RESEARCH DEPARTMENT REPORT SERIES no. 94-2007 ISSN 1749-8775

TRERITHICK HOUSE, POLYPHANT, CORNWALL
TREE-RING ANALYSIS OF TIMBERS

SCIENTIFIC DATING REPORT

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ARCHAEOLOGICAL SCIENCE

ENGLISH HERITAGE

Research Department Report Series 94/2007

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Summary

Dendrochronological analysis undertaken on samples taken from the roofs of the Hall and West ranges of this building complex resulted in the construction of two site sequences.

The first, TRKHSQ01, contains seven samples taken from the timbers of the Hall roof and spans the period AD 1503–1673. One of the dated samples was felled in AD 1673 with interpretation of the heartwood/sapwood boundary on the other samples suggesting these were also felled in AD 1673.

The second site sequence, containing samples from the roof of the West range, could not be dated.

Prior to tree-ring analysis being undertaken at this building, the Hall and West ranges had both been dated to the late-sixteenth century. It is now known that the roof of the Hall range is built from timbers felled in AD 1673, demonstrating that the present roof is in fact a replacement. It is unfortunate that none of the timbers of the West range roof have been dated and so at this time it is not known whether these also represent a replacement or belong to the original building.

Keywords

Dendrochronology
Standing Building

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Introduction

Trerithick House is a grade-II* listed, two storey, medieval hall house, currently undergoing refurbishment. It is located approximately 1.5km west of Polyphant, near Launceston (SX 2478982125; Figs 1 and 2).

The Hall range faces east and is of three-room and through-passage plan; the lower end (to the south) is heated by an end stack, the hall by a front lateral stack, and the inner room by a stack in the rear wall (Fig 3). To this was added a gabled two-storey porch which has the datestone, 'AN DO 1585 BY M + IH' (Fig 4). Stylistically, and by its association with the porch, the Hall range is also thought to date to the late-sixteenth century and is likely to pre-date AD 1585. The stair projection which adjoins the rear of the hall was added in the seventeenth or eighteenth century.

Set to the front and at a slight angle to this Hall range is the South-east range, thought to be seventeenth century (Fig 5). To the rear of the Hall range are a further two ranges, forming a courtyard (Fig 6). The range immediately to the rear of the parlour (here referred to the West range), is thought to date to the late-sixteenth century but being partly rebuilt in the early-eighteenth century (Fig 7). At 90° to this and running parallel to the Hall range is another range (the Rear range), currently a series of outbuildings. This originally had the datestone 'ANNO DOMINI 1575 BY JOHN HECKS' but this has since been reset in the South-east range.

Acknowledgements

The Laboratory would like to thank Mr and Mrs Aldrich-Blake, the owners of the property, for allowing the work to be undertaken and their hospitality throughout its duration. The above building description is based on Trerithick House's Listed Building Description. Figures 6, 11, and 12, on which Eric Berry has marked truss positions, was produced by Parkes Lees Architects of Launceston, incorporating Ordnance Survey data. Thanks are also given to the English Heritage Scientific Dating Section and Cathy Tyers of Sheffield University Dendrochronology Laboratory for their advice and assistance throughout the production of this report.

Aims and Objectives

Sampling and analysis by tree-ring dating was commissioned and funded by English Heritage. It was requested by Francis Kelly, Historic Buildings Inspector at their South-West Regional Office, to inform statutory advice in the context of an application for Listed Building Consent.

The brief initially focussed on two areas; the Hall range and the South-east range. The Hall range roof consists of five trusses with principal rafters and collars, with purlins and common rafters between them (Fig 8). At the northern end, the roof is hipped, but this is not thought to be original. By gaining a date for the main timbers of this roof and also those relating to the northern hip, it was hoped to provide a construction date for this part of the building and a date for the possible modification of the roof.

The roof of the South-east range is of five trusses, the timbers of which are a mixture of possibly original (ie, seventeenth century), more recent, and some which appear to be modern. It was hoped to provide a date for the addition of this range.

During sampling of the Hall range roof it was found possible, with some difficulty, to enter the roof of the range to the west of it. Here was seen another potentially original, late-sixteenth century roof, again consisting of five trusses with principal rafters and collars, and common rafters and purlins between (Figs 9 and 10). Following discussions it was agreed to include this roof in the brief in the hope of providing a construction date for this part of the building.

Sampling

Unfortunately, the timbers of the northern hip of the Hall range roof were not considered suitable for tree-ring analysis being either from fast grown trees with insufficient growth rings, reused and/or inserted, and so this part of the roof was not sampled. A number of the timbers of the main roof structure could also be seen to be wide-ringed; however, several of the principal rafters were thought to contain sufficient rings and were duly sampled. The timbers of the West range were again varied, but enough suitable timbers were seen to make sampling worthwhile. As mentioned above, the roof of the South-east range was constructed from a mixture of potentially original and more recent timber. Unfortunately, the older-looking timbers had very wide growth-ring patterns, demonstrating they were derived from fast-grown trees and were thus unsuitable for tree-ring analysis, and so were not sampled. The opportunity was taken to inspect the timbers of the Rear range, but this roof was seen to be a relatively modern replacement.

A total of 18 timbers was sampled in the Hall and West range roofs. Each sample was given the code TRK-H (for Trerithick House) and numbered 01–18. Samples TRK-H01–07 are from the Hall roof and samples TRK-H08–18 from the West range roof. The position of samples was noted at the time of sampling and has been marked on Figures 11 and 12. Further details relating to the samples can be found in Table 1. Trusses were numbered from north-south and from west-east.

Analysis, Results, and Interpretation

At this stage it was noticed that three of the samples taken from the West range (TRK-H10, TRK-H15, and TRK-H16) had too few rings to make secure dating a possibility and these samples were rejected prior to measurement. The remaining 15 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 15 samples were compared with each other by the Litton/Zainodin grouping procedure (see appendix).

At a least value of t=6.8, all seven of the Hall samples matched each other and were combined at the relevant offset positions to form TRKHSQ01, a site sequence of 171 rings (Fig 13). This site sequence was then compared with a large number of relevant reference chronologies for oak where it was found to match at a first-ring date of AD 1503 and a last-measured ring date of AD 1673. The evidence for this dating is given by the t-values in Table 2.

One of the samples (TRK-H05) within this site sequence has complete sapwood and the last-measured ring date of AD 1673, the felling date of the timber represented. The other six samples from the Hall roof have the heartwood/sapwood boundary ring, the dates of which are broadly contemporary, being within 11 years of each other, and with TRK-H05, suggesting that these were also felled in AD 1673.

At a least value of t=11.8, five of the samples from the West range matched each other and were combined at the relevant offset positions to form TRKHSQ02, a site sequence of 126 rings (Fig 14). Attempts to date this site sequence by comparing it against the reference material were unsuccessful.

The remaining three ungrouped samples were then individually compared against the reference material but again this proved unsuccessful and all remain undated.

Discussion

Prior to the tree-ring analysis being undertaken, both the Hall and West ranges had been dated to the late-sixteenth century on the basis of inscriptions and structural features. It is now known that the roof of the Hall range is actually constructed with timbers felled in AD 1673. This demonstrates that, rather than being the original structure, the extant roof in this part of the building would appear to be a replacement dating to the late-seventeenth century.

Unfortunately, no timbers from the West range roof have been dated and so it is not possible to say whether this is the original, late-sixteenth century roof or not. Although there is no cross-matching between the two site sequences (TRKHSQ01 containing samples from the Hall range roof and TRKHSQ02 containing samples from the West range roof), this does not necessarily mean the two roofs are of different dates, but could simply be due to different woodland sources being utilised. Indeed, stylistically the West range roof does appear very similar to that of the Hall range, which might suggest it is also a later replacement dating to the late-seventeenth century, or perhaps to the early-eighteenth century rebuilding known to have occurred to this part of the building.

Although tree-ring analysis has been unable to provide a date for the West range roof, it is possible to say that, by looking at the relative heartwood/sapwood boundary ring position of the samples in site sequence TRKHSQ02 (Figure 14), it is likely that, as with the Hall roof, this roof is also constructed from timbers of a single felling and therefore, was the result of a single phase of construction.

The good intra-site matching seen with the samples from each roof suggests in both cases construction was undertaken utilising a coherent series of trees taken from a single source. In the case of the samples from the West range roof, all group at the high value of t=11.8 which suggests that not only were all trees used from the same woodland, but potentially even from the same woodland stand. In fact the value at which samples TRK-H09 and TRK-H12, south principal rafters from trusses 1 and 2 of the West range, match (t=25.4) suggests these two beams are cut from the same tree.

It is unclear why the timbers of the West range could not be dated. Site chronologies which are relatively short in length and poorly replicated with only a small number of samples incorporated are more likely to remain undated. However, the West range site sequence (TRKHSQ02) contains five samples and at 126 rings is of good length and so the chances of successful dating would normally be expected to be reasonable. There is nothing obviously unusual about the growth patterns of the samples, being neither unduly compacted nor complacent, which might have suggested a major growth disturbance in the trees represented and hence inhibited successful matching with reference chronologies.

However, it is still possible, that although not immediately obvious, the trees were subjected to highly localised growing conditions, which could have masked the overall climatic signal necessary for successful dating. The importance of a strong localised network of reference data in certain areas of the country has been highlighted by the research investigation in mid-Devon, jointly funded by English Heritage and Devon County Council (Groves 2005).

Prior to the successful dating of timbers at nearby Treludick House (Arnold and Howard 2007), which in turn allowed a number of other seventeenth-century structures, including the Hall timbers here at Trerithick House, to be dated, most of the relatively few sites successfully analysed in Cornwall dated to between approximately AD 1450 to AD 1550. If the Trerithick House West range roof was of its expected date, the site sequence would be expected to overlap with at least some of these. However, if this roof is a later replacement, as might be suggested by the dating of the Hall roof, there would be little reference material with which to match it, especially if it does date to the early-eighteenth century rebuilding of this range.

The successful dating of the Hall timbers of Trerithick House is of importance, not only in improving our understanding of this building itself but also in improving and extending the localised network of reference data for the south-west. It is hoped that continuing work, gathering data from the south-west may at some point in the future allow the currently undated site sequence, TRKHSQ02, to also be successfully dated.

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Table 1: Details of tree-ring samples from the Trerithick House, Polyphant, Cornwall

Sample number	Sample location	Total rings*	Sapwood rings**	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
<u>Hall range</u>						
TRK-H01	East principal rafter, truss 2	87	h/s	1557	1643	1643
TRK-H02	East principal rafter, truss 3	80	18	1586	1647	1665
TRK-H03	West principal rafter, truss 3	144	h/s	1503	1646	1646
TRK-H04	East principal rafter, truss 4	83	h/s	1554	1636	1636
TRK-H05	West principal rafter, truss 4	115	30C	1559	1643	1673
TRK-H06	East principal rafter, truss 5	127	h/s	1510	1636	1636
TRK-H07	West principal rafter, truss 5	126	h/s	1516	1641	1641
<u>West range</u>						
TRK-H08	North principal rafter, truss 1	96	20	----	----	----
TRK-H09	South principal rafter, truss 1	109	05	----	----	----
TRK-H10	Collar, truss 1	NM	--	----	----	----
TRK-H11	North principal rafter, truss 2	79	16	----	----	----
TRK-H12	South principal rafter, truss 2	106	08	----	----	----
TRK-H13	Collar, truss 2	51	19	----	----	----
TRK-H14	North principal rafter, truss 3	82	21C	----	----	----
TRK-H15	Collar, truss 3	NM	--	----	----	----
TRK-H16	North principal rafter, truss 5	NM	--	----	----	----
TRK-H17	North-west hip rafter	72	h/s	----	----	----
TRK-H18	South-west hip rafter	108	--	----	----	----

*NM = not measured

**h/s = the heartwood/sapwood ring is the last ring on the sample

C = complete sapwood retained on sample, last measured ring is the felling date

Table 2: Results of the cross-matching of site sequence TRKHSQ01 and relevant reference chronologies when the first-ring date is AD 1503 and the last-ring date is AD 1673

Reference chronology	*t*-value	Span of chronology	Reference
Treludick House, nr Egloskerry, Cornwall	7.4	AD 1516–1630	Arnold and Howard 2007
Lower Coombe Farmhouse, Bradninch, Devon	5.9	AD 1548–1624	Miles 2003
Chaffcombe, Down St Mary, Devon	5.1	AD 1531–1667	Groves 2005
Leigh Barton, nr Churchstow, Devon	4.9	AD 1485–1604	Groves 2006
Swaylands Barn, Penshurst, Kent	4.6	AD 1515–1616	Arnold *et al* 2001
Ightham Mote, NW Range, Kent	4.3	AD 1465–1586	Howard *et al* 1997
Godolphin House, Cornwall	4.2	AD 1376-1620	Tyers and Tyers forthcoming
St Martin's Church, East Looe, Cornwall	4.1	AD 1445–1580	Arnold *et al* 2006

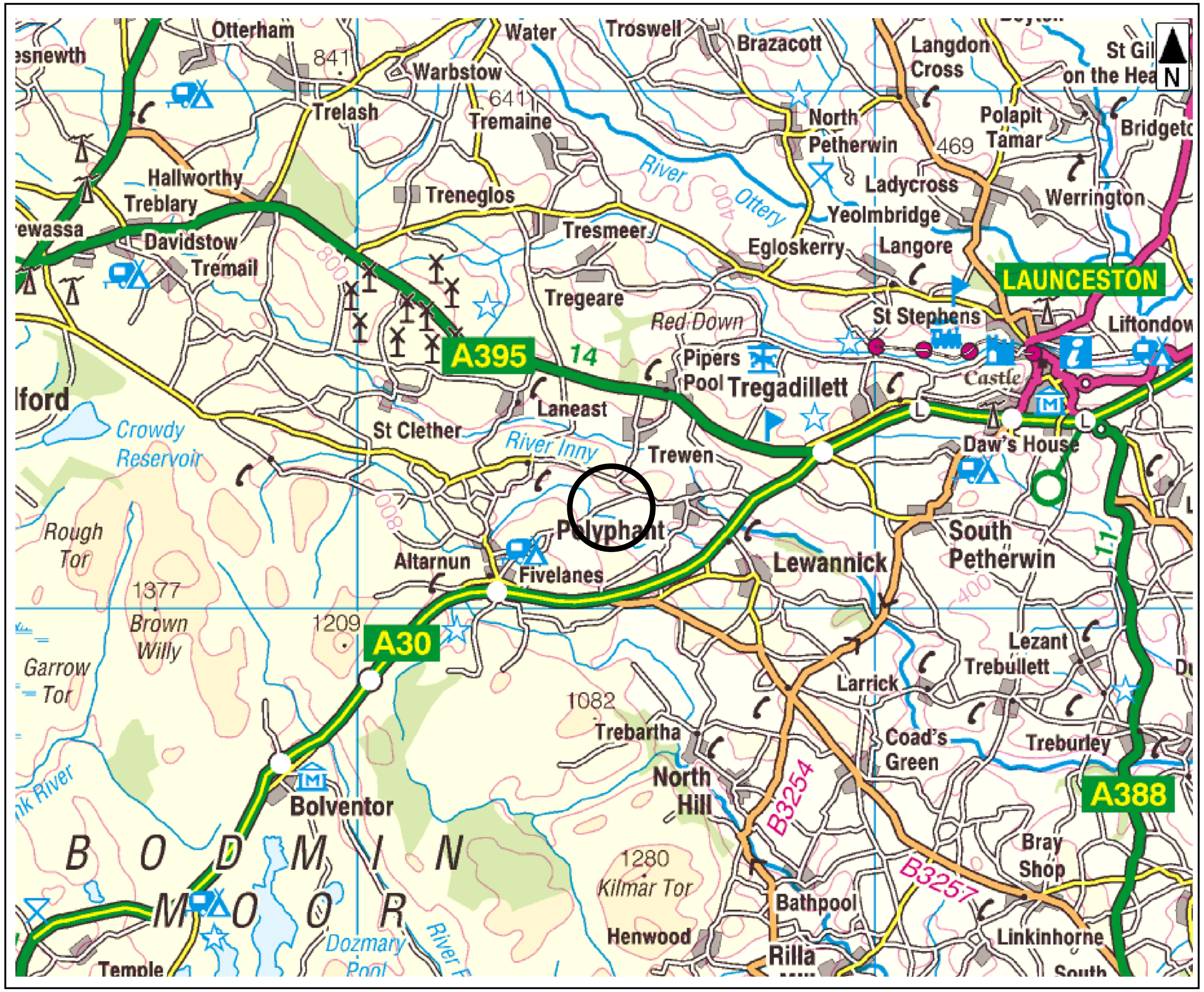


Figure 1: Map to show the general location of Trerithick, Cornwall

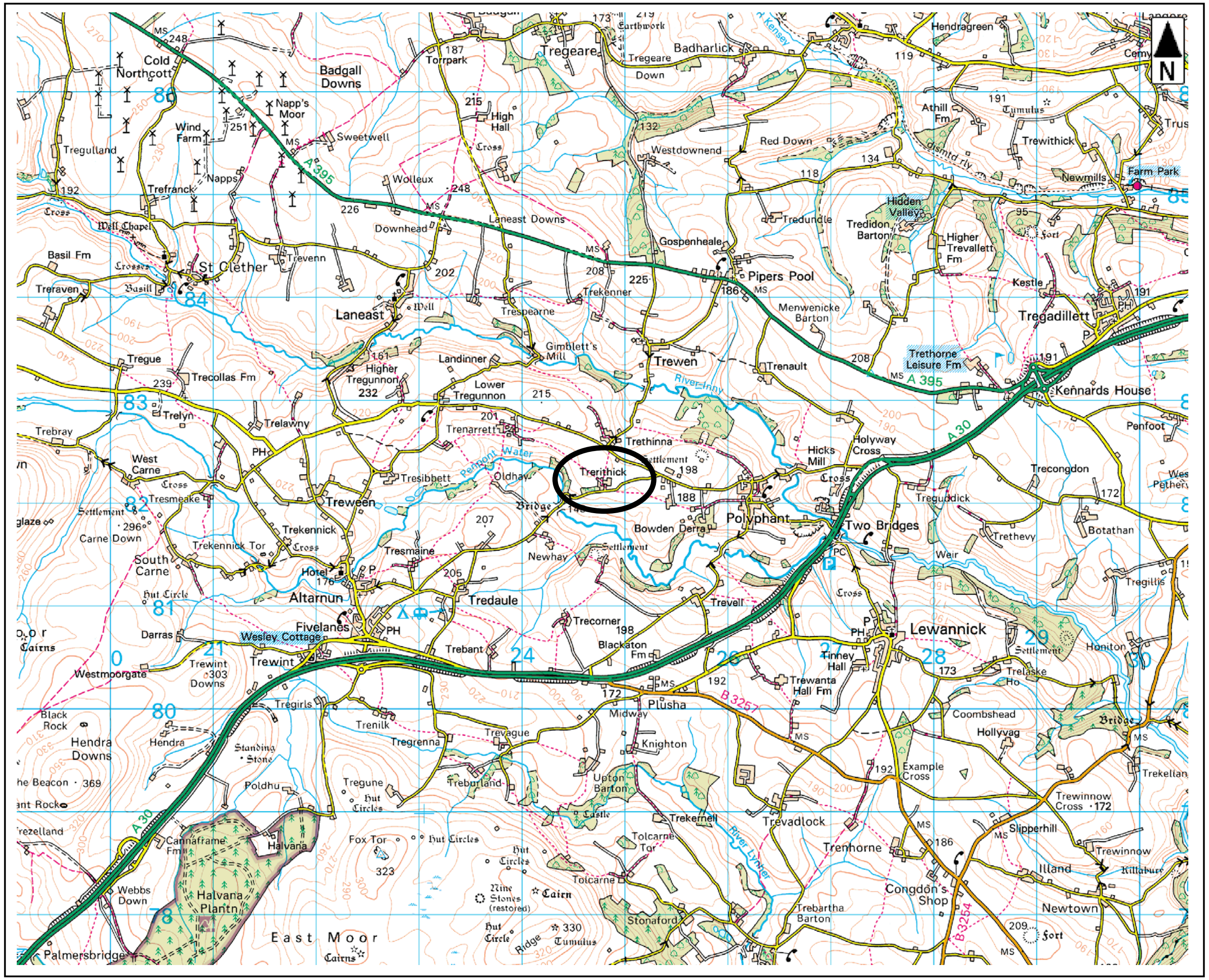


Figure 2: Map to show the location of Trerithick House

Figure 3: Hall range with porch addition

Figure 4: Datestone on the porch ‘AN DO 1585 BY M + IH’

Figure 5: South-east range

Figure 6: Plan of Trerithick House, Hall range outlined in red, West range in blue (supplied by Eric Berry, based on a plan by Parkes Lees Architects incorporating Ordnance Survey data)

Figure 7: West range

Figure 8: Trerithick House, Hall range (looking north)

Figure 9: Trerithick House; West range (looking west)

Figure 10: Trerithick House; West range, showing the ‘dimple’ carpenters mark (looking west)

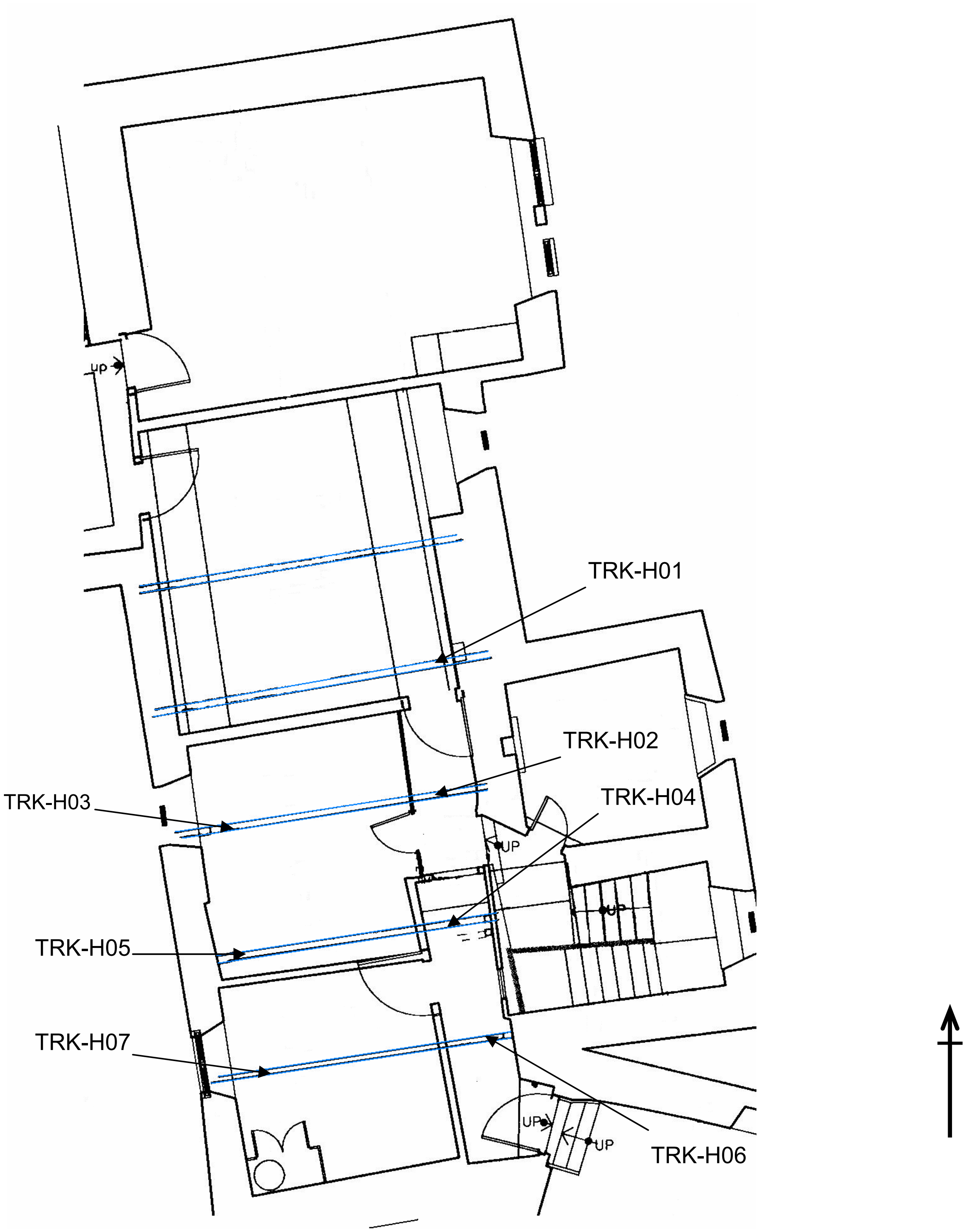


Figure 11: Plan of the Hall range with trusses marked, showing the location of samples TRK-H01–07 (supplied by Eric Berry, based on a plan by Parkes Lees Architects, incorporating Ordnance Survey data)

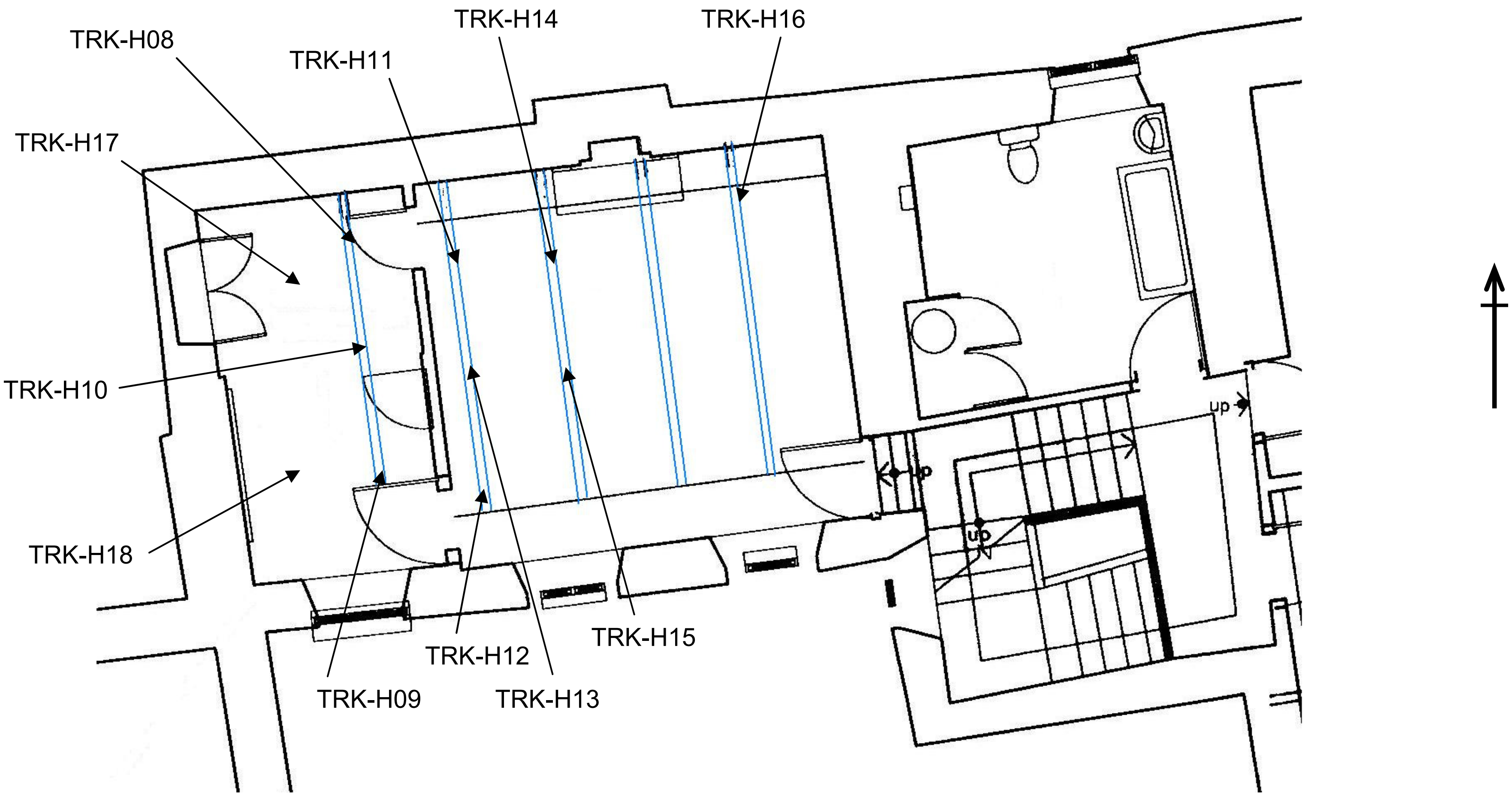
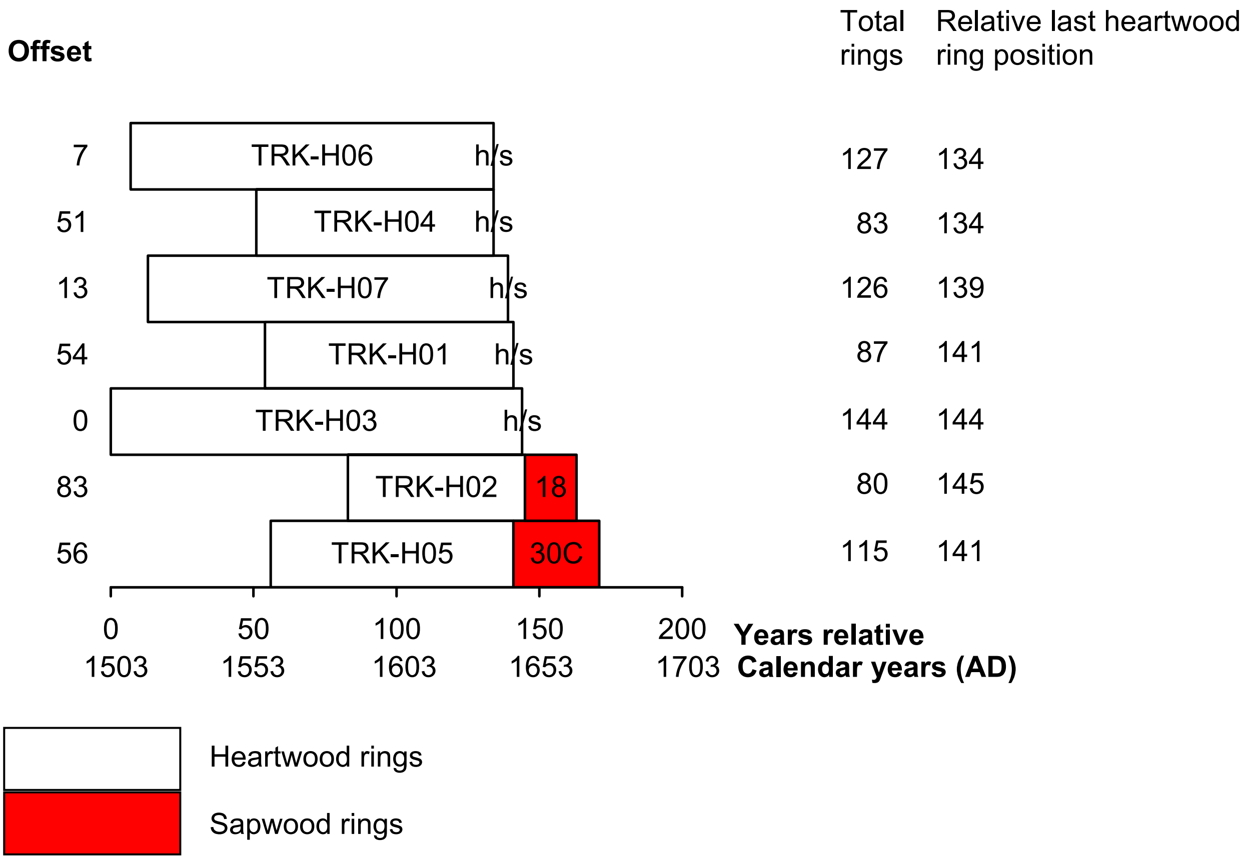
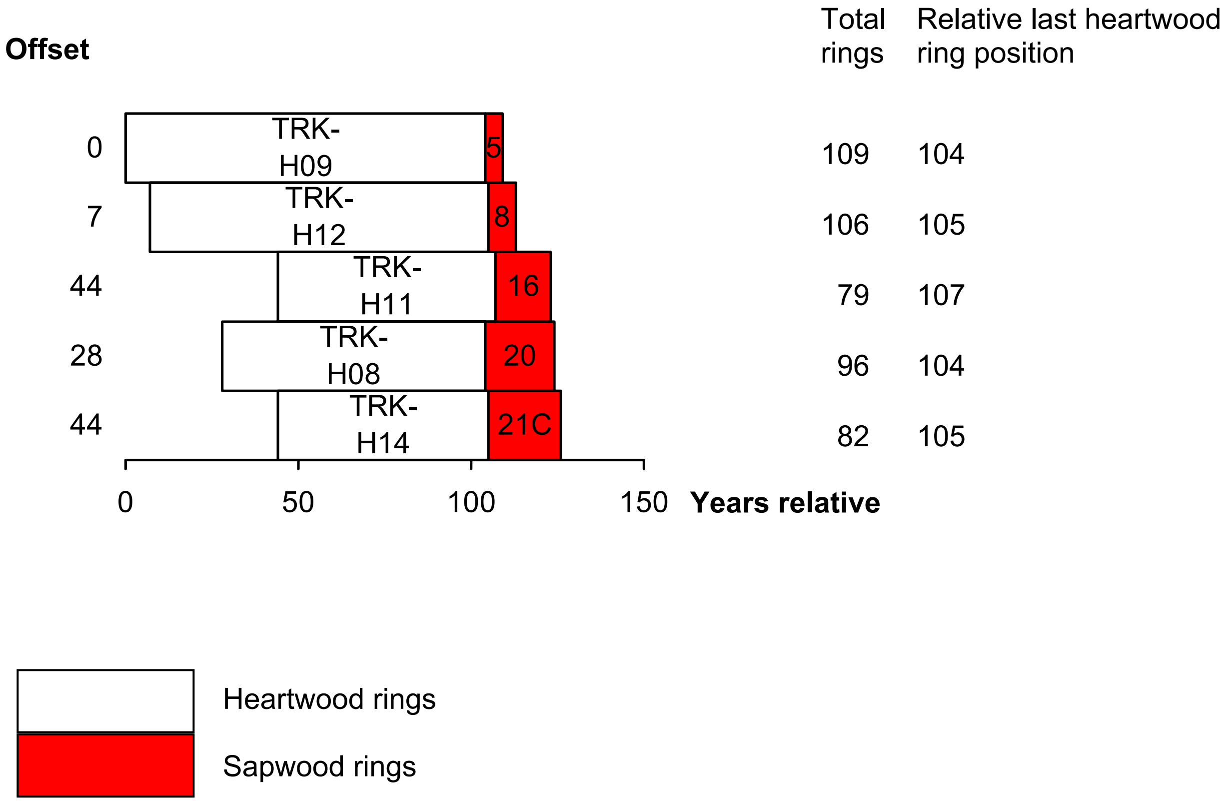


Figure 12: Plan of the West range, with trusses marked, showing the location of samples TRK-H08–18 (supplied by Eric Berry, based on a plan by Parkes Lees Architects, incorporating Ordnance Survey data)



h/s = the heartwood/sapwood boundary ring is the last ring on the sample
C = complete sapwood retained on sample, last measured ring is the felling date

Figure 13: Bar diagram of samples in dated site sequence TRKHSQ01



C = complete sapwood retained on sample, last measured ring is the felling date

Figure 14: Bar diagram of samples in undated site sequence TRKHSQ02

Data of measured samples – measurements in 0.01mm units

TRK-H01A 87
273 244 241 144 149 212 166 145 104 116 111 112 151 87 117 70 132 196 119 84
128 82 134 170 102 114 199 186 135 205 243 219 205 142 248 240 133 101 119 150
117 99 103 117 131 100 129 133 119 119 107 94 55 94 153 149 101 109 154 99
80 149 153 172 71 99 103 126 134 165 126 118 150 145 188 143 115 109 160 138
147 168 266 163 184 119 104
TRK-H01B 87
208 278 248 139 151 218 166 149 99 108 119 120 137 100 105 87 119 204 102 93
100 75 147 155 104 120 192 204 116 228 202 238 180 174 213 290 114 100 120 120
134 95 99 102 162 105 133 136 102 112 124 81 58 71 175 145 97 122 142 88
81 141 156 149 73 106 114 128 119 181 134 106 171 145 172 140 123 108 167 128
139 174 265 153 196 124 110
TRK-H02A 80
271 238 250 192 179 171 192 142 148 180 194 156 144 133 119 193 160 173 201 145
184 174 138 69 129 188 154 194 203 193 127 127 176 142 209 96 143 144 160 98
172 123 127 200 152 155 127 104 95 104 99 136 135 117 120 151 99 75 97 100
100 92 89 83 61 61 63 68 85 90 85 103 103 73 94 56 66 44 57 90
TRK-H02B 80
244 234 240 203 170 174 191 146 148 180 189 159 147 134 115 212 158 168 206 142
187 173 131 78 128 182 152 193 201 194 136 120 169 143 205 104 144 142 161 100
171 123 117 206 151 153 139 98 92 107 93 138 140 119 120 152 101 77 104 90
109 82 99 79 70 62 65 69 102 72 86 97 107 74 103 63 64 40 58 91
TRK-H03A 144
270 286 245 147 205 219 217 101 174 113 178 277 112 115 188 158 216 197 260 185
154 142 175 140 153 191 113 105 170 116 95 97 103 111 162 118 126 142 119 111
174 106 107 97 126 85 167 112 113 107 94 165 144 128 178 157 139 97 130 210
170 145 159 148 124 120 129 121 131 94 83 116 142 72 115 69 109 141 128 112
173 228 169 158 170 154 189 160 241 272 116 107 154 169 164 129 93 94 141 112
124 181 125 118 129 109 45 119 159 141 121 107 143 75 88 118 128 167 66 125
80 117 110 153 102 88 133 138 118 144 100 101 131 115 162 112 141 112 153 94
102 129 141 127
TRK-H03B 144
209 283 268 174 205 219 197 82 218 98 182 277 100 126 192 174 217 205 257 181
158 143 176 143 153 194 119 100 172 114 92 113 99 113 168 120 124 155 117 122
170 104 102 88 134 91 143 119 115 102 102 165 149 125 171 176 125 102 126 213
172 141 166 149 122 124 124 134 144 82 86 120 137 75 108 78 117 126 134 115
162 211 167 146 167 155 194 153 252 263 106 119 169 171 159 130 93 94 134 120
119 178 132 119 132 106 47 120 153 149 122 101 145 74 87 119 126 174 58 126
92 130 122 172 92 87 137 128 135 114 105 84 134 116 164 102 152 113 140 92
97 123 129 113
TRK-H04A 83
136 160 103 168 168 132 107 134 154 108 111 114 112 97 117 118 89 120 93 94
127 95 80 75 61 101 114 92 99 85 125 99 67 68 76 72 70 101 120 72
83 105 98 87 89 70 80 101 77 96 106 101 109 96 95 68 96 129 120 102
116 132 69 54 108 67 109 62 98 61 94 93 113 64 74 78 81 122 86 67
52 69 75
TRK-H04B 83
145 154 104 166 167 162 110 127 148 111 109 117 108 92 122 111 87 126 90 91
145 94 79 70 66 103 115 87 95 96 125 110 69 97 79 79 86 79 89 69
87 93 99 95 93 84 81 102 83 92 96 106 85 98 89 69 99 120 126 106
109 141 66 59 96 76 104 68 99 53 89 87 112 67 80 77 88 115 89 63
64 65 77

TRK-H05A 102
118 123 206 139 73 130 84 144 133 92 113 138 167 91 120 126 93 98 73 124
159 118 127 131 99 108 106 91 79 108 90 113 106 91 100 87 67 44 83 111
90 106 101 141 74 64 82 79 94 57 78 74 70 69 85 57 62 99 71 100
77 64 44 74 86 80 69 58 62 81 50 58 68 70 60 48 55 72 43 41
41 54 48 57 83 58 58 61 54 48 51 67 91 74 59 56 53 46 59 101
93 121
TRK-H05B 85
119 138 142 197 181 143 159 211 184 146 189 171 143 121 121 204 152 87 112 68
140 161 105 121 183 171 81 110 130 82 96 77 87 121 90 113 88 113 93 102
86 92 138 92 103 109 98 90 80 57 53 78 118 104 104 95 119 75 50 93
74 83 55 82 68 72 52 88 58 67 85 79 121 75 62 47 68 79 84 71
57 72 71 56 52
TRK-H06A 127
231 236 205 262 134 132 79 167 215 228 174 119 159 119 117 153 166 177 257 164
123 236 141 168 183 240 168 180 230 191 170 218 171 178 102 107 123 121 105 163
123 136 139 126 153 141 104 149 135 148 111 125 159 113 119 104 141 111 121 117
88 123 72 113 138 93 76 87 71 109 131 106 95 116 134 125 122 79 83 86
85 95 100 70 73 84 80 74 72 64 60 105 62 90 93 88 84 101 60 59
75 118 92 91 78 104 63 36 59 65 77 49 72 42 63 55 96 62 52 86
65 80 45 49 36 57 51
TRK-H06B 127
260 237 226 294 126 133 86 189 156 262 158 141 160 117 106 141 161 185 242 178
121 249 140 175 179 238 160 189 239 186 190 209 152 157 116 103 120 134 115 155
116 147 127 126 140 133 103 162 131 147 111 122 169 110 123 97 134 114 122 115
92 131 80 91 147 91 73 87 70 105 138 100 101 109 132 133 112 84 81 89
66 105 97 76 75 88 72 65 69 64 67 91 83 71 105 85 106 98 66 50
84 115 91 78 91 100 61 45 50 72 89 40 60 51 51 68 82 51 53 80
69 80 48 48 45 56 46
TRK-H07A 126
130 290 190 263 192 167 154 166 137 153 131 131 161 122 78 154 154 139 176 134
157 158 187 166 125 133 122 138 100 106 134 163 139 187 161 178 131 139 158 171
111 165 186 189 132 142 177 133 112 141 154 153 121 143 106 132 101 119 171 118
69 87 58 113 142 92 118 123 156 114 129 108 106 120 95 104 74 82 110 113
109 97 87 72 79 82 71 101 74 81 85 86 56 40 82 98 83 68 61 79
52 38 54 47 67 43 55 43 49 42 63 49 63 71 59 78 47 49 47 60
50 65 58 48 57 47
TRK-H07B 126
155 299 182 279 201 187 153 179 138 160 138 133 184 114 81 171 159 157 177 147
166 159 197 168 128 138 120 147 93 114 139 163 135 200 162 177 127 146 163 181
140 152 176 190 112 139 186 133 125 134 153 153 123 145 107 126 112 121 172 118
69 86 59 109 133 88 120 136 146 103 124 107 102 121 99 93 79 81 109 106
126 85 95 76 72 82 76 97 80 71 90 77 57 51 84 94 73 61 69 76
55 39 65 55 68 32 65 55 51 36 67 59 56 77 70 50 64 46 34 56
52 58 50 52 54 38
TRK-H08A 78
278 306 320 285 169 113 157 259 252 187 152 134 193 141 187 211 257 276 208 221
166 272 213 263 226 269 293 223 164 214 131 270 168 231 200 173 182 198 203 160
209 244 231 298 269 198 243 147 168 211 200 277 269 288 166 168 236 216 158 226
204 229 223 146 177 187 225 268 191 150 149 143 153 186 172 226 142 150
TRK-H08B 61
126 185 193 198 151 199 238 235 264 263 202 219 154 197 209 205 265 261 271 167
185 229 219 168 233 208 226 253 117 180 181 239 277 180 161 146 148 163 161 200
220 145 116 159 154 133 120 155 167 168 132 97 183 110 170 149 157 179 128 125
159

TRK-H09A 109
143 73 99 149 146 193 178 146 136 139 435 197 192 110 169 114 200 204 178 296
245 171 162 135 110 273 235 210 246 254 261 247 211 150 198 280 251 206 238 181
193 133 140 161 236 191 202 254 181 283 219 230 195 251 267 212 159 161 153 238
164 225 253 221 221 219 198 149 219 239 234 268 235 196 236 154 183 179 203 265
258 257 144 156 193 209 148 207 172 226 222 114 177 193 248 278 196 185 151 173
154 188 219 217 130 128 146 199 110
TRK-H09B 109
99 66 99 159 141 182 188 171 153 166 420 181 202 117 141 115 200 186 201 318
251 172 151 137 125 266 226 211 250 261 255 249 215 146 223 294 253 212 244 222
202 124 143 162 247 212 212 253 179 291 217 250 198 240 273 216 158 160 150 241
165 232 253 228 220 212 192 153 217 253 230 269 235 197 227 155 181 181 200 266
259 256 149 160 188 204 149 200 181 225 229 127 176 190 252 279 191 186 156 174
159 187 223 200 165 123 124 200 131
TRK-H11A 79
251 202 210 211 165 240 237 230 222 230 300 246 161 168 168 244 206 239 257 258
223 229 185 151 224 237 221 262 218 201 230 137 176 174 197 225 222 229 158 151
196 249 170 188 162 222 231 125 171 147 196 255 171 174 138 161 160 165 204 195
138 117 157 151 162 137 182 163 168 124 113 165 136 182 185 155 173 113 92
TRK-H11B 79
197 231 215 217 166 241 253 216 227 246 311 229 164 181 151 236 204 233 253 253
218 223 193 159 198 235 228 260 232 205 198 145 166 180 208 221 225 228 142 159
203 249 169 194 173 245 226 135 174 137 209 285 183 176 152 150 170 156 205 175
126 123 181 155 149 132 180 158 176 127 120 161 140 186 186 152 178 112 76
TRK-H12A 106
112 122 99 227 130 140 110 144 81 169 145 162 261 222 190 155 149 102 255 210
202 249 236 260 238 222 172 203 274 252 175 214 184 212 144 171 190 265 222 230
255 203 308 248 257 222 270 314 244 180 171 156 274 184 229 252 227 222 202 175
129 214 226 213 248 221 197 199 117 146 143 195 208 203 221 141 138 179 189 142
194 174 218 244 121 162 160 199 263 187 172 146 155 135 178 213 217 165 135 171
128 165 133 136 149 157
TRK-H12B 106
136 119 94 282 146 147 117 133 73 181 156 157 268 247 183 156 146 112 219 223
198 235 247 246 240 239 172 185 260 257 184 214 186 212 132 140 179 273 229 214
278 216 327 249 259 222 264 315 246 197 183 162 254 182 229 263 226 233 215 185
138 216 231 213 259 224 197 198 120 146 151 203 208 223 217 138 141 178 195 127
196 184 242 212 117 161 150 197 257 190 171 147 149 149 175 206 222 161 135 168
139 139 130 117 140 160
TRK-H13A 51
264 329 257 307 285 419 280 158 145 209 232 152 348 291 264 297 222 191 156 175
177 119 74 68 81 74 91 103 127 139 86 100 141 93 94 126 129 153 144 129
106 79 112 175 156 149 178 249 212 77 85
TRK-H13B 51
236 313 264 307 270 441 275 159 148 184 252 141 351 289 281 295 232 189 122 193
176 112 84 51 81 85 79 96 140 136 79 119 119 110 80 120 141 162 151 139
110 92 114 173 162 136 191 243 211 82 81
TRK-H14A 82
290 224 246 271 220 237 297 206 261 257 313 223 223 233 163 265 156 256 314 238
246 220 231 166 233 213 249 279 236 194 179 119 165 204 207 223 251 260 166 170
226 219 201 204 210 215 234 119 144 167 193 272 193 156 129 152 159 180 205 179
123 98 148 135 106 101 130 156 155 129 113 152 136 162 161 167 177 174 148 215
152 117

TRK-H14B 72
253 220 211 269 157 301 186 263 293 245 243 241 232 159 219 215 238 287 213 198
177 138 177 203 198 256 260 270 196 171 224 213 208 239 214 215 246 115 152 182
217 271 211 133 113 166 156 187 216 191 138 111 155 116 106 85 143 171 171 126
112 177 133 187 169 176 187 168 135 221 126 136
TRK-H17A 51
100 168 190 138 181 132 207 118 100 88 159 82 97 121 75 42 47 107 114 100
94 88 145 108 160 126 91 61 68 126 105 103 91 91 55 102 61 45 76 83
134 108 148 98 94 62 54 52 80 166 142
TRK-H17B 64
159 226 299 159 119 165 78 55 62 116 142 155 156 116 132 156 214 178 123 92
113 155 132 170 125 158 90 129 87 68 156 131 209 189 225 168 145 107 61 91
116 204 121 187 67 69 83 137 103 107 79 80 98 42 28 68 122 121 102 115
158 78 88 71
TRK-H18A 108
290 484 282 225 160 200 128 108 91 126 202 139 132 134 153 159 180 213 202 121
164 144 151 149 74 84 101 117 100 83 116 119 124 104 150 125 71 101 115 100
54 61 95 70 159 186 172 171 120 112 88 96 79 74 116 102 136 56 113 38
34 40 60 107 120 71 79 88 53 61 54 43 51 109 125 157 136 97 167 127
189 162 152 112 148 70 85 88 46 39 49 76 97 107 112 112 135 110 152 106
104 79 63 137 98 106 93 85
TRK-H18B 108
235 484 327 241 162 193 135 131 78 131 197 137 127 122 161 156 179 217 199 118
161 131 115 122 67 86 93 119 101 82 114 120 125 104 146 116 75 97 119 111
46 67 73 78 173 171 186 191 128 110 96 85 77 71 121 99 144 55 102 36
29 39 47 112 116 78 88 87 44 73 53 33 67 105 127 165 125 96 165 136
183 164 148 100 154 74 69 102 52 38 41 82 97 110 121 110 134 120 140 105
109 74 63 135 93 105 89 76

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 1988). 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 1 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 1, 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 2 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 2; it is about 15cm long and 1cm 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 1: 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 2: Cross-section of a rafter showing the presence of sapwood rings in the left-hand corner, the arrow is pointing to the heartwood/sapwood boundary (H/S). Also a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil

Figure 3: 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 4: 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 2. 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 3).

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 4). 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 5 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 5. 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 5 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 2, 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 2 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 2cm, 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 6 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 6. 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 7. 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	

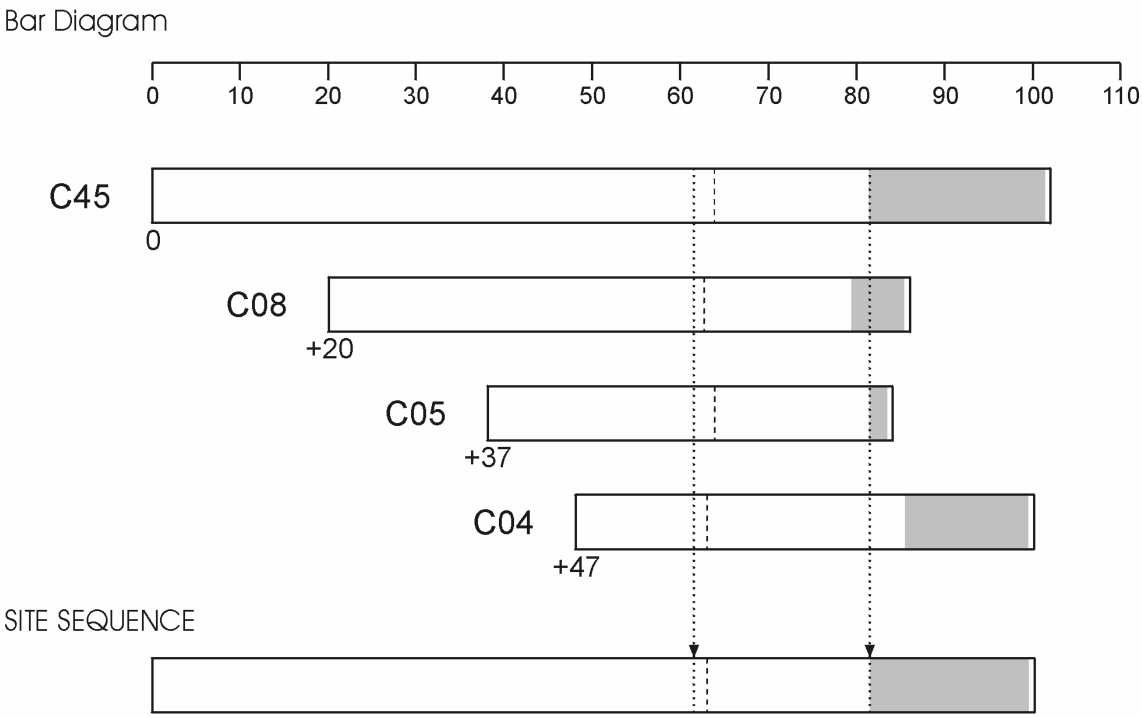


Figure 5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them.

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

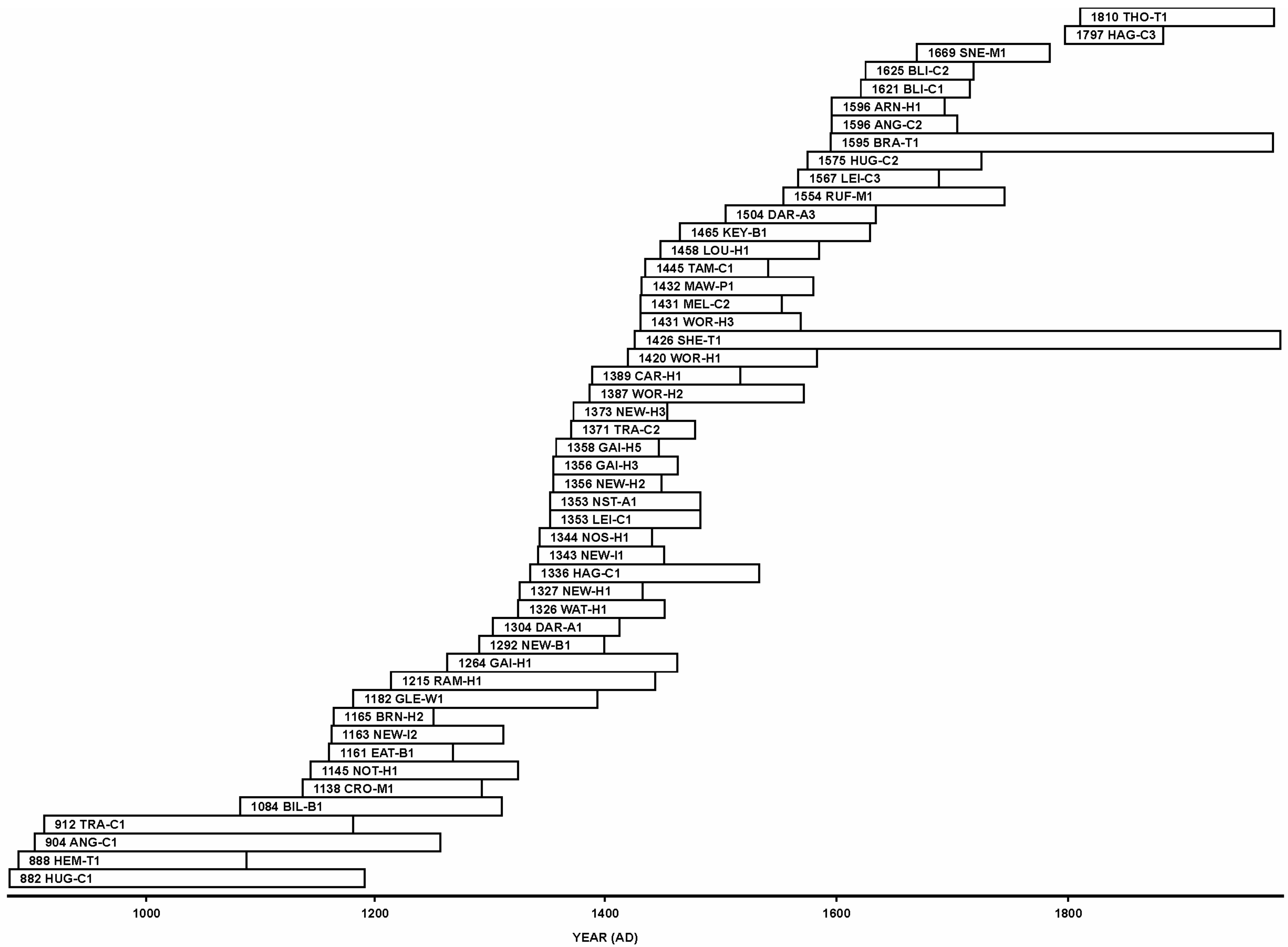
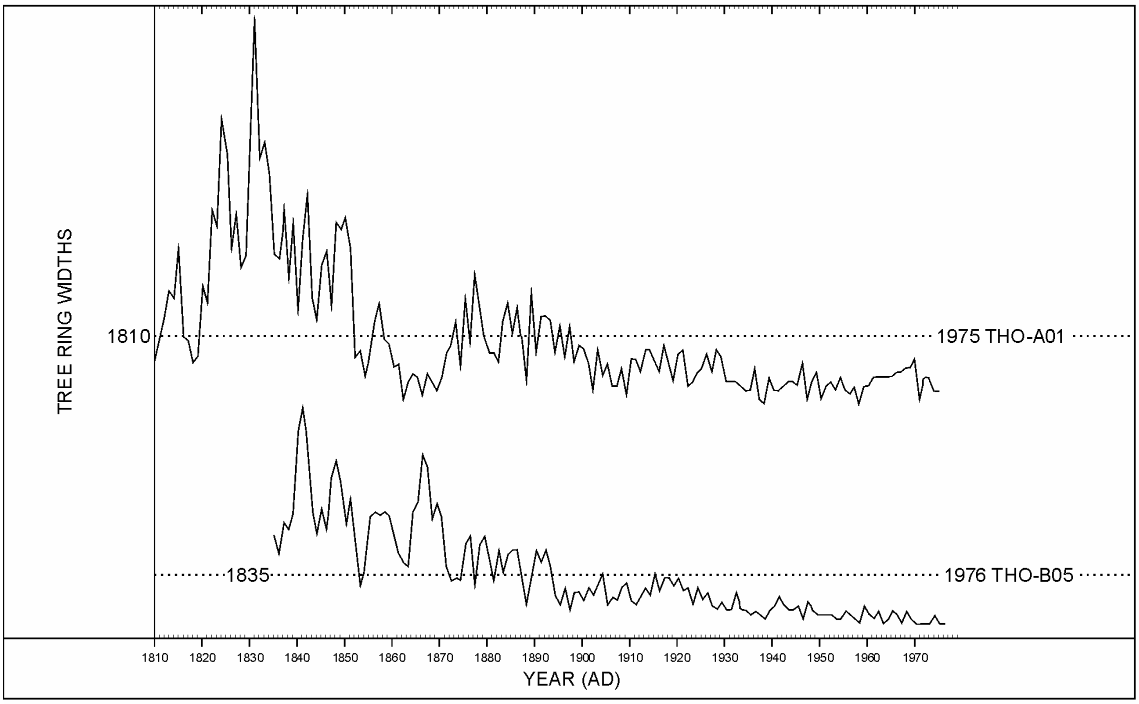


Figure 6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

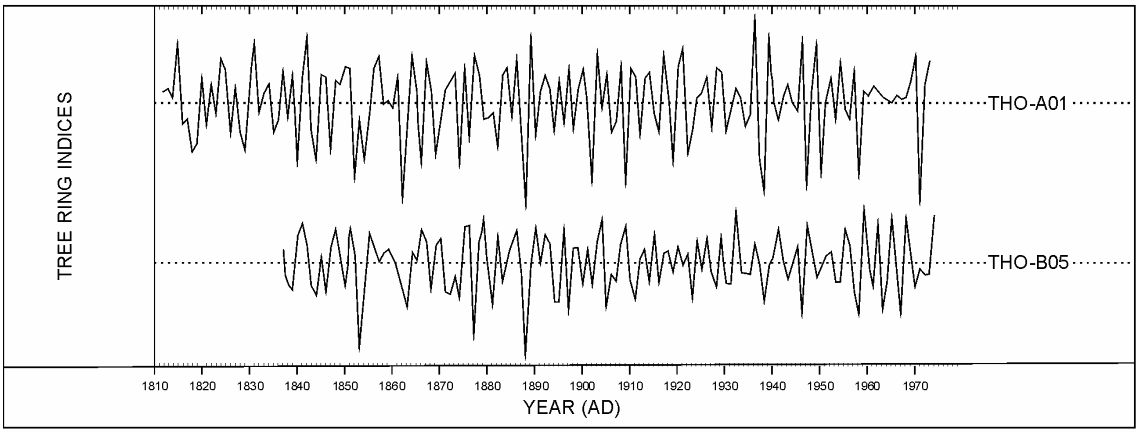


Figure 7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known. Here the ring widths are plotted vertically, one for each year, so that peaks represent wide rings and troughs narrow ones. Notice the growth-trends in each; on average the earlier rings of the young tree are wider than the later ones of the older tree in both sequences

Figure 7 (b): The *Baillie-Pilcher* indices of the above widths. The growth-trends have been removed completely

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