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WARREN FARM, CHARTERHOUSE, PRIDDY, SOMERSET TREE-RING ANALYSIS OF TIMBERS

SCIENTIFIC DATING REPORT

Alison Arnold and Robert Howard

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WARREN FARM, CHARTERHOUSE, PRIDDY, SOMERSET

TREE-RING ANALYSIS OF TIMBERS

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SUMMARY

Ten samples were taken from the timbers of the roof at this building. Subsequent analysis resulted in the production and dating of a single site sequence.
Site sequence WRNFSQ04 contains six samples and spans the period AD 1303–1500. Two samples were found to have overlapping felling date ranges of AD 1481–1506 and AD 1499–1524 with the remaining four dated samples having earliest possible felling dates ranging from the late-fourteenth to the early-sixteenth centuries. These results suggest that several different felling phases are represented by the timbers of this roof.

CONTRIBUTORS

Alison Arnold and Robert Howard

ACKNOWLEDGEMENTS

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ARCHIVE LOCATION

Somerset SMR
Somerset Heritage Centre
Brunel Way
Norton Fitzwarren
Taunton
TA2 6SF

DATE OF INVESTIGATION

2010/11

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INTRODUCTION

This unlisted medieval building, located near the Somerset town of Cheddar (Figs 1–3; ST 4998 5496), was identified during the English Heritage Mendip Project; a project aimed at improving the understanding of the historic environment of the Mendip Hills Area of Outstanding Natural Beauty. The building is on a former monastic estate and probably dates from the fourteenth or fifteenth century, although its medieval origins are not recognisable from the outside (Fig 4).

The surviving roof structure consists of two arch-braced and collared trusses of which the arch braces have been removed (Figs 5 and 6). The collar of truss 2 is thought to be reused (Fig 6). The location of the trusses within the building are indicated on Figure 7.

SAMPLING

Sampling was requested by Barry Jones to provide a precise date for the surviving medieval part of the building, and contribute to the forthcoming publication on the Mendip Hills.

A total of ten timbers was sampled. Each sample was given the code WRN-F (for Warren Farm) and numbered 01–10. The location of samples was noted at the time of sampling and has been marked on Figures 8 and 9. Further details relating to the samples can be found in Table 1.

ANALYSIS AND RESULTS

All ten samples were prepared by sanding and polishing and their growth-ring widths measured; the data of these measurements are given at the end of the report. These samples were compared with each other by the Litton/Zainodin grouping procedure (see Appendix). At a value of t=4.5, eight samples had grouped into four pairs.

Firstly, samples WRN-F01 and WRN-F02 matched each other at a value of t=10.1. These two samples were combined at the relevant offset positions to form WRNFSQ01, a site sequence of 135 rings (Fig 10). This site sequence was compared against a series of relevant reference chronologies for oak, where it was found to match consistently and securely at a first-ring date of AD 1303 and a last-measured ring date of AD 1437. The evidence for this dating is given by the t-values in Table 2.

Secondly, samples WRN-F04 and WRN-F05 matched each other at a value of t=8.1 and were combined to form WRNFSQ02, a site sequence of 75 rings (Fig 11). This site sequence was dated as spanning the period AD 1426–1500 (Table 3).

Samples WRN-F03 and WRN-F06 matched each other at a value of t=9.7 and were combined to form WRNFSQ03, a site sequence of 92 rings (Fig 12). This site sequence was dated as spanning the period AD 1393–1484 (Table 4). The level at which this site sequence matches against the reference material is not as great as that of WRNFSQ01 and WRNFSQ02, however, the values gained are still of a sufficient level and consistency to demonstrate secure dating.

It was then noted that both WRNFSQ01 and WRNFSQ02 matched WRNFSQ03 at the expected offset positions at the least value of t=4.0 and 3.7, respectively. A further site sequence was then constructed containing all six samples at their respective offset positions (Fig 13). This site sequence was again compared against the reference chronologies where it was matched at a first-ring date of AD 1303 and a last-measured ring date of AD 1500. The evidence for this dating is given by the t-values in Table 5. This intra-sequence cross-matching at the expected dates lends further support to the original dating of WRNFSQ03.

Only two of these samples (WRN-F03 and WRN-F06) have the heartwood/sapwood boundary ring. In the case of WRN-F03 this is AD1466, allowing an estimated felling date to be calculated for the timber represented of AD 1481–1506. The heartwood/sapwood boundary ring date of WRN-F06 is a little later at AD 1484, giving an estimated felling date range of AD 1499–1524. None of the other four dated samples have the heartwood/sapwood boundary ring but with last measured heartwood ring dates of AD 1382 (WRN-F02), AD 1437 (WRN-F01), AD 1490 (WRN-F04), and AD 1500 (WRN-F05,) the earliest possible estimated felling dates for these timbers would be AD 1398, AD 1453, AD 1506, and AD 1516, respectively.

A further two samples (WRN-F08 and WRN-F09) matched each other at a value of t=13.4 and were combined to form site sequence WRNSQ05 (Fig 14) but attempts to date this site sequence and the two remaining ungrouped samples were unsuccessful and all these samples remain undated.

All felling date ranges have been calculated using the estimate that 95% of mature oak trees in this area have between 15 and 40 sapwood rings.

DISCUSSION

Prior to tree-ring analysis being undertaken this building was thought to have its origins in the fourteenth or fifteenth century.

Dendrochronological analysis has successfully dated six of the roof timbers. One, a collar, is now known to have been felled at some time between AD 1481–1506, with a second collar having an estimated felling date range of AD 1499–1524. These two felling date ranges do just overlap which make it possible that both timbers were felled at the same time, in the first few years of the sixteenth century. However, it is also possible that these two timbers were felled a number of years apart.

The estimated earliest possible felling dates for the other four dated timbers range from AD 1398 (WRN-F02) to AD 1516 (WRN-F05). Without the heartwood/sapwood boundary ring it is not possible to draw any clear conclusion as to whether these four principal rafters are broadly coeval with each other or the two dated collars, nor how many felling phases they represent. They may have all been felled at the same time, with perhaps the two samples from the north and south principal rafters of truss 1 (WRN-F01, WRN-F02) being the inner portions of the trees represented by the north and south principal rafters of truss 2 (WRN-F04, WRN-F05), with all four being felled some time after AD 1515. Alternatively, it may be that the roof is constructed from timber of differing dates. Perhaps supporting this is the fact that at least one of the collars (WRN-F06) displayed signs of having been used previously.

It is unfortunate that due to a number of the timbers being badly degraded on the surface, the heartwood/sapwood boundary ring is missing, making it impossible to determine closer felling date/date ranges. Ironically, four of the samples which do have the heartwood/sapwood boundary ring could not be dated.

BIBLIOGRAPHY

Alcock, N W, Warwick University, Howard, R E, Laxton, R R, and Litton, C D, Nottingham University Tree-ring Dating Laboratory, and Miles, D, 1991 Leverhulme Cruck Project Results: 1990, *Vernacular Architect*, 22, 45–7

Arnold, A J and Howard, R E, 2006 Church of St Ildierna, Lansallos, Cornwall; Tree-Ring Analysis of timbers from the roofs and pews, Centre for Archaeol Rep 49/2006

Arnold, A J, Howard, R E, and Litton, C D, 2003 Tree-ring analysis of timbers from Kingswood Abbey Gatehouse, Kingswood, Gloucestershire, Centre for Archaeol Rep, 21/2003

Arnold, A J, Howard, R E, and Litton, C D, 2008 Nottingham Tree-ring Dating Laboratory, *Vernacular Architect*, 39, 119–28

Bridge, M, 1988 The Dendrochronological Dating of Buildings in Southern England, *Medieval Archaeol*, 32, 166–74

Bridge, M, 1997 *Tree-ring Analysis of Timbers from Buildings at Forty Hall, Enfield, London,* Anc Mon Lab Rep, 103/1997

Bridge, M, *2000 Tree-ring Analysis of Timbers from St Andrew's Church, Ford, West Sussex*, Anc Mon Lab Rep, 27/2000

Bridge, M C, 2003a *Tree-Ring Analysis of Timbers from Reigate Priory School, Bell Street, Reigate, Surrey*, Centre for Archaeol Rep, 76/2003

Bridge, M C, 2003b *Tree-Ring Analysis of Timbers from Old Worden Hall, Euxton Lane, Chorley, Lancashire*, Centre for Archaeol Rep, 47/2003

Howard, R E, 2000 unpubl site chronology for Brockworth Court, Hall and Cross-wing, Brockworth, Glos, unpubl computer file *BRKASQ02(183)*, NTRDL

Howard, R E, Laxton, R R, Litton, C D, and Simpson, W G, 1992 Nottingham University Tree-Ring Dating Laboratory: results, *Vernacular Architect*,, 23, 51–6

Lewis, E, 1995 A sixteenth century painted ceiling from Winchester College, *Proc Hampshire Field Club and Archaeol Soc*, 51, 137–65

Miles, D H, and Worthington, M J, 1998 Tree-ring dates for buildings: List 90, *Vernacular Architect*, 29, 111–7

Miles, D, Worthington, M J, and Dallimore, J, 1997 Tree-ring dates for Somerset 1: List 84, *Vernacular Architect*, 28, 172–4

Miles, D, 2003 Dating Buildings and Dendrochronology in Hampshire in *Hampshire Houses 1250–1700: Their Dating and Development* (E Roberts), 220–26

Tyers, I, and Hibberd, H, 1993 Tree-ring dates from Museum of London Archaeology Service: List 53, *Vernacular Architect*, 24, 50–4

Tyers, I, 1996 *Tree-ring analysis of six secular buildings from the City of Hereford*, Anc Mon Lab Rep, 17/96

Tyers, I, 1999 *Tree-ring analysis of three buildings from the Clarendon Estate, Wiltshire*, ARCUS Rep, 429

Tyers, I, 2005 *Report on the Tree-Ring Analysis of Properties in Eardisley, Herefordshire*, ARCUS Rep, 895

TABLES

Table 1: Details of tree-ring samples from Warren Farm, Charterhouse, Priddy, Somerset

Sample number	Sample location	Total rings	Sapwood rings*	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
WRN-F01	North principal rafter, truss 1	125	--	1313	----	1437
WRN-F02	South principal rafter, truss 1	80	--	1303	----	1382
WRN-F03	Collar, truss 1	74	h/s	1393	1466	1466
WRN-F04	North principal rafter, truss 2	65	--	1426	----	1490
WRN-F05	South principal rafter, truss 2	54	--	1447	----	1500
WRN-F06	Collar, truss 2 (reused)	86	h/s	1399	1484	1484
WRN-F07	North lower purlin, east gable to truss 1	56	h/s	----	----	----
WRN-F08	South lower purlin, east gable to truss 1	48	h/s	----	----	----
WRN-F09	North lower purlin, truss 2 to west gable	58	h/s	----	----	----
WRN-F10	South lower purlin, truss 2 to west gable	56	h/s	----	----	----

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

Table 2: Results of the cross-matching of site sequence WRNFSQ01 and relevant reference chronologies when the first-ring date is AD 1303 and the last-ring date is AD 1437

Reference chronology	*t*-value	Span of chronology	Reference
Kingswood Abbey Gatehouse, Gloscestershire	7.7	AD 1307–1428	Arnold *et al* 2003
Hampshire county chrionology	7.4	AD 443–1972	Miles 2003
Mucknell Farm, Stoulton, nr Pershore, Worcestershire	6.8	AD 1193–1438	Arnold *et al* 2008
St Ildierna, Lansallos, Cornwall	6.6	AD 1355–1514	Arnold and Howard 2006
St Andrews Church, Ford, West Sussex	6.4	AD 1286–1511	Bridge 2000
Queen Manor Farm Granary, Clarendon, Wiltshire	6.2	AD 1337–1602	Tyers 1999
Brockworth Court (house), Gloucestershire	6.1	AD 1281–1447	Howard 2000 unpubl

Table 3: Results of the cross-matching of site sequence WRNFSQ02 and relevant reference chronologies when the first-ring date is AD 1426 and the last-ring date is AD 1500

Reference chronology	*t*-value	Span of chronology	Reference
Reigate Priory School, Reigate, Surrey	6.2	AD 1384–1545	Bridge 2003a
Speke Hall, Merseyside	6.0	AD 1387–1598	Howard *et al* 1992
Farmers Club, Hereford, Herefordshire	5.9	AD 1313–1617	Tyers 1996
Worden Old Hall, Chorley, Lancashire	5.9	AD 1415–1531	Bridge 2003b
Winchester College panels, Hampshire	5.9	AD 1403–1537	Lewis 1995
Bower House Farm, Hever, Kent	5.9	AD 1376–1499	Brown pers comm
St Thomas Tower, Tower of London	5.8	AD 1349–1511	Tyers and Hibberd 1993

Table 4: Results of the cross-matching of site sequence WRNFSQ03 and relevant reference chronologies when the first-ring date is AD 1393 and the last-ring date is AD 1484

Reference chronology	*t*-value	Span of chronology	Reference
Kingswood Abbey Gatehouse, Gloucestershire	6.1	AD 1307–1428	Arnold *et al* 2003
Forty Hall Stable, Enfield, London	5.9	AD 1364–1475	Bridge 1997
Southern England	5.8	AD 1083–1981	Bridge 1988
St Andrews Church, Ford, West Sussex	5.7	AD 1286–1511	Bridge 2000
Eardisley Lower House, Herefordshire	4.9	AD 1364–1499	Tyers 2005
Willington Dovecote, Bedfordshire	4.9	AD 1394–1542	Miles and Worthington 1998
16-18 High Street, Bruton, Somerset	4.8	AD 1363–1453	Miles *et al* 1997

Table 5: Results of the cross-matching of site sequence WRNFSQ04 and relevant reference chronologies when the first-ring date is AD 1303 and the last-ring date is AD 1500

Reference chronology	*t*-value	Span of chronology	Reference
Kingswood Abbey Gatehouse, Gloucestershire	10.0	AD 1307–1428	Arnold *et al* 2003
St Andrews Church, Ford, West Sussex	8.3	AD 1286–1511	Bridge 2000
Farmers Club, Hereford, Herefordshire	7.3	AD 1313–1617	Tyers 1996
Reigate Priory School, Reigate, Surrey	6.8	AD 1384–1545	Bridge 2003a
Willington Dovecote, Bedfordshire	6.8	AD 1394–1542	Miles and Worthington 1998
Mucknell Farm, Stoulton, nr Pershore, Worcestershire	6.5	AD 1193–1438	Arnold *et al* 2008
Bremhill Farm, Calne, Wiltshire	6.4	AD 1353–1484	Alcock *et al* 1991

FIGURES

Figure 1: Map to show the general location of Priddy, Somerset (based on the Ordnance Survey map with permission of the Controller of Her Majesty's Stationery Office, ©Crown Copyright)

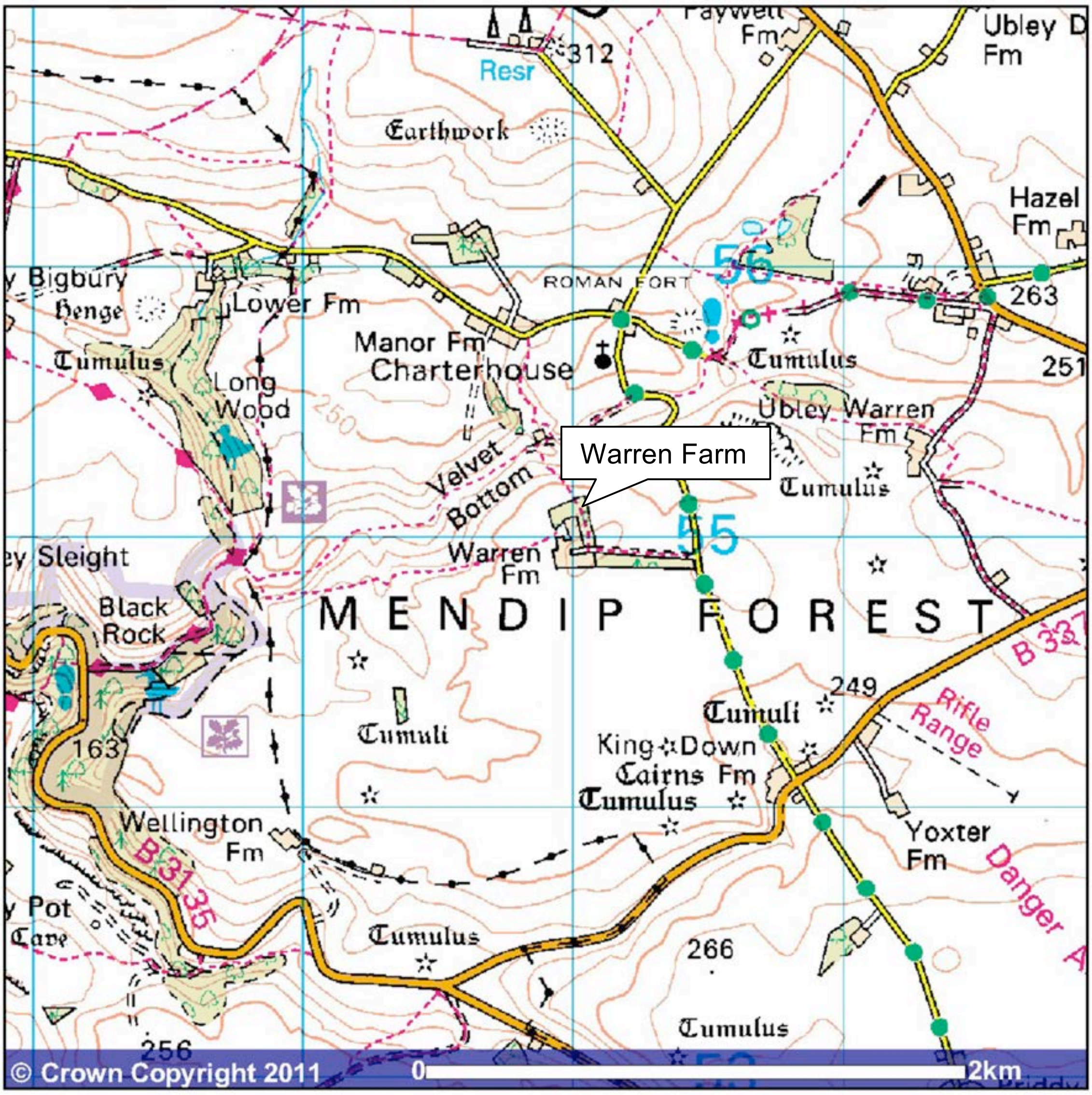


Figure 2: Map to show the approximate location of Warren Farm (based on the Ordnance Survey map, with permission of the Controller of Her Majesty's Stationery Office, ©Crown Copyright)

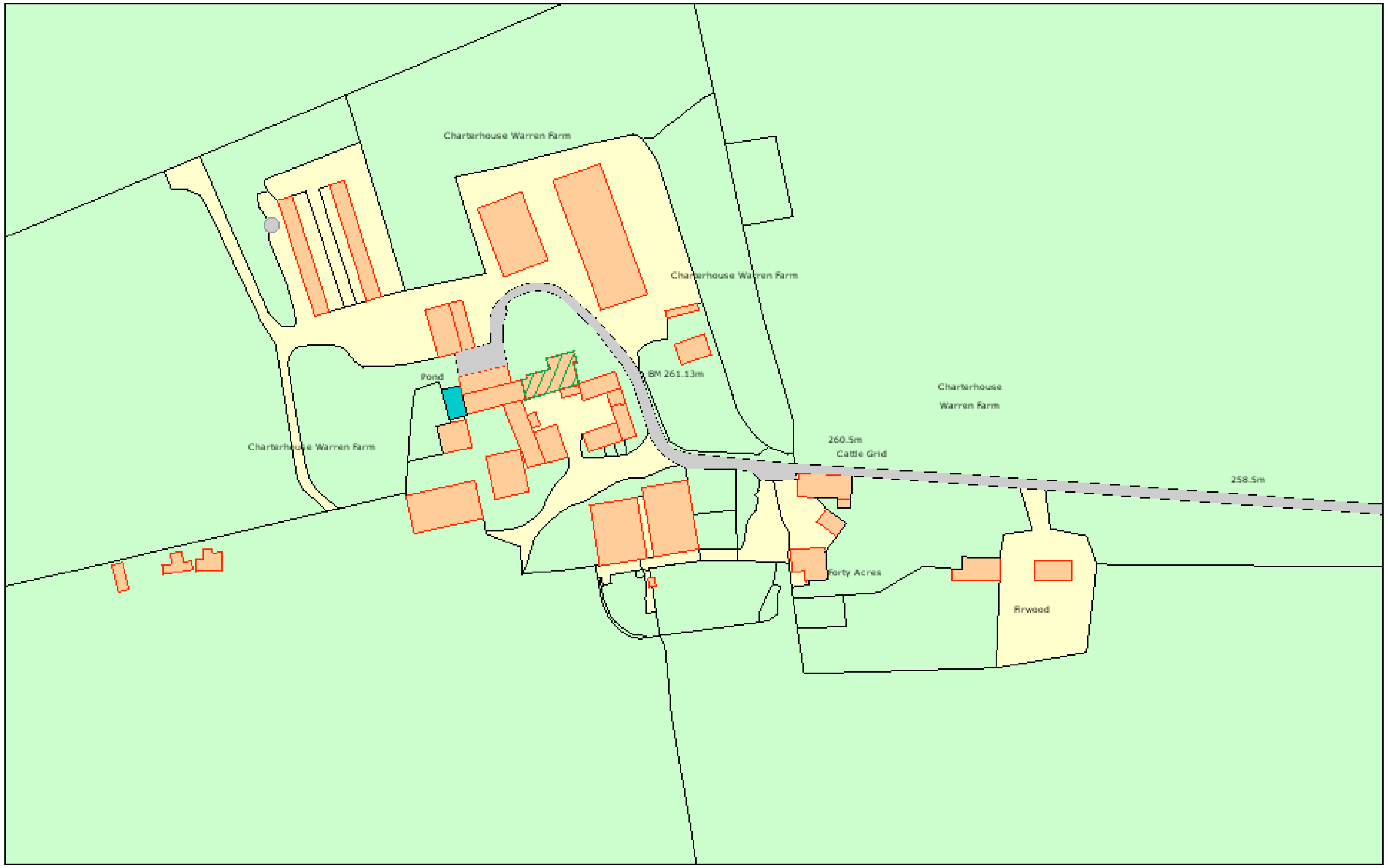


Figure 3: Map to show Warren Farm (hashed in green),(based on the Ordnance Survey map, with the permission of the Controller of Her Majesty's Stationery Office, ©Crown Copyright)

Figure 4: Front of Warren Farmhouse, taken from the south

Figure 5: Truss 1, taken from the east

Figure 6: Truss 2, taken from the west

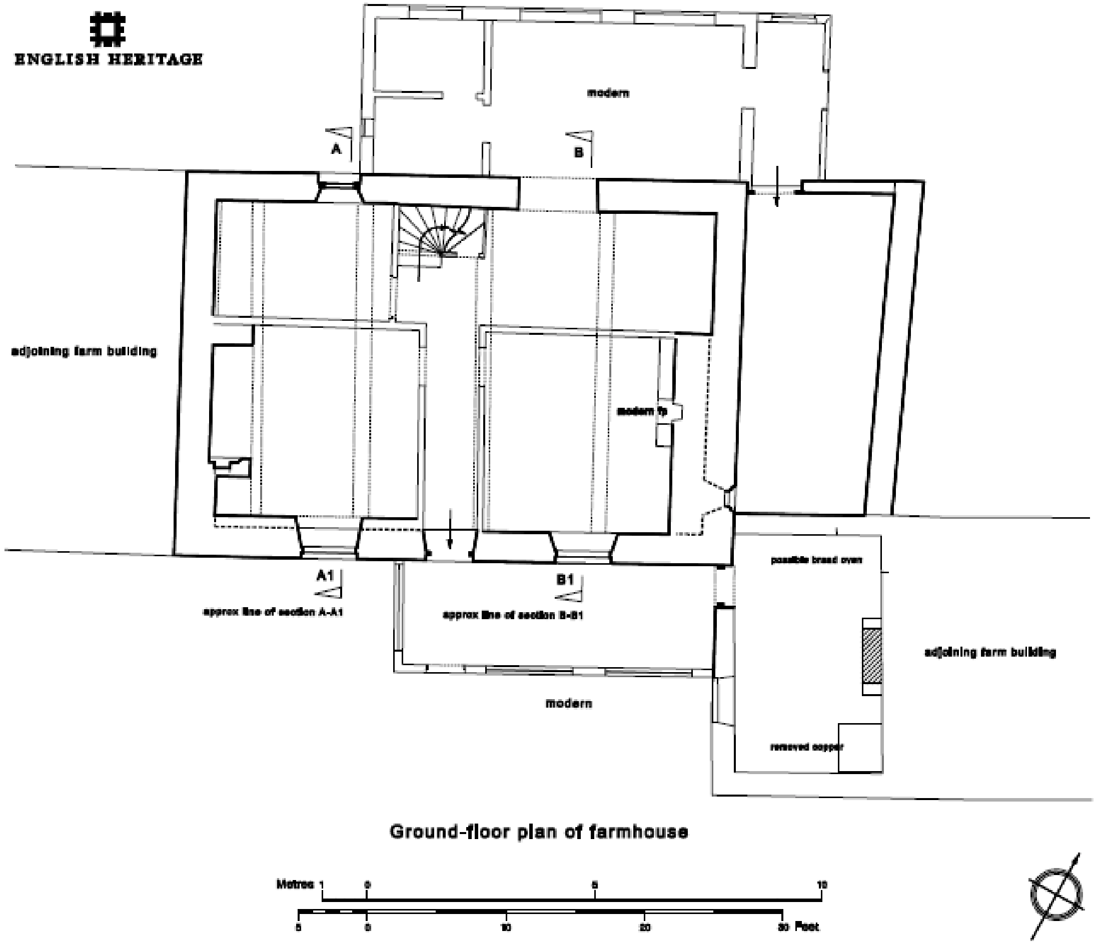


Figure 7: Ground-floor plan showing layout of building and location of section drawings (Barry Jones)

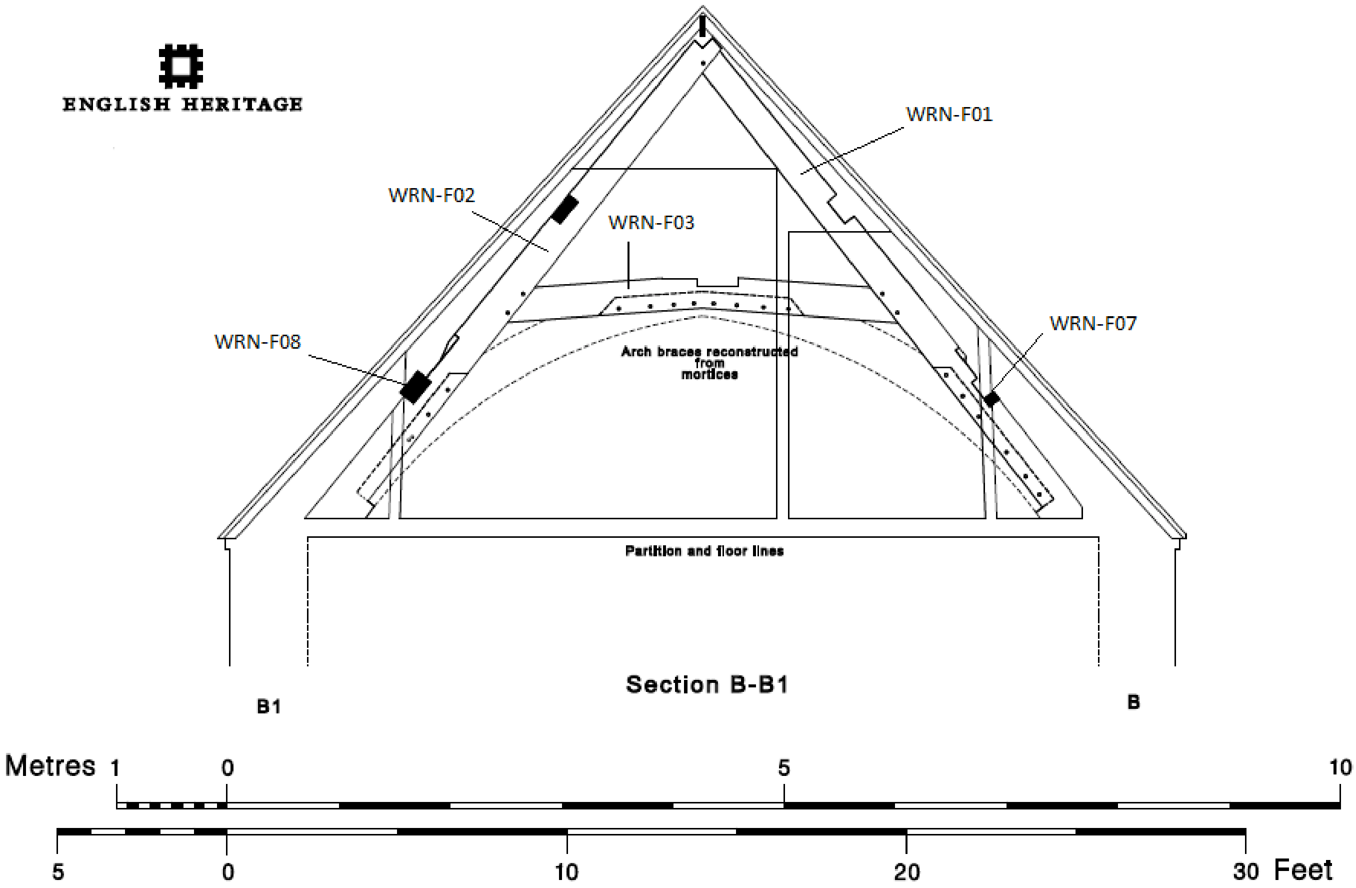


Figure 8: Truss 1; showing the location of samples WRN-F01-03, WRN-F07, and WRN-F08 (Barry Jones)

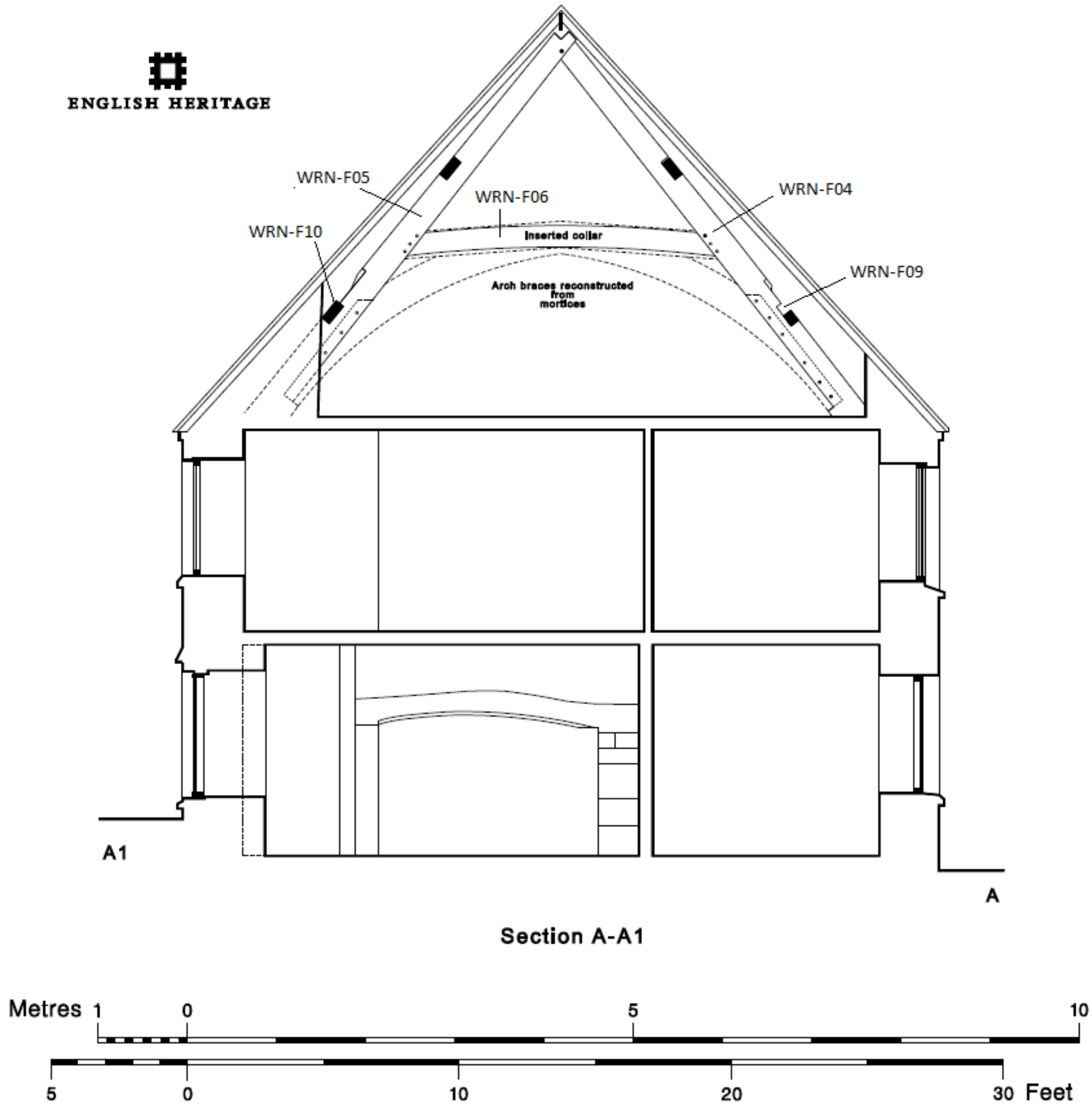


Figure 9: Truss 2; showing the location of samples WRN-F04–06 and WRN-F09–10

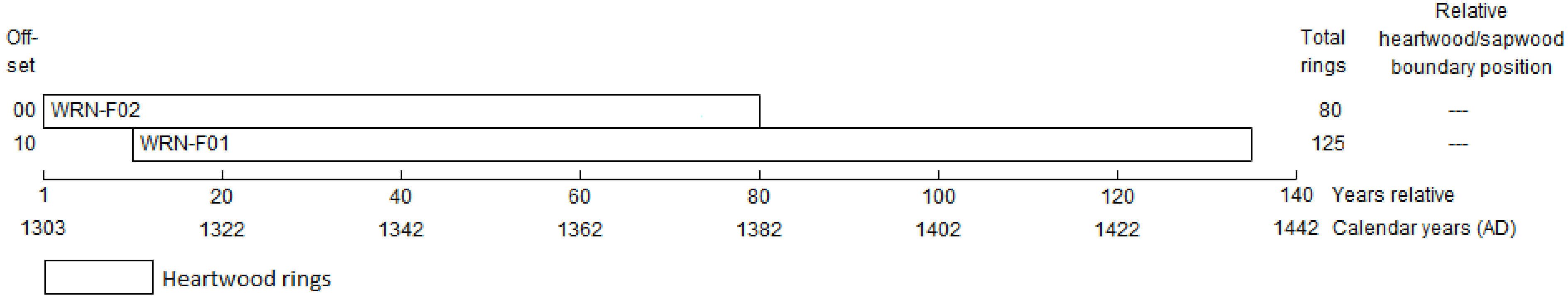


Figure 10: Bar diagram of samples in site sequence WRNFSQ01

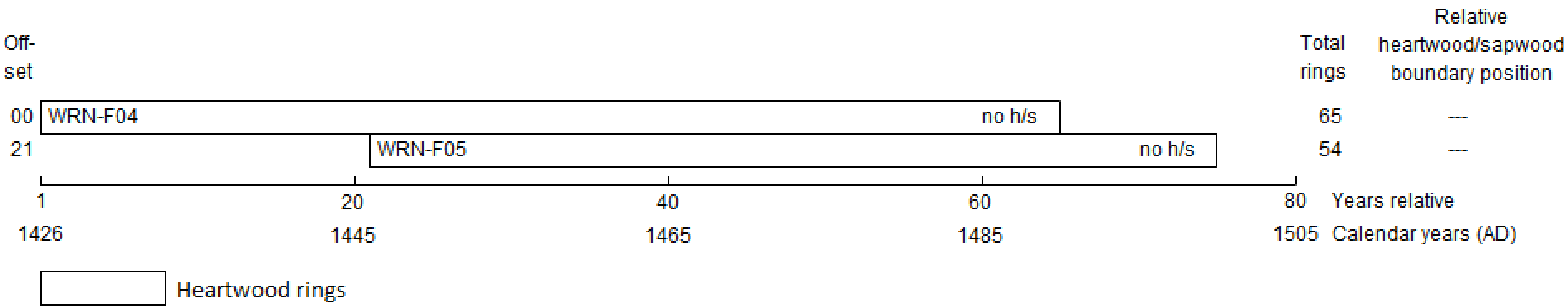


Figure 11: Bar diagram of samples in site sequence WRNFSQ02

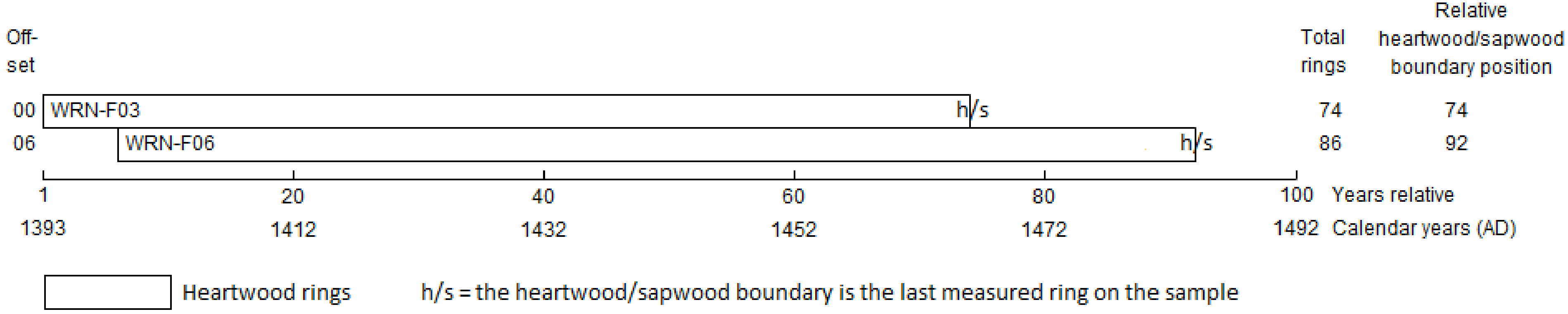


Figure 12: Bar diagram of samples in site sequence WRNFSQ03

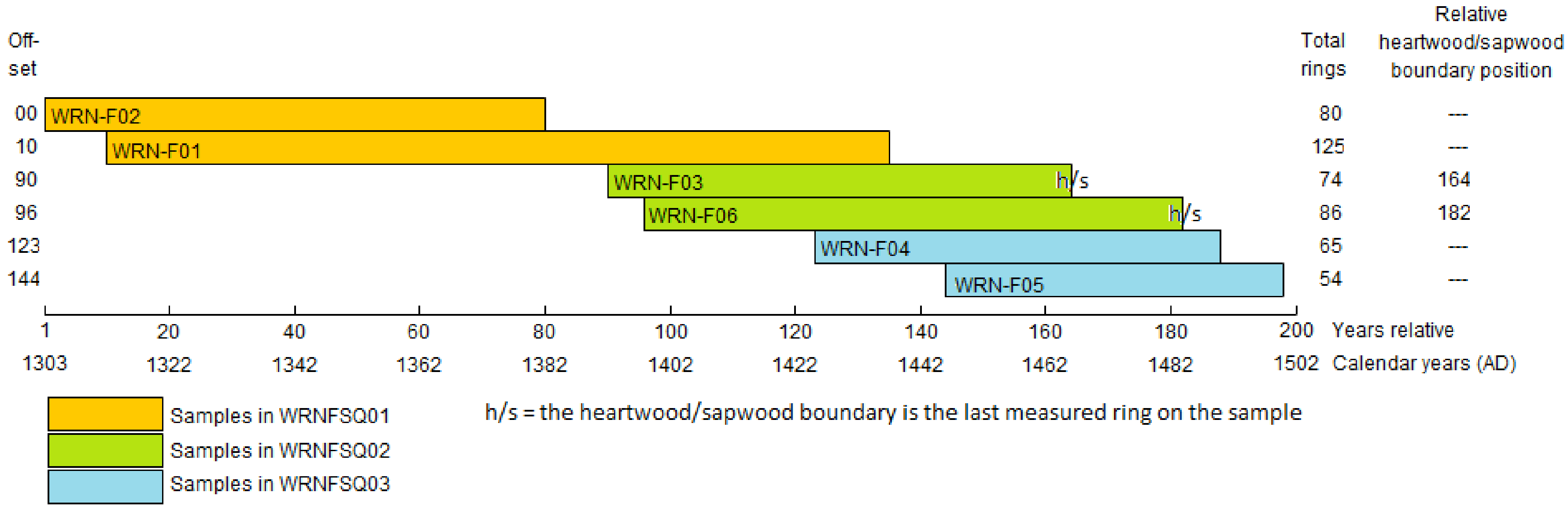


Figure 13: Bar diagram of samples in site sequence WRNFSQ04

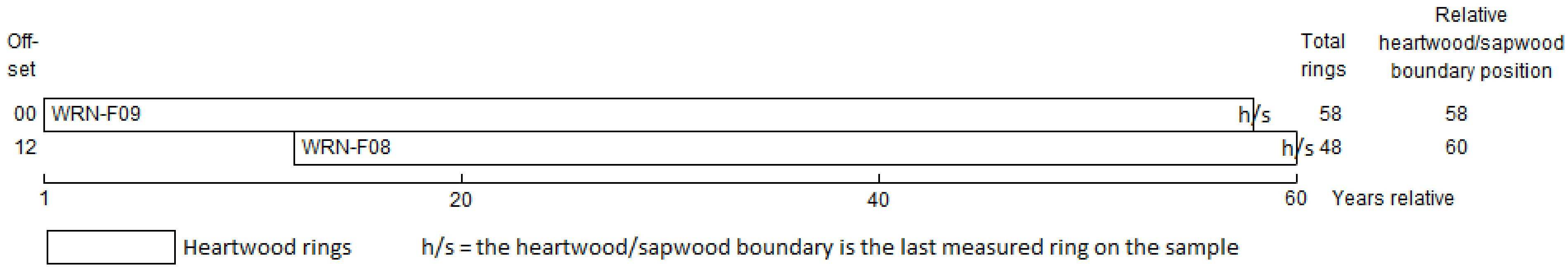


Figure 14: Bar diagram of samples in undated site sequence WRNFSQ05

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

WRN-F01A 125
730 614 678 638 599 506 592 442 523 561 547 428 325 189 277 288 208 270 166 251
202 218 261 293 261 275 262 203 183 189 172 101 148 114 173 215 268 286 332 203
275 232 270 245 211 171 115 102 141 139 235 210 154 165 90 165 168 117 101 87
75 71 86 71 77 93 92 134 107 98 97 94 121 128 117 121 95 70 88 52
68 77 83 120 99 111 147 135 106 68 76 87 44 85 87 101 74 73 53 52
56 44 56 57 48 60 48 62 75 63 87 76 65 50 43 66 46 50 52 100
78 91 86 86 124
WRN-F01B 125
712 644 668 608 622 509 596 440 526 557 559 435 329 185 316 282 208 266 176 210
230 203 267 303 253 264 265 198 203 174 174 102 140 126 173 215 269 284 340 205
267 216 259 201 247 169 114 109 133 143 235 217 158 152 103 153 176 119 99 102
72 67 83 71 79 89 99 132 106 89 101 90 130 120 108 122 89 73 78 64
59 78 78 116 97 112 149 134 104 63 77 85 51 83 85 104 75 76 52 57
54 41 63 58 54 47 51 60 62 66 80 78 58 53 48 55 51 57 58 88
87 74 91 96 127
WRN-F02A 80
273 376 424 478 331 305 207 175 236 257 281 185 344 373 340 218 207 164 170 215
187 136 112 91 169 152 119 137 69 104 119 107 128 130 98 99 131 111 105 112
82 62 84 68 94 91 146 126 122 85 99 106 104 90 111 80 60 68 75 84
165 186 107 91 61 95 107 81 63 57 54 77 87 52 86 80 113 141 119 85
WRN-F02B 80
289 352 424 478 326 326 199 173 236 265 286 217 344 364 347 221 235 168 168 208
205 145 107 94 172 158 116 126 70 119 110 100 136 118 101 89 138 104 111 107
80 59 84 76 82 96 143 124 113 89 96 106 106 89 119 69 60 75 75 85
173 175 110 91 56 95 112 72 68 63 48 80 80 56 81 82 124 137 121 81
WRN-F03A 74
168 184 209 253 216 253 210 192 358 190 235 267 188 327 325 281 216 181 129 122
107 117 176 223 195 188 175 274 269 236 253 290 140 117 124 189 187 189 178 248
178 211 237 227 266 306 184 179 180 187 169 134 138 130 192 163 183 174 151 99
68 68 106 114 127 94 75 143 108 53 109 124 77 120
WRN-F03B 74
163 193 209 275 219 247 191 176 330 180 230 260 179 340 325 290 209 185 128 118
102 113 177 223 179 189 175 273 291 240 258 273 143 116 112 189 173 199 197 266
164 202 210 218 270 314 168 189 179 186 169 144 128 120 183 163 181 181 156 88
66 71 110 116 127 98 76 149 105 56 115 114 86 103
WRN-F04A 65
144 176 234 179 118 170 175 169 239 145 188 272 315 281 211 268 281 330 353 330
269 286 206 252 233 190 118 157 223 216 261 276 274 220 250 194 193 215 169 201
217 208 167 109 184 183 172 195 253 352 353 207 164 164 235 227 160 222 313 286
251 274 266 182 179
WRN-F04B 65
178 169 215 197 114 170 143 159 215 143 184 276 296 294 204 279 281 331 385 335
272 297 225 244 233 199 111 172 222 222 270 279 268 238 252 191 188 217 169 204
223 211 172 112 187 194 171 192 251 357 362 206 167 171 235 222 160 222 308 285
249 276 262 183 194

WRN-F05A 54
258 224 257 274 173 185 173 248 264 329 397 358 267 381 294 256 245 205 301 285
320 284 163 223 223 211 255 259 421 382 195 114 136 265 313 216 290 331 308 348
354 309 241 324 247 242 267 281 250 496 279 208 260 172
WRN-F05B 54
260 223 256 267 185 163 195 250 268 332 414 380 272 377 290 248 246 207 301 281
324 280 160 223 229 214 259 255 425 384 191 105 137 257 309 220 294 328 304 344
352 312 244 307 262 239 266 285 247 499 282 205 223 177
WRN-F06A 86
300 342 454 271 300 377 325 529 434 396 375 331 313 269 255 232 336 364 278 286
211 357 303 269 283 331 186 182 202 296 262 305 216 293 213 266 245 237 234 341
209 209 250 212 190 254 216 155 249 124 174 205 189 88 58 49 95 105 112 48
58 76 81 62 86 75 70 61 62 49 42 60 48 69 72 66 72 84 64 60
64 71 66 43 40 43
WRN-F06B 86
307 338 458 267 331 437 318 513 452 406 371 338 317 270 256 230 344 367 278 276
206 359 299 274 279 330 187 204 198 297 263 309 225 285 210 268 242 239 237 332
214 224 230 218 181 266 212 157 247 121 172 205 186 83 64 51 95 107 107 53
54 78 83 60 70 72 79 44 59 50 41 59 60 57 60 75 76 94 54 55
67 84 44 39 45 46
WRN-F07A 56
292 403 316 314 362 355 304 267 201 307 213 205 202 204 184 173 178 113 88 108
179 495 238 307 274 240 251 158 175 215 200 202 206 153 182 216 141 125 134 200
121 130 111 159 221 213 182 203 72 102 116 140 83 38 32 44
WRN-F07B 56
412 417 318 306 361 346 303 271 205 305 220 206 202 206 186 171 180 111 94 108
180 491 274 298 261 224 248 139 156 204 187 225 203 152 175 220 137 122 127 200
115 134 114 155 223 218 168 199 86 93 128 147 82 47 41 50
WRN-F08A 48
214 316 360 159 363 273 315 399 454 462 452 369 338 288 309 268 309 389 408 372
508 438 419 369 167 118 157 370 340 187 218 172 178 122 125 115 177 198 116 133
114 88 93 169 236 282 266 234
WRN-F08B 48
210 339 388 148 352 262 324 398 459 464 453 370 341 294 309 262 310 388 402 379
511 452 396 380 164 130 170 384 343 188 222 170 176 121 123 117 175 195 122 125
119 91 89 181 228 294 260 240
WRN-F09A 58
100 62 103 149 144 185 141 193 172 276 225 188 209 330 384 151 374 276 316 399
489 440 450 372 388 299 304 250 277 358 413 367 459 407 487 393 167 126 192 281
265 150 212 186 162 123 117 99 145 189 146 145 100 93 84 113 185 181
WRN-F09B 58
89 74 91 151 142 170 148 191 153 263 235 192 205 322 384 152 376 278 290 401
482 441 445 372 371 291 309 247 274 368 419 366 454 419 476 390 162 129 193 284
256 159 218 184 159 122 116 102 143 190 140 149 100 90 88 112 183 185
WRN-F10A 56
139 335 271 312 384 279 280 222 246 141 81 41 26 34 53 79 147 107 54 57
85 163 99 176 123 77 117 184 245 239 235 198 154 160 175 168 190 199 233 257
229 197 243 146 106 162 219 250 172 175 223 216 153 91 124 130
WRN-F10B 56
145 347 281 314 375 279 282 228 260 165 80 53 32 39 62 79 157 108 63 47
82 143 107 175 130 64 125 186 244 237 242 191 153 155 167 165 194 179 229 249
218 196 236 141 102 169 221 246 172 170 228 215 158 88 123 131

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 A1 where, for example, the widest rings appear at irregular intervals. This is the key to dating by tree rings, or rather, by their widths. Records of the average ring widths for oaks, one for each year for the last 1000 years or more, are available for different areas. These are called master chronologies. Because of the random-like nature of these sequences of widths, there is usually only one position at which a sequence of ring widths from a sample of oak timber with at least 70 rings will match a master. This will date the timber and, in particular, the last ring.

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

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

1. **Inspecting the Building and Sampling the Timbers.** Together with a building historian the timbers in a building are inspected to try to ensure that those sampled are not reused or later insertions. Sampling is almost always done by coring into the timber, which has the great advantage that we can sample *in situ* timbers and those judged best to give the date of construction, or phase of construction if there is more than one in the building. The timbers to be sampled are also inspected to see how many rings they have. We normally look for timbers with at least 70 rings, and preferably more. With fewer rings than this, 50 for example, sequences of widths become difficult to match to a unique

position within a master sequence of ring widths and so are difficult to date (Litton and Zainodin 1991). The cross-section of the rafter shown in Figure A2 has about 120 rings; about 20 of which are sapwood rings – the lighter rings on the outside. Similarly the core has just over 100 rings with a few sapwood rings.

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

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

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

All sampling by the Laboratory is undertaken according to current Health and Safety Standards. The Laboratory's dendrochronologists are insured.

Figure A1: A wedge of oak from a tree felled in 1976. It shows the annual growth rings, one for each year from the innermost ring to the last ring on the outside just inside the bark. The year of each ring can be determined by counting back from the outside ring, which grew in 1976

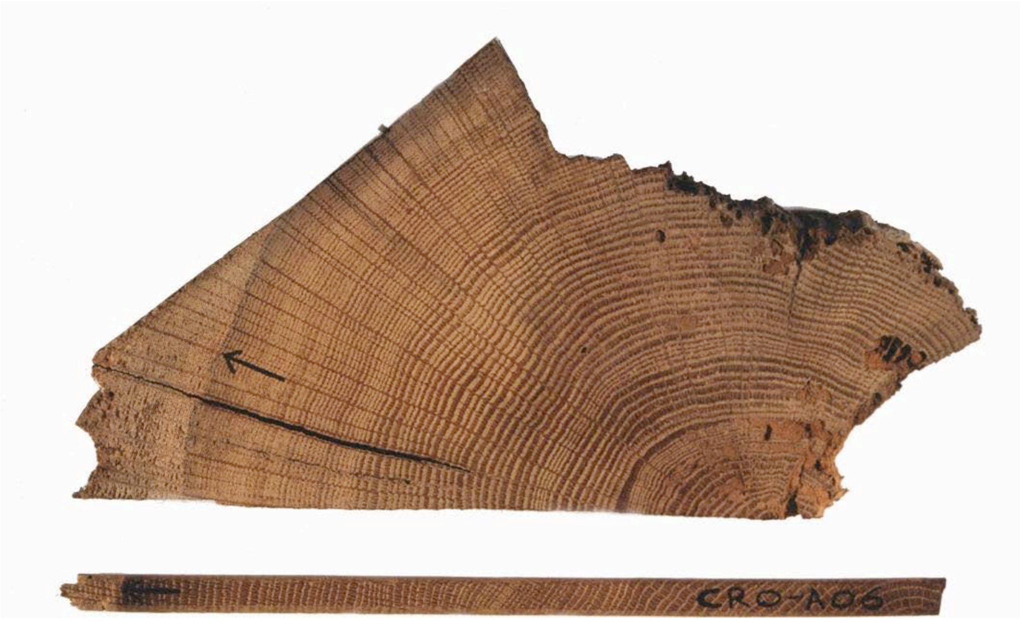


Figure A2: Cross-section of a rafter, showing sapwood rings in the left-hand corner, the arrow points to the heartwood/sapwood boundary (H/S); and a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil

Figure A3: Measuring ring widths under a microscope. The microscope is fixed while the sample is on a moving platform. The total sequence of widths is measured twice to ensure that an error has not been made. This type of apparatus is needed to process a large number of samples on a regular basis

Figure A4: Three cores from timbers in a building. They come from trees growing at the same time. Notice that, although the sequences of widths look similar, they are not identical. This is typical

2. Measuring Ring Widths. Each core is sanded down with a belt sander using medium-grit paper and then finished by hand with flourgrade-grit paper. The rings are then clearly visible and differentiated from each other with a result very much like that shown in Figure A2. The core is then mounted on a movable table below a microscope and the ring-widths measured individually from the innermost ring to the outermost. The widths are automatically recorded in a computer file as they are measured (see Fig A3).

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

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

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

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

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

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

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

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

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

5. Estimating the Date of Construction. There is a considerable body of evidence collected by dendrochronologists over the years that oak timbers used in buildings were not seasoned in medieval or early modern times (English Heritage 1998; Miles 1997, 50–5). Hence, provided that all the samples in a building have estimated felling-date ranges broadly in agreement with each other, so that they appear to have been felled as a group, then this should give an accurate estimate of the period when the structure was built, or soon after (Laxton *et al* 2001, fig 8; 34–5, where 'associated groups of fellings' are discussed in detail). However, if there is any evidence of storage before use, or if there is evidence the oak came from abroad (eg Baltic boards), then some allowance has to be made for this.

6. Master Chronological Sequences. Ultimately, to date a sequence of ring widths, or a site sequence, we need a master sequence of dated ring widths with which to cross-match it, a Master Chronology. To construct such a sequence we have to start with a sequence of widths whose dates are known and this means beginning with a sequence from an oak tree whose date of felling is known. In Figure A6 such a sequence is SHE-T, which came from a tree in Sherwood Forest which was blown down in a recent gale. After this other sequences which cross-match with it are added and gradually the sequence is 'pushed back in time' as far as the age of samples will allow. This process is illustrated in Figure A6. We have a master chronological sequence of widths for Nottinghamshire and East Midlands oak for each year from AD 882 to 1981. It is described in great detail in Laxton and Litton (1988), but the components it contains are shown here in the form of a bar diagram. As can be seen, it is well replicated in that for each year in this period there are several sample sequences having widths for that year. The master is the average of these. This master can now be used to date oak from this area and from the surrounding areas where the climate is very similar to that in the East Midlands. The Laboratory has also constructed a master for Kent (Laxton and Litton 1989). The method the Laboratory uses to construct a master sequence, such as the East Midlands and Kent, is completely objective and uses the Litton-Zainodin grouping procedure (Laxton *et al* 1988). Other laboratories and individuals have constructed masters for other areas and have made them available. As well as these masters, local (dated) site chronologies can be used to date other buildings from nearby. The Laboratory has hundreds of these site sequences from many parts of England and Wales covering many short periods.

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

t-value/offset Matrix

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

Bar Diagram

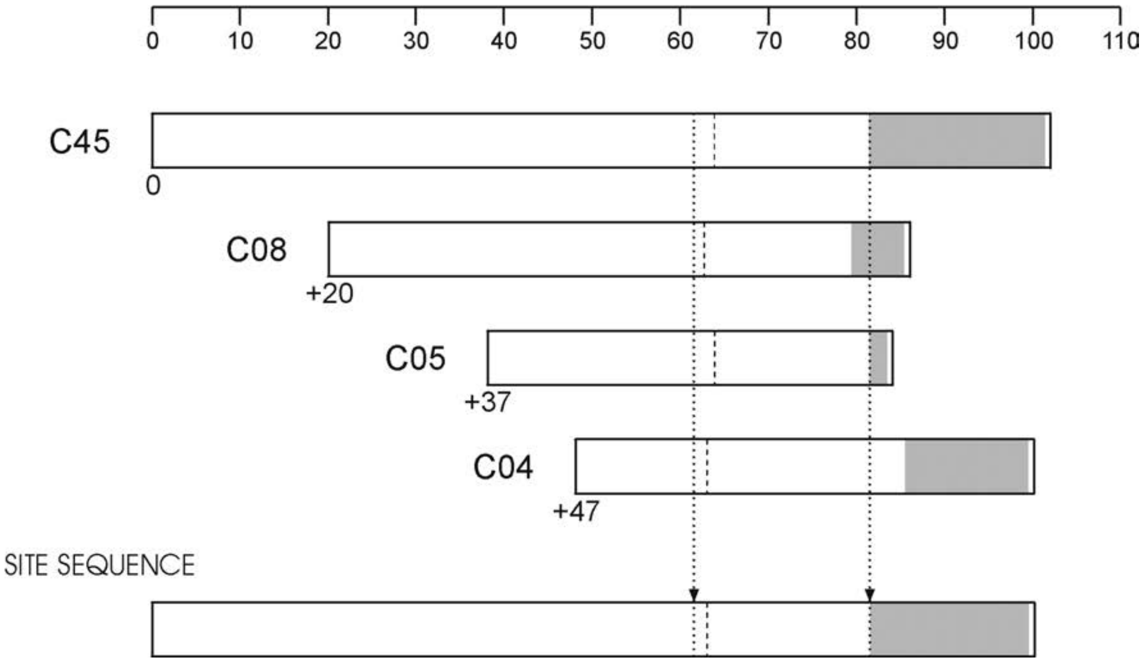


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

The bar diagram represents these sequences without the rings themselves. The length of the bar is proportional to the number of rings in the sequence. Here the four sequences are set at relative positions (offsets) to each other at which they have maximum correlation as measured by the *t*-values. The *t*-value/offset matrix contains the maximum *t*-values below the diagonal and the offsets above it. Thus, the maximum *t*-value between C08 and C45 occurs at the offset of +20 rings and the *t*-value is then 5.6. The site sequence is composed of the average of the corresponding widths, as illustrated with one width

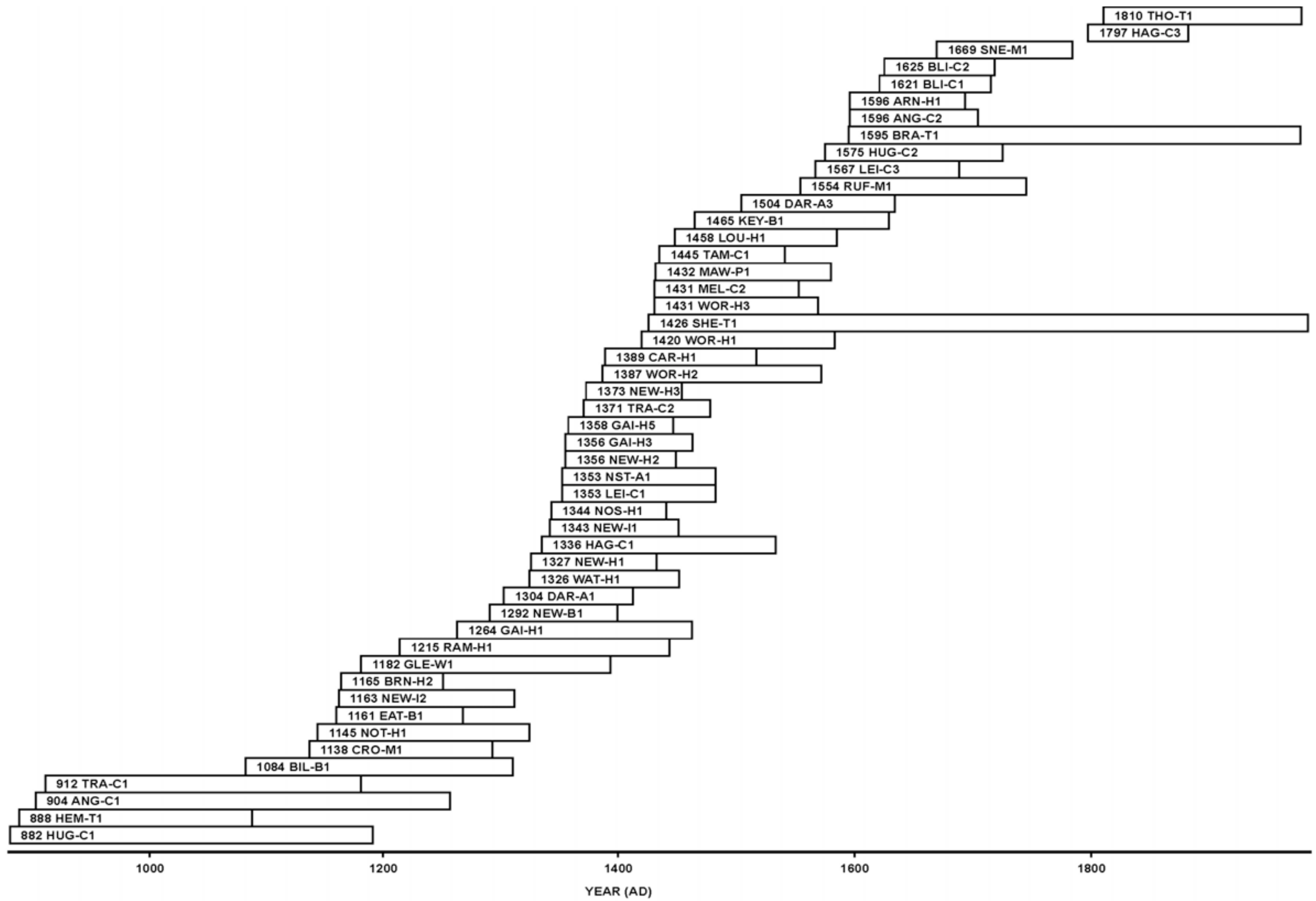
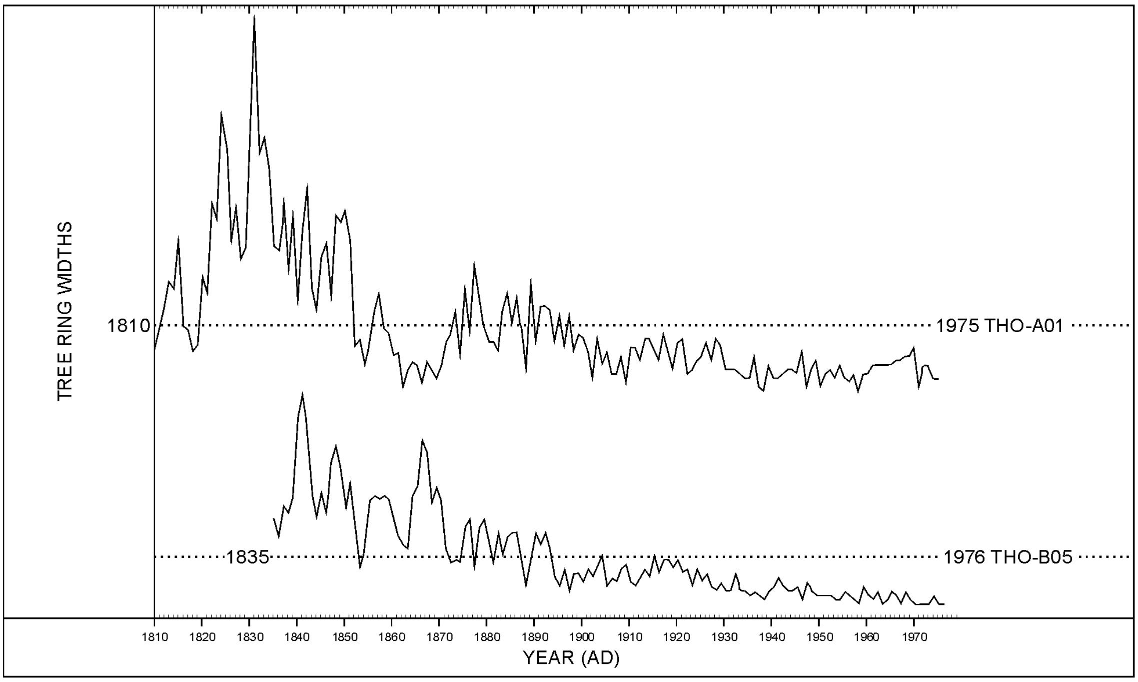


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

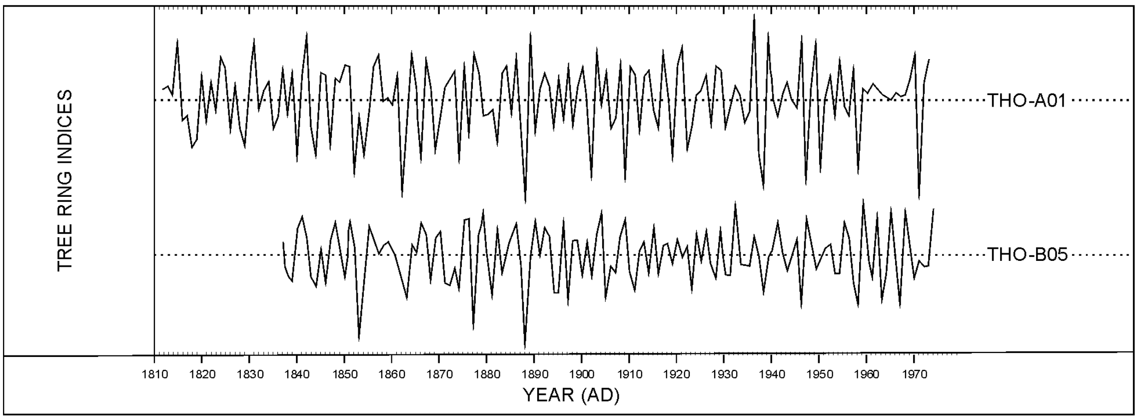


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

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

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

The growth trends have been removed completely

References

Baillie, M G L, and Pilcher, J R, 1973 A simple cross-dating program for tree-ring research, *Tree-Ring Bull*, 33, 7–14

English Heritage, 1998 *Dendrochronology: Guidelines on Producing and Interpreting Dendrochronological Dates*, London

Hillam, J, Morgan, R A, and Tyers, I, 1987 Sapwood estimates and the dating of short ring sequences, *Applications of tree-ring studies*, BAR Int Ser, 3, 165–85

Howard, R E, Laxton, R R, Litton, C D, and Simpson, W G, 1984–95 Nottingham University Tree-Ring Dating Laboratory results, *Vernacular Architect*, 15–26

Hughes, M K, Milson, S J, and Legett, P A, 1981 Sapwood estimates in the interpretation of tree-ring dates, *J Archaeol Sci*, 8, 381–90

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

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

Laxton, R R, and Litton, C D, 1989 Construction of a Kent master dendrochronological sequence for oak, AD 1158 to 1540, *Medieval Archaeol*, 33, 90–8

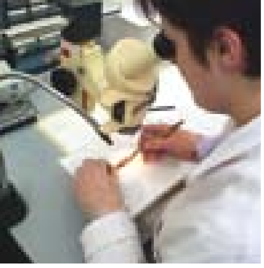
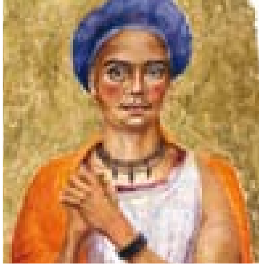
Laxton, R R, Litton, C D, and Howard, R E, 2001 *Timber: Dendrochronology of Roof Timbers at Lincoln Cathedral*, Engl Heritage Res Trans, 7

Litton, C D, and Zainodin, H J, 1991 Statistical models of dendrochronology, *J Archaeol Sci*¸18, 29–40

Miles, D W H, 1997 The interpretation, presentation and use of tree-ring dates, *Vernacular Architect*, 28, 40–56

Pearson, S, 1995 *The Medieval Houses of Kent, an Historical Analysis*, London

Rackham, O, 1976 *Trees and Woodland in the British Landscape*, London



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