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Sneath's Mill, near Lutton Gowts, Lincolnshire

Tree-ring Analysis of Oak Timbers

Alison Arnold, Robert Howard and Cathy Tyers

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SNEATH'S MILL,
NEAR LUTTON GOWTS,
LINCOLNSHIRE

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SUMMARY

Dendrochronological analysis was undertaken on 10 of the 19 core samples obtained from timbers of Sneath's Mill, near Lutton Gowts, Lincolnshire; nine samples had too few rings for reliable analysis. This analysis produced a single site chronology comprising eight samples with an overall length of 136 rings. These rings were dated as spanning the years AD 1593–1728. Interpretation of the sapwood on the dated samples suggests that the these timbers were cut as part of a single episode of felling in the late AD 1720s, with at least one timber being cut in AD 1728. The two other measured samples remain ungrouped and undated.

CONTRIBUTORS

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ACKNOWLEDGEMENTS

Bobbie Ashton (Sneath's Mill Trust), Luke Bonwick (Bonwick Milling Heritage Consultancy), and Jon Breckon (Historic England Heritage at Risk Projects Officer), are thanked for their help in arranging access for sampling and for information on the history and possible development of the mill. FAS Heritage is thanked for the provision of the plans and sections and permission to use them in this report. Finally we would like to thank Shahina Farid (Historic England Scientific Dating Team) for commissioning and facilitating this programme of tree-ring analysis.

ARCHIVE LOCATION

Lincolnshire Historic Environment Record
Planning Services,
Environment and Economy Directorate
Witham Park House
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DATE OF INVESTIGATION

2016

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CONTENTS

INTRODUCTION

Sneath's Mill stands to the west side of the road between Lutton Gowts and Long Sutton (Figs 1a–c) and lies just within the parish of Long Sutton. It is a Grade I listed tower mill which is currently on the Heritage at Risk Register, the structure being supported by an internal scaffold (Figs 2a–b). The mill, now without its four sails, is an octagonal building of four storeys and largely made of brick. The mill with its surviving poll end sail mounting and trundle gear is a unique survival in Lincolnshire.

The listing entry of 1976 describes the interior thus: *"Interior contains oak wind shaft with iron poll end and clasp arm brake wheel. Clasp arm wallower, crudely cogged, being a trundle or face gear-wheel. Wooden upright shaft with a clasp arm great spur wheel. Drive to flour dresser largely intact and mostly of wood driven by a pinion from the great spur wheel."* However various timbers, including the wind shaft, were removed from the mill around 1985 and stored either outside or in an adjacent open-bayed shed (Figs 3a–b). The roof of the mill was in a state of serious disrepair and thus the interior was exposed to the elements until recently when a temporary covering was erected.

Above the doorway on the south side is an ashlar plaque inscribed *'T.D.Ayliff 1779'*. This, combined with documentary evidence, has been taken to indicate a construction date between 1777 and 1779 (FAS Heritage 2010) but it has also been previously suggested that this inscription may mark the casing in brick of a wooden smock mill moved to this site (Sass 1978). The windmill went out of use following storm damage in the 1930s and the subsequent retirement of the miller John Sneath (FAS Heritage 2010).

SAMPLING

A dendrochronological survey was requested by Jon Breckon, Historic England Heritage at Risk Projects Officer, to inform and complement a potential small development grant for investigative work. It was hoped that this would provide independent dating evidence for the construction of the mill, the date of its machinery, and the date(s) of any later modifications. Such evidence would aid the understanding of the historic development of the mill and its significance, and hence inform plans for its future management and potential conservation and restoration.

Thus, after an initial assessment of the timbers as to their suitability for tree-ring analysis, particularly in respect of their condition after long-term exposure and consequent decay, a total of 19 samples (17 *in situ* and two *ex situ*) was obtained by coring. Each sample was given the code SNT-M (for Sneath's Mill) and numbered 01–19 (Table 1, Figs 4a–f). In this report the 'front' of the Mill, containing the ground-floor entrance door, is deemed to be facing south, with the ‘rear’ facing north. The timbers have been located by reference to their floor frame, being further identified on a north-south or east-west basis as appropriate.

ANALYSIS AND RESULTS

Each of the 19 samples obtained was prepared by sanding and polishing at which time it was seen that nine of these had less than the 40 rings here deemed necessary for reliable dating. These nine samples were therefore rejected from this programme of analysis. It should however be noted that in several instances, including the two *ex situ* timbers, the rejected cores were the result of the timber being in a state of decay such that sampling by coring was highly problematic. The annual growth ring widths of the remaining 10 samples were measured, the data of these measurements being given at the end of this report.

The data of the 10 measured samples were then compared with each other by the Litton/Zainodin grouping procedure (see Appendix). This comparative process resulted in the production of a single group of eight cross-matching samples, these matching with each other as shown in Figure 5.

These eight cross-matching samples were combined at their indicated offset positions to form site chronology SNTMSQ01, this having an overall length of 136 rings. Site chronology SNTMSQ01 was then compared to an extensive corpus of reference material for oak, this indicating a consistent and repeated match with a series of these when the date of its first ring is AD 1593 and the date of its last measured ring is AD 1728 (Table 2).

INTERPRETATION

Of the eight samples dated in site chronology SNTMSQ01, one sample (SNT-M06) retains sapwood complete to the bark (Table 1; Fig 5). This means that it has the last growth ring produced by the tree represented before it was cut. This last growth ring, and thus the felling of the tree, is dated AD 1728. A further dated sample (SNT-M11) is from a timber which had complete sapwood present. However, due to the fragile and decayed nature of the sapwood, the outer *circa* 10mm were lost from the sample during coring (Table 1; Fig 5). Allowing for the number of sapwood rings in this lost section of core (based on the average ring width and overall growth trends), and given that latest measured ring is dated AD 1720, it is very likely that the source timber was also felled in the late-AD 1720s.

Samples SNT-M05, SNT-M12, and SNT-M13 retain incomplete sapwood (Table 1; Fig 5) and have heartwood/sapwood boundaries of very similar dates to those two timbers felled in the late-AD 1720s. The average date of the heartwood/sapwood boundary on these three samples is AD 1703 which, using a sapwood estimate of 15–40 rings (the usual 95% confidence interval), would thus give the timbers represented an estimated felling date in the range AD 1718–43. The felling date of the timbers represented by the remaining three dated samples, SNT-M08, SNT-M09, and SNT-M14, cannot be determined. This is because not only have they lost all their sapwood rings, but also, in not having the heartwood/sapwood boundary, an unknown number of heartwood rings as well. With last heartwood rings dates of AD 1694, AD 1697, and AD 1696, and using a minimum sapwood estimate of 15 rings, it is unlikely that the timbers represented were felled before AD 1709, AD 1712, and AD 1711 respectively. This, combined with the overall level of cross-matching between all eight samples which includes a series of *t*-values in excess of 6, suggests that it is likely that all eight dated samples are coeval and hence all felled in the late-AD 1720s. The level of cross-matching (t = 16.6) between two samples (SNT-M05, SNT-M13) indicates that the two timbers represented, main beams to second and first floors respectively, were potentially derived from a single tree.

CONCLUSION

The tree-ring analysis demonstrates that it is likely that the dated samples from Sneath's Mill, representing timbers from the first and second floor frames, a window lintel at first floor level and the central post, were cut as part of a single programme of felling in the late-AD 1720s. This clearly pre-dates the 1779 inscription and thus further historical and architectural investigation will have to address this discrepancy. In addition, should a restoration be agreed and get underway, it may prove feasible to extend the dendrochronological investigation to encompass additional structural timbers and those associated with the machinery which may further elucidate the half-century difference between the dated structural timbers and the inscription.

The overall level of cross-matching between the dated samples suggests that the timbers represented were derived from trees growing in a single, although perhaps extensive, woodland. Site chronology SNTMSQ01 cross-matches extensively with reference material from many parts of England but, as may be noted from Table 2, it shows the strongest levels of similarity with reference chronologies from eastern England, particularly those from sites in the surrounding counties suggesting that the timber utilised is of relatively local origin. It is however notable that none of the reference chronologies that SNTMSQ01 matches particularly well are that local. This, however, is at least in part due to the paucity of relevant reference material for the local likely source area, a deficiency which the samples from Sneath's Mill will go some way toward improving.

Despite having sufficient rings for reliable analysis, two samples, SNT-M04 and M16, remain ungrouped and undated. Neither of these samples show any sign of distortion or disturbance to their growth rings, and the reason for the lack of dating is unknown. It is, however, a frequent feature of tree-ring analysis to find that some samples will not group or date, and in this respect Sneath's Mill, with 80% of its measured samples dated, may be considered a success.

BIBLIOGRAPHY

Arnold, A J, and Howard, R E, 2013 *Oakham Castle, Castle Lane, Oakham, Rutland: Tree-ring Analysis of Timbers,* English Heritage Res Rep Ser, **23/2013**

Arnold, A J, Howard, R E, and Litton, C D, 2005 *Tree-ring Analysis of Timbers from the Riding School, Bolsover Castle, Bolsover, Derbyshire*, Centre for Archaeol Rep, **40/2005**

Arnold, A J, Howard, R E, and Litton, C D, 2008 Nottingham Tree-ring Dating Laboratory: Additional Dendrochronology Dates, list 24, *Vernacular Architect*, **39**, 107–11

Arnold, A J, Howard, R E, and Tyers, C, 2008 *Apethorpe Hall, Apethorpe, Northamptonshire: Tree-ring Analysis of Timbers*, English Heritage Res Dep Rep Ser, **87/2008**

Arnold, A J, Howard, R E, and Tyers, C, forthcoming a *Kirby Hall, Deene, Corby, Northamptonshire: Tree-ring Analysis of Timbers,* Historic England Res Rep Ser

Arnold, A J, Howard, R E, and Tyers, C, forthcoming b *The Bede House, Church Lane, Lyddington, Rutland: Tree-ring Analysis of Timbers,* Historic England Res Rep Ser

Arnold, A J, and Howard, R E, 2011 unpubl Tree-ring Analysis of Timbers from Bardney Manor Barn, Horncastle Road, Bardney, West Lindsey, Lincolnshire – Nottingham Tree-ring Dating Laboratory unpubl computer file *BDNASQ01*

FAS Heritage, 2010 *Sneath's Mill, Long Sutton, Lincolnshire – Archaeological Assessment,* Field Archaeology Specialists report, **FAS2010 461 LGS369**

Hurford, M, Howard, R E, and Tyers, C, 2010 *Pitchforks and Numbers 1 and 2 Greasley Cottage, Main Street, Norwell, Nottinghamshire: Tree-ring Analysis of Timbers*, English Heritage Res Dep Rep Ser, **50/2010**

Sass, J A, 1978 Long Sutton, Sneath's Mill, *Lincolnshire History and Archaeology,* **13**, 63–6

TABLES

Table 1: Details of tree-ring samples from Sneath's Mill, near Lutton Gowts, Lincolnshire

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
SNT-M01	3rd floor frame, main north-south beam, west side	nm	---	------	------	------
SNT-M02	3rd floor frame, main north-south beam, east side	nm	---	------	------	------
SNT-M03	3rd floor frame, middle joist	nm	---	------	------	------
SNT-M04	2nd floor frame, main east-west beam, north side	58	h/s	------	------	------
SNT-M05	2nd floor frame, main east-west beam, south side	119	5	1593	1706	1711
SNT-M06	2nd floor frame, joist to north-west	64	26C	1665	1702	1728
SNT-M07	2nd floor frame, joist to west	nm	---	------	------	------
SNT-M08	2nd floor frame, joist to south-west	69	no h/s	1626	------	1694
SNT-M09	2nd floor frame, joist to south-west	72	no h/s	1626	------	1697
SNT-M10	2nd floor frame, joist to south-west	nm	---	------	------	------
SNT-M11	1st floor, west window, inner lintel	74	14c	1647	1706	1720
SNT-M12	1st floor, central main post	116	19	1602	1698	1717
SNT-M13	1st floor frame, main north-south beam, east middle	111	2	1598	1706	1708
SNT-M14	1st floor frame, main north-south beam, west middle	81	no h/s	1616	------	1696
SNT-M15	1st floor frame, main north-south beam, south side	nm	---	------	------	------
SNT-M16	Ground floor, east window, inner lintel	62	h/s	------	------	------
SNT-M17	Ground floor, doorway lintel	nm	---	------	------	------
SNT-M18	*Ex situ*, wind shaft	nm	---	------	------	------
SNT-M19	*Ex situ*, ?tiebeam?, unknown location	nm	---	------	------	------

h/s = the heartwood/sapwood ring is the last ring on the sample
nm = not measured
c = complete sapwood is found on the timber, but all or part has been lost from the sample in coring
C = complete sapwood is retained on the sample, the last measured ring date is the felling date of the tree represented

Table 2: Results of the cross-matching of site sequence SNTMSQ01 and relevant reference chronologies when the first-ring date is AD 1593 and the last-ring date is AD 1728

Reference chronology	Span of chronology	*t*-value	Reference
Kirby Hall, Deene, Corby, Northamptonshire	AD 1509 – 1795	14.1	(Arnold *et al* forthcoming a)
Apethorpe Hall, Apethorpe, Northamptonshire	AD 1292 – 1740	12.8	(Arnold *et al* 2008)
Wheatsheaf, Cropwell Bishop, Nottinghamshire	AD 1604 – 1703	9.8	(Arnold *et al* 2008)
Riding House, Bolsover Castle, Derbyshire	AD 1494 – 1744	8.7	(Arnold *et al* 2005)
Bede House, Lyddington, Rutland	AD 1645 – 1744	8.5	(Arnold *et al* forthcoming b)
Manor Barn, Bardney, Lincolnshire	AD 1591 – 1700	8.4	(Arnold and Howard 2011 unpubl)
Pitchforks, Norwell, Nottinghamshire	AD 1624 – 1747	8.4	(Hurford *et al* 2010)
Oakham Castle, Oakham, Rutland	AD 1598 – 1737	8.3	(Arnold and Howard 2013)

FIGURES

Figure 1a: Map to show the general location of Lutton Gowts, just north of Long Sutton. © Crown Copyright and database right 2016. All rights reserved. Ordnance Survey Licence number 100024900

Figure 1b: Map to show the location of Sneath's Mill, just south of Lutton Gowts and north of Long Sutton. © Crown Copyright and database right 2016. All rights reserved. Ordnance Survey Licence number 100024900

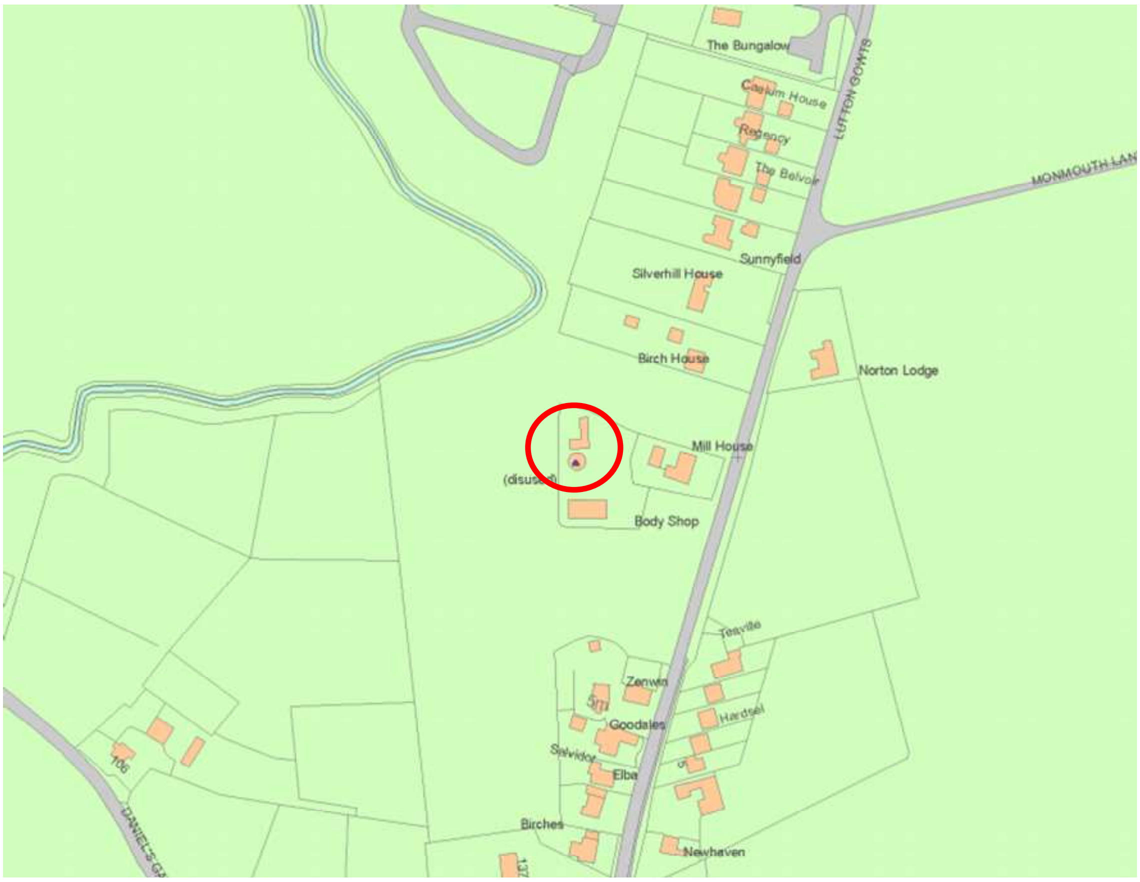


Figure 1c: Map to show the detailed location of Sneath's Mill. © Crown Copyright and database right 2016. All rights reserved. Ordnance Survey Licence number 100024900

Figure 2a–b: Interior views of Sneath's Mill showing timber structure and scaffold support (photographs Robert Howard)

Figure 3a–b: Views of the ex situ mill timbers (photographs Robert Howard)

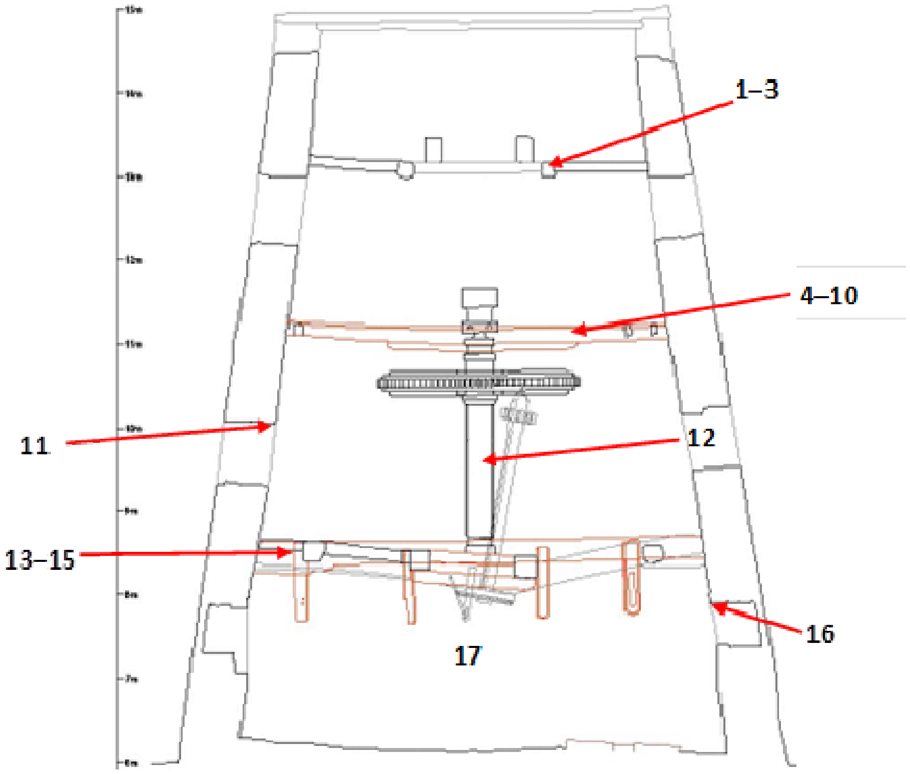


Figure 4a: Section through the mill showing the levels at which samples were taken (after FAS Heritage)

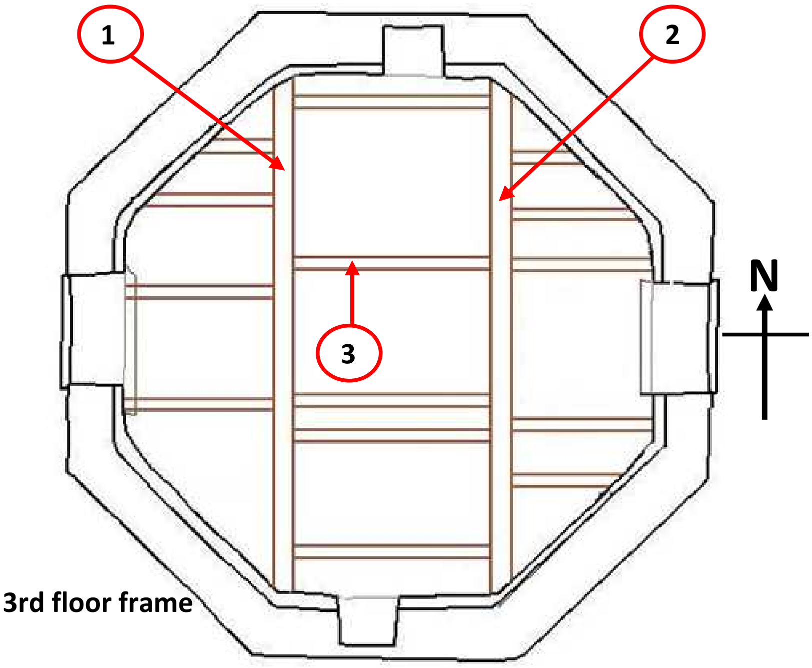


Figure 4b: Plan to help locate sampled timbers (after FAS Heritage)

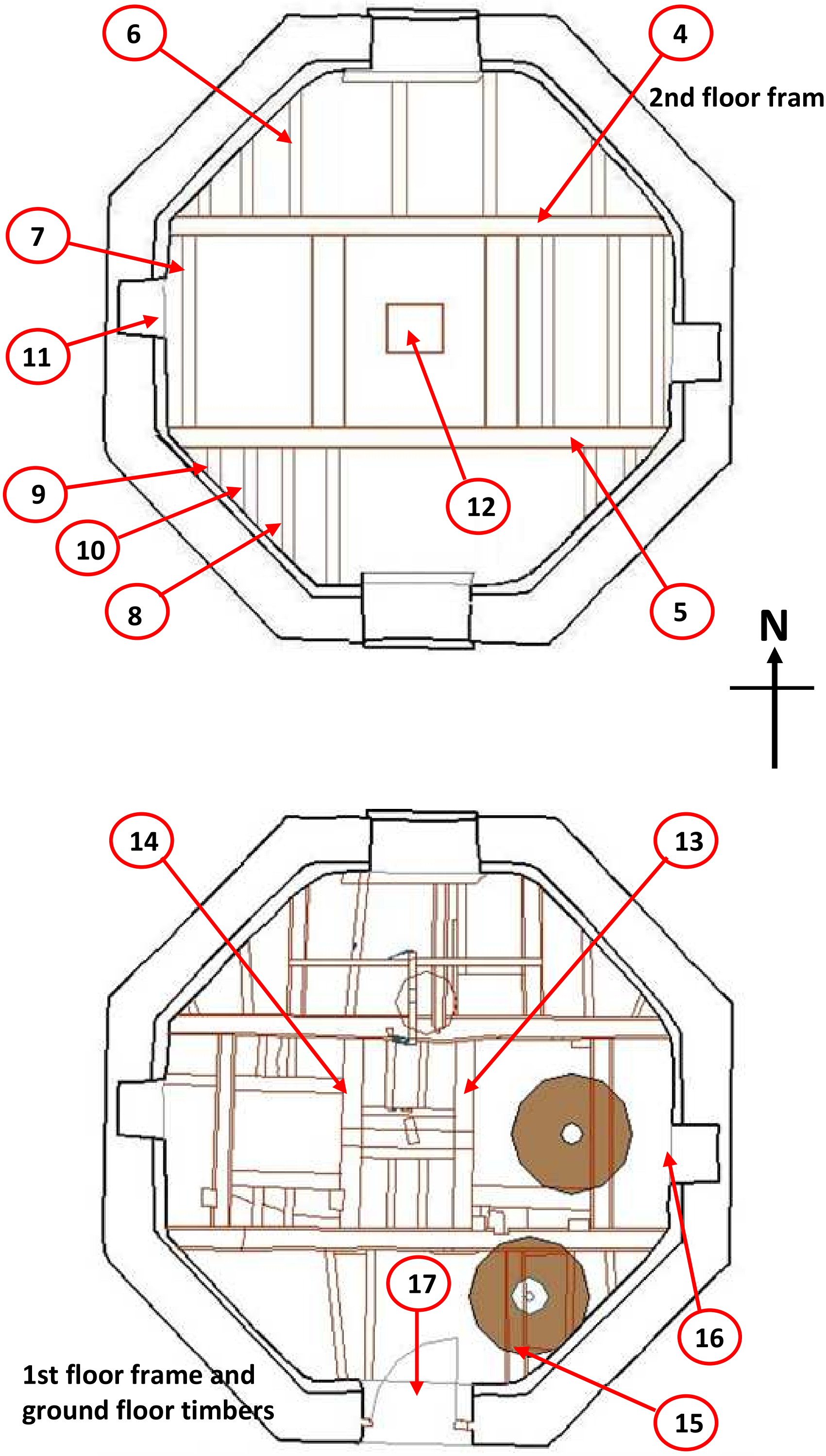
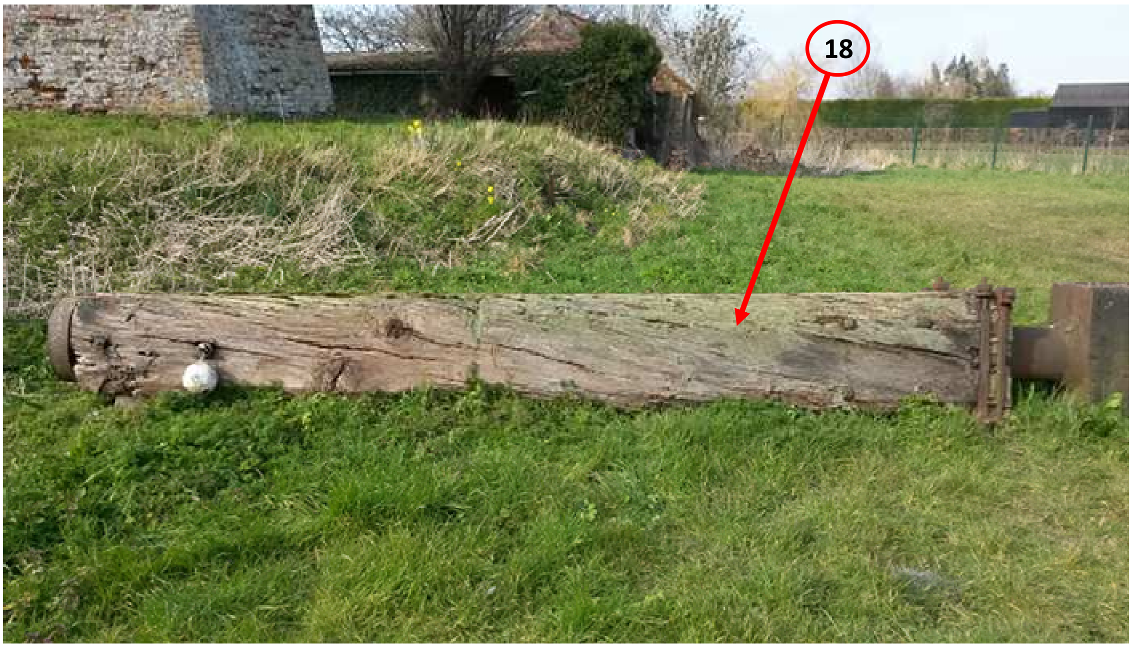


Figure 4c–d: Plans to help locate sampled timbers (after FAS Heritage)



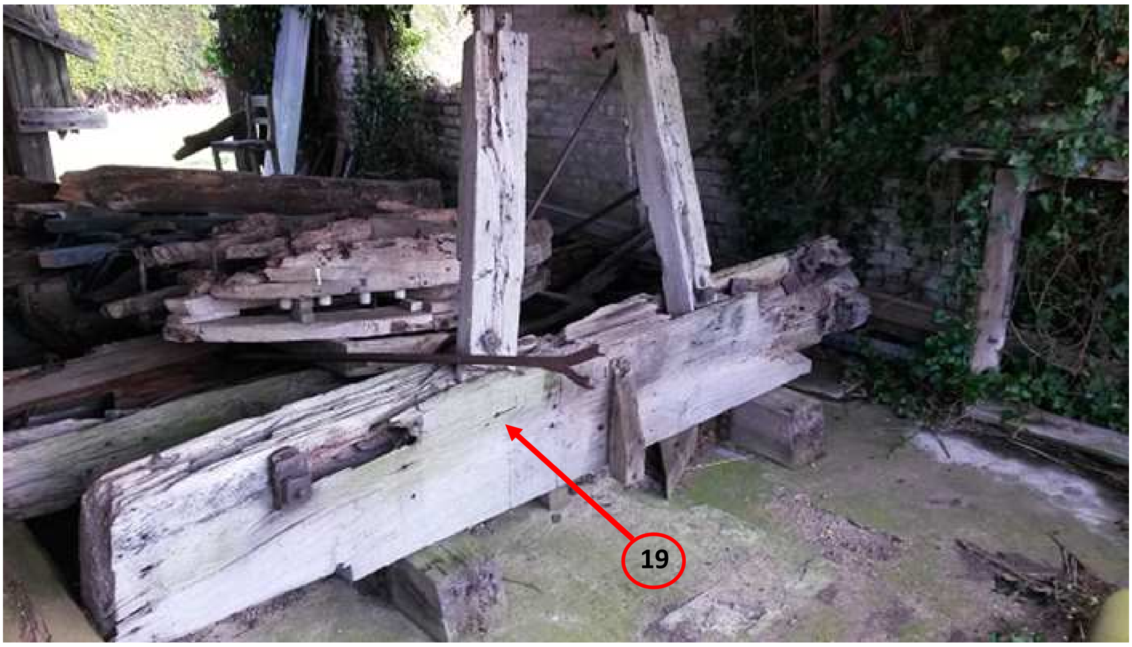
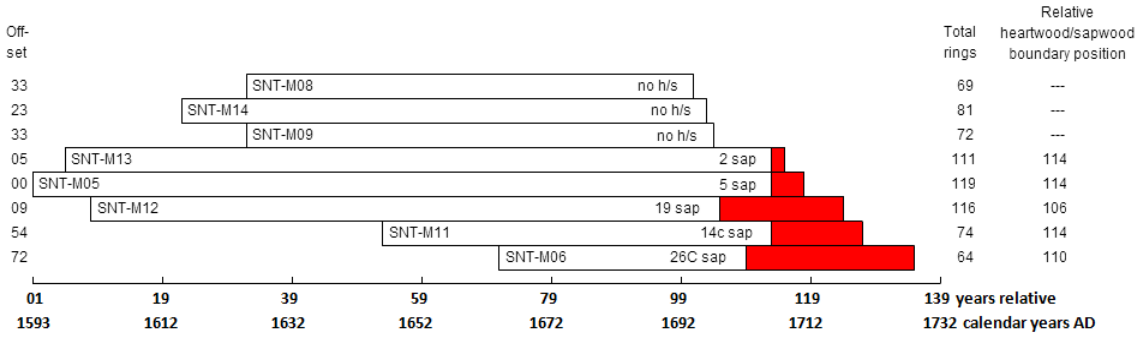


Figure 4e–f: Views to identify sampled ex-situ timbers (Photographs Robert Howard)



white bars = heartwood rings;
shaded bars = sapwood rings
h/s = heartwood/sapwood boundary;
c = complete sapwood is found on the timber, but all or part has been lost from the sample in coring
C = complete sapwood is retained on the sample, the last measured ring date is the felling date of the tree represented

Figure 5: Bar diagram of the samples in site chronology SNTMSQ01

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

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SNT-M04A 58
283 257 247 330 285 293 219 232 262 248 360 252 225 392 378 346 430 343 451 352
280 298 337 334 400 388 244 378 265 195 228 329 365 290 256 212 198 251 139 205
200 178 289 328 110 212 178 200 259 297 217 325 226 366 203 161 207 226
SNT-M04B 58
284 266 223 249 303 304 201 247 289 284 364 250 230 407 384 345 443 335 465 360
306 306 354 325 407 395 276 368 275 196 229 325 359 290 256 215 192 253 140 214
200 177 290 309 123 203 188 197 262 300 208 291 228 386 204 167 212 288
SNT-M05A 119
298 378 281 268 281 311 275 199 217 422 412 275 135 205 258 320 348 275 293 235
361 250 196 257 354 320 223 254 171 210 215 167 193 296 345 248 236 120 212 236
153  96 134 117 173 295 248 191 233 127 200 298 282 303 198 296 193 209 155 125
117 137 215 221 211 228 191 196 184 206 157 143 148 200 272 255 238 195 271 267
242 218 187 179 283 356 234 284 186 342 231 155 150 311 248 220 203 115 128 219
205 181 173 189 284 274 262 155 180 202 275 227 169 189 164 147 330 191 246
SNT-M05B 119
272 379 276 268 267 305 273 201 209 433 412 275 152 232 210 296 374 279 288 236
356 261 191 242 355 311 221 260 179 203 217 157 192 271 368 254 251 126 242 246
159  90 131 117 159 323 234 208 209 117 215 296 264 294 204 295 206 205 150 134
118 129 215 216 212 239 176 203 177 212 160 140 151 203 286 239 226 196 274 269
237 226 172 181 283 323 243 282 190 344 231 171 147 312 252 228 216 118 136 221
213 178 175 192 281 297 259 156 184 208 266 247 157 185 159 125 320 199 244
SNT-M06A 64
262 497 318 343 339 291 119 139 117 114  86 171 337 301 207 190 142 255 198 139
103 153 196 198 150 117 175 121  95 171 207 207 205 189 167 118 110  87 153 117
 73 116  58  95 170  45 128 119 175 170 159 121 148 103  98 125 165 187  79 125
131 100 134 129
SNT-M06B 64
370 350 344 350 334 291 121 126 121 119  66 187 339 264 203 191 141 265 200 151
101 154 203 230 133 114 167 123  73 176 190 215 209 170 160 128  96  82 148 121
 73 125  64  93 165  64 123 142 168 185 151 131 142  98  78 151 140 182 101 120
139 101 139 131
SNT-M08A 69
169 146 207 212 237 318 293 268 150 165 434 358 255 267 261 299 306 361 318 338
314 219 293 246 242 223 154 146 107 300 211 218 253 123 137 108 104 148 118  98
 79 129 107 103 120  93  99  92  62  60  78 134 126 100  81  77 132  59  70  57
 98 103  89 109  54  56  60  68 100
SNT-M08B 69
172 145 212 211 241 312 296 261 150 167 432 369 228 252 271 296 308 365 329 321
307 224 285 238 220 214 170 110 109 340 212 207 251 140 129 110 100 159 101 121
 87 131 120 106 106 101 100  90  56  57  95 123 138 100  79  86 128  65  75  53
100 125  87  93  57  59  59  59 104
SNT-M09A 72
180 201 176 142 135 156 194 245 150 140 138 144 192 180 167 148 110 155 142 141
203 133 188 135 138 100  67  89 110 171 132 122 173 139 174 148 144 159 130 124
112 114 127 107 139 174 120 168 145  98  79 148 149 120 132  82 107 131  90  79
176 131 146 142  92 107  90 106  98  90 116 121
SNT-M09B 72
200 190 184 149 131 169 237 260 170 137 141 146 191 184 160 152 110 135 152 143
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207 131 200 121 133 103  65  97 113 154 125 106 179 121 175 166 139 158 139 124
107 121 141 117 122 185 135 153 126 109  95 151 162 119 130  94 103 129  85  78
178 145 154 141  84 109  84  98 103  91 116 126
SNT-M11A 74
266 384 230 195 120 104 101 145 221 135 162 190 105  76 130 176 157 100  67  89
 94 215 185 225 197 134 187 100 101  79 200 203 293 202  97 165 135  75  89 150
117 206 206  95  80  57  75  64  46  64  89 101  89  76  64  75  80  73  59  62
 58  53  42  54  68  92  85  53  81  90  76  48  63  89
SNT-M11B 74
256 399 229 212 119  92 101 140 221 155 160 189 112  76 129 173 166  90  72  85
102 210 192 225 203 134 183 100 107  77 203 201 285 198 101 169 137  80  75 164
123 200 173  90  77  66  70  63  51  57  96  98  86  74  61  68  79  57  54  51
 51  53  49  53  62  95  85  59  71  86  75  57  75  95
SNT-M12A 116
389 417 487 429 448 422 284 246 196 149 322 413 345 245 318 439 480 421 402 331
351 426 271 271 371 345 364 405 217 213 297 248 168 132 128 193 221 256 304 264
148 244 237 295 306 213 287 243 215 190 134 135 139 306 238 157 227 132 174 321
261 210 203 140 158 209 232 220 243 290 226 259 162 127 110 253 300 284 203 153
203 221 146 141 352 303 290 213 156 112  83 153 162 150 178 189 229 165 115 118
 84 124 133 145 221 129 113 142 106 180 140 165 138 161 113 152
SNT-M12B 116
403 422 502 448 447 461 294 224 212 136 332 414 352 237 327 443 464 425 398 296
356 435 254 290 367 326 378 404 215 203 290 257 154 139 131 182 232 246 328 253
161 236 238 286 309 215 275 252 213 181 138 136 138 309 221 171 237 131 177 332
249 209 209 150 146 209 233 209 251 278 217 251 168 125 118 257 289 298 197 148
213 218 134 133 364 304 291 211 153 107  99 150 171 146 174 189 221 179 110 112
 91 148 125 133 223 132 116 142 116 161 162 150 125 176 123 155
SNT-M13A 111
376 290 224 256 355 355 284 181 252 310 370 405 372 396 319 519 409 269 308 450
442 307 433 361 312 370 228 264 396 414 344 321 140 304 364 241 112 153  93 179
322 291 300 278 149 312 287 317 321 200 329 262 236 150 208 191 187 396 212 278
253 175 229 266 225 182 169 214 243 271 247 163 161 225 217 205 206 150 159 246
196 168 218 137 303 281 162 106 240 178 214 158  89 100 117 218 141 140 165 244
243 176 117 130 123 233 168 137 106 164  80
SNT-M13B 111
345 287 243 259 351 359 290 159 273 307 371 413 368 448 303 524 407 264 307 451
457 306 435 364 300 342 245 259 390 404 381 346 142 301 356 229 112 151  94 177
312 293 294 284 136 293 272 312 328 234 327 260 231 150 208 187 173 406 212 259
285 159 225 264 238 185 169 204 253 268 247 175 153 218 228 195 200 143 171 243
181 170 212 140 305 284 150 112 251 182 200 161 100  87 146 212 131 162 160 213
264 175 108 133 126 206 192 125 100 152  88
SNT-M14A 81
120 136 114  70  97 101  96  96 112 123 121 125 157 145 103 105 144 105  82 101
111 119 174 139 182 177 140 125 132 132 121 103 121  77  79  92  96  64  68 124
 99 107 104 141  86  53  32  53  61  85 103  98 130 120 143 169 137 169 109 131
132 203 175 175  96  79 114 100 101 134 150 155 147 109 107  93 137 126 105 118
137
SNT-M14B 81
123 127 112  83 100  99  94  88 120 118 123 124 153 141 104 122 142  94  92 101
114 121 165 143 164 194 155 135 137 166 118  91 125  75  80  96  92  66  74 128
 93 109 114 132  94  48  48  53  52  71  83  95 142 112 131 179 136 148 120 137
128 205 173 174  95  90 107 101  98 135 148 160 138 108 103  92 134 125 105 120
140
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SNT-M16A 62
240 323 231 165 175 232 225 180 345 373 296 217 203 178 234 187 183 213 129 138
117 117 112 100  97 146 207 114 146 148 175 225 225 171 146 120 114 148  84  81
 62  79  97 106 125 134  98  90  52  64  53  47  60  48  87  70  92  64  90  98
103 159
SNT-M16B 62
229 314 263 154 179 252 211 191 344 346 314 225 158 175 214 189 164 212 121 142
108 110  80  96  83 139 231 146 146 154 182 221 198 164 162 126  91 160  83  84
 59  76 102 105 114 132  96  88  48  66  50  45  58  48  93  80  95  67  90 100
100 162
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APPENDIX: TREE-RING DATING

The Principles of Tree-Ring Dating

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

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

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

1. Inspecting the Building and Sampling the Timbers. Together with a building historian the timbers in a building are inspected to try to ensure that those sampled are not reused or later insertions. Sampling is almost always done by coring into the timber, which has the great advantage that we can

sample *in situ* timbers and those judged best to give the date of construction, or phase of construction if there is more than one in the building. The timbers to be sampled are also inspected to see how many rings they have. We normally look for timbers with at least 70 rings, and preferably more. With fewer rings than this, 50 for example, sequences of widths become difficult to match to a unique position within a master sequence of ring widths and so are difficult to date (Litton and Zainodin 1991). The cross-section of the rafter shown in Figure A2 has about 120 rings; about 20 of which are sapwood rings — the lighter rings on the outside. Similarly the core has just over 100 rings with a few sapwood rings.

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

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

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

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

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

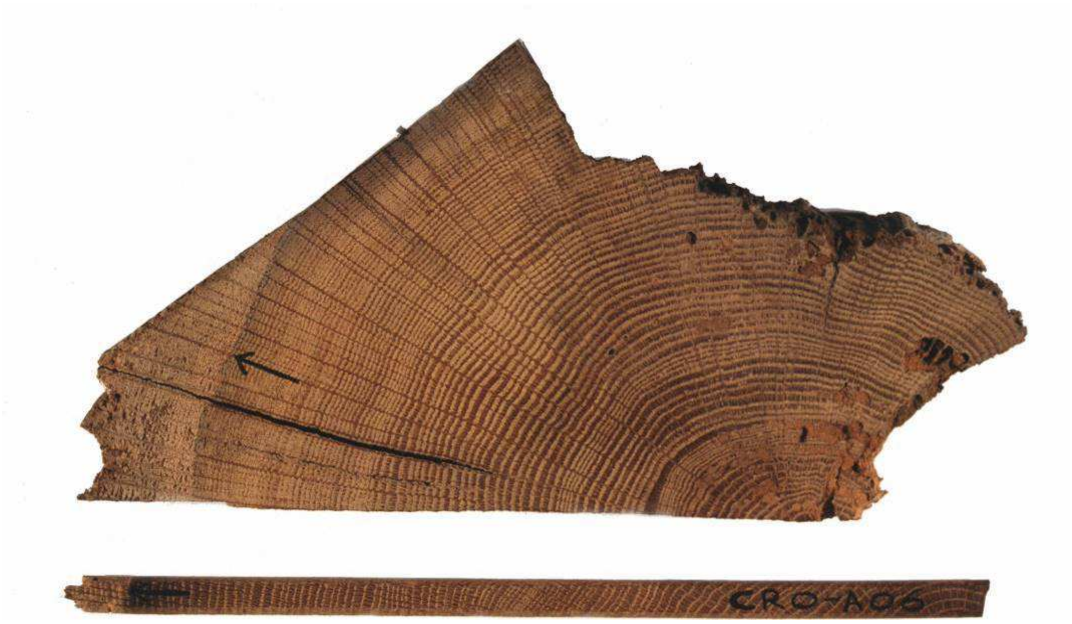


Figure A2: Cross-section of a rafter, showing sapwood rings in the left-hand corner, the arrow points to the heartwood/sapwood boundary (H/S); and a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil

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

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

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

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

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

It is standard practice in our Laboratory first to cross-match as many as possible of the ring-width sequences of the samples in a building and then to form an average from them. This average is called a site sequence of the building being dated and is illustrated in Figure A5. The fifth bar at the bottom is a site sequence for a roof at Lincoln Cathedral and is constructed from the matching sequences of the four timbers. The site sequence width for each year is the average of the widths in each of the sample sequences which has a width for that year. Thus in Figure 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 complement of, say, 15 to 35 years to the date of the last heartwood ring (called the heartwood/ sapwood boundary or transition ring and denoted H/S). Fortunately it is often easy for a trained dendrochronologist to identify this boundary on a timber. If a timber does not have its heartwood/sapwood boundary, then only a *post quem* date for felling is possible.

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

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

7. Ring-Width Indices. Tree-ring dating can be done by cross-matching the ring widths themselves, as described above. However, it is advantageous to modify the widths first. Because different trees grow at different rates and because a young oak grows in a different way from an older oak, irrespective of the climate, the widths are first standardized before any matching between them is attempted. These standard widths are known as ring-width indices and were first used in dendrochronology by Baillie and Pilcher (1973). The exact form

they take is explained in this paper and in the appendix of Laxton and Litton (1988) and is illustrated in the graphs in Figure A7. Here ring-widths are plotted vertically, one for each year of growth. In the upper sequence of (a), the generally large early growth after 1810 is very apparent as is the smaller later growth from about 1900 onwards when the tree is maturing. A similar phenomenon can be observed in the lower sequence of (a) starting in 1835. In both the widths are also changing rapidly from year to year. The peaks are the wide rings and the troughs are the narrow rings corresponding to good and poor growing seasons, respectively. The two corresponding sequence of Baillie-Pilcher indices are plotted in (b) where the differences in the immature and mature growths have been removed and only the rapidly changing peaks and troughs remain, that are associated with the common climatic signal. This makes cross-matching easier.

t-value/offset Matrix

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

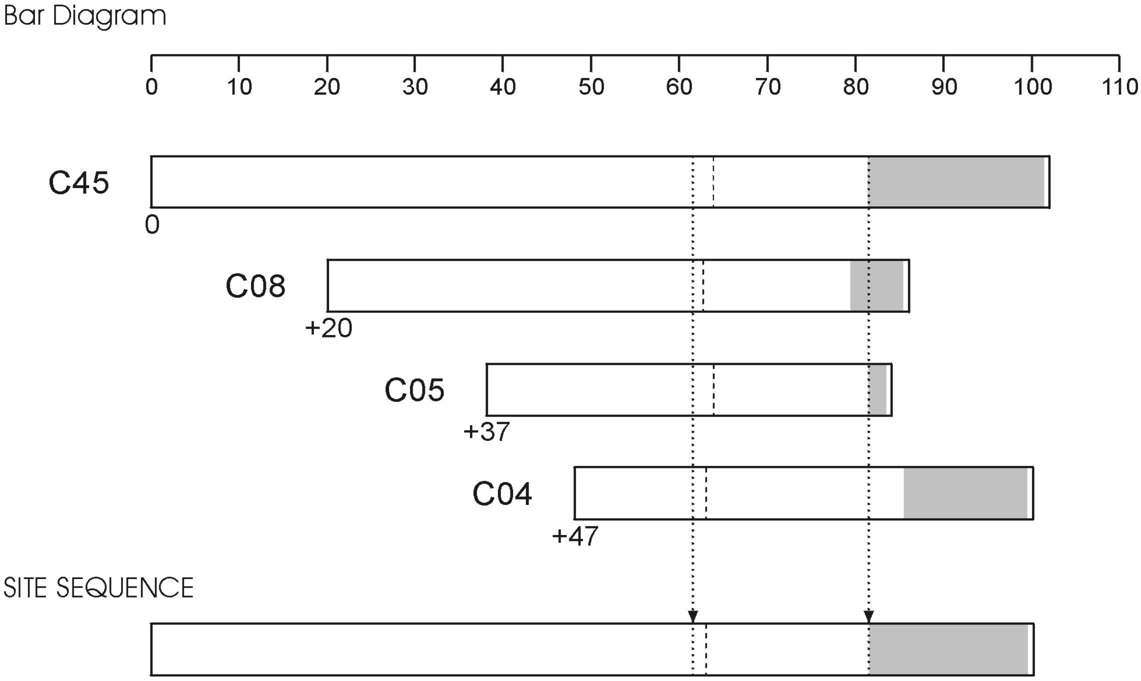


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

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

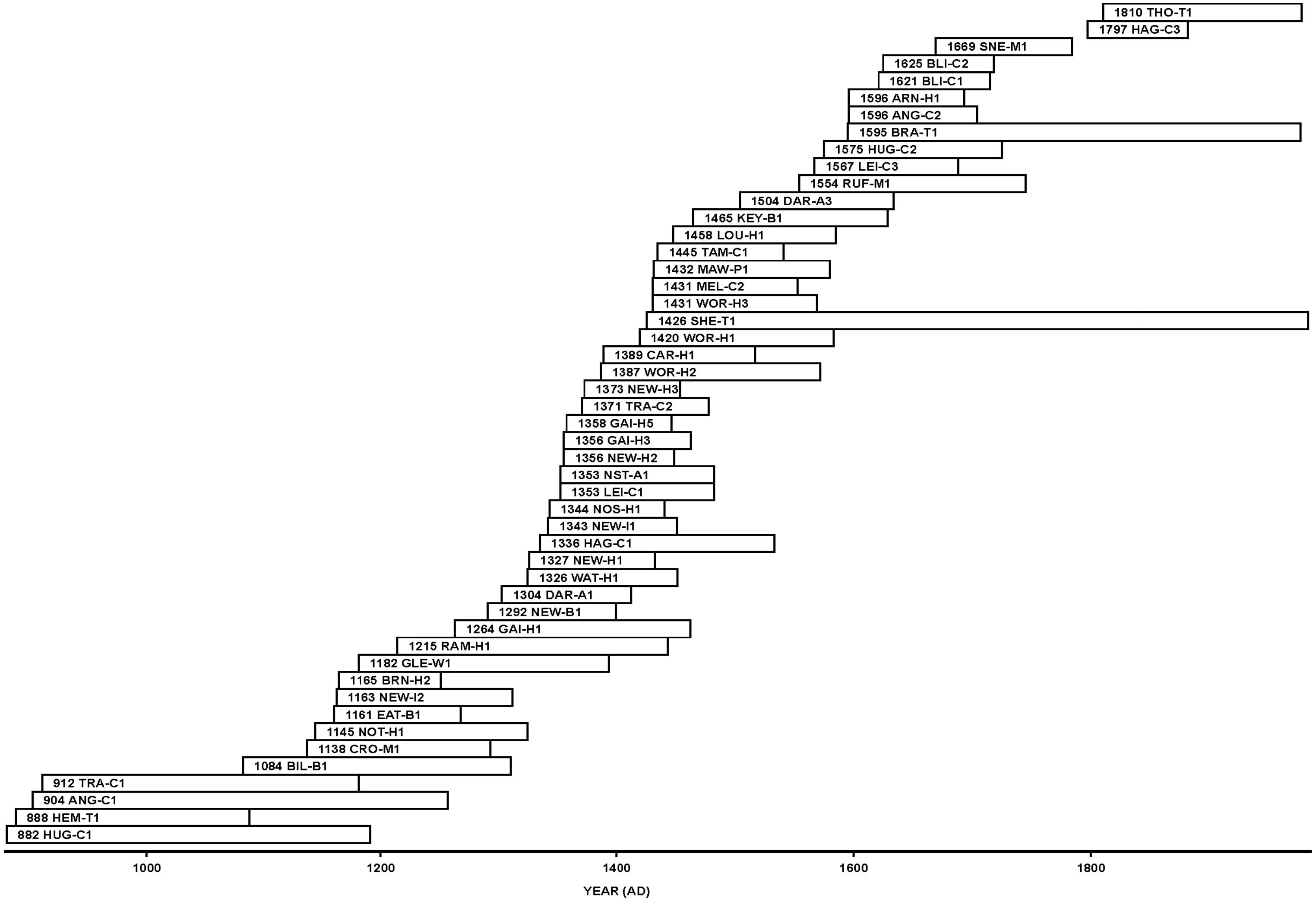
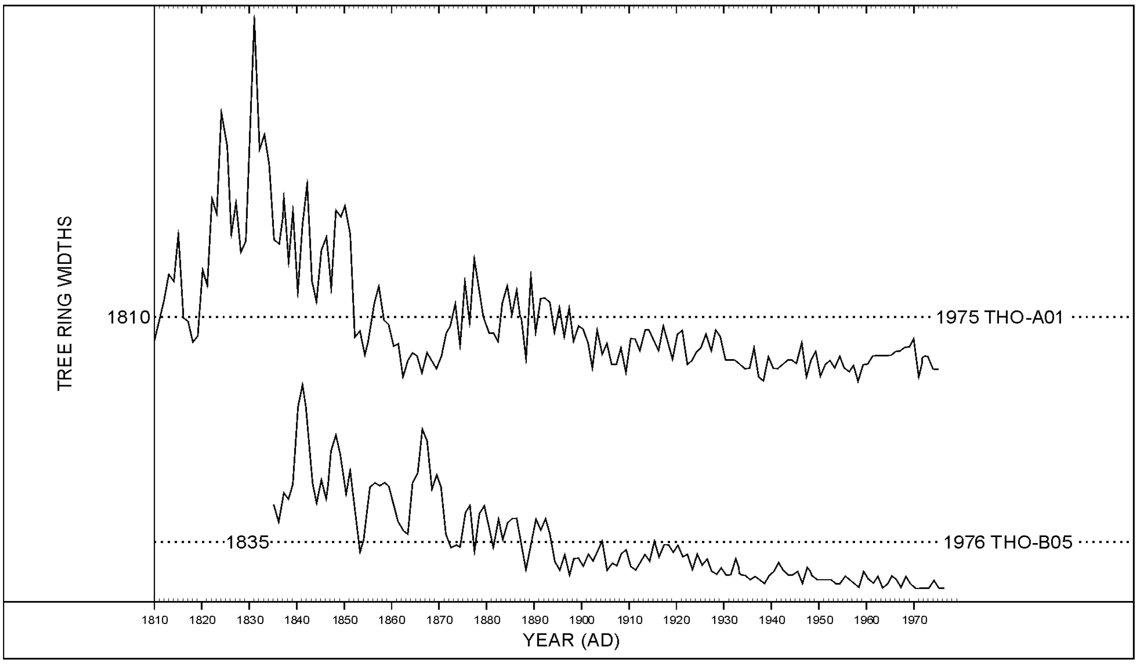


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

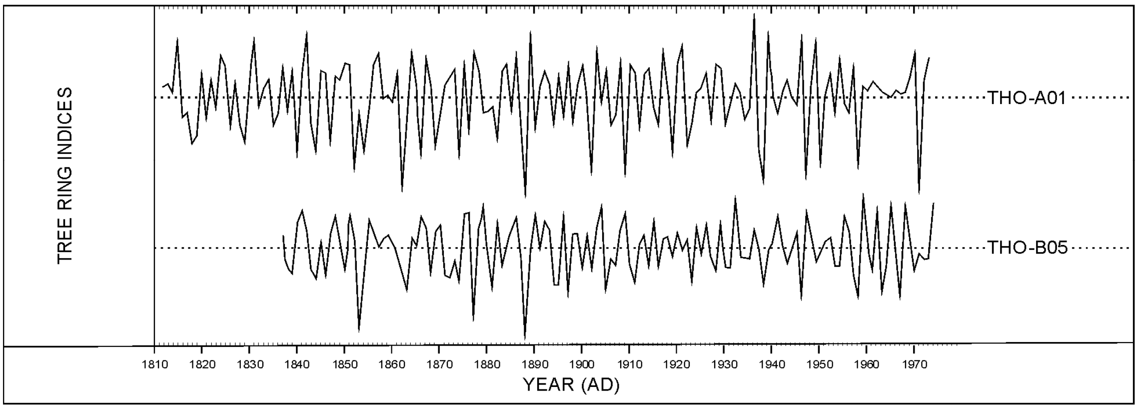


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

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

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

The growth trends have been removed completely.

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

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**

Howard, R E, Laxton, R R, Litton, C D, and Simpson, W G, 1992 List 44 no 17 - Nottingham University Tree-Ring Dating Laboratory: tree-ring dates for buildings in the East Midlands, *Vernacular Architect*, **23**, 51–6.

Laxton, 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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