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SCOTT'S COTTAGE, BATHLEY LANE, NORWELL, NOTTINGHAMSHIRE
TREE-RING ANALYSIS OF TIMBERS

SCIENTIFIC DATING REPORT

Matt Hurford, Robert Howard and Cathy Tyers

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SUMMARY

Dendrochronological analysis was undertaken on eight out of nine samples taken from Scott's Cottage, Norwell. This resulted in the dating of three individual samples, NRW-G06, G08, and G09. Sample NRW-G06 has an overall length of 151 rings, which can be dated as spanning the years AD 1444–1594; NRW-G08 has an overall length of 67 rings, which can be dated as spanning the years AD 1331–97; and NRW-G09 has an overall length of 55 rings, which can be dated as spanning the years AD 1355–1409. Interpretation of the sapwood and the heartwood/sapwood boundaries on the dated samples indicates that the truss 3 tiebeam is derived from a timber with an estimated felling date range of AD 1609–34 and the south brace from the truss 3 east wall post to the wall plate is derived from a timber with an estimated felling date range of AD 1412–37. The truss 2 west wall post was probably felled after AD 1424. This indicates the presence of at least two separate felling periods within this clearly disparate group of timbers. Five measured samples remain ungrouped and undated.

CONTRIBUTORS

Matt Hurford, Robert Howard, and Cathy Tyers

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ARCHIVE LOCATION

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INTRODUCTION

Scott's Cottage, a grade II listed building, lies to the east of Bathley Lane, near its junction with Main Street, in Norwell (SK 76989 61583, Figs 1–2). The following information is summarised from the listed building description (http://lbonline.english-heritage.org.uk) and Jones (pers comm). It consists of a two-bay timber-framed range, orientated very broadly from north to south with the west elevation lying parallel with Bathley Lane, with a continuous rear outshut and further extension giving it an L-shape ground plan. It is clad in brick and has a pantile roof. It is attributed to the seventeenth century in the listing, though it is now believed to have earlier origins as an open-hall house, with a floor being inserted at a later date. Graffiti, the earliest identifiable of which dates to AD 1715, although other markings could date to the seventeenth century, are present on the east wall post of central extant truss. Internally sections of the three extant trusses are visible, together with braces, stud partitions, and some elements of the original roof structure; these include wall posts, tiebeams and braces from the wall post to the tiebeam, suggesting it may originally have been a principal rafter roof. Empty mortices present on the outer face of the west wall post of the south gable wall (the east wall post is obscured by the addition of a porch) suggest that the building originally extended to the south, probably by another bay.

The tree-ring dating, funded by English Heritage as part of a dendrochronological training programme for the first author, forms part of a wider project being undertaken by Norwell Parish Heritage Group. This wider project is funded with a Heritage Lottery Fund grant awarded to Norwell Parish Heritage Group in AD 2006 to facilitate the production of a Village Trail, a Children's Trail, and a number of booklets, one of which is devoted to the timber-framed buildings of the village (Jones 2009). The dendrochronological analysis of the timbers is intended to provide independent dating evidence to aid the understanding of the timber-framed buildings in Norwell and their historic development. Historical analysis on the crafts and trades within the village is providing a social dimension for the usage of a number of buildings, at least from the nineteenth century onwards. Tracing their earlier history is problematic, as they were almost entirely in the hands of Southwell Minster from the eleventh century to the AD 1950s and the surviving records relating to ownership and occupancy are often unhelpful for the location and identification of current buildings. It is hoped that evidence derived from the tree-ring dating project will assist in the identification of occupation, usage, and ownership, which at present is limited to the late nineteenth century onwards.

SAMPLING

A total of nine samples was obtained, each being given the code NRW-G (for Norwell, site 'G') and numbered 01–09. The positions of these samples are marked on the drawings provided (Figs 4–7). The trusses are numbered from 2 to 4 from south to north based on the evidence that the structure originally extended further to the south. Details of the samples are given in Table 1.

ANALYSIS, INTERPRETATION, AND DISCUSSION

Each of the nine samples obtained was prepared by sanding and polishing. It was seen at this point that one sample, NRW-G07, had insufficient rings for reliable dating and so it was rejected from this programme of analysis. The annual growth rings of the remaining eight samples were, however, measured, the data of these measurements being given at the end of this report.

The growth-ring widths of all eight measured samples were compared with each other by the Litton/Zainodin grouping procedure (see Appendix). None of the samples cross-matched with each other at sufficiently high *t*-values to allow the formation of any site chronologies, and so each sample was compared individually with a series of relevant reference chronologies for oak. This resulted in three individual samples being successfully dated (Tables 2–4 and Fig 8).

Sample NRW-G06, the truss 3 tiebeam, has been dated as spanning the years AD 1444–1594. Its heartwood/sapwood boundary is present. Using the 95% confidence limits of 15–40 sapwood rings appropriate for mature oaks in this part of England, an estimated felling date of AD 1609–34 is obtained. Sample NRW-G08, the south brace from the truss 3 east wall post to the wall plate in bay 2, has been dated as spanning the years AD 1331–97. It also retains its heartwood/sapwood boundary, hence an estimated felling date range of AD 1412–37 is obtained. Sample NRW-G09, the truss 2 west wall post, has been dated as spanning the years AD 1355–1409. Its heartwood/sapwood boundary is not present and it is thus not possible to calculate its likely felling date range, but it was probably felled after AD 1424.

These results indicate that the tiebeam and brace, both associated with truss 3, represent two separate felling periods in the order of two centuries apart. The truss 2 west wall post is clearly broadly coeval with the truss 3 brace but, bearing in mind the lack of conclusive cross-matching between these two sequences, it could equally represent a third different felling period. This information, combined with the lack of dating evidence from the remaining timber elements, is clearly inconclusive as to the initial construction and subsequent modifications or repairs of Scott's Cottage. However, it clearly does contain at least some timbers dating to the fifteenth century, which could imply that the building does have medieval origins, although on the basis of only two timbers this remains unproven. Further structural and documentary research may elucidate the dating evidence derived from the dendrochronological analysis.

Analysis has shown that the samples NRW-G06 and G09 are likely to have been derived from relatively local woodland (Tables 2 and 4), as the highest *t* values, and thus the greatest degree of similarity, is with reference chronologies from this region. In contrast, sample NRW-G08 (Table 3) matches better with chronologies from slightly further afield, which, though suggestive of the timber potentially originating from woodland a greater distance from Norwell than the other two samples, could simply be a reflection of it having a more general climatic signal.

BIBLIOGRAPHY

Arnold, A J, Howard, R E, and Litton, C D, 2003 *Tree-ring analysis of timbers from the nave roof, St Peter's Church, Claybrooke Parva, Leicestershire*, Centre for Archaeol Rep, 19/2003

Arnold, A J, Howard, R E, and Litton, C D 2006 *The Guildhall Complex and Pedagogue's House, Stratford upon Avon, Warwickshire: tree-ring analysis of timbers,* English Heritage Res Dep Rep Ser, 68/2006

Arnold, A J, Howard, R E, and Litton, C D, 2006 *Kingsbury Hall, Kingsbury, Warwickshire: tree-ring analysis of timbers,* English Heritage Res Dep Ser, 53/2006

Arnold, A J, Howard, R E, and Litton, C D, 2008 List 197 – Dendrochronology Dates from Nottingham Tree-Ring Dating Laboratory, *Vernacular Architect*, 39, 119-28

Arnold, A J, Howard, R E, Laxton, R R, and Litton, C D, 2002 *The urban development of Newark-on-Trent: a dendrochronological approach*, Centre for Archaeol Rep 95/2002

Groves, C, 1997 *Dendrochronological analysis of Ightfield Hall Farm Barn, Ightfield, Whitchurch, Shropshire,* Anc Mon Lab Rep, 91/97

Groves, C, and Hillam, J, 1990 Tree-ring dates from Sheffield University: List 36, *Vernacular Architect,* 21, 44

Groves, C, and Hillam, J, 1997 Tree-ring analysis and dating of timbers, in *A multi-period salt production site at Droitwich: Excavations at Upwich* (ed J D Hurst), CBA Res Rep, 107, 121–6

Howard, R E, Laxton, R R, Litton, C D, and Simpson, W G, 1987 List 20 – Nottingham University Tree-Ring Dating Laboratory results, *Vernacular Architect,* 18, 53–4

Howard, R E, Laxton, R R, Litton, C D, and Simpson, W G, 1994 List 57 – Nottingham University Tree-Ring Dating Laboratory: results, *Vernacular Architect*, 25, 36–40

Hurford, M, Howard, R E, and Tyers, C, 2010a *Auld Cottage, Main Street, Norwell, Nottinghamshire: tree-ring analysis of timbers,* English Heritage Res Dep Rep Ser, 43/2010

Hurford, M, Howard, R E, and Tyers, C, 2010b *Old House, Main Street, Norwell, Nottinghamshire: tree-ring analysis of timbers,* English Heritage Res Dep Rep Ser, 52/2010

Hurford, M, Howard, R E, and Tyers, C, 2010c *Ivy Cottage, Main Street, Norwell, Nottinghamshire: tree-ring analysis of timbers,* English Heritage Res Dep Rep Ser, 53/2010

Jones, M, 2009 *Norwell Heritage Booklet 1 - Norwell Buildings*, Nottingham

Laxton, R R, and Litton, C D, 1988 *An East Midlands master tree-ring chronology and its use for dating vernacular buildings,* University of Nottingham, Dept of Classical and Archaeol Studies, Monograph Series, III

Laxton, R R, Litton, C D, and Simpson, W G, 1984 List 12 Nottingham University Tree-Ring Dating Laboratory: tree-ring dates for buildings in Eastern and Midland England, *Vernacular Architect*, 15, 65–8

Miles, D, 1994 *The tree-ring dating of the Priest's House Museum, 23–27 High Street, Wimborne Minster, Dorset*, Anc Mon Lab Rep, 39/94

Miles, D, 2001 *Tree-ring dating of the Galleried Building and 'Dairy', 40 Broad Street, Leominster, Herefordshire*, Centre for Archaeol Rep, 38/2001

Tyers, I, 1997 *Tree-ring analysis of timbers from Sinai Park, Staffordshire*, Anc Mon Lab Rep, 80/97

Tyers, I, 1998 *Tree-ring analysis of oak timbers from St Nicholas' Church, Warndon, Worcestershire*, Anc Mon Lab Rep, 34/98

Tyers, I, 2002 *Tree-ring analysis of timbers from Chethams Library and School, Long Millgate, Manchester*, Centre for Archaeol Rep, 5/2002

Tyers, I, 2003 *Tree-ring analysis of oak timbers from a building on the Lea Road Foundry Site, Church Street, Dronfield, Derbyshire*, Centre for Archaeol Rep, 80/2003

TABLES

Table 1: Details of tree-ring samples from Scott's Cottage, Bathley Lane, Norwell, Nottinghamshire

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
NRW-G01	Truss 4, tiebeam	98	13c	----	----	----
NRW-G02	Truss 4, west wall post	115	no h/s	----	----	----
NRW-G03	Bay 3, east wall plate	63	h/s	----	----	----
NRW-G04	Bay 3, east common rafter 5	67	13	----	----	----
NRW-G05	Bay 3, west common rafter 5	68	7	----	----	----
NRW-G06	Truss 3, tiebeam	151	h/s	AD 1444	AD 1594	AD 1594
NRW-G07	Truss 3, east wall post	nm	--	----	----	---
NRW-G08	Bay 2, south brace from truss 3 east wall post to wall plate	67	h/s	AD 1331	AD 1397	AD 1397
NRW-G09	Truss 2, west wall post	55	no h/s	AD 1355	----	AD 1409

h/s = the heartwood/sapwood ring is the last ring on the sample
c=complete sapwood exists on the timber but part of the sapwood has been lost from the sample during coring

Table 2: Results of the cross-matching of site sequence NRW-G06 and relevant reference chronologies when the first-ring date is AD 1444 and the last-ring date is AD 1594

Reference chronology	*t*-value	Span of chronology	Reference
East Midlands regional master chronology	7.3	AD 882–1981	(Laxton and Litton 1988)
Wakelyn Old Hall, Hilton, Derbyshire	7.2	AD 1415–1573	(Arnold *et al* 2008)
Sinai Park, Staffordshire	7.1	AD 1227–1750	(Tyers 1997)
Mansfield Woodhouse Priory, Nottinghamshire	7.0	AD 1432–1579	(Howard *et al* 1987)
21 Church St, Mansfield, Nottinghamshire	6.6	AD 1439–1584	(Howard *et al* 1994)
5 Church St, Newark, Nottinghamshire	6.5	AD 1403–1655	(Arnold *et al* 2002)
Kent House, Ridgeway, Derbyshire	6.5	AD 1431–1646	(Groves and Hillam 1990)
Kingsbury Hall, Kingsbury, Warwickshire	6.4	AD 1391–1564	(Arnold *et al* 2006)

Table 3: Results of the cross-matching of site sequence NRW-G08 and relevant reference chronologies when the first-ring date is AD 1331 and the last-ring date is AD 1397.

Reference chronology	*t*-value	Span of chronology	Reference
Chethams Library, Manchester	6.3	AD 1185–1428	(Tyers 2002)
St Nicholas Church, Warndon, Worcestershire	6.2	AD 1348–1424	(Tyers 1998)
Priests House, Wimbourne Minster, Dorset	5.9	AD 1259–1634	(Miles 1994)
Upwich, Droitwich, Worcestershire	5.8	AD 946–1415	(Groves and Hillam 1997)
Ightfield Hall Barn, Shropshire	5.6	AD 1341–1566	(Groves 1997)
40 Broad Street, Leominster, Herefordshire	5.6	AD 1338–1499	(Miles 2001)
Guildhall Complex/Pedagogues House, Stratford upon Avon, Warwickshire	5.4	AD 1305–1403	(Arnold *et al* 2006)
St Peters Church, Claybrooke Parva, Leicestershire	5.2	AD 1271–1416	(Arnold *et al* 2003)

Table 4: Results of the cross-matching of site sequence NRW-G09 and relevant reference chronologies when the first-ring date is AD 1355 and the last-ring date is AD 1409

Reference chronology	*t*-value	Span of chronology	Reference
East Midlands regional master chronology	7.3	AD 882–1981	(Laxton and Litton 1988)
Newstead Abbey, Newstead, Nottinghamshire	6.4	AD 1353–1495	(Laxton *et al* 1984)
Auld Cottage, Norwell, Nottinghamshire	6.0	AD 1335–1512	(Hurford *et al* 2010a)
Old House, Norwell, Nottinghamshire	5.9	AD 1340–1494	(Hurford *et al* 2010b)
Gainsborough Old Hall, Lincolnshire	5.9	AD 1356–1462	(Howard *et al* 1987)
Hagworthingham Church, Lincolnshire	5.6	AD 1336–1533	(Laxton *et al* 1984)
Lea Road Foundry site, Dronfield, Derbyshire	5.5	AD 1344–1526	(Tyers 2003)
Ivy Cottage, Norwell, Nottinghamshire	5.5	AD 1350–1463	(Hurford *et al* 2010c)

FIGURES

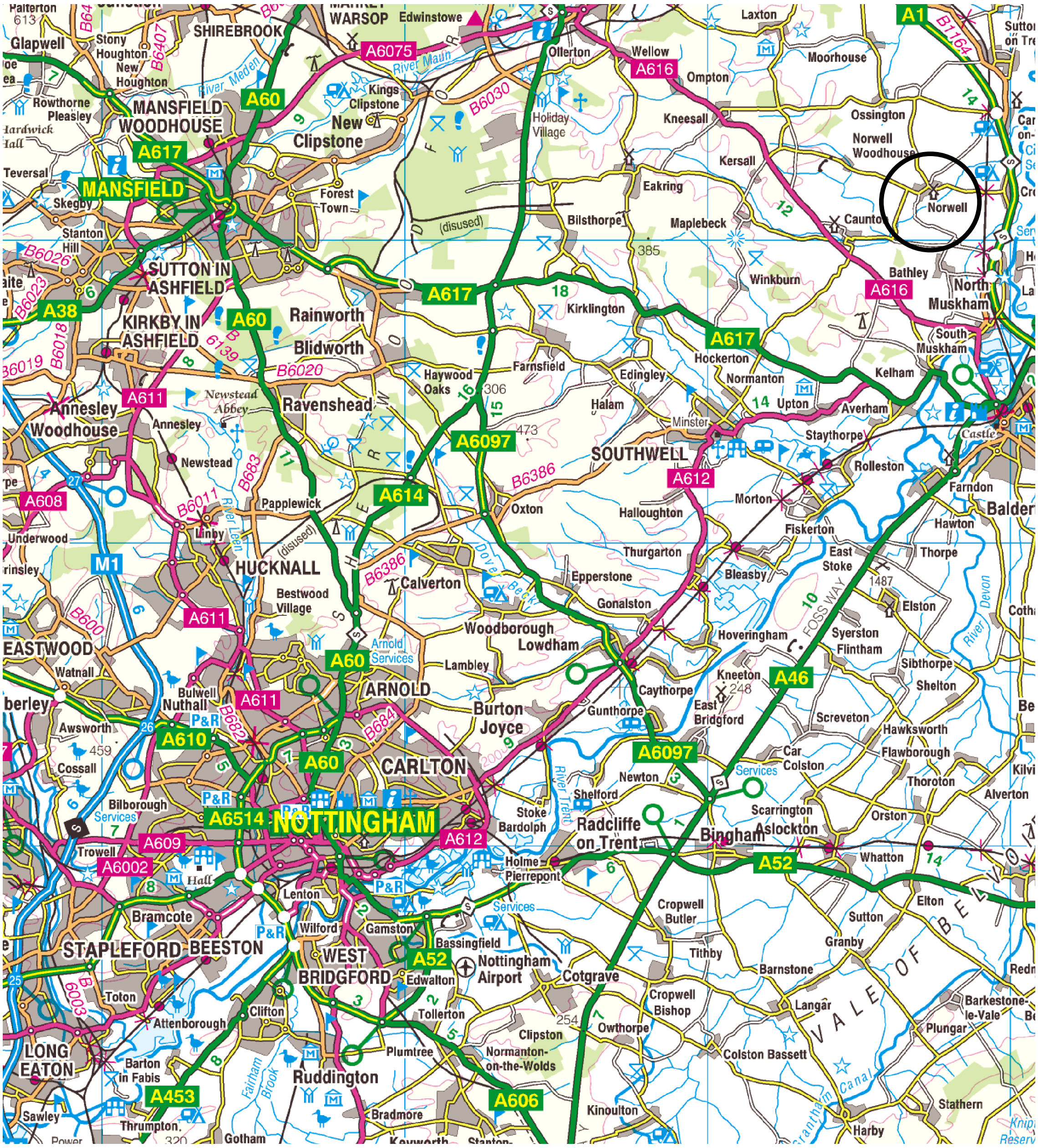


Figure 1: Map to show general location of Scott's Cottage, Norwell, Nottinghamshire

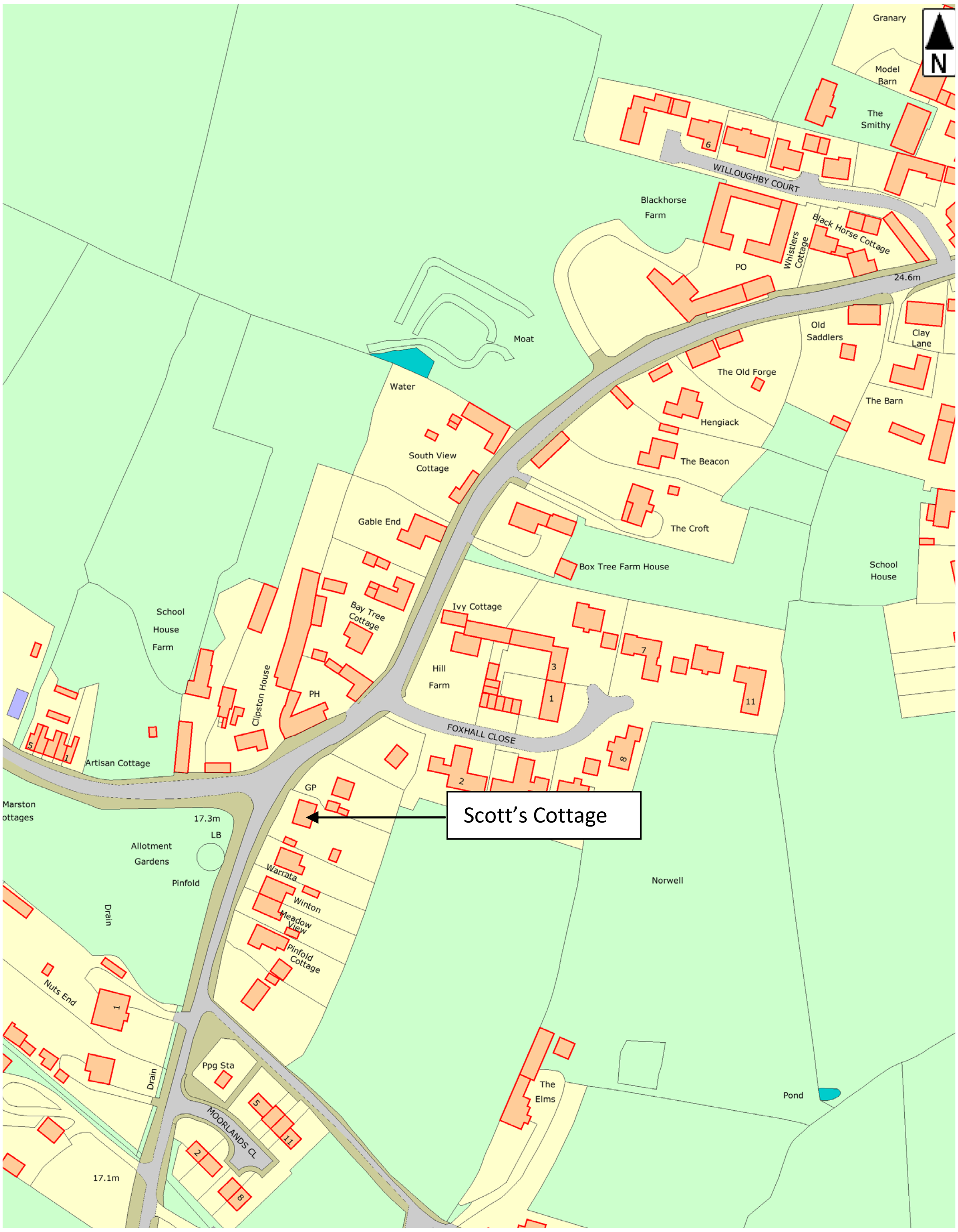


Figure 2: Map to show the location of Scott's Cottage, Norwell

Figure 3: The west elevation of the extant two-bay timber framed range of Scott's Cottage

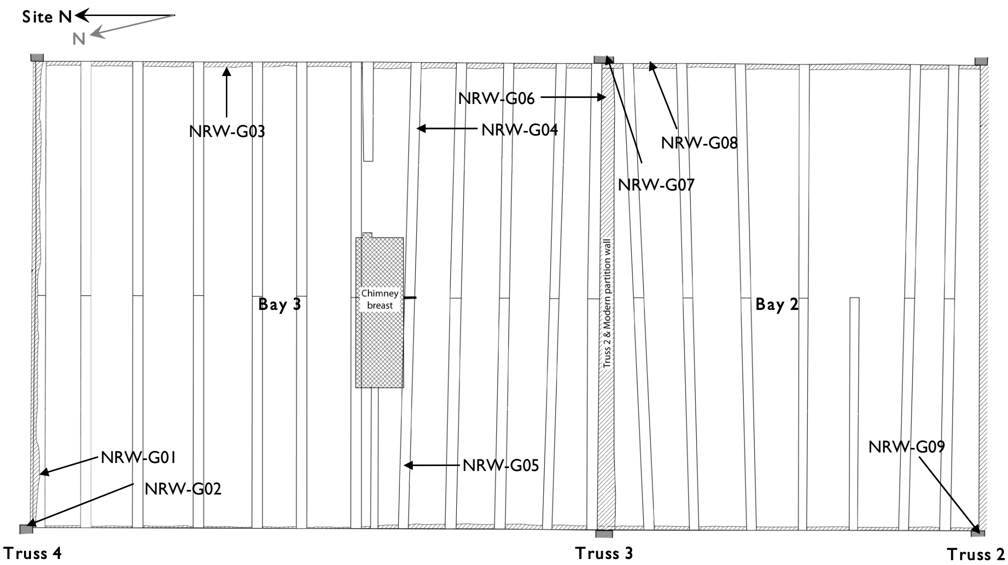


Figure 4: Plan showing the truss and bay numbering scheme and sample locations

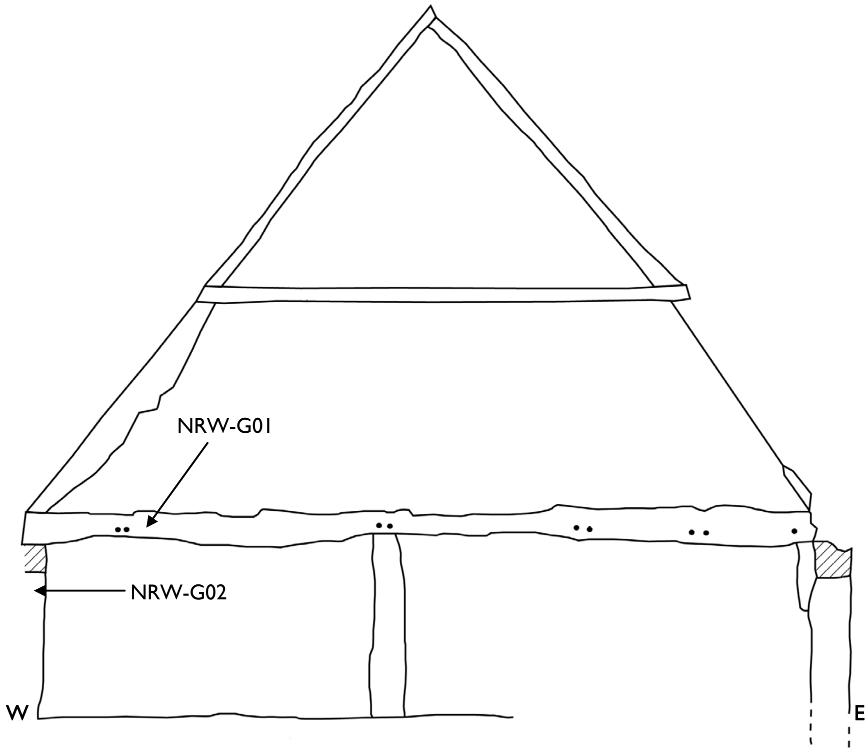


Figure 5: Truss 4 sample locations viewed looking north

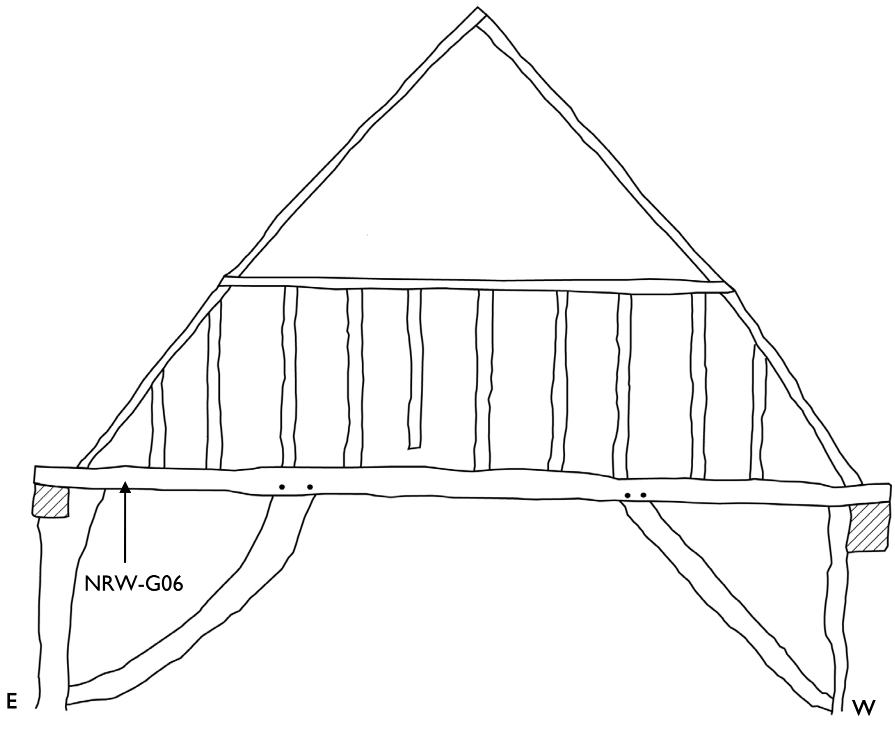


Figure 6: Truss 3 sample location viewed looking south

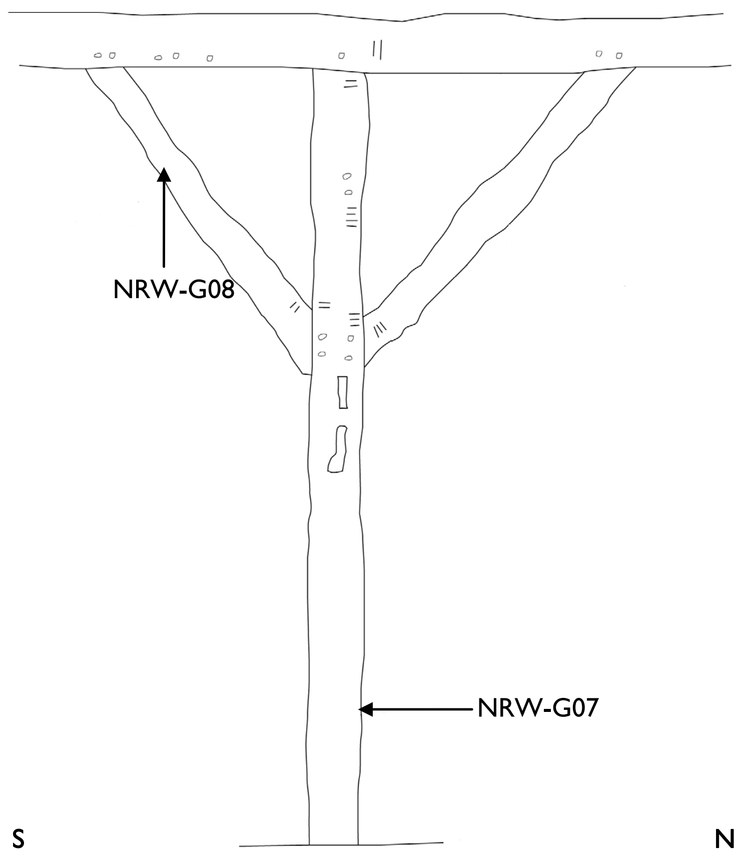


Figure 7: Truss 3 sample locations on the east wall post and south brace viewed looking west

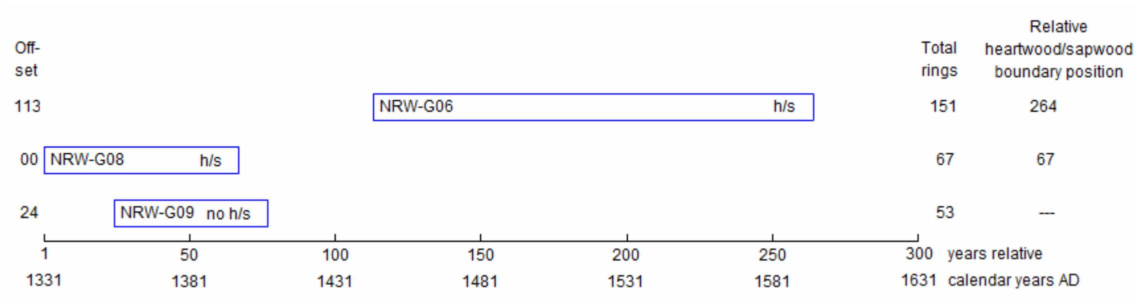


Figure 8: Bar diagram of the dated samples from Scott's Cottage

white bars = heartwood rings;
h/s = the last ring of the sample is at the heartwood/sapwood boundary

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

NRW-G01A 98
466 534 299 327 257 306 39 34 40 65 69 101 135 98 122 176 123 143 156 194
219 128 97 182 123 85 143 175 127 148 100 131 81 93 73 109 106 125 230 185
142 116 73 143 136 147 159 132 100 72 135 228 340 355 202 236 161 70 80 82
141 168 188 150 178 208 135 214 107 173 142 134 312 196 472 249 315 362 408 394
377 345 353 347 364 395 361 539 248 361 172 145 78 116 84 90 113 148
NRW-G01B 98
463 519 339 341 275 287 44 36 40 52 74 96 137 87 131 184 120 139 149 196
406 205 118 157 122 82 121 125 101 120 56 90 63 68 66 102 99 112 205 190
124 98 67 125 136 111 131 123 98 79 146 204 427 324 200 252 158 69 76 73
130 163 214 154 202 211 132 170 111 169 179 131 336 246 547 306 362 377 407 434
378 371 309 348 365 394 334 548 247 346 202 139 92 91 106 97 111 160
NRW-G02A 115
456 439 305 429 347 205 489 493 404 354 318 439 404 446 634 416 268 304 263 280
303 228 208 145 339 273 425 288 329 258 351 287 172 125 116 83 99 92 69 96
98 135 126 154 133 129 101 170 111 114 119 105 216 117 109 83 150 144 122 72
63 108 110 82 77 90 119 85 98 87 80 76 73 96 91 96 78 70 82 75
65 89 76 52 78 42 81 43 88 80 99 84 88 70 81 71 102 78 109 93
99 135 144 142 79 100 91 98 93 97 95 119 134 140 149
NRW-G02B 85
309 268 244 172 189 76 109 98 67 89 89 133 150 150 127 137 87 165 113 112
101 108 203 123 98 97 147 132 122 71 63 105 108 82 80 90 125 92 99 80
70 64 58 85 82 70 74 77 54 69 54 74 70 67 66 43 70 62 74 80
87 77 82 92 72 80 106 71 120 91 113 147 155 143 90 98 86 116 99 87
109 113 128 128 149
NRW-G03A 63
192 398 329 152 201 210 266 142 191 283 191 153 154 121 112 159 298 231 163 140
110 152 195 187 210 218 219 301 262 256 295 540 475 314 157 134 137 92 173 176
291 254 272 301 232 250 154 262 311 309 465 325 713 368 468 438 528 373 407 451
381 299 364
NRW-G03B 63
257 396 313 166 219 222 282 189 182 283 192 153 148 124 107 164 291 283 149 150
103 153 195 191 212 253 211 275 280 255 295 543 465 320 154 161 125 103 180 194
260 243 259 293 241 250 142 259 304 330 483 300 718 373 487 462 454 364 407 409
382 318 364
NRW-G04A 67
51 61 60 98 71 45 54 64 231 423 412 337 331 393 229 233 318 353 419 412
204 258 275 311 128 154 87 124 166 423 197 239 165 124 105 174 202 140 180 139
102 127 79 103 147 155 105 103 131 154 202 142 111 189 116 140 132 119 117 107
109 146 120 176 137 86 92
NRW-G04B 67
76 62 60 98 67 45 53 62 234 416 420 335 325 399 219 260 356 358 434 421
205 262 281 317 129 154 96 113 169 428 222 253 156 126 109 168 196 141 183 140
107 119 76 102 157 157 120 112 144 151 198 142 117 189 121 141 137 125 112 115
118 152 121 175 127 94 170
NRW-G05A 68
95 136 90 77 103 112 236 215 165 111 123 74 64 115 103 63 68 82 191 334
265 163 207 155 105 154 211 184 179 169 91 108 156 135 71 106 81 91 108 350
267 237 182 93 79 148 207 130 127 118 80 116 74 93 109 109 91 107 118 119
132 180 155 103 112 98 127 103

NRW-G05B 68
126 140 92 77 108 114 267 196 170 93 117 78 70 114 104 66 63 84 174 316
283 159 217 161 93 163 200 187 179 153 100 110 150 134 80 97 79 94 108 363
278 246 180 91 83 149 203 134 127 113 80 114 70 85 120 117 90 110 123 123
142 177 155 127 92 102 112 126
NRW-G06A 151
365 278 318 318 356 311 219 384 168 186 265 282 351 255 230 196 273 205 290 214
172 211 204 198 306 347 260 243 234 213 221 273 179 194 222 315 273 312 228 286
236 243 182 272 217 185 148 100 93 129 123 149 150 103 91 95 105 86 67 73
98 98 96 69 72 78 96 73 103 99 100 95 130 107 55 80 94 86 98 47
74 40 62 80 78 86 71 113 93 127 172 150 162 150 238 179 175 201 147 185
190 157 160 113 145 176 102 81 66 78 69 125 69 63 104 156 198 133 176 99
159 118 114 98 122 157 216 173 201 183 261 225 125 82 67 120 124 119 108 112
107 109 131 108 118 123 155 138 133 138 178
NRW-G06B 151
313 274 316 329 361 312 240 331 170 183 273 265 350 284 261 242 273 213 287 218
173 214 207 204 372 483 339 301 269 245 258 323 213 208 262 364 294 369 239 304
282 245 191 300 263 197 172 114 95 136 137 148 164 133 82 122 142 112 78 91
111 143 106 84 67 82 128 90 151 144 119 118 129 121 66 111 89 113 121 56
59 44 55 85 70 82 77 147 123 163 194 196 181 206 301 235 203 239 165 205
185 163 151 102 158 161 93 92 38 66 53 110 67 63 88 148 232 138 168 113
146 103 116 103 122 157 223 169 176 200 278 212 129 90 70 116 121 109 100 133
93 117 128 109 127 121 145 145 130 143 184
NRW-G08A 67
112 202 273 277 230 157 148 169 213 124 132 131 116 106 410 236 294 432 373 156
187 116 168 358 251 244 219 233 201 114 108 180 230 192 127 119 123 113 116 89
70 82 103 84 68 76 67 71 75 79 80 71 68 63 72 78 76 62 71 58
55 49 49 62 61 55 107
NRW-G08B 67
119 210 260 281 243 155 142 176 221 131 127 125 120 111 402 231 302 430 369 163
190 115 171 351 252 239 232 225 206 122 100 185 228 186 124 127 114 123 113 88
71 79 101 85 69 76 68 78 76 79 77 73 63 64 80 76 63 74 75 55
55 55 48 59 69 56 82
NRW-G09A 55
188 432 296 288 447 254 191 367 322 289 165 192 224 172 313 346 200 239 271 274
125 136 239 277 293 204 101 81 66 68 61 91 120 91 75 67 64 69 67 80
73 77 70 77 72 88 111 97 95 101 134 116 98 114 167
NRW-G09B 55
195 426 262 279 444 248 196 398 368 288 183 187 232 166 307 348 196 240 291 263
121 160 230 287 290 215 94 91 89 64 77 101 117 80 74 75 54 69 61 89
66 74 66 81 65 91 107 102 91 114 124 118 100 117 183

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

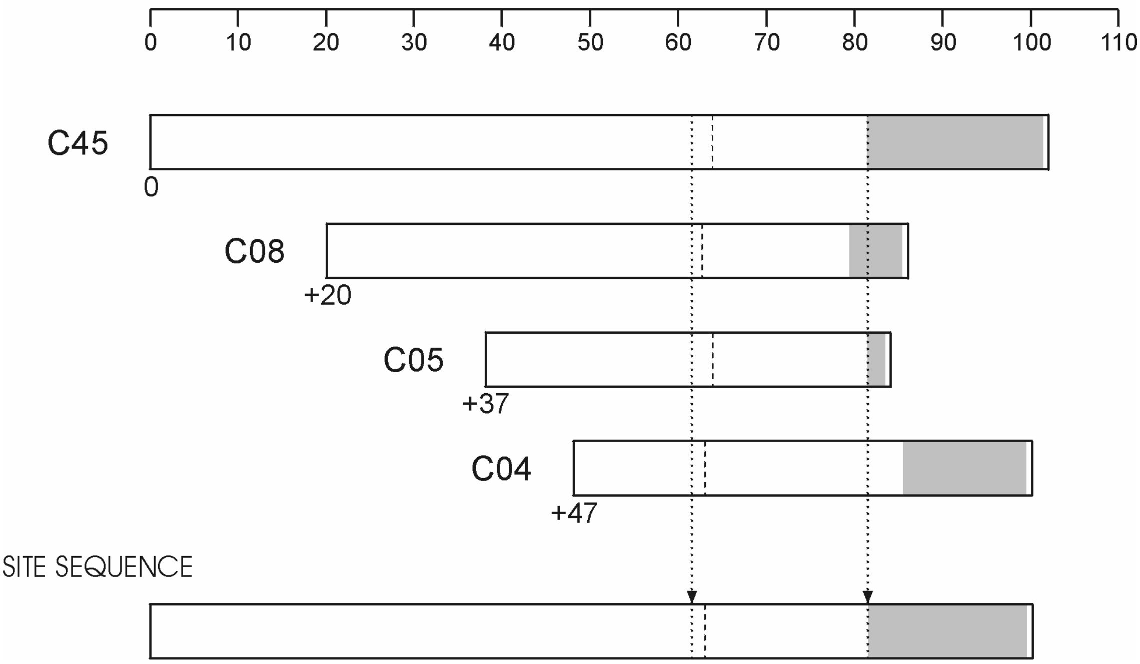


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

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

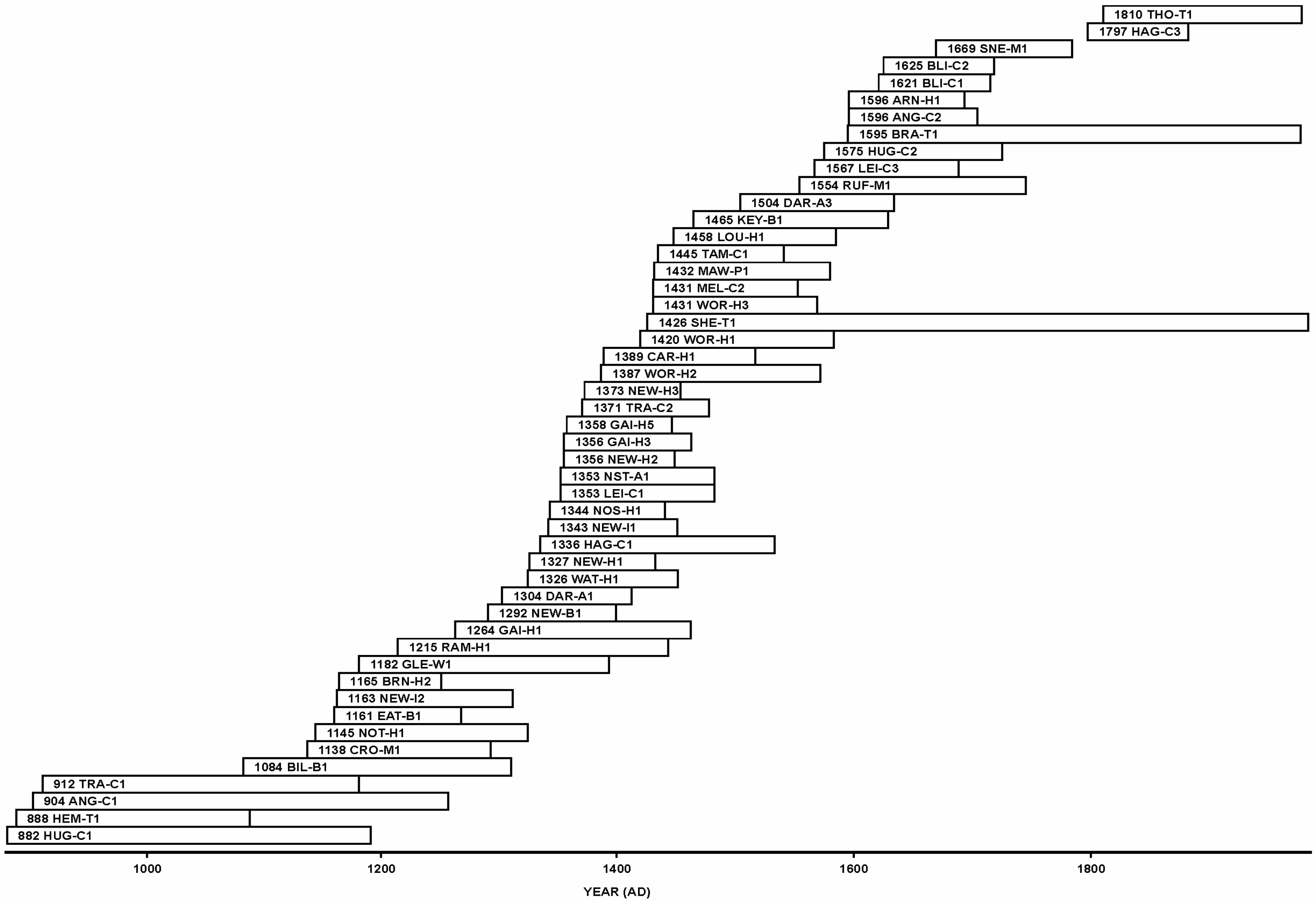
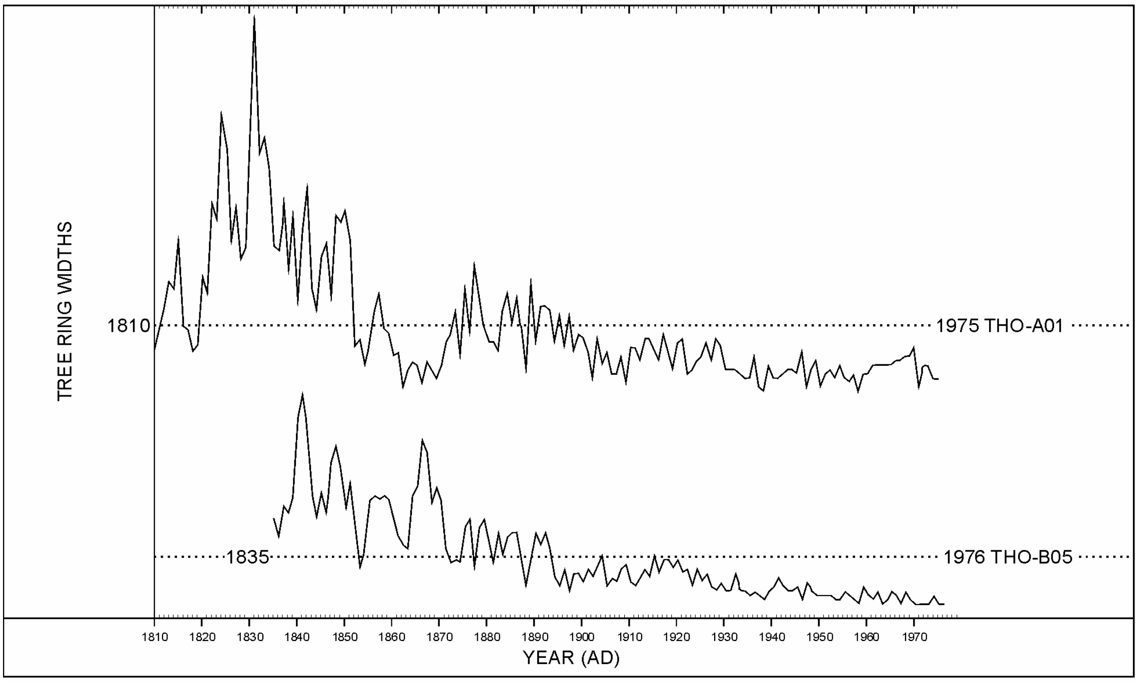


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

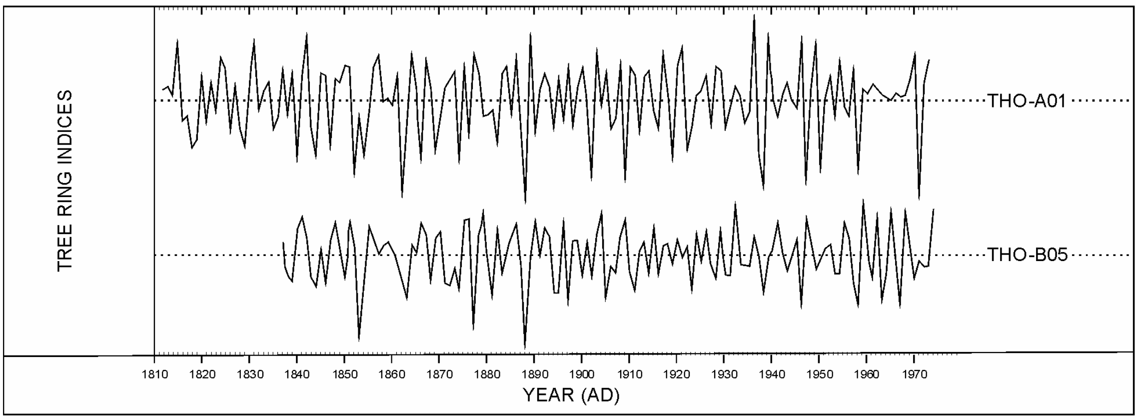


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

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