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Barn at Whitewebbs Farm Whitewebbs Road Enfield London

Tree-ring Analysis of Timbers

Alison Arnold, Robert Howard, and Cathy Tyers

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BARN AT WHITEWEBBS FARM
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SUMMARY
Dendrochronological analysis was undertaken on samples obtained from 24 oak timbers from the primary phase of the barn, the porch, and the lean-to animal stalls. This analysis resulted in the production of a single site sequence, WHTWSQ01, accounting for 17 samples and spanning the period AD 1390–1566. Interpretation of surviving sapwood indicates that felling of the timbers utilised within the main body of the barn occurred in, or around, AD 1566, with construction following shortly after. Two of the timbers used in the lean-to animal stalls were also felled in AD 1566, which could suggest that the two parts of the building are contemporary or more likely could signify the use of salvaged beams within a later addition. No timbers from the porch were dated.

CONTRIBUTORS
Alison Arnold, Robert Howard, and Cathy Tyers

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CONTENTS

INTRODUCTION

The barn at Whitewebbs Farm was part of a small group of cottages and farm buildings which grew up around the Whitewebbs mansion, in the London Borough of Enfield (Fig 1). It is Grade II listed and whilst the listing entry (LEN 1079480) indicates that it probably dates to the later seventeenth century, it has more recently been suggested that it is sixteenth- or early seventeenth-century in date. The description below is based on that provided by Ian Harper (pers comm).

The main section of the barn, the westernmost six-bays, is timber-framed and set on metre-high brick plinth walls (Figs 2–4). It has an extended cart entrance, or porch, on the south side (Figs 2 and 5) and later lean-to animal stalls (Figs 2 and 6), also on the south side. This main section of the barn consists of seven queen-post, principal rafter, and tiebeam trusses, each with a collar and brace from tiebeam to the main post (Fig 3). Between these trusses are common rafters, two tiers of clasped purlins and further braces (Fig 3). There is unusual upturned wind-bracing above the middle rails of the side walls, which spring from mid-span of the middle rails to the junctions of the frame posts with the wall plates (Fig 4). The framing of both the main section of the barn and the lean-to is clad externally with horizontal shiplap timber boarding, which is suffering from decay. There is evidence that this boarding had been arranged in panels recessed into the framing by means of rebates on the corners of the upright posts of the main frames, and consequently over-sailed the wind-braces and vertical studs, which had been set back behind the outer plane of the framing.

The easternmost three-bays of the barn are much decayed and partially collapsed. Although this portion of the barn follows the form of the trusses in the main section of the barn to the west, this part is thought to be a nineteenth-century addition and is constructed from softwood. It contains two additional cart entrances.

SAMPLING

Dendrochronological analysis was requested by Ian Harper, Historic England Heritage at Risk Architect, to provide independent dating evidence to understand the significance of the unusual form of construction, and to inform advice on repair and restoration.

Samples were taken from 24 oak (*Quercus* spp) timbers associated with the main barn, the porch, and the lean-to animal stalls. Each sample was given the code WHT-W and numbered 01–24. Further details relating to the samples can be found in Table 1. The location of sampled timbers has been indicated on Figures 7–14, with trusses having been numbered from east to west as indicated in Figure 2.

The shiplap boarding was also assessed for its potential for dendrochronological dating purposes. The boarding was a mixture of softwood, elm (*Ulmus* spp), and oak. The softwood boards to the upper levels and gables appeared to be relatively modern, potentially twentieth-century in date, although some softwood boards to the lower levels were possibly earlier, perhaps nineteenth-century in date. Many boards appeared to be elm but a smaller number of boards were noted as potentially oak. Overall the boards were considered to have poor potential for reliable dendrochronological analysis but it was thought that amongst this large assemblage of boards it might be possible to identify some boards derived from longer-lived trees that could potentially warrant attempting dendrochronological analysis. However, it was agreed that the boards would be excluded from this dendrochronological programme as any attempt to undertake analysis would be best carried out during future repairs when boards might be replaced, or removed temporarily, thus allowing appropriate access for sampling or direct measurement.

ANALYSIS AND RESULTS

Two of the samples taken from the lean-to animal stalls were found to have too few rings for secure dating and so were rejected prior to measuring. The remaining 22 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. All measurements were then compared with each other by the Litton/Zainodin grouping programme (see Appendix), resulting in 17 samples cross-matching to form a single group at a minimum *t*-value of 5.5.

These 17 samples were combined at the relevant offset position to form WHTWSQ01, a site sequence of 177 rings (Fig 15). This site sequence was cross-matched consistently and securely against a series of reference chronologies for oak at a first-measured ring date of AD 1390 and a last-measured ring date of AD 1566 (Table 2).

Attempts to date the remaining ungrouped samples by comparing them individually against the same suite of reference chronologies were unsuccessful and all, therefore, remain undated.

INTERPRETATION

Analysis has resulted in the successful dating of 17 timbers, 15 from the main barn and two from the lean-to animal stalls (Table 1; Fig 15). Felling date ranges have been calculated using the estimate that 95% of mature oak trees from this area have between 15 and 40 sapwood rings.

Main barn

Fifteen of the timbers from the westernmost six-bays of the barn have been dated, six of which have complete sapwood and the last-measured ring date of AD 1566, the felling date of the timbers represented. The other nine dated samples all have the heartwood/sapwood boundary, the dates of which are broadly contemporary and suggestive of a single felling. The average heartwood/sapwood date for these nine samples is AD 1544 which, allowing for an outermost measured ring of AD 1565 on samples WHT-W01 and WHT-W13 (both with incomplete sapwood), produces an estimated felling date range of AD 1566–84. This, combined with the overall level of cross-matching of this entire group of 15 dated timbers, is consistent with them having also been felled in, or around, AD 1566.

Lean-to animal stalls

Two of the samples taken from this part of the building have also been dated. These two samples have similar heartwood/sapwood boundary ring dates, suggestive of contemporary felling. The average heartwood/sapwood boundary ring date is AD 1546, allowing an estimated felling date to be calculated for the two timbers represented to within the range AD 1566–86. This felling date range allows for sample WHT-W22 having a last-measured ring date of AD 1565, with incomplete sapwood.

DISCUSSION AND CONCLUSION

The tree-ring analysis has successfully dated a series of timbers utilised within the main primary phase of the barn as having been felled in, or around, AD 1566, with construction likely to have occurred shortly after. Previously, the barn had been dated on stylistic grounds to the later seventeenth century or more recently to the sixteenth or seventeenth century. The dendrochronology analysis now places it firmly in the mid-sixteenth century.

Two of the sampled studs from the lean-to animal stalls have also been dated. Both are now known to have been felled in AD 1566–86. The high level of similarity between these two ring series and those from the main barn is consistent with a coherent group of trees representing a single felling period, suggesting that they are also likely to have been felled in AD 1566. However, although this might usually signify the lean-to animal stall being coeval with the main barn structure, this seems unlikely. Although both of the oak timbers represented by these samples were pegged into the (softwood) wall plate, other timbers contained within this structure were not oak and were not pegged in. Indeed, visually the beams utilised had a very mixed appearance more suggestive of the use of timbers from various sources rather than a coherent group. Given how well the ring series from these two studs cross-match with the rest of the dated timbers, it is possible that these two studs represent the reuse of beams salvaged from elsewhere within the barn, potentially from the rebuilt eastern end.

The overall cross-matching between the dated timbers from the main barn and lean-to animal stall suggests that they are likely to be derived from a single woodland source. The site sequence, WHTWSQ01, shows the highest levels of similarity with other sites from the south-east (Table 2), which implies that this woodland source is relatively local.

It is unfortunate that none of the porch timbers have been dated, most likely this is due to the lack of grouping within these samples and that they are all relatively short – none of them having more than 55 growth rings. Indeed, the majority of the timbers utilised within the porch could be seen during the assessment to be fast grown and unsuitable for analysis with too few growth rings for reliable dating. The samples taken from the rest of the barn (with the exception of the two unmeasured samples from the lean-to animal stall) are much slower grown (see raw ring-width data below). This would suggest that the construction of the porch is either of a different date, or utilised a different woodland source – the latter being considered unlikely if construction was contemporary with the main barn.

The shiplap boarding also remains undated at present but should be reconsidered if the boards become more readily accessible during future repairs.

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TABLES

Table 1: Details of tree-ring samples taken from the Barn at Whitewebbs Farm, Whitewebbs Road, Enfield, London

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
Main barn, westernmost six bays						
WHT-W01	Tiebeam, truss 1	143	35	1423	1530	1565
WHT-W02	North mid rail, truss 1-2	167	21C	1400	1545	1566
WHT-W03	North main post, truss 2	168	22C	1399	1544	1566
WHT-W04	South main post, truss 2	116	25C	1451	1541	1566
WHT-W05	Tiebeam truss 2	148	h/s	1390	1537	1537
WHT-W06	South archbrace, truss 2	140	h/s	1409	1548	1548
WHT-W07	North main post, truss 3	154	10	1409	1552	1562
WHT-W08	South main post, truss 3	54	26C	1513	1540	1566
WHT-W09	Tiebeam, truss 3	171	25C	1396	1541	1566
WHT-W10	South archbrace, truss 3	162	h/s	----	----	----
WHT-W11	South main post, truss 4	88	19	1477	1545	1564
WHT-W12	South archbrace, truss 4	129	h/s	1415	1543	1543
WHT-W13	South main post, truss 5	110	14	1456	1551	1565
WHT-W14	Tiebeam, truss 5	88	15	1475	1547	1562
WHT-W15	North main post, truss 6	170	19C	1397	1547	1566
WHT-W16	Tiebeam, truss 6	95	11	1460	1543	1554
Porch						
WHT-W17	South-east corner post	45	h/s	----	----	----
WHT-W18	East wall plate	46	11	----	----	----
WHT-W19	West mid rail	55	h/s	----	----	----
WHT-W20	Mid beam/floor beam	55	h/s	----	----	----

Table 1: continued

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
Lean-to animal stalls						
WHT-W21	Sill – west wall	NM	--	----	----	----
WHT-W22	Stud 3 – west wall	144	20	1422	1545	1565
WHT-W23	Stud 7 – west wall	161	12	1399	1547	1559
WHT-W24	West wallplate (north end)	NM	--	----	----	----

NM = not measured
h/s = the heartwood/sapwood boundary is the last-measured ring
C = complete sapwood retained on sample, last-measured ring is the felling date

Table 2: Results of the cross-matching of site sequence WHTWSQ01 and the reference chronologies when the first-ring date is AD 1390 and the last-measured ring date is AD 1566

Reference chronology	*t*–value	Span of chronology (AD)	Reference
Hays Wharf, Southwark, London	13.4	1248–1647	Tyers 1996a; Tyers 1996b
Bruce Castle, Tottenham, London	9.9	1421–1544	Bridge 1998
Queen Elizabeth Hunting Lodge, Chingford, London	9.7	1398–1541	Tyers 1993
Windsor Castle, Berkshire	9.6	1192–1613	Tyers *et al* 1997
Alcester Town Hall, Alcester, Warwickshire	9.6	1374–1625	Arnold and Howard 2019
Headstone Manor Barn, Harrow, Middlesex	9.3	1374–1505	Howard *et al* 2000
Cobham Hall, Cobham, Kent	9.1	1317–1662	Arnold *et al* 2003
London Charterhouse, London	8.8	1382–1545	Howard *et al* 1997
Broomfield House, Enfield, London	8.5	1446–1562	Bridge 1997
Moyns Park, Birdbrook, Essex	8.3	1431–1606	Tyers 1999

Figure 1: Maps to show the location of the barn under investigation at Whitewebbs Farm, Enfield, London, marked in red. Scale: top right 1:20000; bottom 1:4000. © Crown Copyright and database right 2020. All rights reserved. Ordnance Survey Licence number 100024900. © British Crown and SeaZone Solutions Ltd 2020. All rights reserved. Licence number 102006.006. © Historic England

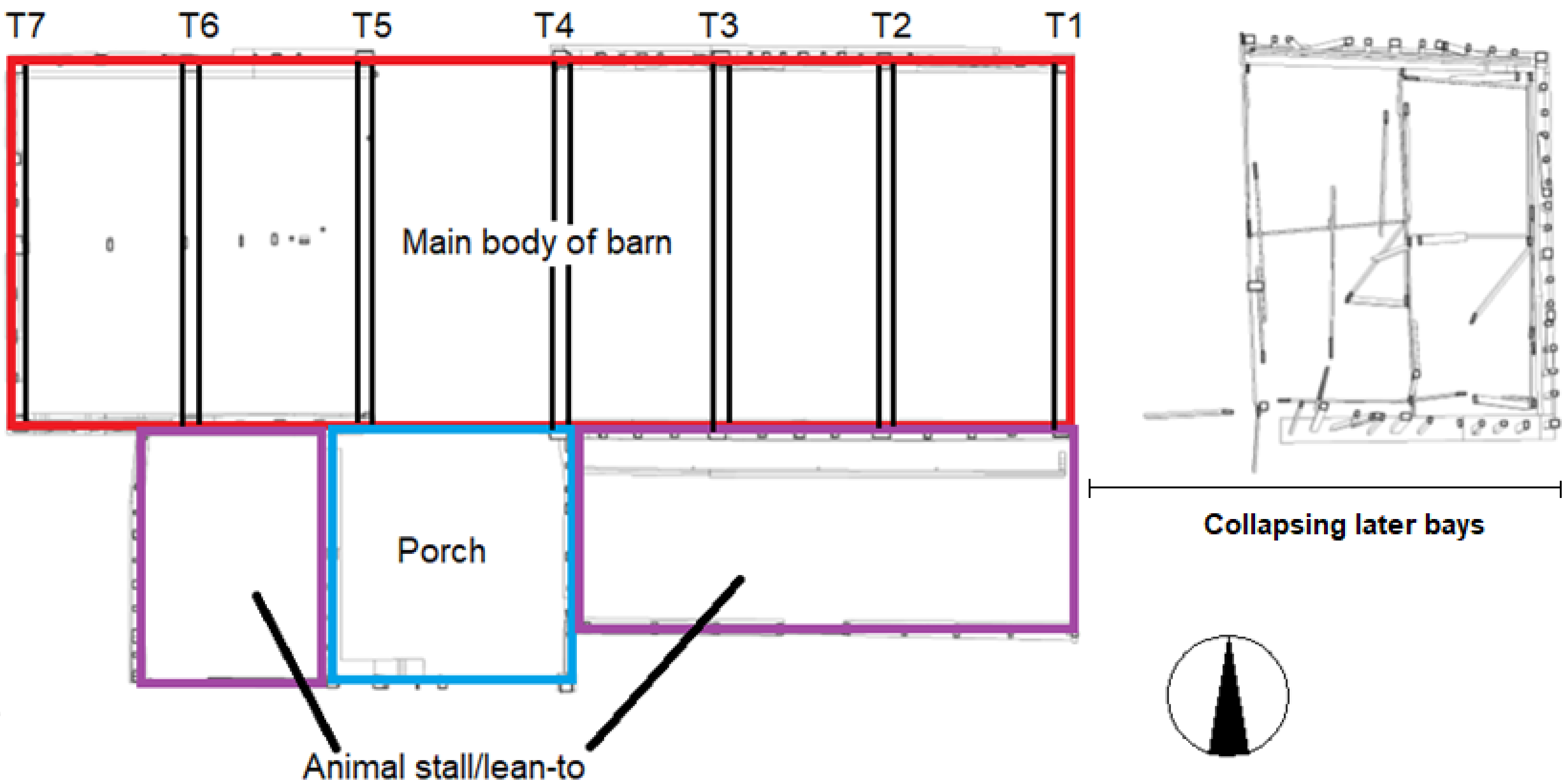

Figure 2: Plan of barn, showing the main barn (red) including approximate truss positions, the porch (blue), and the lean-to animal stalls (purple) (after ATD London Ltd)

Figure 3: The roof over the main body of the barn, photograph taken from the west (photograph Alison Arnold)

Figure 4: North wall of the barn with its unusual bracing, photograph taken from the north-east (photograph Alison Arnold)

Figure 5: Porch, photograph taken from the north (photograph Alison Arnold)

Figure 6: East wall of the lean-to animal stall sampled, photograph taken from the north-east (photograph Alison Arnold)

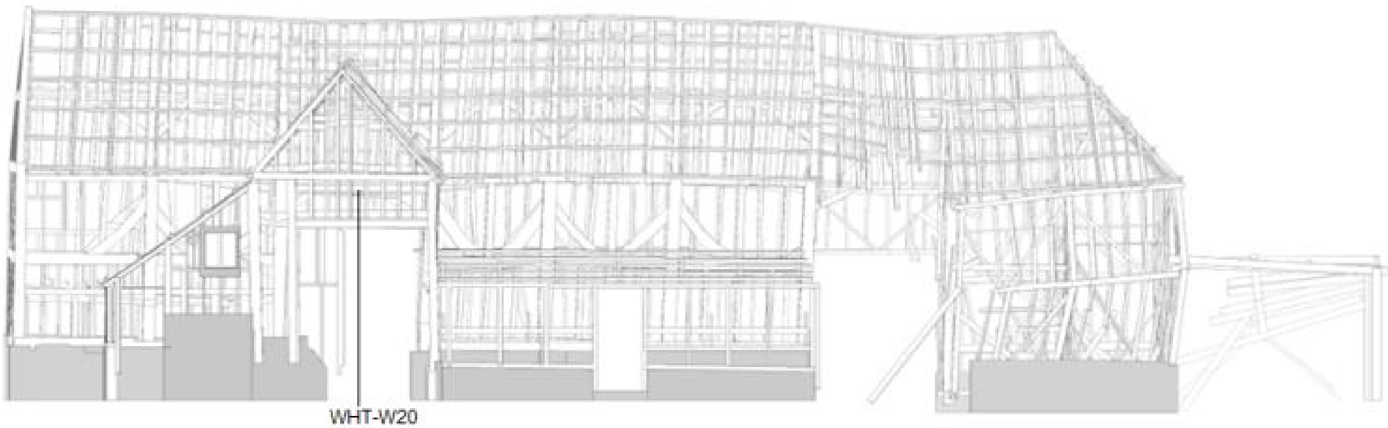

Figure 7: South elevation, showing the location of sample WHT-W20 (after ATD London Ltd)

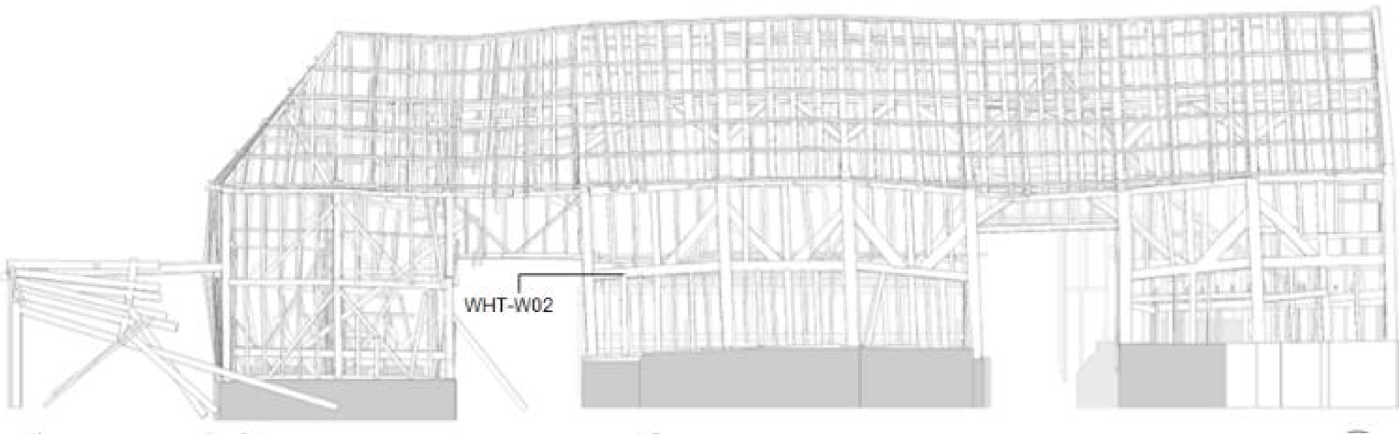

Figure 8: North elevation, showing the location of sample WHT-W02 (after ATD London Ltd)

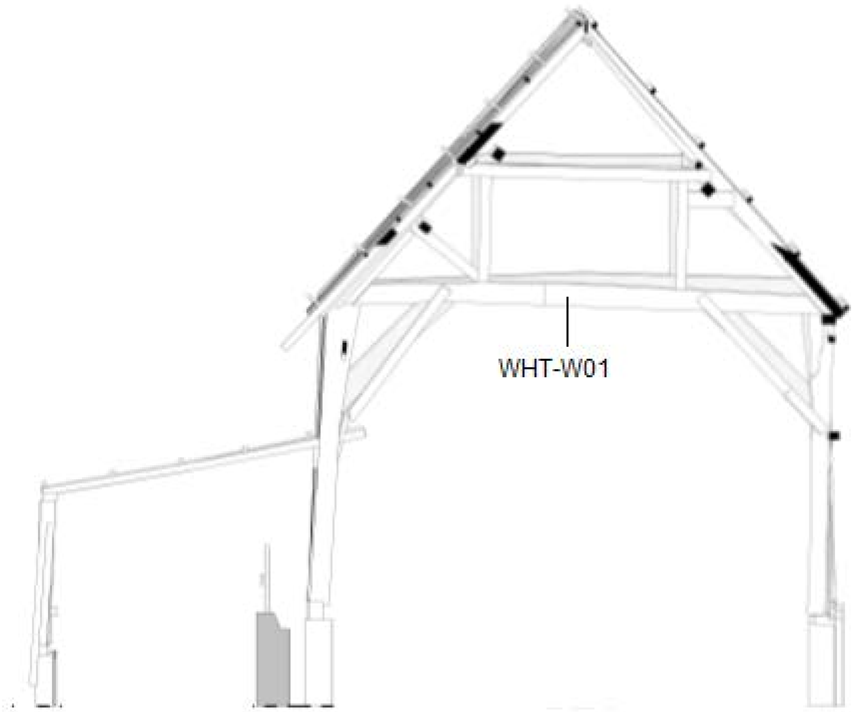

Figure 9: Section through Truss 1, east face, showing the sampled timber, WHT-W01 (after ATD London Ltd)

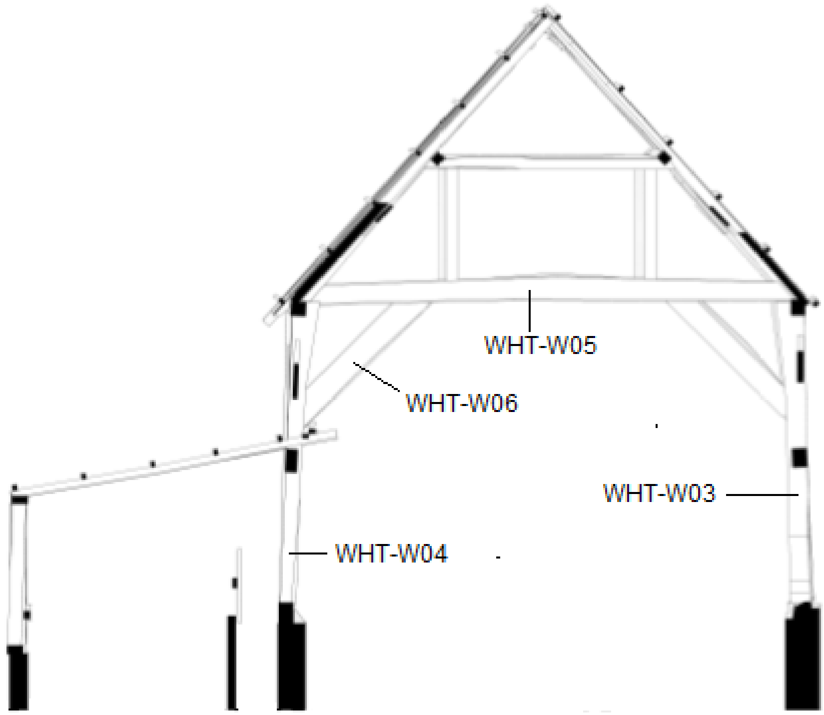

Figure 10: Section through Truss 2, east face, showing the sampled timbers, WHT-W03-06 (after ATD London Ltd)

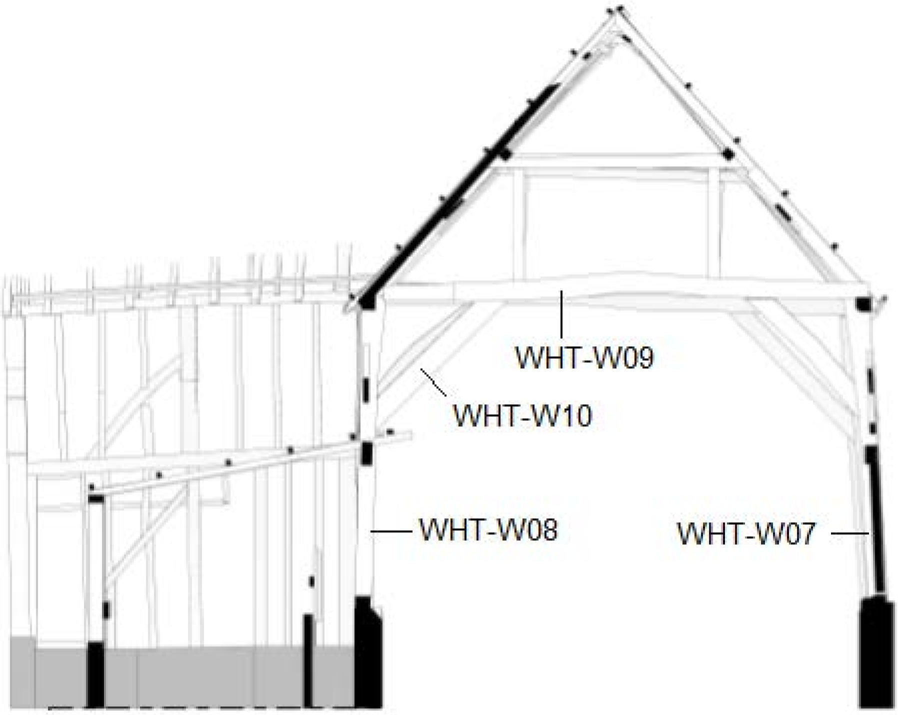

Figure 11: Section through Truss 3, east face, showing the sampled timbers, WHT-W07-10 (after ATD London Ltd)

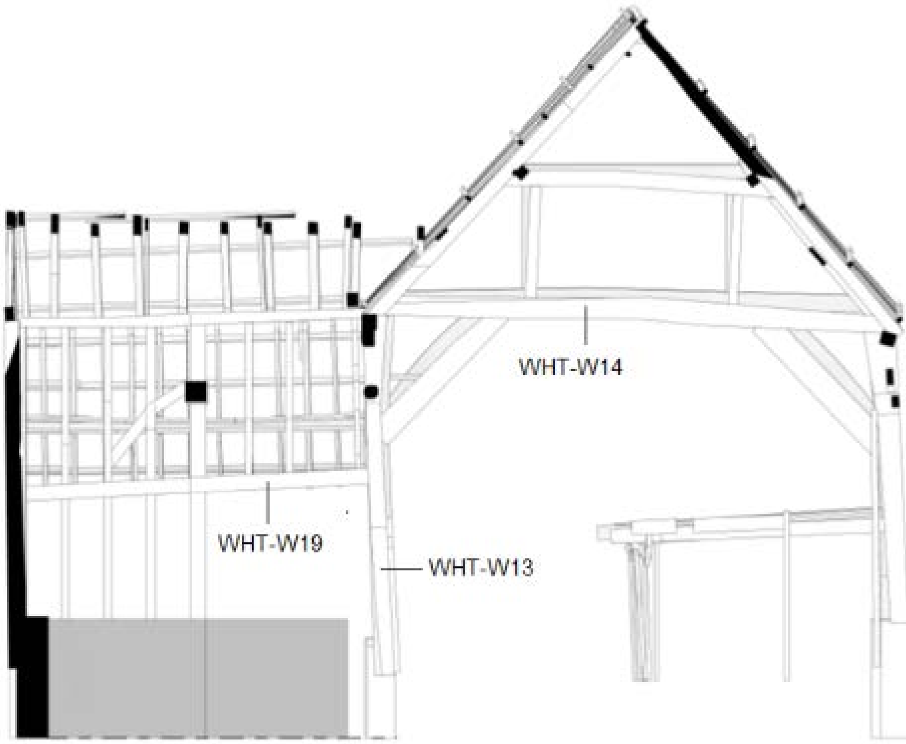

Figure 12: Section through Truss 4, east face, showing the sampled timbers, WHT-W13-14, and WHT-W19 (after ATD London Ltd)

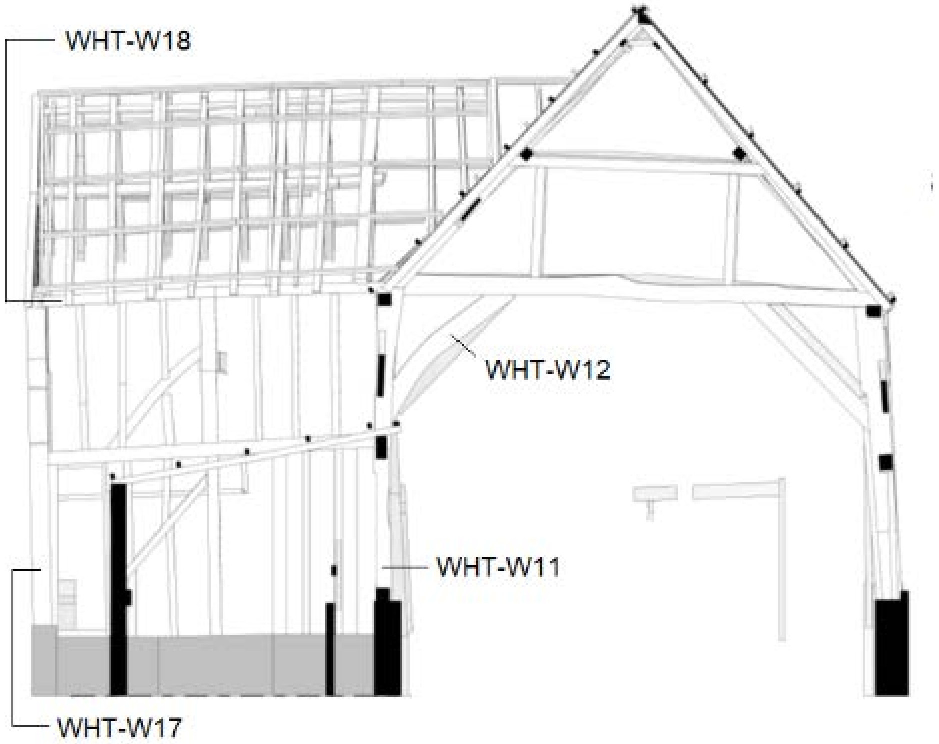

Figure 13: Section through Truss 5, east face, showing the sampled timbers, WHT-W11-12 and WHT-W17-18 (after ATD London Ltd)

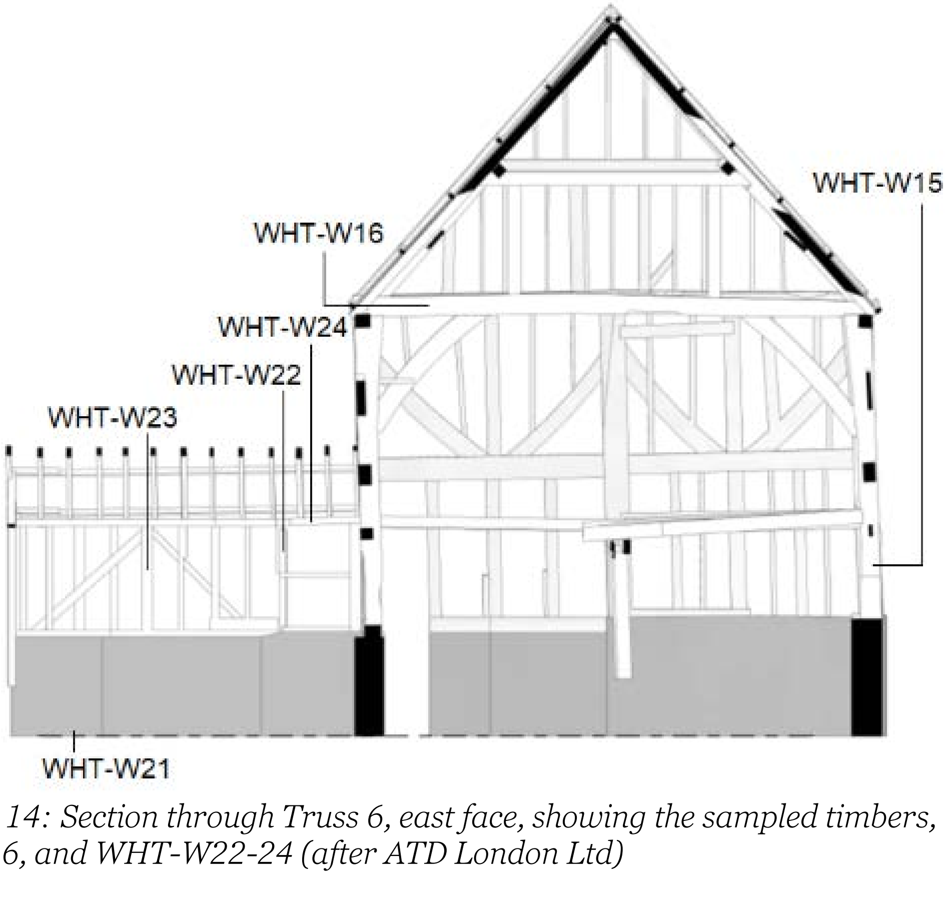

Figure 14: Section through Truss 6, east face, showing the sampled timbers, WHT-W15-16, and WHT-W22-24 (after ATD London Ltd)

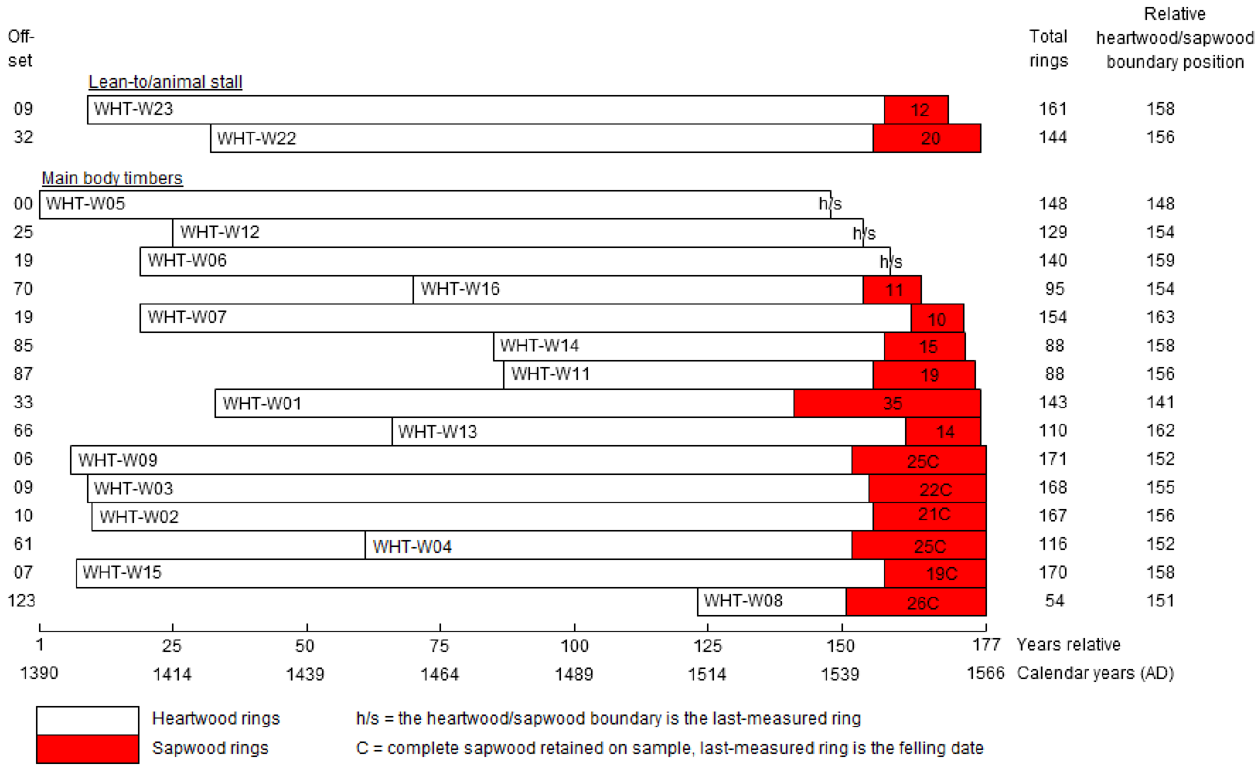

Figure 15: Bar diagram to show the relative position of samples in site sequence WHTWSQ01, sorted by area

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

WHT-W01A 143
151 123 154 122 130 162 180 165 217 216 164 203 311 170 171 217 222 218 171 170
150 151 140 153 156 163 196 176 179 180 130 172 149 152 145 115 104 116 116 85
101 66 97 109 68 79 133 120 103 91 91 76 93 73 72 87 64 63 83 70
57 57 48 80 67 77 61 53 62 66 71 57 62 73 71 57 69 63 74 59
53 54 54 45 44 49 59 56 79 62 57 66 77 74 56 66 85 66 53 85
65 69 65 70 70 97 98 86 106 74 74 66 104 86 84 66 83 66 98 67
87 65 79 77 65 83 98 68 76 75 87 86 115 98 76 62 69 64 73 49
58 68 57
WHT-W01B 143
160 111 149 134 117 159 188 148 211 232 160 198 310 172 152 205 209 242 181 160
136 153 145 150 156 163 198 179 176 181 132 193 156 167 154 114 104 114 114 86
95 75 107 104 67 94 126 128 109 93 95 81 98 72 97 81 85 66 92 76
60 66 53 65 67 68 64 59 62 71 63 60 60 78 67 58 64 67 75 61
60 57 51 50 40 50 63 60 73 65 52 58 79 65 54 67 81 72 56 87
64 68 72 62 77 93 111 87 115 72 78 64 109 90 78 71 78 81 68 66
111 64 78 73 62 89 94 75 72 70 92 76 115 92 79 59 68 64 69 55
54 70 60
WHT-W02A 167
82 72 53 40 55 62 372
335 361 205 207 163 122 132 153 142 90 88 115 152
135 125 92 104 132 122 80 109 132 104 95 96 123 99 68 75 70 60 68 66
58 69 89 74 100 97 82 89 86 78 67 91 58 68 73 62 72 70 51 73
56 67 57 66 52 81 78 58 74 82 75 65 81 64 76 62 70 52 48 53
57 73 92 71 40 51 60 52 60 45 49 59 58 52 47 60 53 68 64 59
60 60 58 107 89 163 199 118 89 93 88 107 90 80 72 82 51 44 68 75
62 35 47 54 58 48 74 78 102 92 67 76 56 71 60 57 77 75 66 183
263 163 87 130 82 77 72 73 94 109 71 96 88 104 103 129 93 105 123 96
145 104 117 111 96 90 70
WHT-W02B 167
83 77 51 45 45 73 374 324 381 207 196 159 119 131 156 132 96 88 118 151
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54 40 32 56 62 50 65 77 111 97 59 82 52 72 53 60 76 74 71 166
257 153 76 128 76 85 72 76 96 106 71 92 82 109 102 127 95 102 126 106
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WHT-W03A 168
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92 122 141 126 97 101 89 78 53 71 51 65 35 51 42 32 25 17 21 21
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80 105 136 120 111 117 77 60 46 58 61 80 96 77 70 75 53 60 70 76
64 58 67 92 62 48 66 54 37 51 41 51 47 72 68 129 97 75 90 82
89 96 118 88 106 118 104 119 93 110 102 141 101 88 84 69 85 85 62 60
103 111 103 91 90 77 123 107 62 73 66 68 104 96 97 106 85 108 96 109
137 130 133 94 97 70 79 99 105 62 88 53 48 33 41 51 39 48 34 39
64 54 58 74 66 76 86 88 95 114 149 93 78 64 60 80 52 85 93 114
162 165 141 92 64 60 64 102 116 152 186 255 154 95 164 113 146 101 116 178
212 180 179 140 147 142 189 172 130 116 154 202 150 168
WHT-W08A 54
176 254 320 150 130 162 165 153 123 159 127 135 108 149 113 133 99 89 128 80
81 99 95 140 115 130 121 118 111 112 169 101 231 103 88 120 158 83 110 86
147 140 156 109 85 98 90 104 95 112 107 110 103 83
WHT-W08B 54
182 239 338 133 133 147 182 155 119 153 114 160 107 159 115 114 113 86 117 84
85 96 100 146 120 128 122 131 108 110 169 96 233 96 88 116 169 80 103 86
157 139 153 109 90 93 90 109 94 113 101 120 103 77
WHT-W09A 171
295 222 143 91 69 77 68 129 209 224 259 315 278 254 246 225 180 172 153 149
118 119 133 89 109 125 100 130 127 114 95 87 103 90 103 103 144 122 62 102
86 74 102 90 105 86 95 84 103 90 108 102 81 64 45 42 54 48 75 57
71 82 69 38 47 30 47 60 50 60 72 46 49 68 77 62 76 71 62 76
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73 68 48 56 34 34 31 34 35 39 45 32 34 40 51 34 44 37 45 53
48 55 55 64 56 46 46 26 29 36 45 66 70 69 55 65 50 64 56 57
69 59 64 62 90 90 79 87 78 100 71 90 97 109 82 101 78 115 112 137
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WHT-W09B 171
304 223 152 79 79 63 75 127 217 226 240 319 281 251 231 231 196 173 169 148
111 136 143 92 114 122 100 117 139 103 102 85 105 96 95 107 147 114 64 103
102 73 109 108 117 94 102 92 107 94 115 98 80 63 46 42 56 49 77 56
67 81 71 48 37 32 42 64 45 64 76 44 48 73 82 59 70 71 64 74
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59 52 56 68 56 47 43 34 32 35 44 57 76 74 48 66 52 54 66 50
64 59 60 64 81 96 79 88 82 97 72 84 99 111 101 99 81 102 106 137
121 80 80 102 97 96 71 69 105 109 89
WHT-W10A 162
271 153 191 199 274 307 250 325 500 246 237 174 227 197 208 250 207 200 210 244
210 186 115 76 121 181 192 131 135 105 117 121 115 90 109 84 64 45 54 66
61 68 76 53 75 68 56 44 32 49 42 38 51 46 50 41 33 46 47 44
41 46 28 56 43 45 43 39 46 42 39 36 43 49 46 32 34 50 39 40
31 35 29 26 24 26 30 38 32 37 34 33 35 40 36 41 25 37 25 29
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64 51 77 57 57 86 83 108 79 96 98 106 109 116 107 58 86 95 142 80
76 85 87 147 85 117 120 121 108 113 110 70 79 91 80 98 150 162 179 208
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WHT-W10B 162
282 159 181 293 287 306 247 357 416 278 240 184 239 197 211 241 201 195 209 245
208 203 118 77 106 181 186 137 132 107 112 104 111 96 106 80 56 45 49 75
66 68 79 60 69 70 51 42 39 55 40 36 50 51 47 40 32 51 44 43
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75 90 85 146 89 105 122 132 93 112 109 75 79 79 80 93 151 164 179 204
129 129
WHT-W11A 88
158 157 251 183 196 201 167 201 166 170 158 160 198 204 146 140 181 149 126 310
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220 334 440 263 222 347 194 227 216 291 285 269 266 274 270 167 209 187 249 220
201 198 221 212 248 157 308 161 316 165 159 220 320 160 193 153 210 218 315 173
138 143 123 175 176 156 146 91
WHT-W11B 88
150 156 251 177 194 206 163 179 178 171 152 155 195 203 143 139 182 158 121 310
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219 332 438 273 217 351 192 230 211 292 302 271 289 282 296 164 213 184 253 220
206 195 232 199 251 170 306 160 314 166 153 206 311 144 203 145 212 215 305 197
143 137 123 166 154 145 167 199
WHT-W12A 129
86 58 71 83 82 88 133 88 95 96 59 75 74 91 71 64 63 107 90 71
71 65 51 36 38 71 50 65 74 122 136 159 192 174 158 132 168 141 102 200
134 105 102 121 107 132 113 101 138 86 126 147 141 209 240 247 169 161 165 149
188 161 110 103 115 140 170 147 148 130 129 124 125 109 128 104 111 76 73 70
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141 108 114 186 239 161 142 117 110 98 105 92 119 159 186 207 221 153 138 119
170 155 163 129 130 155 146 93 140
WHT-W12B 129
98 61 68 77 67 86 126 72 99 84 63 62 60 73 71 82 57 120 92 83
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82 95 126 120 143 93 69 53 49 52 62 66 55 70 89 99 83 93 83 90
143 111 112 187 235 157 149 121 106 91 109 90 120 157 188 210 223 153 143 114
163 148 164 130 145 153 143 95 137
WHT-W13A 110

135 108 106 94 84 81 82 90 66 85 87 65 70 73 88 90 72 86 64 89
69 45 65 39 62 113 80 83 53 48 65 53 73 55 76 73 60 73 68 66
60 70 82 96 59 70 51 66 63 85 83 53 82 105 95 106 164 128 152 173
111 81 241 194 148 130 120 91 94 90 100 118 143 154 134 146 96 115 103 109
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207 239 203 192 305 261 327 214 244 230
WHT-W13B 110
138 104 101 104 72 96 75 92 63 93 75 64 81 62 100 82 79 86 76 78
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51 81 77 102 66 71 51 68 57 91 79 50 77 110 83 113 163 132 142 168
123 76 235 202 147 135 112 95 91 92 98 118 148 159 136 134 96 114 105 109
183 241 229 371 413 380 253 273 309 344 219 293 316 390 262 306 218 221 244 360
202 233 222 187 306 262 324 219 233 230
WHT-W14A 75
453 271 172 154 287 316 427 353 309 234 284 216 222 190 226 263 202 153 158 193
149 183 120 87 176 117 92 100 110 112 94 89 88 84 111 90 143 142 100 99
92 102 66 88 98 64 45 63 51 63 49 49 42 65 63 56 112 91 98 71
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WHT-W14B 65
75 167 122 87 77 102 112 100 77 81 83 112 92 137 156 119 125 88 94 53
88 73 54 47 60 58 60 60 46 45 67 66 72 97 94 92 77 85 109 116
116 134 150 181 143 173 127 142 111 129 150 191 128 151 116 143 148 200 147 138
143 159 181 158 161
WHT-W15A 170
178 334 251 255 146 151 132 127 132 153 129 120 108 104 108 76 86 62 66 55
64 71 67 77 98 58 97 92 75 57 45 56 73 44 74 86 110 103 94 80
75 77 79 86 77 86 81 109 75 74 65 72 62 64 70 60 67 60 60 70
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WHT-W15B 170
186 339 288 256 138 154 112 126 131 154 132 108 117 102 108 81 80 62 72 51
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64 81 71 97 67 80 77 112 76 79 65 71 74 56 73 61 64 60 64 62
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125 212 247 246 166 196 131 116 102 117 154 165 165 152 195 175 149 118 180 215
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168 142 167 139 148 194 145 171 159 150
WHT-W16A 95
345 258 305 428 215 349 342 239 326 331 242 215 219 150 257 306 245 142 105 228
216 249 153 135 148 185 165 211 191 199 145 133 112 142 140 203 253 186 102 137
122 124 90 102 103 136 145 93 110 114 106 97 110 124 112 140 127 69 155 188
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147 148 72 180 150 168 117 109 189 220 145 177 157 204 214
WHT-W16B 95
349 259 298 430 202 355 351 242 324 367 232 217 220 151 264 306 247 146 107 207
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WHT-W17A 45
101 184 212 256 350 251 477 615 264 149 156 149 139 261 242 215 435 477 303 212
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WHT-W17B 45
97 180 211 256 350 254 480 614 276 159 155 140 134 244 247 216 439 484 306 211
239 204 225 296 199 239 281 319 265 263 244 244 358 297 244 239 244 222 211 235
132 57 60 57 61
WHT-W18A 46
221 252 434 485 258 344 262 217 246 338 257 246 322 321 265 227 179 206 160 157
155 164 170 203 191 255 234 265 296 259 174 221 196 192 266 75 59 64 82 81
103 141 148 112 277 212
WHT-W18B 46
234 251 403 485 268 345 266 221 241 338 255 247 341 330 270 249 188 207 164 153
153 167 167 196 202 250 245 267 292 273 170 218 187 200 274 59 69 65 87 89
112 128 154 125 264 199
WHT-W19A 55
225 126 179 166 186 119 147 180 539 760 499 362 414 374 344 306 434 232 289 283
506 523 340 397 251 225 64 49 46 42 48 106 123 159 132 101 102 153 205 222
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WHT-W19B 55
219 127 180 166 157 133 122 174 537 765 505 358 413 377 342 306 428 232 291 273
509 528 354 407 250 229 64 50 35 45 57 100 118 157 134 109 95 156 200 217
358 283 336 560 640 566 601 602 576 444 290 287 411 333 283
WHT-W20A 55
304 295 295 177 249 343 708 469 455 511 342 319 325 271 161 170 84 208 331 395
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360 408 326 363 240 87 85 86 142 191 175 175 184 213 168
WHT-W20B 55
309 296 290 181 253 343 713 462 463 509 341 318 343 273 157 181 80 209 331 393
425 318 328 338 118 75 116 137 244 205 283 270 245 274 386 356 329 471 330 238
381 408 325 367 249 86 82 92 133 187 169 186 181 209 198
WHT-W22A 144
117 103 85 59 52 45 45 49 54 63 80 66 56 64 55 35 43 46 35 32
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WHT-W22B 144
114 99 88 60 52 41 52 42 51 62 68 71 56 57 55 45 38 47 33 33
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46 54 49 66 59 40 44 74 74 64 69 71 78 80 84 51 70 80 126 251
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WHT-W23A 161
402 393 381 274 313 411 383 327 261 252 145 188 194 158 169 128 94 78 83 100
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WHT-W23B 161
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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 Buildings* (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	

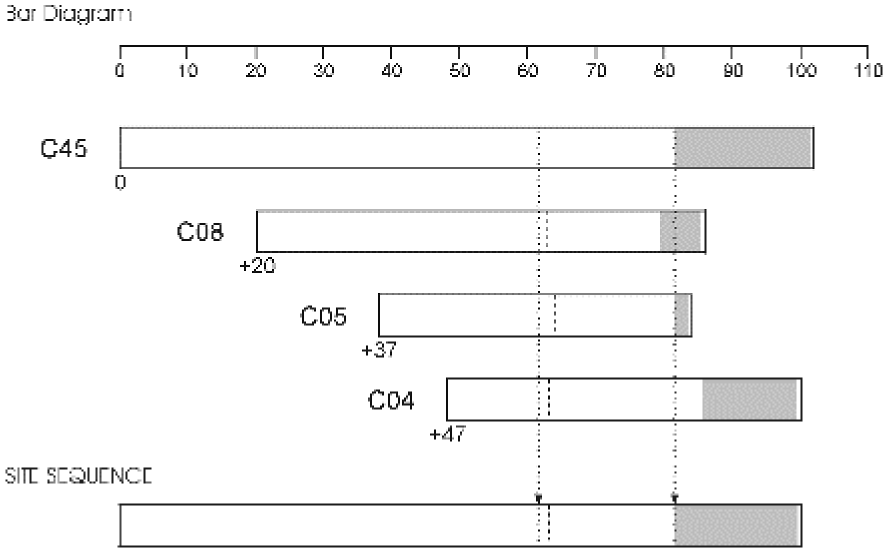


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

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.

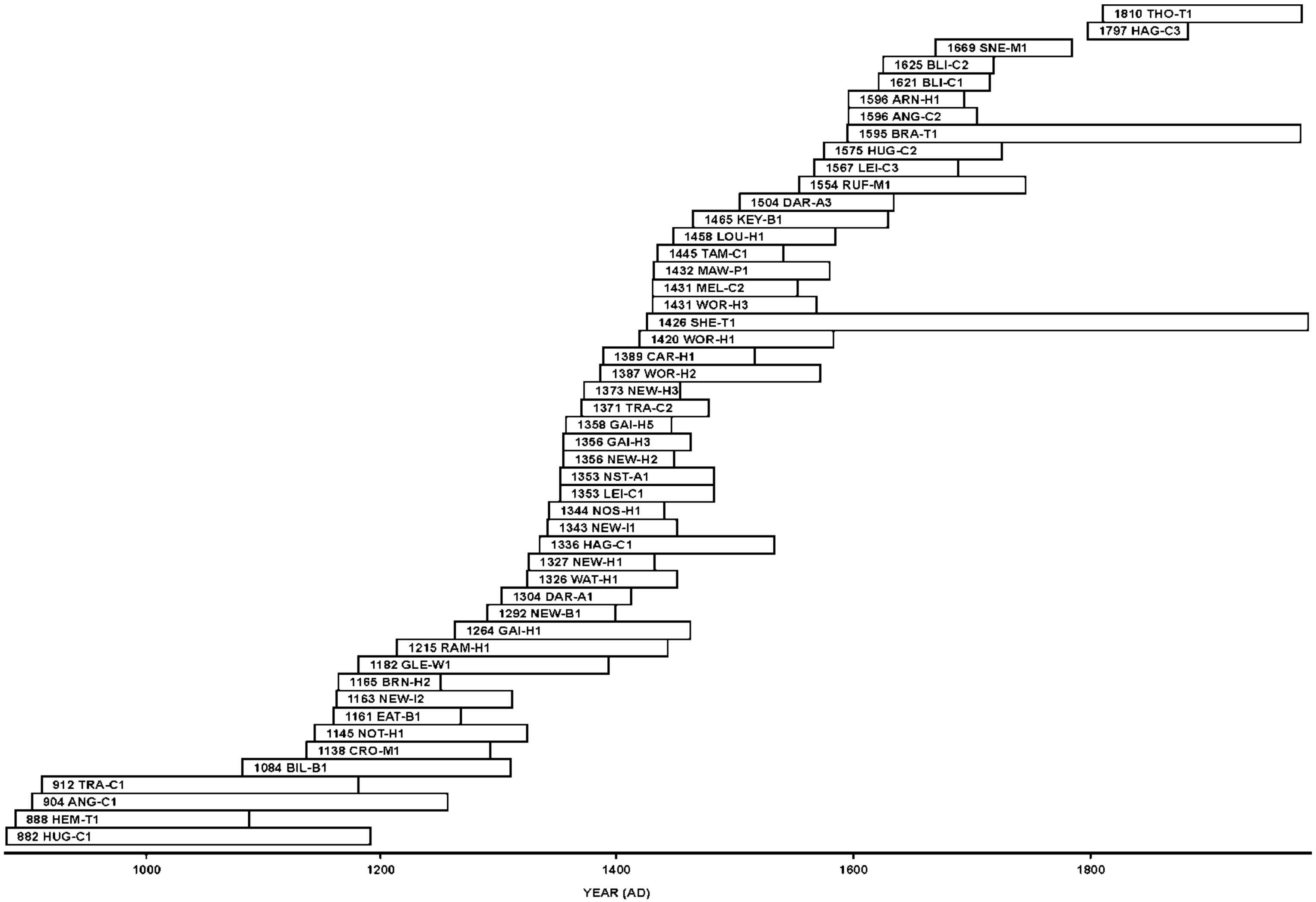
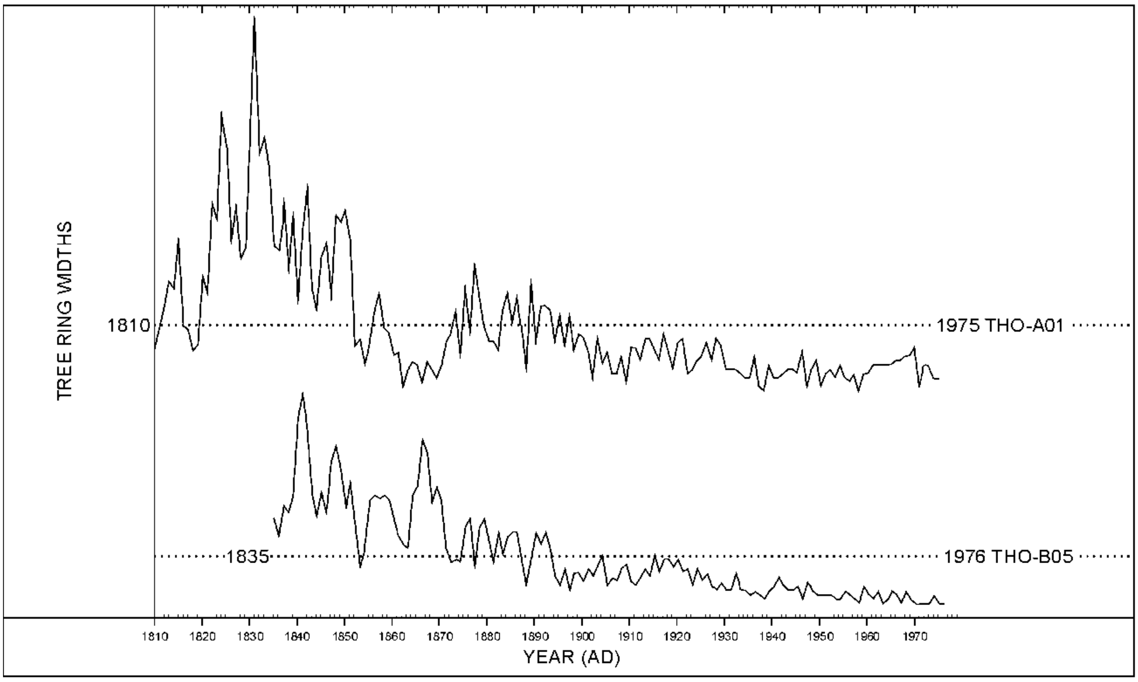


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

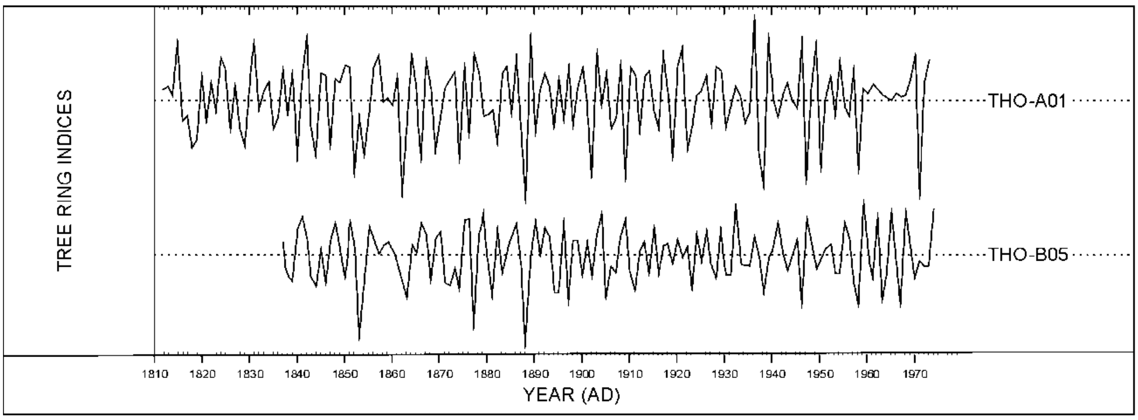


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

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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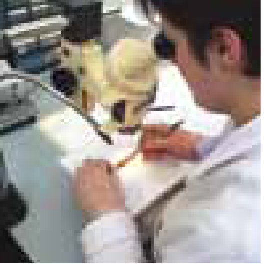
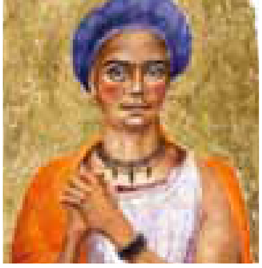


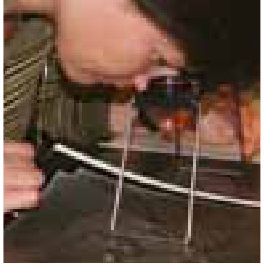


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