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THE SPOTTED DOG (FORMER) PUBLIC HOUSE, 212 UPTON LANE, NEWHAM, LONDON
TREE-RING DATING OF TIMBERS

SCIENTIFIC DATING REPORT

Alison Arnold and Robert Howard

INTERVENTION
AND ANALYSIS

ENGLISH HERITAGE

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SUMMARY
Timbers from the hall and east wing of this building proved unsuitable for analysis. However the analysis of samples from the west wing resulted in the construction and dating of a single site sequence. Site sequence SPDNSQ01 contains three samples and spans the period AD 1346–1467. Interpretation of the sapwood suggests felling of all three timbers in AD 1468–90, with construction of the roof following shortly after.

CONTRIBUTORS
Alison Arnold and Robert Howard

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INTRODUCTION

The Grade II listed Spotted Dog (former) public house, situated just to the south of Forest Gate (Figs 1–3), is thought to be the oldest secular building in the London Borough of Newham. It has been suggested that it was Henry VIII's Forest Gate hunting lodge but was converted to a coaching inn in the early nineteenth century. Other alterations and additions have occurred, including an extensive programme of renovation in 1968 (Fig 4).

At the core of the building is a two-bay timber-framed hall with a crown-post roof (Fig 5). This is thought to be the earliest part of the building and believed to date to the late-fifteenth or early sixteenth century.

Flanking the hall are two-storey, jettied cross-wings, the western one thought to be contemporary with the hall with that to the east being slightly later. In the west wing some wall framing and the crown-post roof survives (Fig 6). Within the east wing there are exposed moulded ceiling beams (Fig 7) with visible roof timbers restricted to tiebeams and the wallplate (Fig 8).

The Spotted Dog is an important and rare survival of a timber framed and weather boarded building in this area of London and is on the English Heritage at Risk register.

SAMPLING

Tree-ring dating was requested by Mike Dunn to inform proposals for the repair and restoration of the building and to provide precise dating evidence in order to better understand the chronological development of the extant building. An assessment undertaken in 2010 had proved inconclusive as to the suitability of timbers due to their being covered in extremely thick black paint and, unfortunately, concerns over health and safety issues led to any sampling being deferred. When investigations were resumed in 2014 it was decided that a small number of cores should be taken from the hall and the east and west wings to confirm the suitability, or otherwise, of the timbers for analysis. Upon revisiting the property with Mike Dunn and talking through the surviving timbers of historic interest it was agreed that the only timber likely to be primary to the hall was a tiebeam and on closer inspection this could be seen to be extremely fast grown. Consequently sampling was restricted to the east and west wings.

Five samples were taken from the floor-frame and roof of the east wing. Of these, four proved to be elm and the fifth was very fast-grown oak with substantially fewer rings than would be necessary for successful dating, and so sampling of this area was abandoned. Cores were taken from six timbers of the roof of the west wing, starting with the most promising. Three of these were suitable for tree-ring dating, two had less than the minimum requisite number of growth rings and the sixth was elm. With the best six timbers only producing three suitable samples the decision was again taken to abandon sampling. Thus a total of only 11 timbers from the two wings was sampled by coring. Each sample was given the code SPD-N and numbered 01–11. The location of all samples was noted at the time of sampling and has been marked on Figures 9 and 10. Further details relating to the samples can be found in Table 1.

ANALYSIS AND RESULTS

The eight unsuitable samples (five being elm and three oak with too few rings for secure dating) were rejected prior to measurement. The remaining three samples were prepared by sanding and polishing and their growth-ring widths measured. The data of these measurements are given at the end of the report. These three samples were then compared with each other by the Litton/Zainodin grouping programme (see Appendix).

All three samples matched each other and were combined at the relevant offset positions to form SPDNSQ01, a site sequence of 122 rings (Fig 11). This site sequence was compared against a series of relevant reference chronologies for oak where it was found to span the period AD 1346–1467. The evidence for this dating is given in Table 2.

INTERPRETATION

Three samples, all from wall posts, have been successfully dated. These three samples all have the heartwood/sapwood boundary ring, which in all cases is broadly contemporary and suggestive of a single felling. The average heartwood/sapwood boundary ring date for these three timbers is AD 1450. Therefore, using the estimate that 95% of mature oak trees from this region have 15–40 sapwood rings we are able to calculate an estimated felling date for the three timbers represented to within the range AD 1468–90. This allows for sample SPD-N02 having a last-measured ring date of AD 1467 with incomplete sapwood.

DISCUSSION

Tree-ring analysis undertaken on samples taken from three wall posts in the west wing has resulted in the successful dating of all three of them to AD 1468–90. This date suggests construction of this part of the building occurred in the latter decades of the fifteenth century. If this wing is indeed contemporary with the hall then this late-fifteenth century date can be also assigned to that part of the building.

The degree of similarity seen between these three samples is of a level to suggest that all three wall posts represented were cut from the same tree (Table 3).

It can be seen (Table 2) that the greatest similarity between site sequence SPDNSQ01 and reference chronologies is found between other sites in London indicating that the timbers in the west wing are likely to be from relatively local regional woodland sources.

It is unfortunate that due to the use of elm and fast-grown oak more of the samples were not suitable for tree-ring dating. However the use of elm, in combination with fast-grown oak, has been noted previously in a number of other buildings in London thought to be of fifteenth century, or slightly earlier, date (Barclay *et al* forthcoming).

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TABLES

Table 1: Details of tree-ring samples from the Spotted Dog (Former) Public House, Newham, London

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
West wing						
SPD-N01	East main post, truss 1	116	10	1346	1451	1461
SPD-N02	West main post, truss 1	94	19	1374	1448	1467
SPD-N03	Mid stud, truss 1	NM	--	----	----	----
SPD-N04	West main post, truss 2	60	04	1396	1451	1455
SPD-N05	West stud post, truss 1	NM	--	----	----	----
SPD-N06	East main post, truss 2 - elm	NM	--	----	----	----
East wing						
SPD-N07	Main floor beam (north side) - elm	NM	--	----	----	----
SPD-N08	East common joist 6 (from north), bay 1 - elm	NM	--	----	----	----
SPD-N09	East common joist 3 (from north), bay 2 - elm	NM	--	----	----	----
SPD-N10	Tiebeam, truss 1	NM	--	----	----	----
SPD-N11	Tiebeam, truss 2 - elm	NM	--	----	----	----

NM = not measured

Table 2: Results of the cross-matching of site sequence SPDNSQ01 and reference chronologies when the first-ring date is AD 1346 and the last-measured ring date is AD 1467

Reference chronology	*t*-value	Span of chronology	Reference
Hays Wharf, Southwark, London	7.2	AD 1248–1647	Tyers 1996a, Tyers 1996b
Cann Hall, Clacton, Essex	7.1	AD 1301–1511	Tyers 1998
St Bartholomew the Less Church, London	6.9	AD 1292–1480	Tyers 2003
White Tower, Tower of London, London	6.7	AD 1260–1489	Miles 2007
St Swithun's Church, Compton Bassett, Wiltshire	6.6	AD 1346–1454	Miles and Worthington 2000
St John's Hospital, Cirencester, Gloucestershire	6.6	AD 1254–1436	Arnold and Howard 2007
The Old Manor, West Lavington, Wiltshire	6.5	AD 1264–1497	Tyers and Hurford 2014
Bankside, Southwark, London	6.4	AD 1313–1476	Tyers 1996c

Table 3: Matrix to show the level of t-values seen between the three matched and dated samples

	SPD-N01	SPD-N02	SPD-N03
SPD-N01	*		
SPD-N02	9.9	*	
SPD-N03	13.2	9.1	*

FIGURES

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

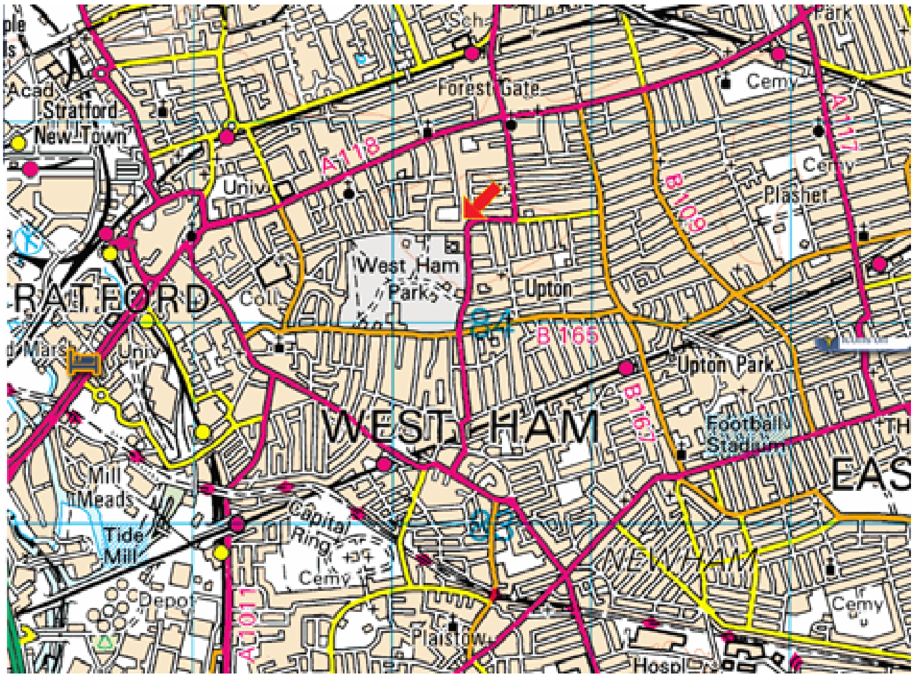


Figure 2: Map to show the location of Newham, arrowed. ©Crown Copyright and database right 2014. All rights reserved. Ordnance Survey Licence number 100024900

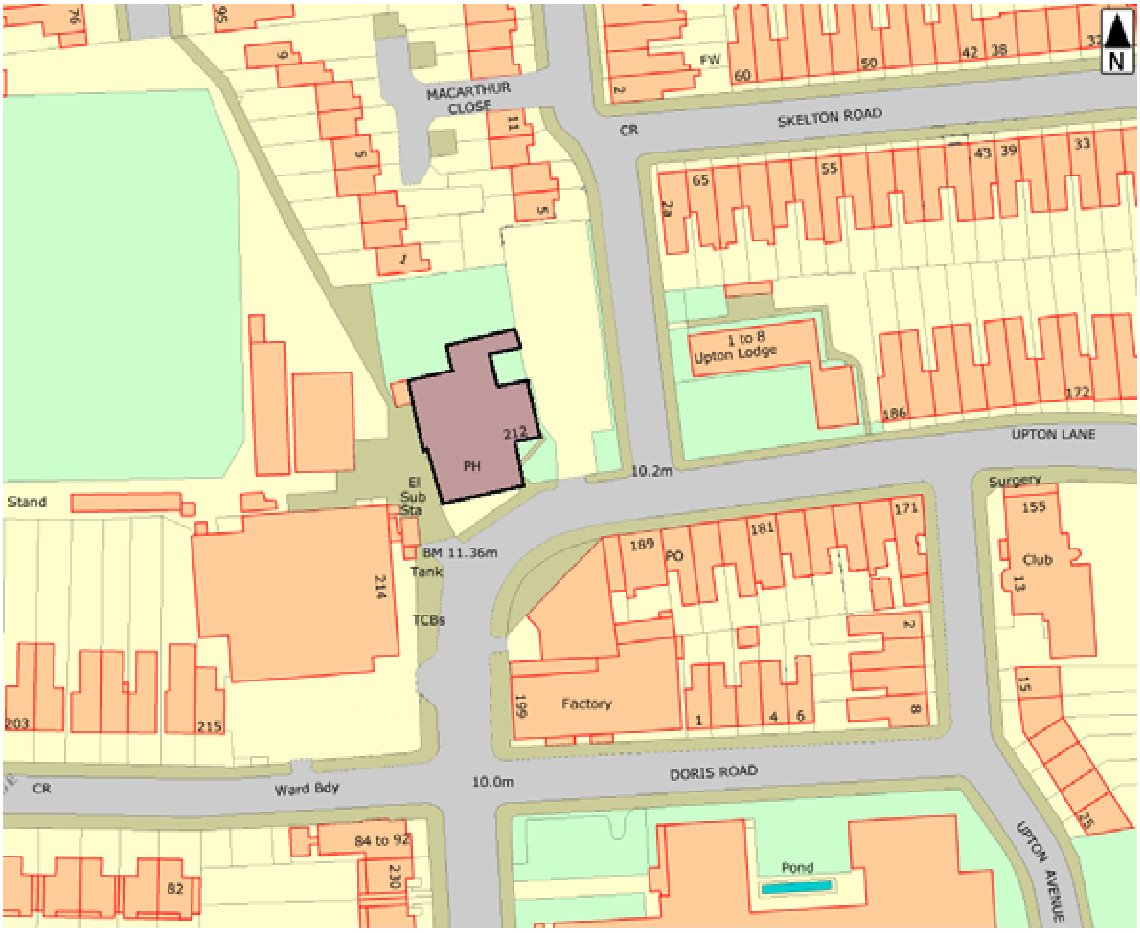


Figure 3: Map to show the location of the former Spotted Dog public house, outlined in black. ©Crown Copyright and database right 2014. All rights reserved. Ordnance Survey Licence number 100024900

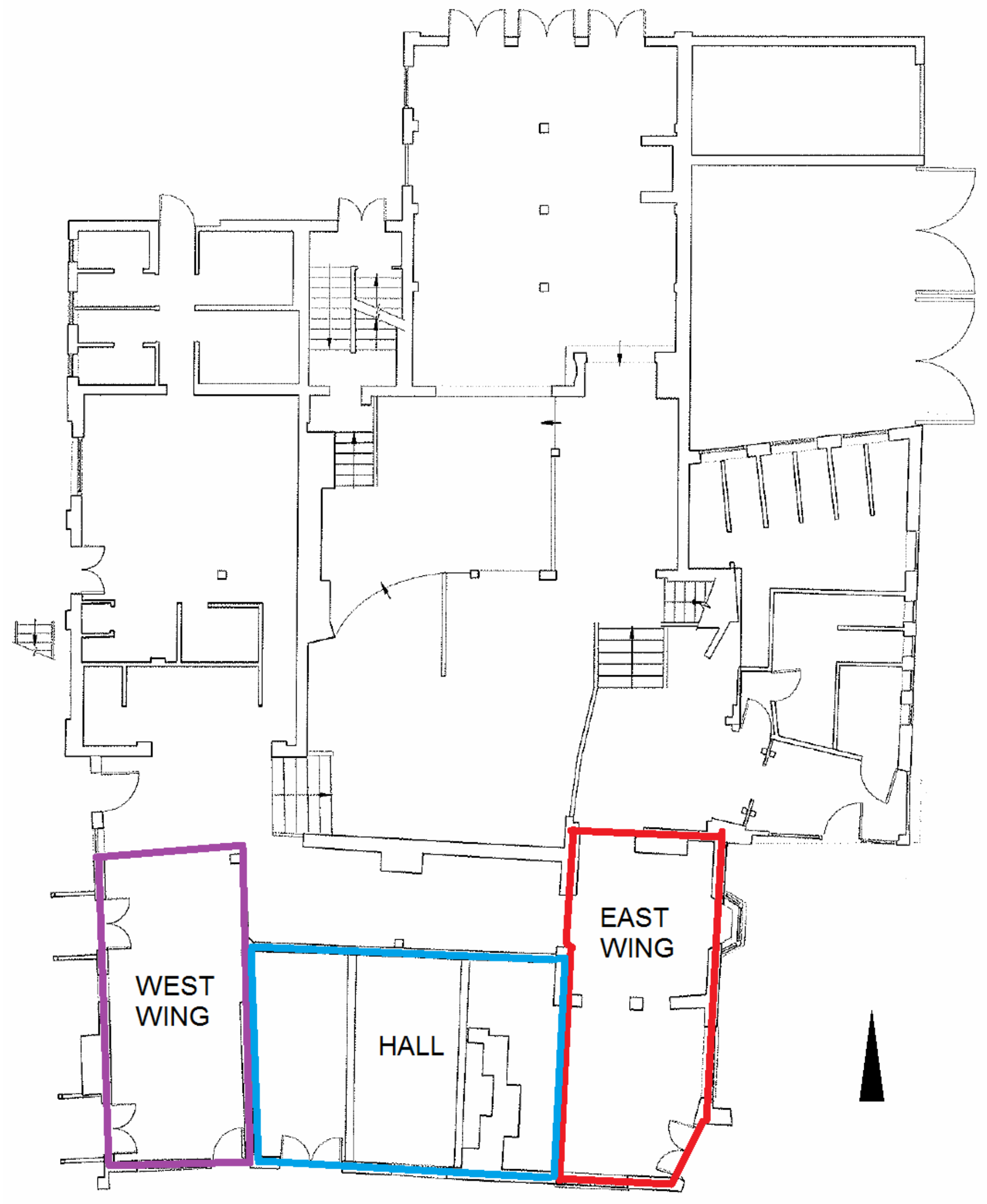


Figure 4: Ground-floor plan of the Spotted Dog (former) public house, showing the areas under investigation (after Butler Hegarty Architects)

Figure 5: Hall range, photograph taken from the west (Robert Howard)

Figure 6: West wing, truss 1, photograph taken from the south (Robert Howard)

Figure 7: East wing, ground-floor ceiling, photograph taken from the north-east (Robert Howard)

Figure 8: East wing, truss 1, photograph taken from the south (Robert Howard)

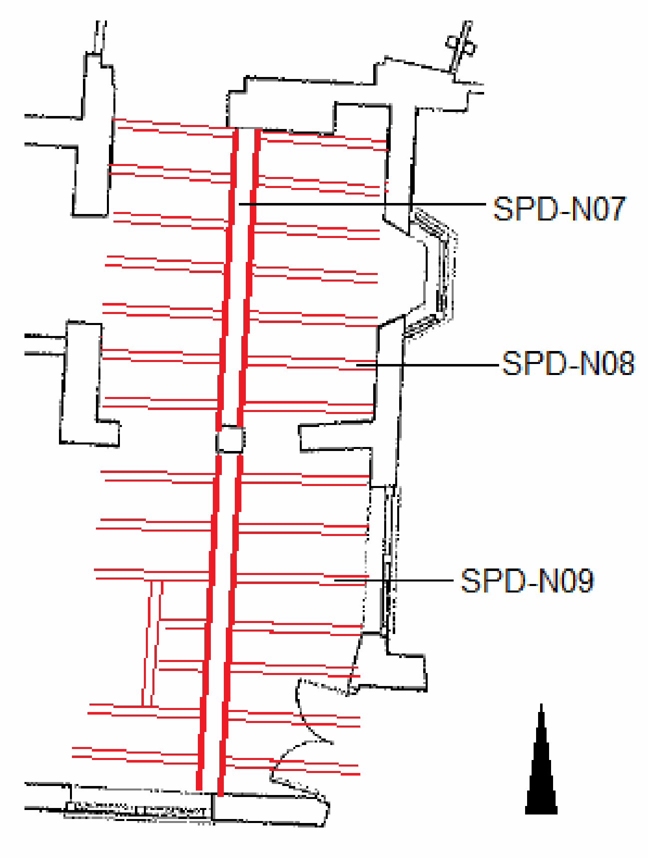


Figure 9: Ground-floor plan, showing the location of samples SPD-N07–09 (after Butler Hegarty Architects)

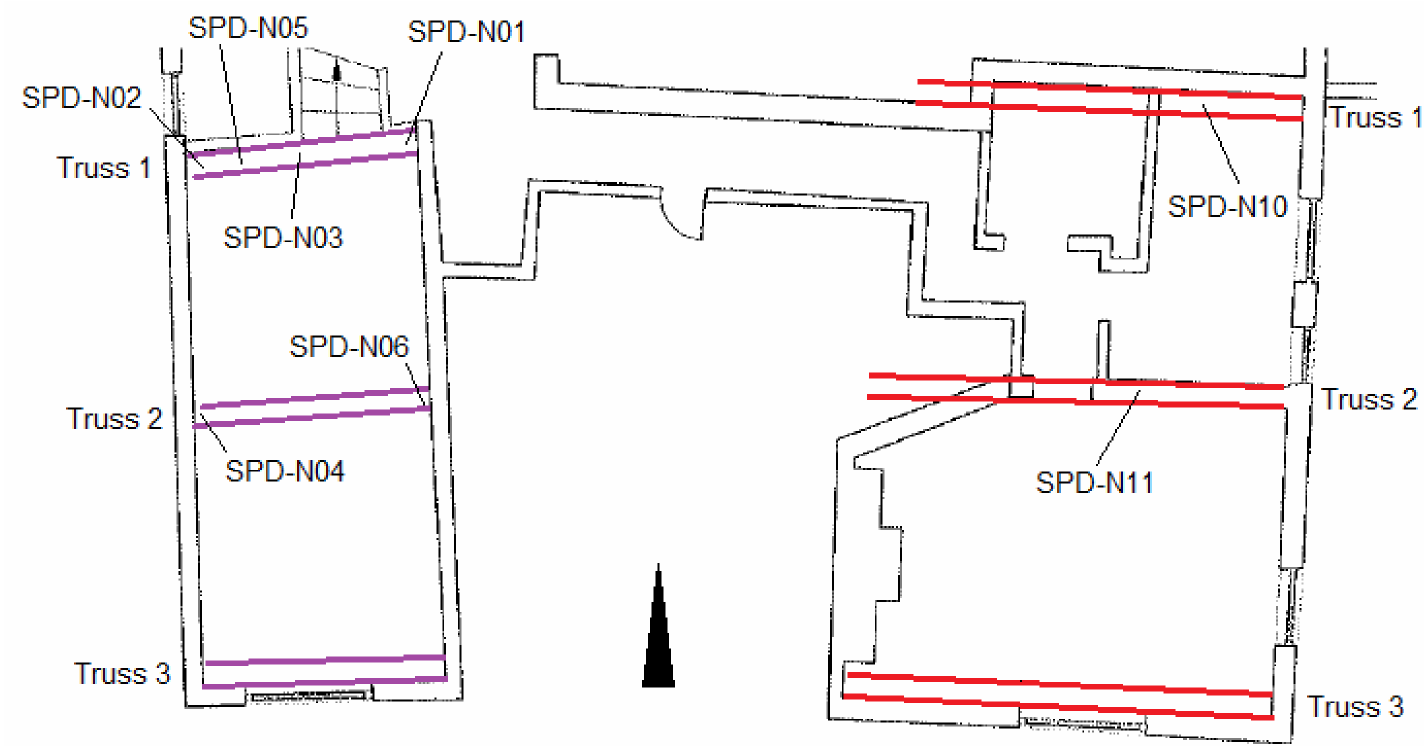


Figure 10: First-floor plan, showing the approximate truss positions and the location of samples SPD-N01–06 and SPD-N10–11 (after Butler Hegarty Architects)

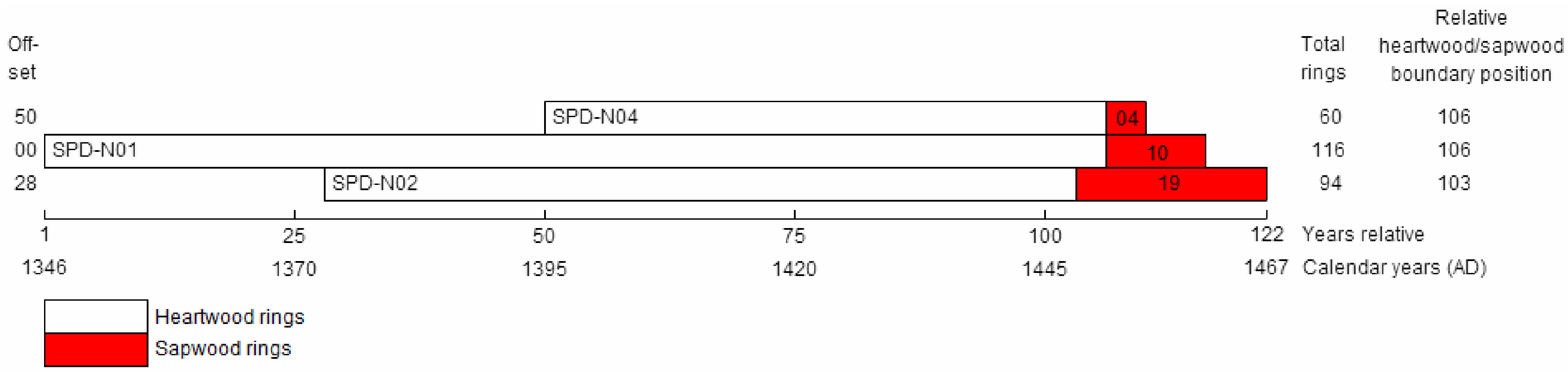


Figure 11: Bar diagram of samples in site sequence SPDNSQ01

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units
SPD-N01A 116
265 304 200 117 157 172 90 76 79 65 72 141 128 149 125 116 226 288 213 138
85 127 165 210 154 132 133 127 162 133 215 190 219 327 364 234 299 144 219 229
258 205 217 169 132 144 154 199 204 198 222 183 225 152 184 234 177 199 253 188
281 140 186 183 198 270 230 181 98 157 132 192 161 176 200 273 217 187 193 133
102 198 313 196 262 286 398 269 338 267 275 325 314 278 222 222 189 207 186 125
96 139 146 184 141 178 128 135 216 181 165 129 142 119 108 110
SPD-N01B 116
262 284 211 114 164 179 86 83 66 72 69 139 122 154 123 124 217 292 209 140
83 128 165 206 148 133 135 118 160 136 220 186 220 344 349 231 290 143 212 237
257 196 213 166 131 151 152 211 203 198 222 188 225 150 184 234 170 212 252 189
285 136 190 183 202 263 229 179 95 158 130 191 163 168 210 268 210 187 192 133
98 184 314 202 256 293 393 263 319 261 275 329 304 271 218 224 169 202 184 127
102 133 143 180 140 185 109 145 212 180 161 118 141 88 112 101
SPD-N02A 94
140 151 297 197 217 254 319 210 236 162 150 193 249 229 339 264 232 186 218 228
176 166 171 144 225 195 131 236 169 159 189 151 185 81 122 158 186 248 220 157
148 149 176 206 195 223 233 244 156 156 165 129 114 158 247 163 191 213 296 192
202 171 196 203 175 128 117 131 118 128 102 84 85 141 123 132 109 151 117 95
161 128 106 96 116 97 90 75 82 58 53 59 68 77
SPD-N02B 94
158 164 285 180 209 245 303 209 225 154 150 187 232 224 320 261 229 176 218 241
184 165 164 142 220 189 125 231 155 152 184 155 196 82 117 154 202 233 218 150
151 159 183 213 196 221 223 240 157 173 160 129 116 155 240 160 194 214 285 187
202 168 188 195 174 127 116 133 114 131 100 88 83 134 123 120 125 156 109 95
155 134 95 105 115 102 90 75 77 60 52 63 68 64
SPD-N04A 60
153 138 127 160 162 261 165 231 274 195 357 153 247 248 242 274 241 172 138 158
138 209 196 159 209 260 158 164 148 113 104 177 279 179 233 265 389 255 275 206
264 306 263 270 188 202 136 168 134 105 83 151 141 196 185 214 136 147 223 209
SPD-N04B 60
148 139 133 160 159 254 182 210 263 198 370 142 238 246 243 271 243 171 135 165
137 220 183 169 196 267 154 163 149 113 108 177 284 176 235 264 387 258 287 204
258 295 262 272 171 210 131 164 142 115 82 146 144 200 188 198 154 136 231 204

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 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

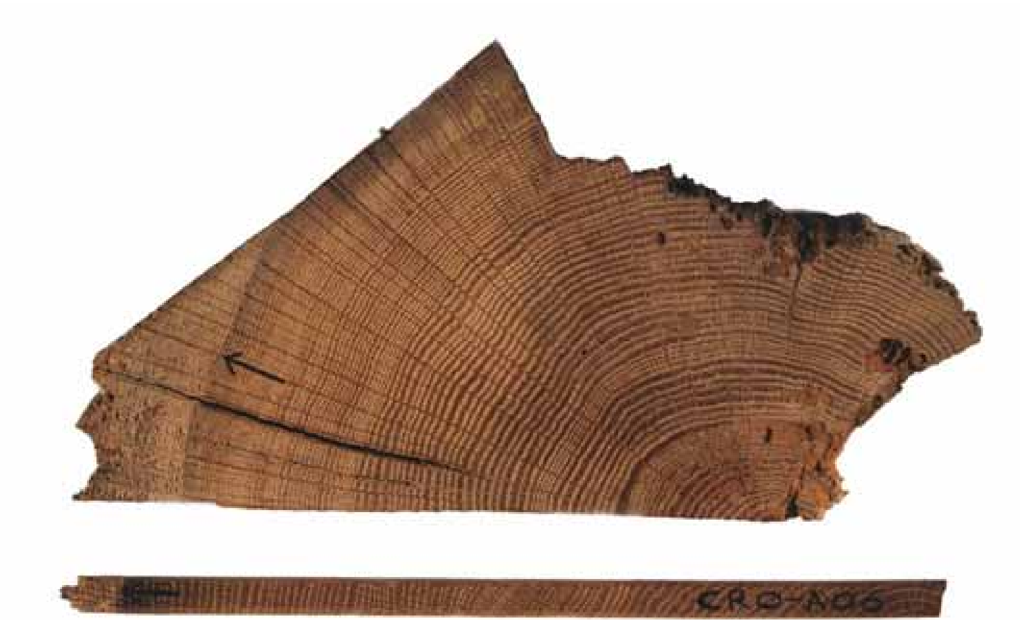


Figure A2: Cross-section of a rafter, showing sapwood rings in the left-hand corner, the arrow points to the heartwood/sapwood boundary (H/S); and a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil

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 flourgrade-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.

t-value/offset Matrix

	C45	C08	C05	C04
C45		+20	+37	+47
C08	5.6		+17	+27
C05	5.2	10.4		+10
C04	5.9	3.7	5.1	

Bar Diagram

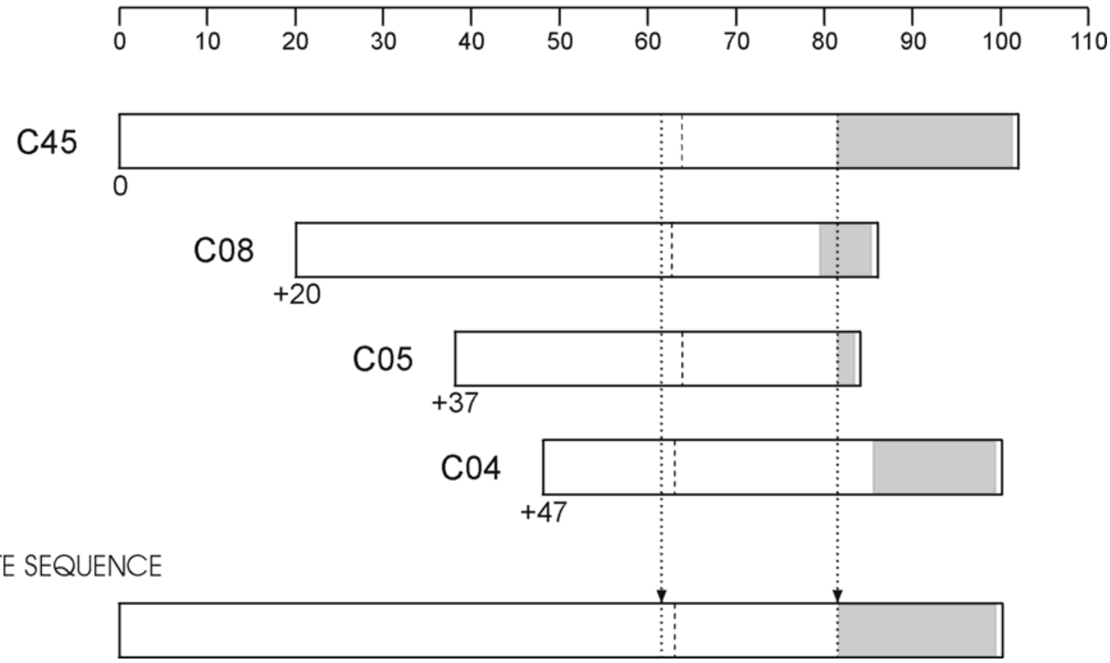


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

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.

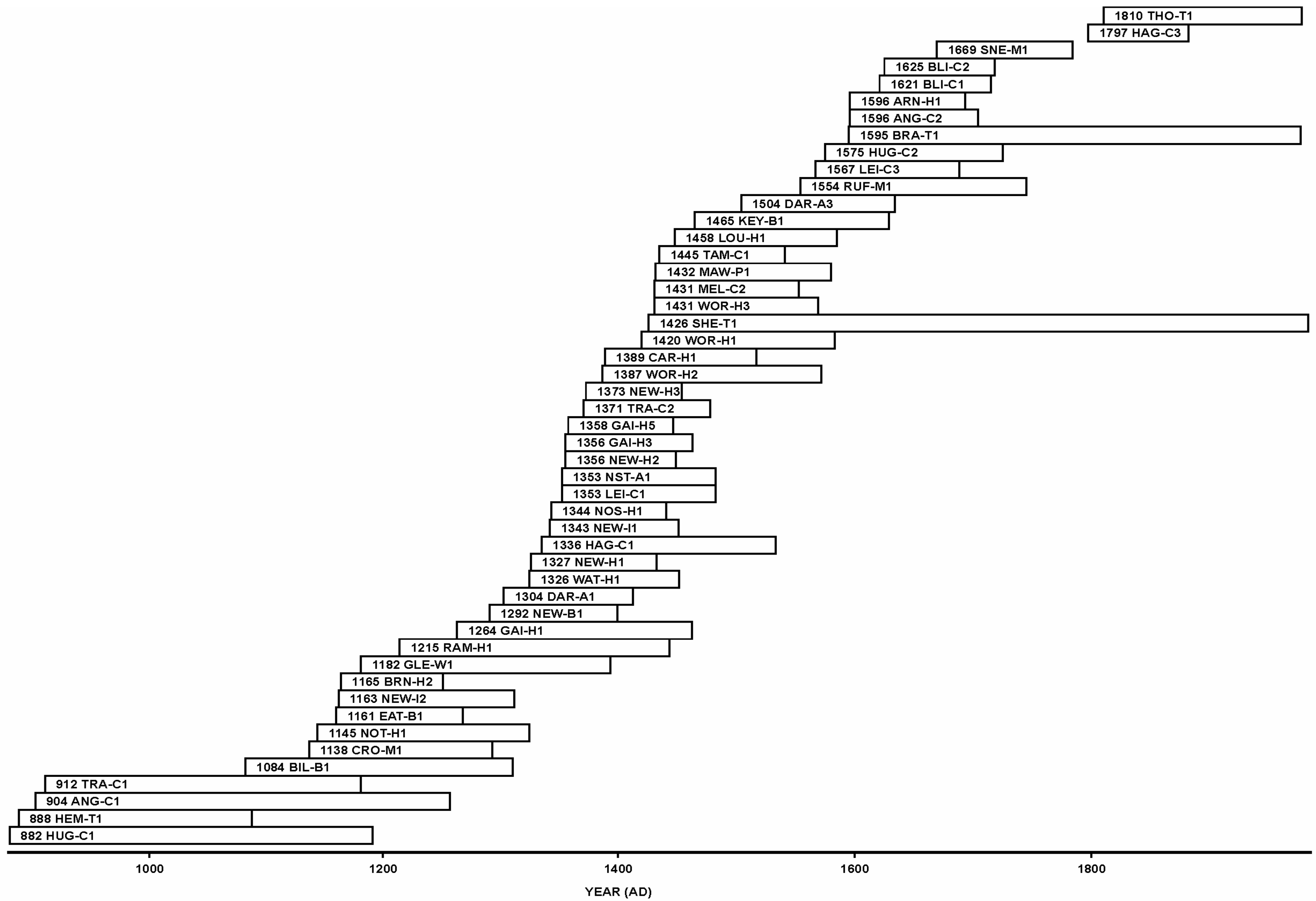
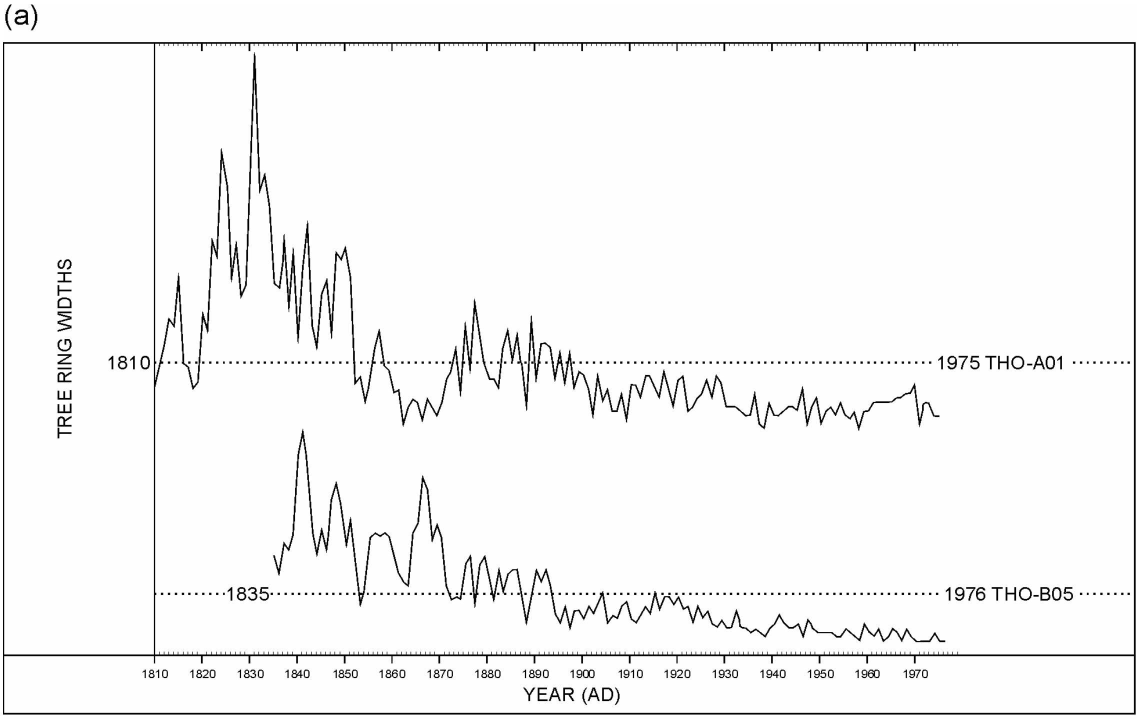


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

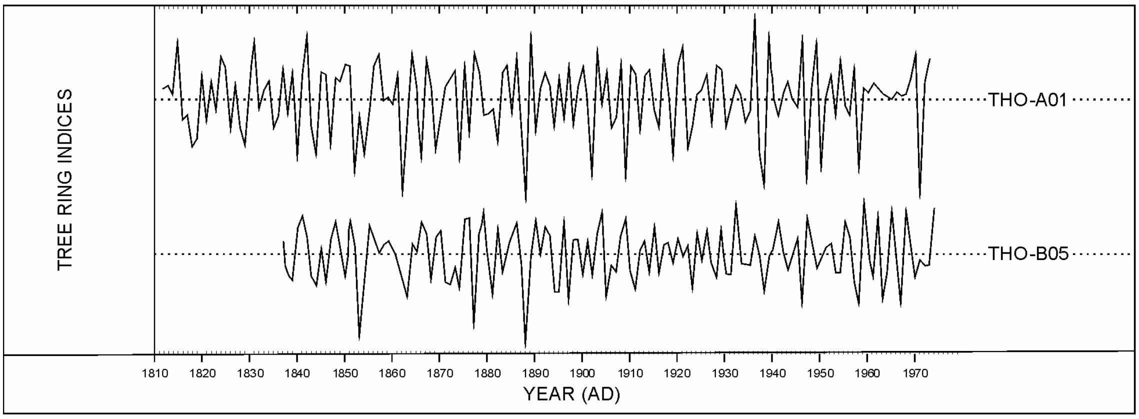


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

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

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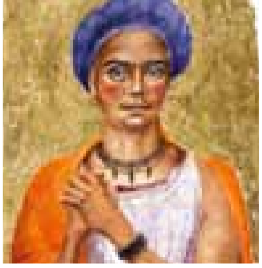


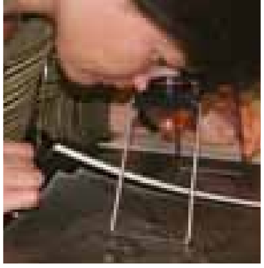


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