be summarised as follows:

<table>
<thead>
<tr>
<th>Site chronology/sample</th>
<th>Number of samples</th>
<th>Number of rings</th>
<th>Date span (where dated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KDMBSQ01</td>
<td>8</td>
<td>150</td>
<td>AD 1260–1409</td>
</tr>
<tr>
<td>KDMBSQ02</td>
<td>2</td>
<td>81</td>
<td>undated</td>
</tr>
<tr>
<td>KDM-B09</td>
<td>1</td>
<td>113</td>
<td>AD 1371–1483</td>
</tr>
<tr>
<td>KDM-B07, KDM-B10, KDM-B14–16</td>
<td>5</td>
<td>---</td>
<td>undated</td>
</tr>
</tbody>
</table>

INTERPRETATION

Two of the samples in site chronology KDMBSQ01 had retained a full complement of sapwood (Fig 13). Sample KDM-B11 appears to have a complete ring for AD 1409, thus suggesting that it was felled during the winter of AD 1409/10. However the highly variable growth (see below) combined with only fragmentary survival of the outer edge of sample KDM-B08 means that it is difficult to determine the season of felling. The outermost ring
of KDM-B08 has spring vessels and some summer growth and hence could have been felled as early as summer AD 1408 or as late as early spring AD 1409.

A further three samples in site chronology KDMBSQ01 were taken at a point where bark edge did survive on the timbers but due to the fragile nature of the sapwood this did not survive coring intact (Fig 13). The amount of sapwood lost was in each case estimated in millimetres in order to allow an approximate felling date to be calculated. This estimate is based on the overall average ring width of the relevant sample rather than that of the outer few rings as in this instance the material shows highly variable growth patterns with no overall marked decrease in growth with age. It is therefore estimated that KDM-B03 was felled c AD 1408, KDM-B04 was felled c AD 1407, and KDM-B06 was felled c AD 1408.

Two of the three remaining samples in site chronology KDMBSQ01 have retained their heartwood/sapwood boundary ring (Fig 13), the average date for this being AD 1380. For consistency the sapwood estimate used in all of the dendrochronological reports on individual buildings within this project is the Nottingham Tree-ring Dating Laboratory estimate of 15–40 (95% confidence rings). This is used to calculate felling date ranges for samples with incomplete sapwood or felled-after dates for samples which are heartwood only. Thus an estimated felling date range of AD 1395–1420 is obtained for these two timbers. The remaining sample has no trace of sapwood thus, by applying the above sapwood estimate, the earliest likely felling date is AD 1371.

All of the dated samples in site chronology KDMBSQ01 are broadly coeval and appear likely to represent a single programme of felling in the latter years of the first decade of the fifteenth century.

Site sequence KDMBSQ02 could not be dated. However, the position of the heartwood/sapwood boundary ring on each sample is within five years (Fig 14) suggesting that they were likely to be part of the same programme of felling.

The individually dated sample, KDM-B09, was also taken at a point where the bark edge did survive on the timber but due to the fragile nature of the sapwood this did not survive coring intact (Fig 13). The sapwood lost comprises a segment containing eight rings plus a further c 5mm. This, therefore, accounts for a total of c 13 lost sapwood rings. However, it is possible that a small number of rings were lost at the break between the main core and the sapwood segment. Hence, an estimated felling date of c AD 1496–1505 is obtained.

**DISCUSSION AND CONCLUSION**

Tree-ring analysis of the samples from the barn at Manor Farm has demonstrated that all but one of the nine dated timbers were probably felled in the latter few years of the first decade of the fifteenth century with construction therefore likely to have occurred at around the turn of that decade. This therefore supports the early fifteenth-century date
indicated on stylistic evidence. Only one timber, a tiebeam, from the base-cruck trusses was dated, but this does demonstrate that the base cruck trusses are likely to be coeval with the post-and-aisle trusses. It is unfortunate that none of the cruck blades from the central two trusses could be dated. However the sampled cruck blade serves to demonstrate the different nature of the timbers employed as cruck blades compared with the rest of the sampled timbers. KDM-B10 contained only 46 rings and yet with an average ring width of 6.98mm was one of the largest timbers found in the barn, with only the other cruck blades showing similar characteristics with respect to size and rate of growth. The trees capable of providing such cruck blades may well have been selected from a slightly different source than the rest of the timbers, one with a more open canopy such as towards the edge of woodland or parkland or hedgerow environments. However, the dendrochronological results combined with the integral nature of the overall structure strongly imply that the barn was the product of a single phase of construction.

A single timber, the east arcade post of truss 8, has been identified as being felled approximately a century later. This may simply be a single replacement timber, but it could represent more widespread alterations to the south end of the barn. Reappraisal of the structural evidence for intervention at this end of the barn may provide clarification.

The undated site sequence KDMBSQ02 comprises the two arcade posts from truss 1 at the north end of the barn. Whilst these are clearly coeval with each other it is not possible to ascertain from the dendrochronological analysis whether they are part of the initial construction of the barn or whether they also represent later alterations. Their overall characteristics are not obviously different from the primary construction material so it may simply be that they are derived from a slightly different woodland source to the dated material rather than being of a different date. Again reassessment of the structural evidence for any potential anomalies may lead to further clarification.

Site chronology KDMBSQ01 and the individually dated sample generally produce the highest t-values, and thus show the greatest degree of similarity, with reference chronologies from the surrounding region (Tables 4 and 5). This suggests that it is likely that the timbers were derived from relatively local woodland sources.

Five samples remain ungrouped and undated. Two of these samples, KDM-B07 and KDM-B15 have no obvious growth abnormalities which would hamper successful cross-matching and dating. However, the remaining samples, along with those in site sequence KDMBSQ02, do show highly variable growth patterns, including abrupt declines and surges in growth rate. Overall, the sampled assemblage does show a wide range in level of sensitivity (a measure of the year-to-year variation in ring width) for oak timbers ranging from 0.14 (KDM-B15) to 0.30 (KDM-B14) indicating a level of disturbance to growth within the assemblage that will have an adverse effect on both cross-matching and dating. The possible causes of growth disturbances include anthropogenic, local environmental, and general environmental effects. Causal factors include management regimes or at least some form of human intervention, such as pollarding or shredding,
localised defoliation by pests, or more general environmental effects such as severe weather conditions (eg drought and late frosts). Unfortunately no definitive answer can be provided from the tree-ring analysis.
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Wiltshire Buildings Record 2012 Manor Farm barn, Kingston Deverill, WBR report, B7334.1
### Table 1: Details of tree-ring samples from Manor Farm barn, Kingston Deverill, Wiltshire

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Sample location</th>
<th>Total rings</th>
<th>Sapwood rings</th>
<th>Average ring width (mm)</th>
<th>Cross-section dimensions (mm)</th>
<th>First measured ring date (AD)</th>
<th>Last heartwood ring date (AD)</th>
<th>Last measured ring date (AD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KDM-B01</td>
<td>Truss 1 west arcade post</td>
<td>67</td>
<td>6</td>
<td>1.56</td>
<td>200x350</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>KDM-B02</td>
<td>Truss 1 east arcade post</td>
<td>81</td>
<td>5</td>
<td>2.33</td>
<td>190x330</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>KDM-B03</td>
<td>Truss 2 east wall cruck post</td>
<td>109</td>
<td>13c (c 15mm sap lost)</td>
<td>2.03</td>
<td>190x260</td>
<td>1293</td>
<td>1388</td>
<td>1401</td>
</tr>
<tr>
<td>KDM-B04</td>
<td>Truss 2 west arcade post</td>
<td>120</td>
<td>8c (c 15mm sap lost)</td>
<td>1.48</td>
<td>330x330</td>
<td>1278</td>
<td>1389</td>
<td>1397</td>
</tr>
<tr>
<td>KDM-B05</td>
<td>Truss 3 west arcade post</td>
<td>122</td>
<td>h/s</td>
<td>1.95</td>
<td>300x300</td>
<td>1260</td>
<td>1381</td>
<td>1381</td>
</tr>
<tr>
<td>KDM-B06</td>
<td>Truss 6 east wall cruck post</td>
<td>64</td>
<td>11c (c 5mm sap lost)</td>
<td>2.25</td>
<td>190x260</td>
<td>1343</td>
<td>1395</td>
<td>1406</td>
</tr>
<tr>
<td>KDM-B07</td>
<td>Truss 6 west arcade post</td>
<td>61</td>
<td>h/s</td>
<td>2.00</td>
<td>310x330</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>KDM-B08</td>
<td>Truss 7 east arcade post</td>
<td>108</td>
<td>16c</td>
<td>1.83</td>
<td>310x320</td>
<td>1301</td>
<td>1392</td>
<td>1408</td>
</tr>
<tr>
<td>KDM-B09</td>
<td>Truss 8 east arcade post</td>
<td>113</td>
<td>h/sc (c 8 unmeasured sap rings and c 5mm sap lost)</td>
<td>1.08</td>
<td>160x270</td>
<td>1371</td>
<td>1483</td>
<td>1483</td>
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<tr>
<td>KDM-B10</td>
<td>Truss 4 west cruck</td>
<td>46</td>
<td>h/s</td>
<td>6.98</td>
<td>310x370</td>
<td>----</td>
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<tr>
<td>KDM-B11</td>
<td>Bay 5 east arcade plate</td>
<td>126</td>
<td>31C</td>
<td>1.43</td>
<td>220x250</td>
<td>1284</td>
<td>1378</td>
<td>1409</td>
</tr>
<tr>
<td>KDM-B12</td>
<td>Truss 5 tiebeam</td>
<td>57</td>
<td>no h/s</td>
<td>2.19</td>
<td>250x310</td>
<td>1305</td>
<td>----</td>
<td>1361</td>
</tr>
<tr>
<td>KDM-B13</td>
<td>Truss 3 tiebeam</td>
<td>84</td>
<td>h/s</td>
<td>1.68</td>
<td>250x310</td>
<td>1296</td>
<td>1379</td>
<td>1379</td>
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<tr>
<td>KDM-B14</td>
<td>Bay 3 brace from truss 3 east arcade post to arcade plate</td>
<td>67</td>
<td>h/s</td>
<td>1.41</td>
<td>210x210</td>
<td>----</td>
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<tr>
<td>KDM-B15</td>
<td>Bay 3 east arcade plate</td>
<td>51</td>
<td>h/s</td>
<td>2.67</td>
<td>210x260</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>KDM-B16</td>
<td>Truss 4 east arch brace from cruck to tiebeam</td>
<td>86</td>
<td>h/s</td>
<td>2.51</td>
<td>140x270</td>
<td>----</td>
<td>----</td>
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</tr>
</tbody>
</table>

h/s = the heartwood/sapwood ring is the last ring on the sample  
c = complete sapwood was present on the timber but a portion of the sapwood was lost during coring  
C = complete sapwood is retained on the sample  
1 = felling season indeterminate  
2 = outermost measured ring appears to be fully formed indicating winter felling
### Table 2: Matrix showing the t-values obtained between the ring sequences in site chronology KDMBSQ01; - indicates t-values less than 3.00; \ indicates overlap of less than 30 years

<table>
<thead>
<tr>
<th></th>
<th>kdm-b03</th>
<th>kdm-b04</th>
<th>kdm-b05</th>
<th>kdm-b06</th>
<th>kdm-b08</th>
<th>kdm-b11</th>
<th>kdm-b12</th>
<th>kdm-b13</th>
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<tbody>
<tr>
<td>kdm-b03</td>
<td>4.80</td>
<td>3.73</td>
<td>-</td>
<td>5.85</td>
<td>3.33</td>
<td>4.30</td>
<td>-</td>
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<td>kdm-b04</td>
<td>4.17</td>
<td>-</td>
<td>5.61</td>
<td>6.70</td>
<td>5.17</td>
<td>4.81</td>
<td></td>
<td></td>
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<tr>
<td>kdm-b05</td>
<td>-</td>
<td>3.69</td>
<td>-</td>
<td>4.52</td>
<td>3.45</td>
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<td>kdm-b06</td>
<td>7.60</td>
<td>3.16</td>
<td>\</td>
<td>-</td>
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<tr>
<td>kdm-b08</td>
<td>3.05</td>
<td>8.00</td>
<td>3.96</td>
<td>3.37</td>
<td>-</td>
<td></td>
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<tr>
<td>kdm-b11</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>3.53</td>
</tr>
</tbody>
</table>

### Table 3: Matrix showing the t-value obtained between the ring sequences in site chronology KDMBSQ02

<table>
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<tr>
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<th>kdm-b02</th>
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</tbody>
</table>
Table 4: Results of the cross-matching of site sequence KDMBSQ01 and relevant reference chronologies when the first-ring date is AD 1260 and the last-ring date is AD 1409

<table>
<thead>
<tr>
<th>Reference chronology</th>
<th>t-value</th>
<th>Span of chronology</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Devizes Castle, Devizes, Wiltshire</td>
<td>8.6</td>
<td>AD 1213–1407</td>
<td>Miles et al 2006</td>
</tr>
<tr>
<td>Old Rectory, Withington, Gloucestershire</td>
<td>6.6</td>
<td>AD 1252–1429</td>
<td>Howard et al 1998</td>
</tr>
<tr>
<td>Lodge Farm, Kingston Lacy, Dorset</td>
<td>6.4</td>
<td>AD 1248–1399</td>
<td>Groves 1994</td>
</tr>
<tr>
<td>Winchcombe Abbey House, Winchcombe, Glouces</td>
<td>6.2</td>
<td>AD 1250–1499</td>
<td>Arnold et al 2008a</td>
</tr>
<tr>
<td>Lacock Abbey, Lacock, Wiltshire</td>
<td>6.2</td>
<td>AD 1292–1441</td>
<td>Ellis et al 1990</td>
</tr>
<tr>
<td>George Inn, Norton St Philip, Somerset</td>
<td>6.2</td>
<td>AD 1258–1457</td>
<td>Miles and Worthington 1998</td>
</tr>
<tr>
<td>St Brannock Church, Braunton, Devon</td>
<td>6.2</td>
<td>AD 1215–1378</td>
<td>Tyers 2004b</td>
</tr>
<tr>
<td>Old Manor, West Lavington, Wiltshire</td>
<td>6.1</td>
<td>AD 1264–1497</td>
<td>Tyers and Hurford 2014</td>
</tr>
</tbody>
</table>

Table 5: Results of the cross-matching of sample KDM-B09 and relevant reference chronologies when the first-ring date is AD 1371 and the last-ring date is AD 1483

<table>
<thead>
<tr>
<th>Reference chronology</th>
<th>t-value</th>
<th>Span of chronology</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bremhill Farm barn, Bremhill, Wiltshire</td>
<td>6.9</td>
<td>AD 1353–1484</td>
<td>Alcock et al 1991</td>
</tr>
<tr>
<td>George Inn, Norton St Philip, Somerset</td>
<td>6.5</td>
<td>AD 1290–1509</td>
<td>Miles and Worthington 1998</td>
</tr>
<tr>
<td>Chawton House, Chawton, Alton, Hampshire</td>
<td>6.5</td>
<td>AD 1289–1589</td>
<td>Miles and Worthington 2002</td>
</tr>
<tr>
<td>Abbots Lodge, Ledbury, Herefordshire</td>
<td>6.3</td>
<td>AD 1274–1519</td>
<td>Arnold et al 2008b</td>
</tr>
<tr>
<td>Old Manor, West Lavington, Wiltshire</td>
<td>6.2</td>
<td>AD 1264–1497</td>
<td>Tyers and Hurford 2014</td>
</tr>
<tr>
<td>Roscarrock, near Port Isaac, Cornwall</td>
<td>6.2</td>
<td>AD 1373–1500</td>
<td>Tyers 2004c</td>
</tr>
<tr>
<td>Old Post Office, Luccombe, Somerset</td>
<td>6.1</td>
<td>AD 1380–1436</td>
<td>Miles et al 2003</td>
</tr>
<tr>
<td>Holy Cross Church, Crediton, Devon</td>
<td>5.9</td>
<td>AD 1317–1536</td>
<td>Tyers 2004d</td>
</tr>
</tbody>
</table>
FIGURES

Figure 1: Map to show the location of Kingston Deverill, Wiltshire. © Crown Copyright and database right 2014. All rights reserved. Ordnance Survey Licence number 100024900

Figure 2: Map to show the location of the barn within the farmyard at Manor Farm, Kingston Deverill. © Crown Copyright and database right 2014. All rights reserved. Ordnance Survey Licence number 100024900
Figure 3: General view of the barn viewed looking north-west (photo Matt Hurford)

Figure 4: Truss 5 viewed looking south-west (photo Matt Hurford)
Figure 5: General view through the barn stood at Truss 2 viewed looking north (photo Matt Hurford)
Figure 6: Plan showing the truss numbering scheme and the location of the samples (based on a drawing by P Filtness)
Figure 7: Truss 2 sample locations viewed looking north (based on a drawing by Nigel Fradgley of English Heritage)

Figure 8: Truss 3 sample locations viewed looking north (based on a drawing by Nigel Fradgley of English Heritage)
Figure 9: Truss 4 sample locations viewed looking north (based on a drawing by Nigel Fradgley of English Heritage)

Figure 10: Truss 5 sample locations viewed looking (based on a drawing by Nigel Fradgley of English Heritage)
Figure 11: Truss 6 sample locations viewed looking north (based on a drawing by Nigel Fradgley of English Heritage)

Figure 12: Truss 7 sample locations viewed looking north (based on a drawing by Nigel Fradgley of English Heritage)
White bars = heartwood rings
hatched bars = estimated lost sapwood rings
Filled bars = measured sapwood rings
lined bars = extant unmeasured sapwood rings
h/s = the last ring on the sample is at the heartwood/sapwood boundary
C = complete sapwood is retained on the sample
c = complete sapwood exists on the timber but part of the sapwood has been lost from the sample in coring

Figure 13: Bar diagram of samples in site chronology KDMBSQ01 and sample KDM-B09
Figure 14: Bar diagram of samples in site chronology KDMBSQ02
DATA OF MEASURED SAMPLES

Measurements in 0.01 mm units

KDM-B01A 67
133 146 203 267 342 226 378 290  88  96 130 100 207 143  77  99  95 120 194 157
101 110  88 171 128 121  93 100 145 131 161 279 282 250 162 168 229 156 144 139
139 108 101 95 110 199 172 174 175 153 142 116 162 204 204 167 124 140 103
134  96 167 107 164 115 148

KDM-B01B 67
139 141 208 264 342 221 381 278  90  91 131  96 181 143  76  97 100 122 190 151
91 113  84 168 129 109  92 104 141 128 174 284 281 253 167 164 232 158 152 137
146  99 110  90 105 137 200 169 179 174 155 138 120 166 198 205 157 124 137 100
140  95 166  94 162 122 141

KDM-B02A 81
75  44  57  66 133 105 213 140 186 139 145 209 292 305 200 326 366 183 107
120 125 210 199 119  89 107 149 204 262 179 366 306 383 357 336 206 124 167 164
210 380 408 354 272 281 496 472 336 272 250 210 297 189 253 253 275 296 390 343
345 212 224 333 433 436 315 200 169 179 174 155 138 120 166 198 205 157 124 137 100
140  95 166  94 162 122 141

KDM-B02B 81
64  52  51  71 101 209 140 179 130 138 203 277 296 194 324 335 173 101
120 126 200 187 126  88  98 133 211 244 172 359 309 363 332 308 126 159 161
205 381 396 345 279 267 507 467 345 271 257 301 194 250 253 274 300 390 350
335 210 225 332 434 436 315 188 151 115 167 104 167 105 200 134 220 302 333 365
375 386

KDM-B03A 109
504 575 491 466 366 295 222 305 423 354 129 107 174 213 276 226 207 196 134 210
253 237 370 419 381 234 148 139 130 179 205 164 149 169 242 230 324 194 152 160
262 244 272 358 169 270 203 192 197 193 219 243 207 162 140 122 252 306 349 154
162 111 112 134 138  83  88 97 147 184 248 201 190 101 126 197 97 105 65 111
119 103 138 152 163 159 199 175 209 149 173 117 145 190 171 189 281 224 114 198
165 123 100 149 158 160 121 115 171

KDM-B03B 109
504 572 490 469 364 298 224 327 407 354 131 116 166 208 282 226 187 192 137 198
251 222 372 414 397 221 142 141 147 177 206 164 153 175 241 232 327 197 157 166
268 250 277 357 191 273 200 194 196 191 218 240 211 158 141 127 253 306 363 145
157 116 111 130 140  80  94  95 151 167 257 195 205 102 109 206  90 112  73 109
102 112 142 162 161 156 211 173 201 153 167 117 147 182 171 189 279 211 113 184
163 115 102 151 154 165 121 122 169

KDM-B04A 120
226 294 224 210 176 234 239 195 157 105 105 145 151 167 164 199 193 266 214 321 299
172 236 262 250 237 183 132 115 141 181 154 141 114 141 117 129 82  71 104 133
84  90  59 120 179 99  78 105 103 125 104  54  41  48  70  82  74  97  76
86 133  95  89 101  86 144 160 90  78  86 111 123 190 151 142 138 139 166 133
135 119 131 201 146 227 197 133 105 155 203 195 230 140 142 129  87 124  76 110
119 118 174 170 170 189 232 272 257 175 233 153 127 167 162 163 121 117 153 132
APPENDIX: TREE-RING DATING

The Principles of Tree-Ring Dating

Tree-ring dating, or dendrochronology as it is known, is discussed in some detail in the Nottingham Tree-ring Dating Laboratory’s Monograph, An East Midlands Master Tree-Ring Chronology and its uses for dating Vernacular Building (Laxton and Litton 1988) and Dendrochronology: Guidelines on Producing and Interpreting Dendrochronological Dates (English Heritage 1998). Here we will give the bare outlines. Each year an oak tree grows an extra ring on the outside of its trunk and all its branches just inside its bark. The width of this annual ring depends largely on the weather during the growing season, about April to October, and possibly also on the weather during the previous year. Good growing seasons give rise to relatively wide rings, poor ones to very narrow rings and average ones to relatively average ring widths. Since the climate is so variable from year to year, almost random-like, the widths of these rings will also appear random-like in sequence, reflecting the seasons. This is illustrated in Figure A1 where, for example, the widest rings appear at irregular intervals. This is the key to dating by tree rings, or rather, by their widths. Records of the average ring widths for oaks, one for each year for the last 1000 years or more, are available for different areas. These are called master chronologies. Because of the random-like nature of these sequences of widths, there is usually only one position at which a sequence of ring widths from a sample of oak timber with at least 70 rings will match a master. This will date the timber and, in particular, the last ring.

If the bark is still on the sample, as in Figure A1, then the date of the last ring will be the date of felling of the oak from which it was cut. There is much evidence that in medieval times oaks cut down for building purposes were used almost immediately, usually within the year or so (Rackham 1976). Hence if bark is present on several main timbers in a building, none of which appear reused or are later insertions, and if they all have the same date for their last ring, then we can be quite confident that this is the date of construction or soon after. If there is no bark on the sample, then we have to make an estimate of the felling date; how this is done is explained below.

The Practice of Tree-Ring Dating at the Nottingham Tree-Ring Dating Laboratory

1. Inspecting the Building and Sampling the Timbers. Together with a building historian the timbers in a building are inspected to try to ensure that those sampled are not reused or later insertions. Sampling is almost always done by coring into the timber, which has the great advantage that we can sample in situ timbers and those judged best to give the date of construction, or phase of construction if there is more than one in the building. The timbers to be sampled are also inspected to see how many rings they have. We normally look for timbers with at least 70 rings, and preferably more. With fewer
rings than this, 50 for example, sequences of widths become difficult to match to a unique position within a master sequence of ring widths and so are difficult to date (Litton and Zainodin 1991). The cross-section of the rafter shown in Figure A2 has about 120 rings; about 20 of which are sapwood rings – the lighter rings on the outside. Similarly the core has just over 100 rings with a few sapwood rings.

To ensure that we are getting the date of the building as a whole, or the whole of a phase of construction if there is more than one, about 8–10 samples per phase are usually taken. Sometimes we take many more, especially if the construction is complicated. One reason for taking so many samples is that, in general, some will fail to give a date. There may be many reasons why a particular sequence of ring widths from a sample of timber fails to give a date even though others from the same building do. For example, a particular tree may have grown in an odd ecological niche, so odd indeed that the widths of its rings were determined by factors other than the local climate! In such circumstances it will be impossible to date a timber from this tree using the master sequence whose widths, we can assume, were predominantly determined by the local climate at the time.

Sampling is done by coring into the timber with a hollow corer attached to an electric drill and usually from its outer rings inwards towards where the centre of the tree, the pith, is judged to be. An illustration of a core is shown in Figure A2; it is about 150mm long and 10mm diameter. Great care has to be taken to ensure that as few as possible of the outer rings are lost in coring. This can be difficult as these outer rings are often very soft (see below on sapwood). Each sample is given a code which identifies uniquely which timber it comes from, which building it is from and where the building is located. For example, CRO-A06 is the sixth core taken from the first building (A) sampled by the Laboratory in Cropwell Bishop. Where it came from in that building will be shown in the sampling records and drawings. No structural damage is done to any timbers by coring, nor does it weaken them.

During the initial inspection of the building and its timbers the dendrochronologist may come to the conclusion that, as far as can be judged, none of the timbers have sufficient rings in them for dating purposes and may advise against sampling to save further unwarranted expense.

All sampling by the Laboratory is undertaken according to current Health and Safety Standards. The Laboratory’s dendrochronologists are insured.
Figure A1: A wedge of oak from a tree felled in 1976. It shows the annual growth rings, one for each year from the innermost ring to the last ring on the outside just inside the bark. The year of each ring can be determined by counting back from the outside ring, which grew in 1976.
Figure A2: Cross-section of a rafter, showing sapwood rings in the left-hand corner, the arrow points to the heartwood/sapwood boundary (H/S); and a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil.

Figure A3: Measuring ring widths under a microscope. The microscope is fixed while the sample is on a moving platform. The total sequence of widths is measured twice to ensure that an error has not been made. This type of apparatus is needed to process a large number of samples on a regular basis.
Figure A4: Three cores from timbers in a building. They come from trees growing at the same time. Notice that, although the sequences of widths look similar, they are not identical. This is typical.
2. **Measuring Ring Widths.** Each core is sanded down with a belt sander using medium-grit paper and then finished by hand with flour-grade-grit paper. The rings are then clearly visible and differentiated from each other with a result very much like that shown in Figure A2. The core is then mounted on a movable table below a microscope and the ring-widths measured individually from the innermost ring to the outermost. The widths are automatically recorded in a computer file as they are measured (see Fig A3).

3. **Cross-Matching and Dating the Samples.** Because of the factors besides the local climate which may determine the annual widths of a tree’s rings, no two sequences of ring widths from different oaks growing at the same time are exactly alike (Fig A4). Indeed, the sequences may not be exactly alike even when the trees are growing near to each other. Consequently, in the Laboratory we do not attempt to match two sequences of ring widths by eye, or graphically, or by any other subjective method. Instead, it is done objectively (ie statistically) on a computer by a process called cross-matching. The output from the computer tells us the extent of correlation between two sample sequences of widths or, if we are dating, between a sample sequence of widths and the master, at each relative position of one to the other (offsets). The extent of the correlation at an offset is determined by the $t$-value (defined in almost any introductory book on statistics). That offset with the maximum $t$-value among the $t$-values at all the offsets will be the best candidate for dating one sequence relative to the other. If one of these is a master chronology, then this will date the other. Experiments carried out in the past with sequences from oaks of known date suggest that a $t$-value of at least 4.5, and preferably at least 5.0, is usually adequate for the dating to be accepted with reasonable confidence (Laxton and Litton 1988; Laxton *et al* 1988; Howard *et al* 1984–1995).

This is illustrated in Figure A5 with timbers from one of the roofs of Lincoln Cathedral. Here four sequences of ring widths, LIN-C04, 05, 08, and 45, have been cross-matched with each other. The ring widths themselves have been omitted in the bar diagram, as is usual, but the offsets at which they best cross-match each other are shown; eg the sequence of ring widths of C08 matches the sequence of ring widths of C45 best when it is at a position starting 20 rings after the first ring of C45, and similarly for the others. The actual $t$-values between the four at these offsets of best correlations are in the matrix. Thus at the offset of +20 rings, the $t$-value between C45 and C08 is 5.6 and is the maximum found between these two among all the positions of one sequence relative to the other.

It is standard practice in our Laboratory first to cross-match as many as possible of the ring-width sequences of the samples in a building and then to form an average from them. This average is called a site sequence of the building being dated and is illustrated in Figure A5. The fifth bar at the bottom is a site sequence for a roof at Lincoln Cathedral and is constructed from the matching sequences of the four timbers. The site sequence width for each year is the average of the widths in each of the sample sequences which has a width for that year. Thus in Fig A5 if the widths shown are 0.8mm for C45, 0.2mm for C08, 0.7mm for C05, and 0.3mm for C04, then the corresponding width of the site
sequence is the average of these, 0.55mm. The actual sequence of widths of this site sequence is stored on the computer. The reason for creating site sequences is that it is usually easier to date an average sequence of ring widths with a master sequence than it is to date the individual component sample sequences separately.

The straightforward method of cross-matching several sample sequences with each other one at a time is called the ‘maximal t-value’ method. The actual method of cross-matching a group of sequences of ring-widths used in the Laboratory involves grouping and averaging the ring-width sequences and is called the ‘Litton-Zainodin Grouping Procedure’. It is a modification of the straightforward method and was successfully developed and tested in the Laboratory and has been published (Litton and Zainodin 1991; Laxton et al 1988).

4. Estimating the Felling Date. As mentioned above, if the bark is present on a sample, then the date of its last ring is the date of the felling of its tree (or the last full year before felling, if it was felled in the first three months of the following calendar year, before any new growth had started, but this is not too important a consideration in most cases). The actual bark may not be present on a timber in a building, though the dendrochronologist who is sampling can often see from its surface that only the bark is missing. In these cases the date of the last ring is still the date of felling.

Quite often some, though not all, of the original outer rings are missing on a timber. The outer rings on an oak, called sapwood rings, are usually lighter than the inner rings, the heartwood, and so are relatively easy to identify. For example, sapwood can be seen in the corner of the rafter and at the outer end of the core in Figure A2, both indicated by arrows. More importantly for dendrochronology, the sapwood is relatively soft and so liable to insect attack and wear and tear. The builder, therefore, may remove some of the sapwood for precisely these reasons. Nevertheless, if at least some of the sapwood rings are left on a sample, we will know that not too many rings have been lost since felling so that the date of the last ring on the sample is only a few years before the date of the original last ring on the tree, and so to the date of felling.

Various estimates have been made and used for the average number of sapwood rings in mature oak trees (English Heritage 1998). A fairly conservative range is between 15 and 50 and that this holds for 95% of mature oaks. This means, of course, that in a small number of cases there could be fewer than 15 and more than 50 sapwood rings. For example, the core CRO-A06 has only 9 sapwood rings and some have obviously been lost over time – either they were removed originally by the carpenter and/or they rotted away in the building and/or they were lost in the coring. It is not known exactly how many sapwood rings are missing, but using the above range the Laboratory would estimate between a minimum of 6 (=15-9) and a maximum of 41 (=50-9). If the last ring of CRO-A06 has been dated to 1500, say, then the estimated felling-date range for the tree from which it came originally would be between 1506 and 1541. The Laboratory uses this estimate for sapwood in areas of England where it has no prior information. It
also uses it when dealing with samples with very many rings, about 120 to the last heartwood ring. But in other areas of England where the Laboratory has accumulated a number of samples with complete sapwood, that is, no sapwood lost since felling, other estimates in place of the conservative range of 15 to 50 are used. In the East Midlands (Laxton et al. 2001) and the east to the south down to Kent (Pearson 1995) where it has sampled extensively in the past, the Laboratory uses the shorter estimate of 15 to 35 sapwood rings in 95% of mature oaks growing in these parts. Since the sample CRO-A06 comes from a house in Cropwell Bishop in the East Midlands, a better estimate of sapwood rings lost since felling is between a minimum of 6 (=15-9) and 26 (=35-9) and the felling would be estimated to have taken place between 1506 and 1526, a shorter period than before. Oak boards quite often come from the Baltic region and in these cases the 95% confidence limits for sapwood are 9 to 36 (Howard et al. 1992, 56).

Even more precise estimates of the felling date and range can often be obtained using knowledge of a particular case and information gathered at the time of sampling. For example, at the time of sampling the dendrochronologist may have noted that the timber from which the core of Figure A2 was taken still had complete sapwood but that some of the soft sapwood rings were lost in coring. By measuring into the timber the depth of sapwood lost, say 20mm, a reasonable estimate can be made of the number of sapwood rings lost, say 12 to 15 rings in this case. By adding on 12 to 15 years to the date of the last ring on the sample a good tight estimate for the range of the felling date can be obtained, which is often better than the 15 to 35 years later we would have estimated without this observation. In the example, the felling is now estimated to have taken place between AD 1512 and 1515, which is much more precise than without this extra information.

Even if all the sapwood rings are missing on a sample, but none of the heartwood rings are, then an estimate of the felling-date range is possible by adding on the full compliment of, say, 15 to 35 years to the date of the last heartwood ring (called the heartwood/sapwood boundary or transition ring and denoted H/S). Fortunately it is often easy for a trained dendrochronologist to identify this boundary on a timber. If a timber does not have its heartwood/sapwood boundary, then only a post quem date for felling is possible.

5. Estimating the Date of Construction. There is a considerable body of evidence collected by dendrochronologists over the years that oak timbers used in buildings were not seasoned in medieval or early modern times (English Heritage 1998; Miles 1997, 50–5). Hence, provided that all the samples in a building have estimated felling-date ranges broadly in agreement with each other, so that they appear to have been felled as a group, then this should give an accurate estimate of the period when the structure was built, or soon after (Laxton et al. 2001, fig 8; 34–5, where ‘associated groups of fellings’ are discussed in detail). However, if there is any evidence of storage before use, or if there is evidence the oak came from abroad (eg Baltic boards), then some allowance has to be made for this.
6. **Master Chronological Sequences.** Ultimately, to date a sequence of ring widths, or a site sequence, we need a master sequence of dated ring widths with which to cross-match it, a Master Chronology. To construct such a sequence we have to start with a sequence of widths whose dates are known and this means beginning with a sequence from an oak tree whose date of felling is known. In Figure A6 such a sequence is SHE-T, which came from a tree in Sherwood Forest which was blown down in a recent gale. After this other sequences which cross-match with it are added and gradually the sequence is ‘pushed back in time’ as far as the age of samples will allow. This process is illustrated in Figure A6. We have a master chronological sequence of widths for Nottinghamshire and East Midlands oak for each year from AD 882 to 1981. It is described in great detail in Laxton and Litton (1988), but the components it contains are shown here in the form of a bar diagram. As can be seen, it is well replicated in that for each year in this period there are several sample sequences having widths for that year. The master is the average of these. This master can now be used to date oak from this area and from the surrounding areas where the climate is very similar to that in the East Midlands. The Laboratory has also constructed a master for Kent (Laxton and Litton 1989). The method the Laboratory uses to construct a master sequence, such as the East Midlands and Kent, is completely objective and uses the Litton-Zainodin grouping procedure (Laxton *et al* 1988). Other laboratories and individuals have constructed masters for other areas and have made them available. As well as these masters, local (dated) site chronologies can be used to date other buildings from nearby. The Laboratory has hundreds of these site sequences from many parts of England and Wales covering many short periods.

7. **Ring-Width Indices.** Tree-ring dating can be done by cross-matching the ring widths themselves, as described above. However, it is advantageous to modify the widths first. Because different trees grow at different rates and because a young oak grows in a different way from an older oak, irrespective of the climate, the widths are first standardized before any matching between them is attempted. These standard widths are known as ring-width indices and were first used in dendrochronology by Baillie and Pilcher (1973). The exact form they take is explained in this paper and in the appendix of Laxton and Litton (1988) and is illustrated in the graphs in Figure A7. Here ring-widths are plotted vertically, one for each year of growth. In the upper sequence of (a), the generally large early growth after 1810 is very apparent as is the smaller later growth from about 1900 onwards when the tree is maturing. A similar phenomenon can be observed in the lower sequence of (a) starting in 1835. In both the widths are also changing rapidly from year to year. The peaks are the wide rings and the troughs are the narrow rings corresponding to good and poor growing seasons, respectively. The two corresponding sequence of Baillie-Pilcher indices are plotted in (b) where the differences in the immature and mature growths have been removed and only the rapidly changing peaks and troughs remain, that are associated with the common climatic signal. This makes cross-matching easier.
Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

The bar diagram represents these sequences without the rings themselves. The length of the bar is proportional to the number of rings in the sequence. Here the four sequences are set at relative positions (offsets) to each other at which they have maximum correlation as measured by the \( t \)-values. The \( t \)-value/offset matrix contains the maximum \( t \)-values below the diagonal and the offsets above it. Thus, the maximum \( t \)-value between C08 and C45 occurs at the offset of +20 rings and the \( t \)-value is then 5.6. The site sequence is composed of the average of the corresponding widths, as illustrated with one width.
Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87
Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

Here the ring widths are plotted vertically, one for each year, so that peaks represent wide rings and troughs narrow ones. Notice the growth-trends in each; on average the earlier rings of the young tree are wider than the later ones of the older tree in both sequences.

Figure A7 (b): The Baillie-Pilcher indices of the above widths

The growth trends have been removed completely.
References


Laxton, R R, Litton, C D, and Howard, R E, 1988 *An East Midlands Master Chronology and its use for dating vernacular buildings*, University of Nottingham, Department of Archaeology Publication, Monograph Series III


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