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WEST BARN, COMMON LANE, PARBOLD, LANCASHIRE
TREE-RING ANALYSIS OF TIMBERS

SCIENTIFIC DATING REPORT

Alison Arnold and Robert Howard

INTERVENTION
AND ANALYSIS

ENGLISH HERITAGE

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TREE-RING ANALYSIS OF TIMBERS

Alison Arnold and Robert Howard

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SUMMARY

Dendrochronological analysis of an extensive range of timbers in this barn has produced a single dated site chronology comprising 21 of the 23 samples measured. This site chronology has an overall length of 129 rings, these rings dated as spanning the years AD 1431–1559. Interpretation of the sapwood present on the samples indicates that all the timbers represented, from the main body of the barn, the north aisle, and the eastern floor frame, were cut as part of a single phase of felling in the late AD1550s.
Two measured samples remain ungrouped and undated.

CONTRIBUTORS

Alison Arnold and Robert Howard

ACKNOWLEDGEMENTS

The Nottingham Tree-ring Dating Laboratory would like to thank the owner of the barn, Mr Martin Ainscoughs, for his support and cooperation with this programme of analysis. We would also like to thank Dylan Jones, consulting architect of A2 Architects, Liverpool, for assisting in arranging access to the site, and for providing plans and other drawings used in this report. Finally we would like to thank Dr Peter Marshall (English Heritage Scientific Dating Team) and Cathy Tyers (Sheffield University Dendrochronology Laboratory) for commissioning this programme of tree-ring dating, for advice, and assistance throughout the production of this report.

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INTRODUCTION

The barn at Parbold under consideration in this report, commonly referred to as the 'west' barn, stands approximately 30 metres south of Fairhurst Hall, off Common Lane, about half a kilometre north of Parbold village (SD 4903 1163, Figs 1–3). This grade II* listed barn, which is described as being of early-eighteenth century date (http://list.english-heritage.org.uk/), is built of sandstone rubble with a stone slate roof. The south wall is pierced by a cart entrance with segmental arch and hood. To the right of this entrance there are a set of external stone steps to a first-floor doorway. The east gable has a doorway with a segmental head and a segmental hood with scrolled ends and central finial. To each side are keyed circular windows. Above is a similar window, while a fourth window lights a rear outshut which appears to be original.

Internally, although the barn is now only aisled on its north side, it is believed that there may have been an aisle to its south side as well, though there are now no timbers to the south wall. The building is divided into six bays (Fig 4) by the east and west gable walls and five principal rafter and tiebeam trusses with high collars set near the apex. There are straight queen struts from the tiebeams to the principal rafters, and slightly curved braces from the north aisle posts to the tiebeams. The trusses support two rows of purlins to each pitch of the roof, there being straight wind braces from the principal rafters to the purlins (Fig 5a).

Slightly curved braces also rise from the north aisle and intermediate posts to the north aisle plate, and there are aisle ties between the aisle posts and the north wall plate. Short, straight queen struts rise from these ties to the principal aisle rafters, these aisle trusses carrying a single row of purlins to the aisle roof (Fig 5b).

At both the east and west ends of the barn there are first floor frames.

SAMPLING

Sampling and analysis by dendrochronology of the timbers within the barn at Parbold were requested by Cathy Tuck, Historic Building Inspector based at English Heritage's North West Regional Office. This analysis was expected to form part of a programme of archaeological recording to inform listed building consent prior to the barn possibly being converted for residential accommodation. It was hoped that tree-ring analysis would provide dating evidence for the original construction of the barn and help to determine the extent of survival of any historic fabric. In particular it was hoped that tree-ring analysis would establish whether the aisle timbers and the floor frames at each end were contemporary with the main body of the barn, as the structural evidence tends to suggest, or are later additions of different dates as has occasionally been argued.

Thus, from the oak timbers available a total of 24 samples was obtained by coring, an attempt being made to obtain sufficient numbers of cores from each area of the building to ensure the production of reliable dating evidence should each part be of a different date. Each sample was given the code PBD-A (for Parbold, site 'A') and numbered 01–24. From the main body of the barn a total of 12 samples, PBD-A01–12, was obtained, with a further six samples, PBD-A13–18, and PBD-A19–24, being obtained from the aisle and east floor frame respectively. No samples were obtained from the small number of what appeared to be relatively modern, possibly early-twentieth century, softwood timbers of the west floor frame, many of these timbers, in any case, being wide-ringed and therefore unsuitable for tree-ring analysis.

The location of the sampled timbers was noted at the time of coring and marked on plans made by Dylan Jones of A2 Architects Ltd and provided by English Heritage. These are reproduced here as Figures 6a–f. Further details relating to the samples can be found in Table 1.

ANALYSIS

Each of the 24 samples obtained was prepared by sanding and polishing. It was seen at this time that one sample, PBD-A24, had less than the minimum of 54 rings here deemed necessary for reliable dating, and it was rejected from this programme of analysis. The annual growth-ring widths of the remaining 23 samples were, however, measured, the data of these measurements being given at the end of this report.

The data of the 23 measured samples were then compared with each other by the Litton/Zainodin grouping procedure (see Appendix), allowing a single group of 21 cross-matching samples to be formed at a minimum value of t=4.0, the 21 samples cross-matching as shown in the bar diagram Figure 7. The cross-matching samples of this group were combined at their indicated offset positions to form PBDASQ01, a site chronology with an overall length of 129 rings.

Site chronology PBDASQ01 was then compared to an extensive corpus of reference material for oak, this indicating a consistent and repeated match with a large number of these when the date of its first ring is AD 1431 and the date of its last measured ring is AD 1559. The evidence for this dating is given in Table 2.

Site chronology PBDASQ01 was also compared to the two remaining measured but ungrouped samples, PBD-A12 and A13, but there was no further satisfactory cross-matching. These two samples were then compared individually to the full corpus of reference data, but again there was no satisfactory cross-matching and both samples must, therefore, remain undated.

INTERPRETATION AND CONCLUSION

Analysis by dendrochronology of 23 measured samples from this building has produced a single site chronology comprising 21 samples, its 129 rings dated as spanning the years AD 1431–1559. As may be seen from Table 1 and Figure 7, one of these samples, PBD-A17, retains complete sapwood (the last ring produced by the tree from which the beam has been derived before it was cut down, this being indicated by upper case 'C' in Table 1 and the bar diagram). This last, complete, sapwood ring, and thus the felling of the tree represented, is dated to AD 1559.

A number of other dated samples, PBD-A02, A04, A07, A11, A14, A16, and A22, also come from timbers which have complete sapwood on them. In these cases, however, due to its decayed and fragile state, portions of the sapwood were lost from the cores in sampling (this being denoted by lower case 'c' in Table 1 and the bar diagram). In such instances it is possible, at the time of sampling, to estimate in millimetres the amount lost from the core. Following analysis of the core, it is then possible to make an estimate of the number of sapwood rings the lost portion of core might have had, based on the average ring width of the measured rings and the overall growth trends present. In respect of these samples from the barn analysed here, the lost rings would suggest that the timbers they represent were all felled in the late AD 1550s, and hence could represent either a single felling programme spanning a small number of years in the late AD 1550s or could represent a single felling in AD 1559.

There is, in addition, little reason to suspect that the remaining dated timbers, those which do not retain complete sapwood, or which have only the heartwood/sapwood boundary present, were not felled in the late AD 1550s as well. The relative position of the heartwood/sapwood boundary on these timbers varies by 22 years from relative position 90 (AD 1520), on sample PBD-A20, to relative position 112 (AD 1542) on sample PBD-A08. Such a variation is consistent with the timbers represented all being cut in a single episode of felling, and, importantly, is very similar to that on the timbers with complete sapwood.

The dendrochronological analysis therefore indicates that all the dated timbers appear coeval and were cut as part of a single programme of felling in the late AD1550s, possibly just in AD 1559. Thus a common construction date for the main barn, the north aisle, and the east floor frame is indicated. It will be noted that this is considerably earlier than the early-eighteenth century ascribed to it in the listing description.

Two samples, PBD-A12 and A13, remain ungrouped and undated, despite both of them having sufficient numbers of rings for reliable analysis. There appears to be nothing unusual about these samples, the rings being neither distorted or compressed, that might account for this lack of dating, and the reason for it is unknown. It is, however, a very common phenomenon in tree-ring analysis with various studies indicating that a 70-80% dating success rate for measured individual samples is normal.

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TABLES

Table 1: Details of tree-ring samples from the West Barn, Parbold

Sample number	Sample location	Total rings	Sapwood rings*	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
	Main barn					
PBD-A01	North aisle post, truss 1	90	h/s	1437	1526	1526
PBD-A02	North aisle post, truss 2	91	12c	1462	1540	1552
PBD-A03	Tiebeam, truss 2	80	h/s	1457	1536	1536
PBD-A04	North principal rafter, truss 2	94	25c	1458	1526	1551
PBD-A05	South principal rafter, truss 2	68	h/s	1458	1525	1525
PBD-A06	North aisle post, truss 3	98	h/s	1431	1528	1528
PBD-A07	Tiebeam, truss 3	96	13c	1450	1532	1545
PBD-A08	South principal rafter, truss 3	87	2	1458	1542	1544
PBD-A09	South lower purlin, truss 3–4	72	h/s	1460	1531	1531
PBD-A10	South principal rafter, truss 4	81	8	1458	1530	1538
PBD-A11	North principal rafter, truss 5	90	18c	1463	1534	1552
PBD-A12	South queen strut, truss 5	66	13c	------	------	------
	North aisle					
PBD-A13	Aisle tie, truss 2	62	10c	------	------	------
PBD-A14	Aisle tie, truss 3	70	13c	1482	1538	1551
PBD-A15	Aisle tie, truss 4	71	h/s	1468	1538	1538
PBD-A16	Aisle rafter, truss 4	76	14c	1476	1537	1551
PBD-A17	Aisle queen strut, truss 4	81	31C	1479	1528	1559
PBD-A18	Aisle rafter, truss 5	68	h/s	1458	1525	1525

Table 1: continued

Sample number	Sample location	Total rings	Sapwood rings*	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
	East floor					
PBD-A19	Main beam middle	72	h/s	1462	1533	1533
PBD-A20	Main beam west	68	2	1455	1520	1522
PBD-A21	West joist 4	54	h/s	1472	1525	1525
PBD-A22	East joist 5	92	24c	1465	1532	1556
PBD-A23	East joist 7	65	h/s	1458	1522	1522
PBD-A24	East joist 12	nm	---			

nm = sample not measured

c = complete sapwood is found on the timber, but all or part has been lost from the sample during 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 PBDASQ01 and relevant reference chronologies when the first-ring date is AD 1431 and the last-ring date is AD 1559

Reference chronology	Span of chronology	t-value	Reference
Speke Hall, Merseyside	AD 1387–1598	8.6	(Howard *et al* 1992)
Hall-I-Th-Wood, Bolton, Greater Manchester	AD 1467–1569	8.1	(Groves 1999)
Worden Old Hall, Chorley, Lancashire	AD 1415–1531	8.0	(Bridge 2003)
Manor House, Sutton in Ashfield, Notts	AD 1441–1656	7.6	(Howard *et al* 1996)
Nether Levens Hall, Cumbria	AD 1395–1541	7.5	(Howard *et al* 1991)
Sizergh Castle, near Kendal, Cumbria	AD 1380–1561	7.5	(Tyers 1999)
Ordsall Hall, Salford, Greater Manchester	AD 1368–1534	7.3	(Arnold *et al* 2004)
Stayley Hall, Stalybridge, Greater Manchester	AD 1387–1565	6.8	(Nayling 2000)

FIGURES

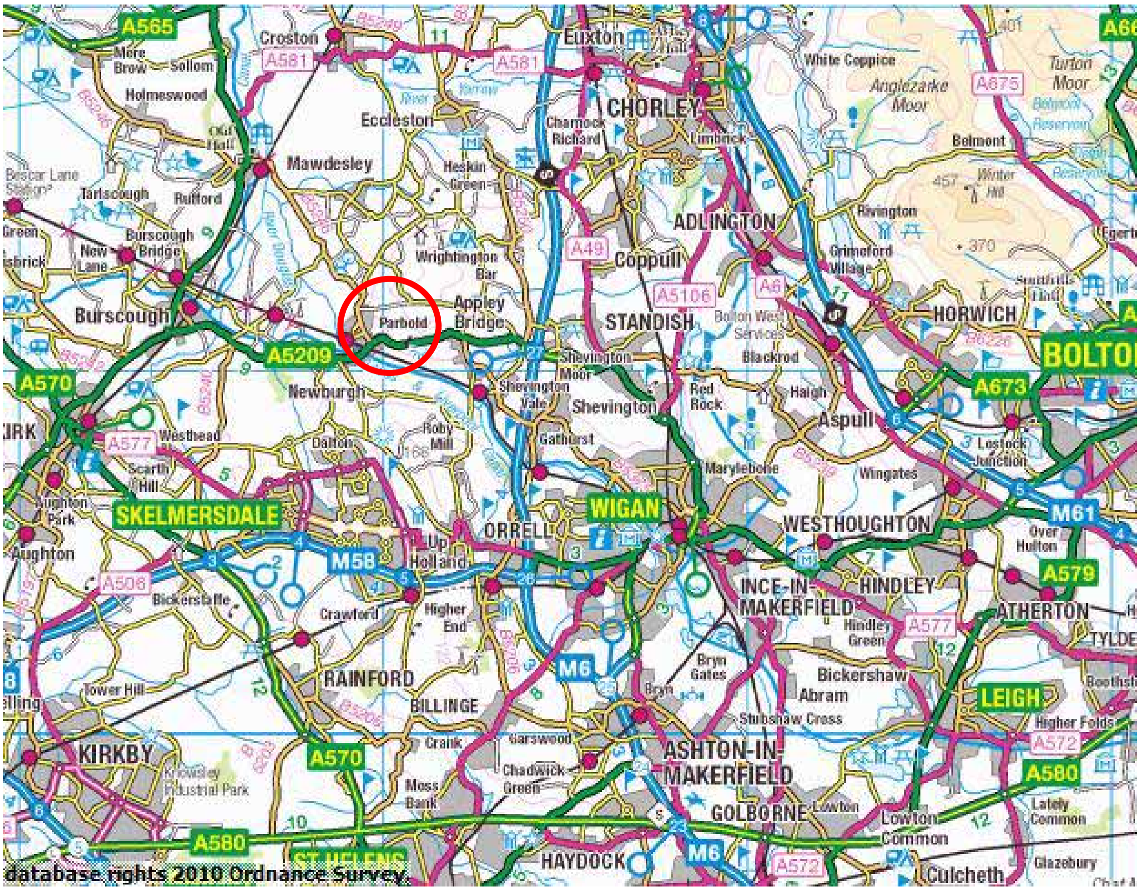


Figure 1: Map to show the general location of Parbold (based on the Ordnance Survey map with permission of the Controller of Her Majesty's Stationery Office, © Crown Copyright)

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

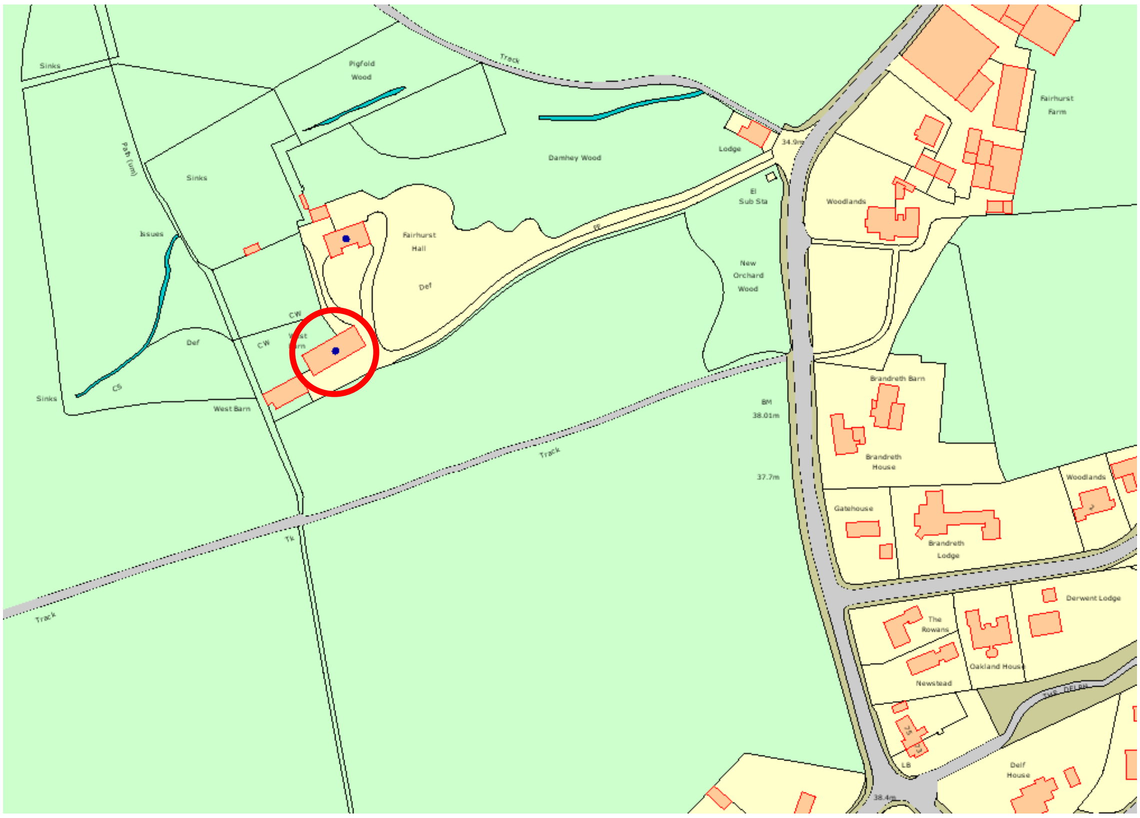


Figure 3: Map to show the location of the west barn (based on the Ordnance Survey map with permission of the Controller of Her Majesty's Stationery Office, ©Crown Copyright)

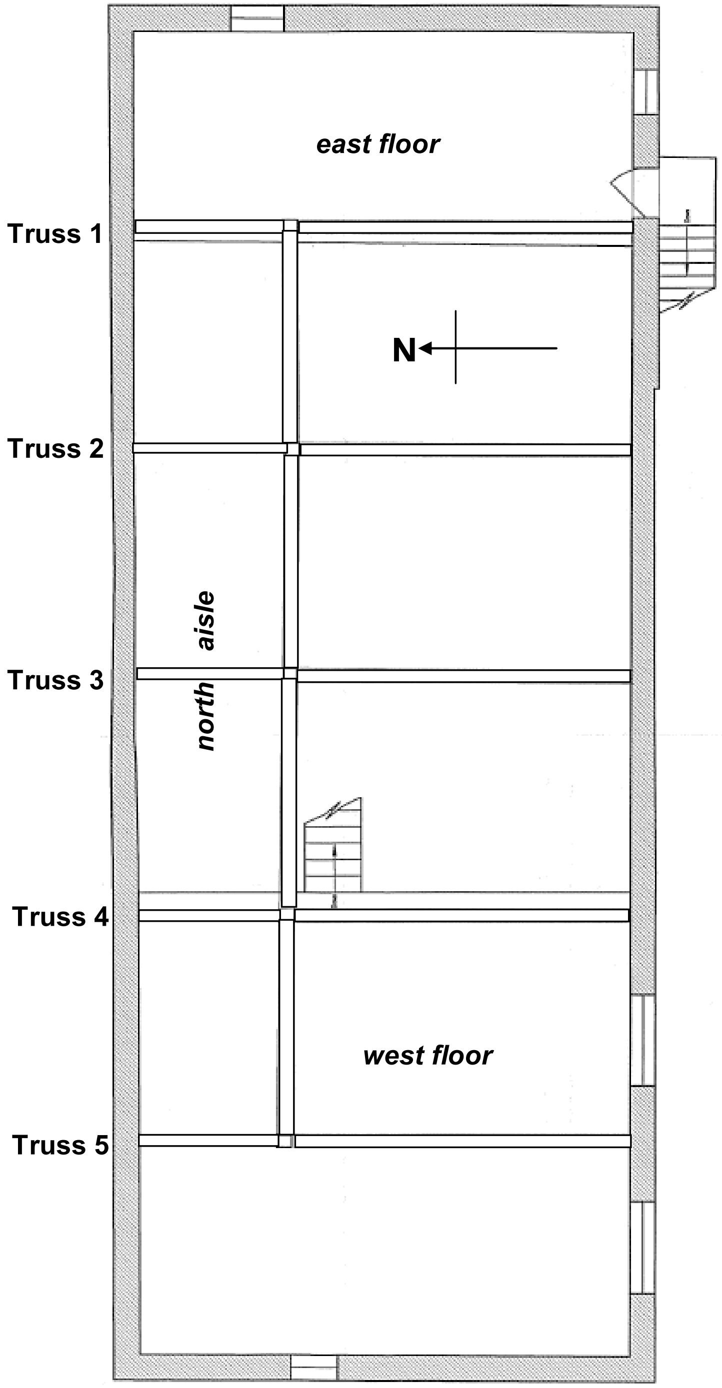


Figure 4: Plan of the barn (after Dylan Jones)

Figure 5a/b: Internal views of the barn

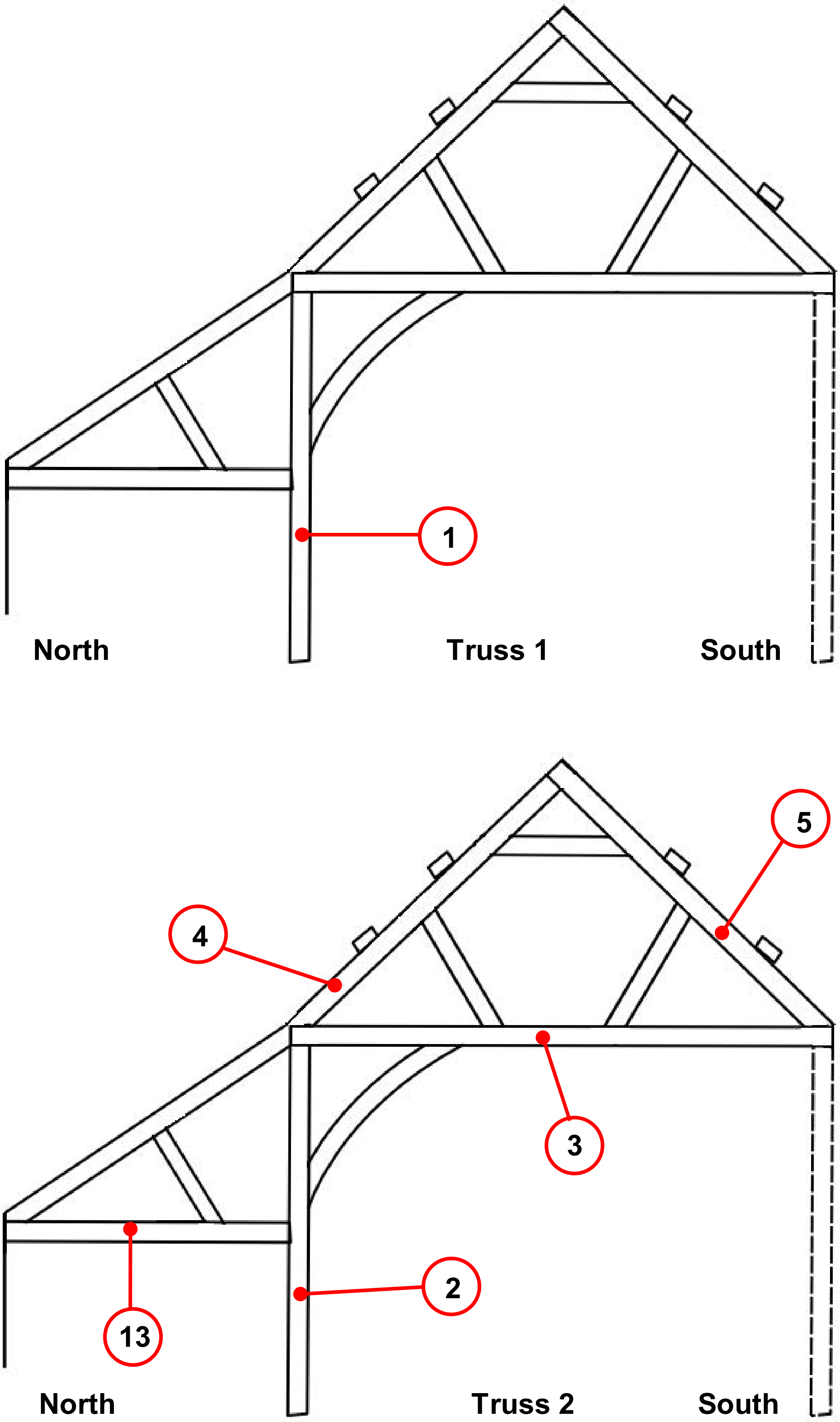
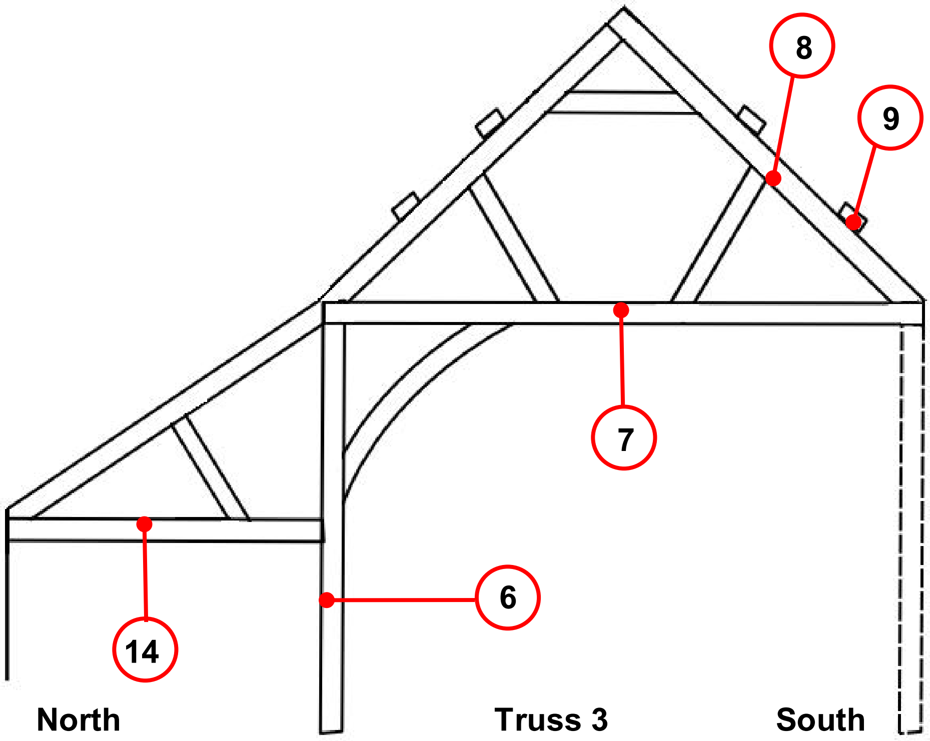


Figure 6a/b: Drawings to show sampled timbers



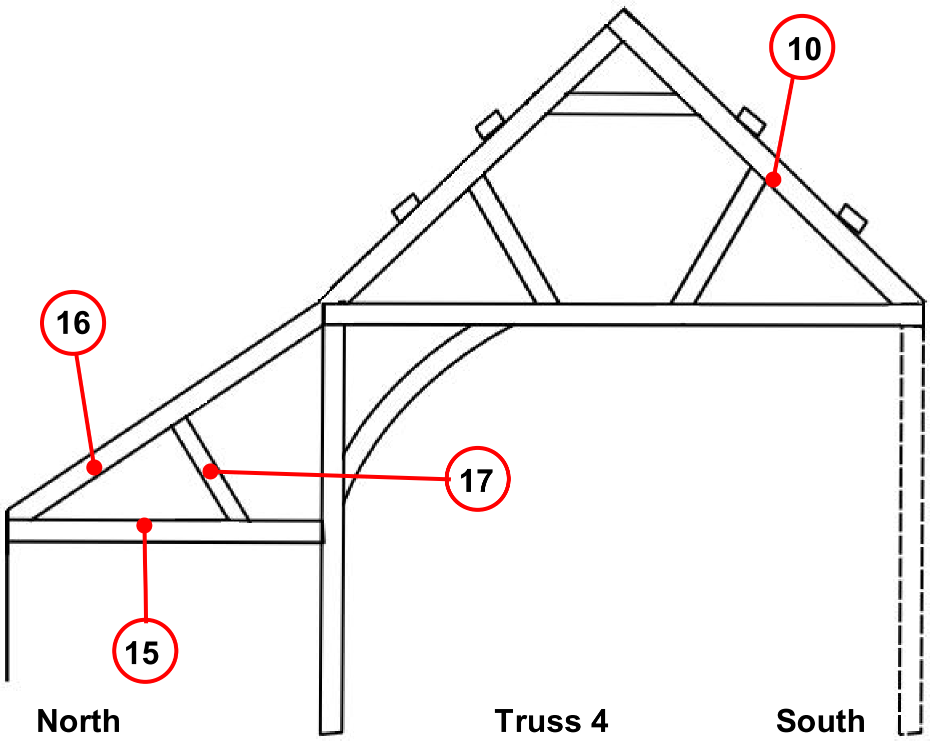


Figure 6c/d: Drawings to show sampled timbers

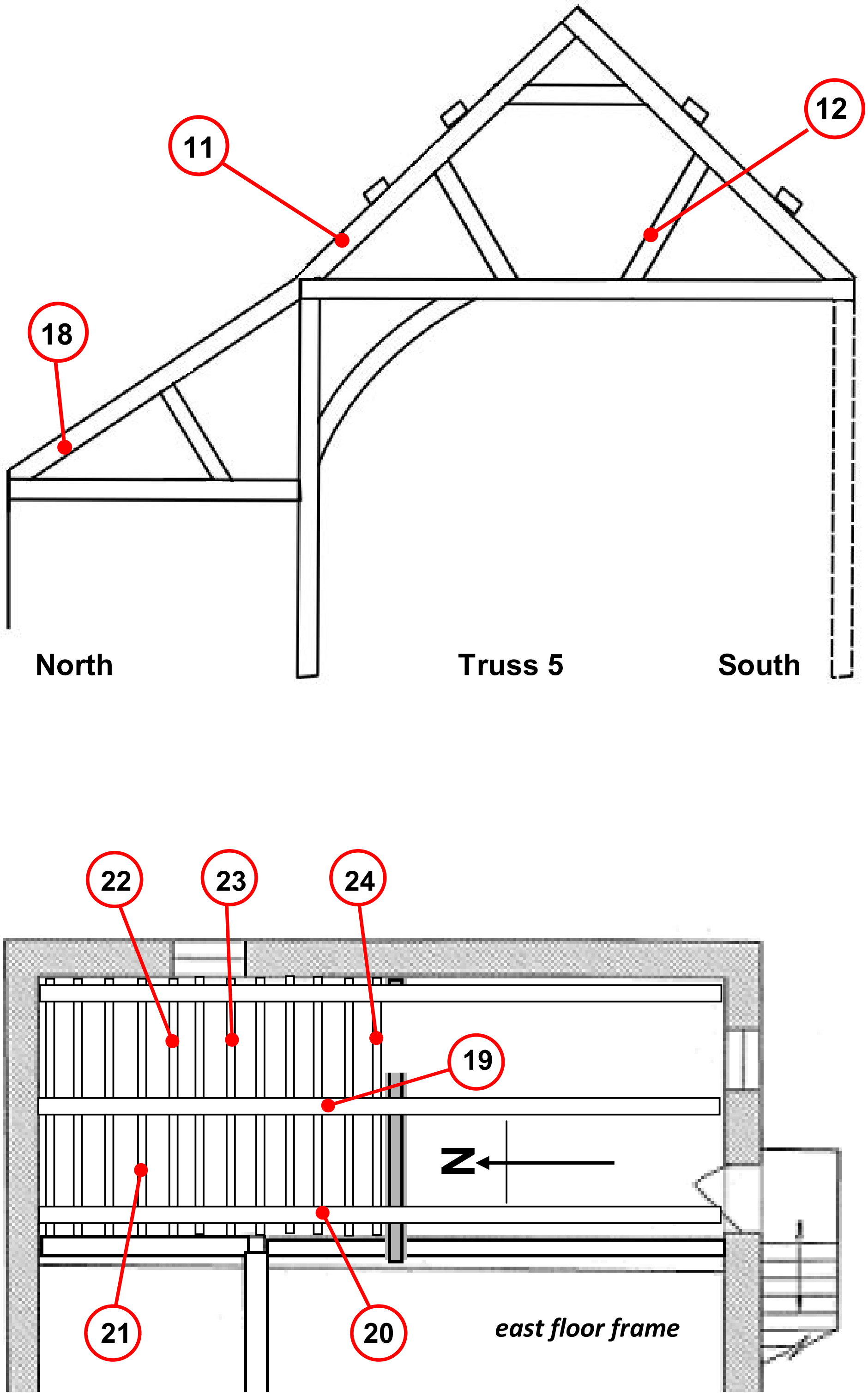
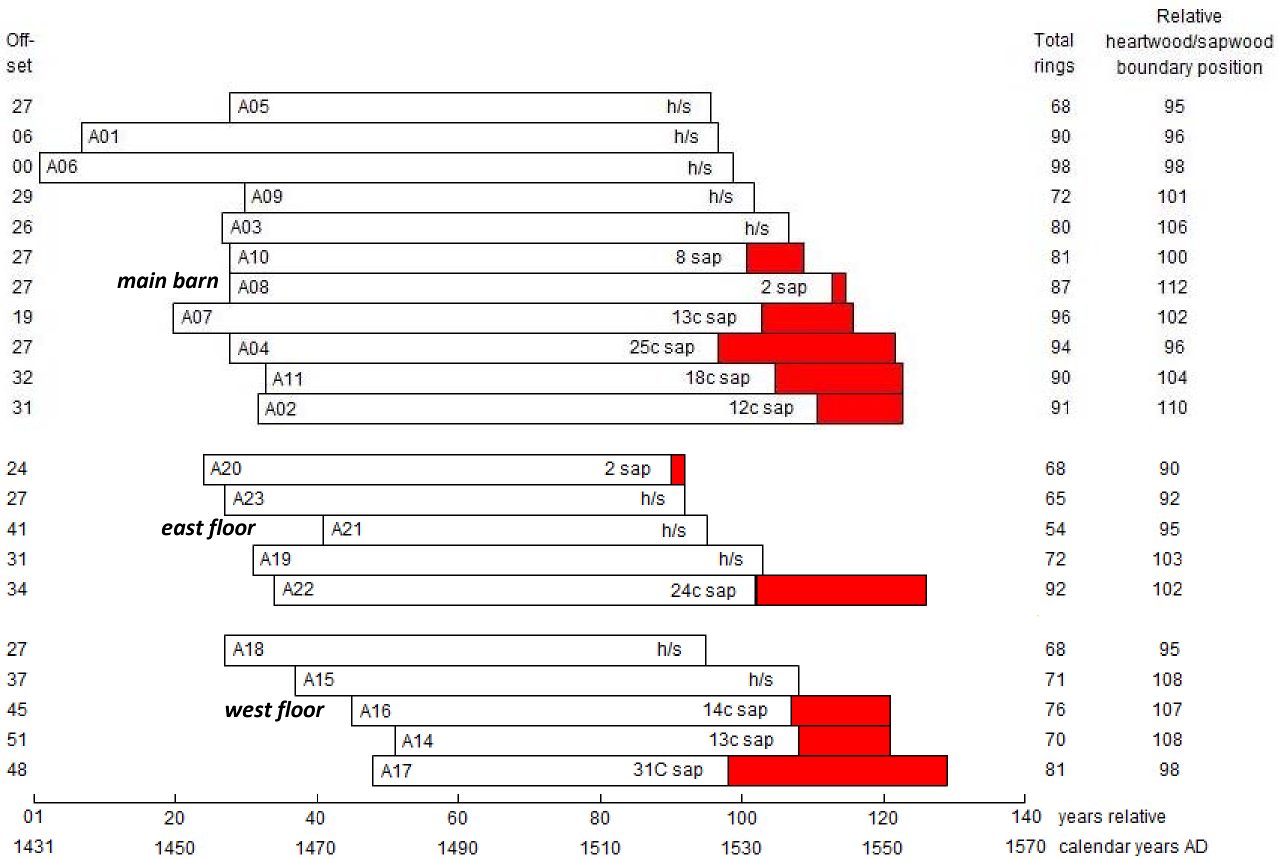


Figure 6e/f: Drawing, and plan of the east floor to show sampled timbers



White bars =heartwood rings, shaded area = sapwood rings. h/s = the last measured ring is at the 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 7: Bar diagram of the samples in site chronology PBDASQ01

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

PBD-A01A 90
418 391 234 298 503 306 282 277 280 211 459 384 613 578 581 609 429 503 472 484
246 232 194 181 199 268 355 278 276 472 660 799 459 682 652 479 779 769 703 434
205 212 199 317 289 308 377 255 278 295 277 236 297 276 169 146 139 183 219 223
217 168 165 167 190 195 172 211 204 253 302 229 224 365 263 239 156 144 139 184
118 120 145 127 112 137 99 118 107 99
PBD-A01B 90
376 401 243 300 481 313 293 251 273 233 458 386 629 575 551 615 435 491 477 493
244 225 203 180 202 267 359 297 267 463 640 805 449 690 704 458 764 763 748 446
173 207 198 336 277 295 377 239 345 310 260 240 288 288 166 152 138 190 214 233
207 160 165 171 191 207 158 232 187 255 295 210 238 349 278 229 171 146 147 162
111 128 142 120 118 125 119 112 101 114
PBD-A02A 91
610 627 465 500 536 568 404 361 390 404 424 467 532 509 298 316 276 412 294 223
149 243 299 307 282 339 189 246 257 253 232 280 261 268 295 215 182 165 163 213
231 107 164 170 177 141 139 191 265 241 238 197 238 204 202 164 249 324 308 286
362 311 300 284 279 366 290 238 287 274 227 204 193 322 276 269 239 267 266 188
168 180 204 228 190 150 158 167 188 161 161
PBD-A02B 91
600 646 448 516 538 550 401 378 384 404 432 465 520 519 277 301 275 400 291 228
148 243 287 311 284 340 204 241 277 238 240 276 259 257 304 211 180 175 160 206
244 117 163 181 183 149 135 195 253 235 252 196 232 193 186 160 261 336 307 282
370 308 298 288 295 375 292 221 280 268 206 212 210 282 303 265 236 260 253 169
168 180 195 212 180 132 162 159 174 166 152
PBD-A03A 80
335 730 308 630 494 641 654 689 795 833 705 798 705 641 298 174 254 233 349 349
262 405 381 432 449 242 450 462 480 408 386 365 383 317 168 144 163 98 258 311
190 187 215 212 91 73 72 83 107 172 117 161 177 201 270 223 142 136 119 248
227 149 131 112 111 209 107 148 142 178 252 147 138 137 222 123 160 169 146 234
PBD-A03B 80
342 769 348 618 517 656 643 662 781 831 763 844 722 681 264 156 269 234 356 368
232 359 392 425 407 238 449 452 495 405 392 394 405 304 178 163 128 110 259 310
187 194 235 226 85 78 75 85 107 182 120 158 177 204 281 231 140 138 108 251
238 150 141 116 114 208 118 145 152 179 249 143 142 141 212 118 156 173 180 241
PBD-A04A 94
922 592 653 544 579 554 523 469 392 514 732 630 527 443 271 422 370 521 414 243
264 240 323 303 305 302 463 184 202 291 158 182 167 123 121 84 164 130 156 119
110 104 130 139 107 138 111 147 151 90 108 132 191 134 138 119 91 76 97 77
182 148 131 164 114 177 152 126 166 133 146 119 67 117 109 126 104 176 122 131
112 101 75 63 52 81 89 94 104 129 131 132 91 123
PBD-A04B 94
901 609 656 524 555 541 521 455 393 512 735 636 528 437 272 411 365 513 409 257
262 231 316 300 304 293 466 188 204 308 145 191 169 131 121 85 159 123 152 124
113 88 150 129 106 135 116 144 150 95 108 143 173 141 144 115 86 80 102 75
168 147 127 160 119 171 151 128 159 135 138 117 85 126 110 111 98 172 134 121
106 107 77 64 49 78 86 99 104 126 130 133 91 131
PBD-A05A 68
779 642 771 743 787 780 425 485 474 620 591 377 450 345 273 363 243 295 344 263

328 304 346 391 260 260 306 235 140 267 259 270 240 221 157 110 165 132 280 181
166 153 221 205 215 165 131 246 262 244 199 297 277 288 309 199 171 214 189 189
284 283 281 322 283 267 311 260
PBD-A05B 68
785 628 779 733 763 779 415 489 488 612 594 377 441 341 281 340 230 294 384 254
345 291 339 412 268 258 297 231 157 263 255 309 231 223 155 102 159 135 273 177
164 148 233 193 204 163 123 237 263 252 204 272 279 297 312 212 166 228 193 173
299 291 279 332 252 274 329 250
PBD-A06A 98
310 448 375 543 353 278 398 417 408 386 541 331 417 492 371 281 469 294 413 289
306 386 331 481 386 354 295 268 237 173 204 235 302 223 240 295 322 353 300 295
358 230 392 544 523 371 227 170 157 231 157 175 247 260 246 245 188 151 148 199
125 122 106 155 168 187 148 121 152 125 171 166 153 162 138 186 161 164 135 169
140 127 104 97 112 133 78 93 90 107 86 106 71 89 79 74 69 97
PBD-A06B 98
331 443 387 535 365 282 390 400 387 405 538 326 428 446 376 249 451 294 427 309
331 419 321 473 389 330 304 271 229 166 216 237 297 213 239 301 313 370 285 324
360 231 400 524 543 368 201 190 148 239 143 178 249 260 234 246 187 146 157 190
115 120 130 156 152 182 157 121 141 120 190 163 159 156 143 184 164 157 140 171
132 132 98 107 107 128 82 89 105 98 89 108 80 88 80 68 72 92
PBD-A07A 96
198 326 536 354 450 307 326 229 222 204 406 311 348 415 329 470 620 495 342 138
165 211 123 250 191 473 303 201 277 302 325 229 291 342 344 386 234 338 154 191
290 217 193 144 238 250 282 133 137 217 158 215 290 170 213 181 196 109 150 189
133 237 143 120 143 127 97 121 111 83 108 120 106 95 123 81 107 123 112 101
129 176 100 79 106 123 142 157 131 96 118 67 75 163 102 107
PBD-A07B 96
214 311 548 352 448 292 333 208 217 217 402 325 329 427 317 473 609 506 351 134
191 218 138 238 191 481 312 192 281 293 331 219 299 350 332 397 224 337 157 199
285 218 203 132 242 260 266 138 140 211 155 217 285 172 213 182 197 117 140 183
145 235 143 123 148 112 115 110 110 92 103 123 107 87 125 73 122 117 111 96
132 176 102 82 104 123 138 158 132 94 125 92 77 144 101 105
PBD-A08A 87
321 262 379 297 439 444 329 530 495 610 457 477 531 394 337 415 475 575 450 353
225 166 291 255 175 228 299 345 271 432 173 224 327 214 155 138 182 192 262 139
134 191 231 212 196 193 256 242 301 237 130 219 249 202 182 125 90 90 97 88
98 106 74 114 172 204 198 151 174 170 214 159 161 186 141 158 157 186 170 178
157 134 147 162 109 154 175
PBD-A08B 87
346 254 342 282 423 456 325 505 512 607 460 471 525 417 335 420 471 581 424 361
222 164 301 257 179 214 308 344 256 448 187 225 305 221 157 143 188 196 266 118
150 193 228 223 201 181 258 238 286 237 139 209 248 203 186 120 99 75 103 94
100 108 73 123 162 206 204 143 176 164 228 152 149 187 151 152 160 193 162 186
138 150 142 167 115 143 173
PBD-A09A 72
246 122 177 161 97 207 226 287 174 181 133 123 158 236 318 350 221 215 131 111
313 354 283 362 476 446 404 664 375 316 299 202 184 255 229 266 358 228 202 213
192 294 393 257 340 174 159 168 147 205 165 262 220 163 132 365 343 327 174 179
75 167 279 300 243 274 254 288 299 231 280 361
PBD-A09B 72
238 126 176 164 93 187 235 297 177 169 132 121 147 250 325 347 242 219 136 92
299 342 290 382 482 433 407 684 359 312 291 214 177 261 235 268 374 211 204 195
180 283 364 268 338 153 160 171 154 207 178 253 236 140 136 373 300 325 199 197

77 151 294 316 254 293 267 272 319 240 277 359
PBD-A10A 81
290 247 478 360 380 390 349 370 496 658 530 435 473 403 319 314 258 637 494 365
306 331 304 248 219 256 237 271 273 443 232 262 291 244 226 147 174 206 205 187
163 165 127 209 251 154 172 218 216 166 189 220 182 247 154 147 109 123 145 173
169 177 173 185 250 225 206 179 171 217 203 130 161 232 139 184 145 187 219 254
274
PBD-A10B 81
292 253 485 349 391 391 341 362 487 658 521 417 472 428 314 318 248 647 489 379
297 334 321 266 217 297 227 258 272 452 239 239 289 245 208 152 174 199 194 196
154 171 128 218 248 148 179 223 217 164 159 227 191 243 159 139 116 121 148 167
170 178 180 185 245 213 215 182 160 243 170 162 151 224 164 165 140 205 204 259
279
PBD-A11A 90
296 343 444 699 476 350 283 208 181 176 554 433 610 475 254 189 226 329 227 225
262 286 339 267 408 231 223 305 179 171 143 334 488 468 205 201 213 184 275 441
308 337 325 255 293 258 429 280 311 350 250 169 155 304 342 288 322 207 273 304
226 273 149 140 171 157 144 73 149 198 187 172 268 244 324 204 192 179 177 79
267 212 171 195 197 159 163 129 156 156
PBD-A11B 90
296 342 436 658 441 354 291 206 181 177 558 455 637 485 246 193 207 317 246 209
262 289 345 269 400 242 220 287 181 149 153 329 480 470 208 202 213 195 246 432
324 335 321 261 297 252 427 270 311 355 246 184 155 293 333 286 308 230 270 295
237 273 137 152 167 154 140 86 140 184 186 180 305 226 304 196 207 180 153 85
266 181 178 226 191 160 161 126 162 160
PBD-A12A 65
177 167 128 107 153 157 151 224 271 188 197 172 114 143 134 121 121 154 178 177
166 246 201 270 318 247 213 224 214 303 224 230 194 212 245 267 282 314 320 394
355 282 235 321 263 267 272 345 262 355 293 257 208 178 169 199 180 180 189 174
144 220 115 149 124 158
PBD-A12B 66
176 176 127 117 145 166 123 227 280 191 175 172 119 138 131 132 130 150 169 171
177 243 204 268 324 239 219 225 216 308 237 223 195 227 239 261 283 312 322 376
317 278 259 317 255 275 279 333 272 332 288 248 199 172 180 212 175 194 197 172
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PBD-A13A 62
421 290 246 198 275 339 369 373 420 494 423 303 415 360 361 303 349 306 207 279
416 469 355 229 134 71 107 134 163 144 106 132 209 263 243 331 417 512 512 384
440 535 275 388 346 443 411 308 267 342 298 322 173 262 148 236 145 182 254 225
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PBD-A13B 62
385 337 240 183 249 351 400 368 437 517 420 303 462 354 344 293 366 269 196 286
409 468 314 230 115 88 102 140 153 148 113 125 208 266 241 348 423 520 513 380
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155 127
PBD-A14A 70
379 453 474 475 461 500 358 299 368 309 269 260 290 371 337 228 166 181 214 277
302 257 219 190 182 129 121 161 111 187 176 117 116 97 106 122 125 120 96 123
172 199 184 158 136 142 106 88 82 112 102 104 68 116 123 149 120 129 124 99
111 92 95 114 142 114 133 119 140 164
PBD-A14B 70
384 462 467 474 473 501 364 285 393 303 283 253 305 393 315 225 170 181 217 267
302 263 223 185 177 138 111 165 112 193 165 118 116 103 89 128 133 117 88 123

173 179 199 162 146 133 103 83 90 108 100 103 69 122 129 137 115 135 128 108
97 82 96 88 160 116 126 130 147 168
PBD-A15A 71
126 145 156 78 77 125 252 413 297 416 377 521 405 374 304 339 422 422 314 472
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239 290 248 286 277 219 218 205 243 207 253 248 224 289 276 239 240 255 219 266
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PBD-A15B 71
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336 365 402 396 373 295 319 514 497 351 277 386 393 399 347 280 295 340 271 211
225 293 254 289 268 207 215 191 259 203 222 247 250 290 291 231 239 249 220 268
240 206 213 264 259 275 207 211 231 199 234
PBD-A16A 76
251 198 238 289 390 190 144 205 282 466 393 460 274 238 402 257 241 232 461 452
427 325 336 255 237 295 282 246 277 216 253 192 280 411 187 288 305 292 168 135
213 308 343 484 412 310 262 219 300 186 173 239 281 251 176 301 243 256 245 280
239 383 215 207 273 238 119 218 171 228 187 147 163 153 103 150
PBD-A16B 76
250 199 251 282 377 199 152 202 287 473 384 468 271 242 400 254 256 232 444 448
442 332 329 258 248 295 280 237 284 228 244 190 280 404 194 289 287 274 175 161
214 296 350 476 413 305 260 209 274 216 178 226 283 251 177 307 242 244 252 275
250 377 220 215 273 245 110 225 178 212 191 167 152 130 99 163
PBD-A17A 81
426 365 321 220 298 405 331 325 491 292 325 421 461 353 331 388 369 475 235 241
254 263 211 274 165 204 236 285 255 175 456 336 419 380 259 175 137 150 192 207
173 160 125 210 220 175 120 110 153 148 125 97 180 141 176 184 188 167 246 171
210 116 161 84 58 162 163 150 220 142 114 115 108 230 120 151 102 75 59 44
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PBD-A17B 81
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187 153 143 216 225 175 120 109 139 155 119 119 156 130 181 185 205 162 223 166
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PBD-A18A 68
167 301 236 251 217 416 411 523 590 447 454 376 288 353 317 352 263 513 412 212
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PBD-A18B 68
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PBD-A19A 72
346 372 300 402 536 486 424 389 307 242 212 302 267 435 313 327 329 241 339 250
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PBD-A19B 72
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217 319 392 432 372 549 355 376 391 247 213 274 236 251 361 185 139 204 180 136
133 123 130 125 153 164 125 180 178 164 175 160 124 133 145 156 167 199 157 169

189 150 143 162 160 141 178 165 125 95 127 117
PBD-A20A 68
191 169 109 201 271 353 276 346 375 238 376 406 373 320 242 290 273 183 227 255
292 253 256 253 214 188 145 154 217 203 230 197 204 115 110 139 156 149 108 102
173 168 119 136 141 147 140 119 99 174 130 120 78 99 124 78 77 67 41 82
55 68 68 53 65 76 66 88
PBD-A20B 68
198 168 109 195 282 323 274 386 384 222 354 384 366 348 251 283 269 184 200 235
300 250 240 253 214 188 151 142 207 199 234 187 214 126 106 151 154 152 95 114
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48 73 68 58 55 75 65 83
PBD-A21A 54
209 288 239 438 300 347 329 485 519 387 443 574 689 612 676 704 322 338 412 320
301 251 343 403 364 323 316 310 356 370 361 295 311 324 277 180 285 259 226 388
220 229 172 185 173 198 294 257 235 280 307 242 277 264
PBD-A21B 54
202 298 237 435 311 337 321 503 529 386 443 570 674 608 704 704 319 327 424 352
294 258 370 383 390 326 308 279 349 381 349 319 348 298 257 183 287 252 243 365
227 236 196 154 179 192 261 260 228 272 299 258 246 279
PBD-A22A 92
320 420 354 334 285 259 298 143 257 269 347 300 249 268 337 288 229 190 277 263
259 212 299 172 156 138 126 123 165 223 168 193 145 127 133 135 152 185 175 218
204 206 165 181 262 242 198 176 177 129 121 113 91 140 136 158 140 123 99 105
111 159 124 135 115 121 101 94 105 122 117 105 105 97 112 107 85 85 100 102
110 124 81 108 118 122 192 137 143 92 85 94
PBD-A22B 92
299 421 362 330 277 244 305 145 256 271 338 320 232 263 348 285 232 205 264 278
233 206 287 185 151 140 123 128 169 206 185 195 146 141 130 122 146 175 184 233
203 211 162 182 255 243 204 179 174 154 105 108 93 147 131 149 133 121 99 113
105 173 125 130 113 113 109 92 109 108 112 99 97 103 126 100 79 75 101 107
106 126 90 106 123 115 197 149 132 96 87 106
PBD-A23A 65
243 266 305 192 162 237 135 151 215 224 257 169 228 229 203 249 289 293 231 208
103 107 233 172 179 170 179 242 290 355 231 173 156 149 155 115 188 582 551 287
218 258 276 373 395 337 419 263 275 185 231 180 199 235 194 157 234 174 370 210
235 416 453 383 382
PBD-A23B 65
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232 411 505 363 353

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

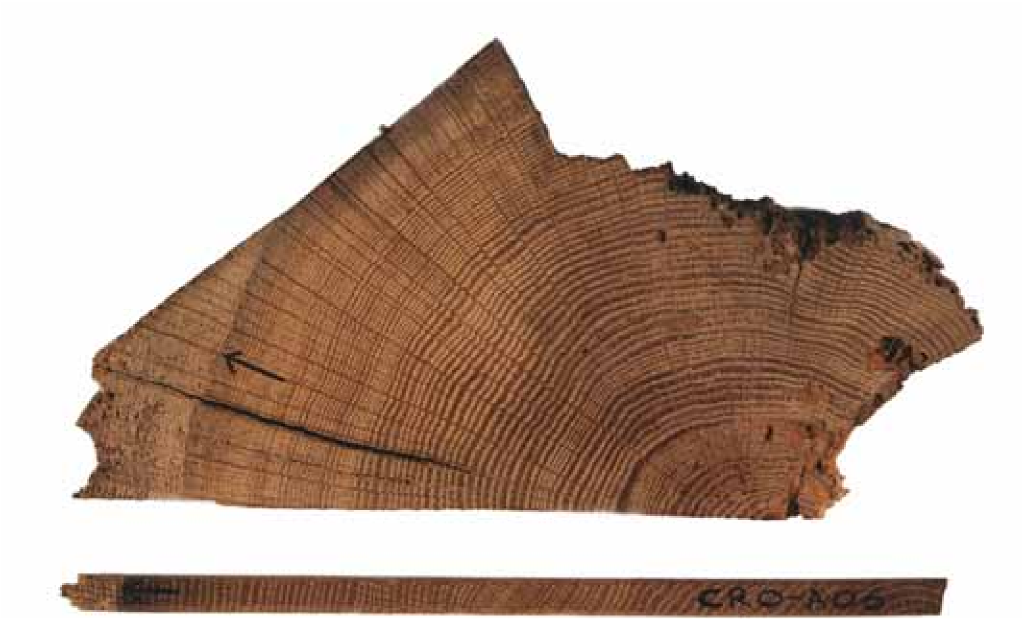


Figure A2: Cross-section of a rafter, showing sapwood rings in the left-hand corner, the arrow points to the heartwood/sapwood boundary (H/S); and a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil

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

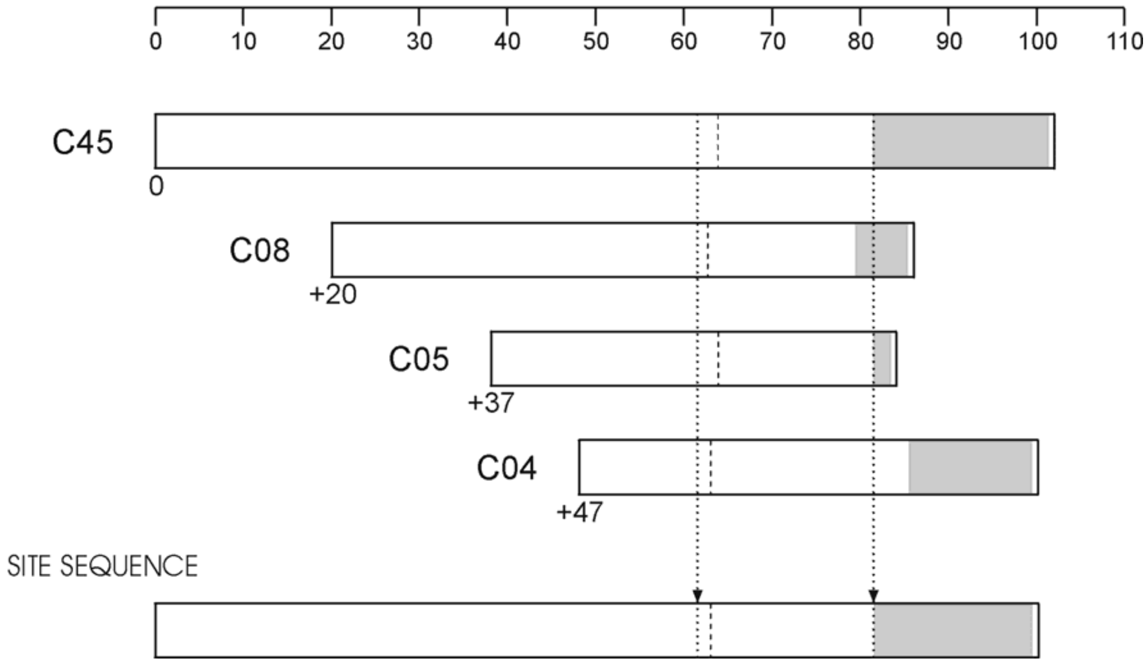


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

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.

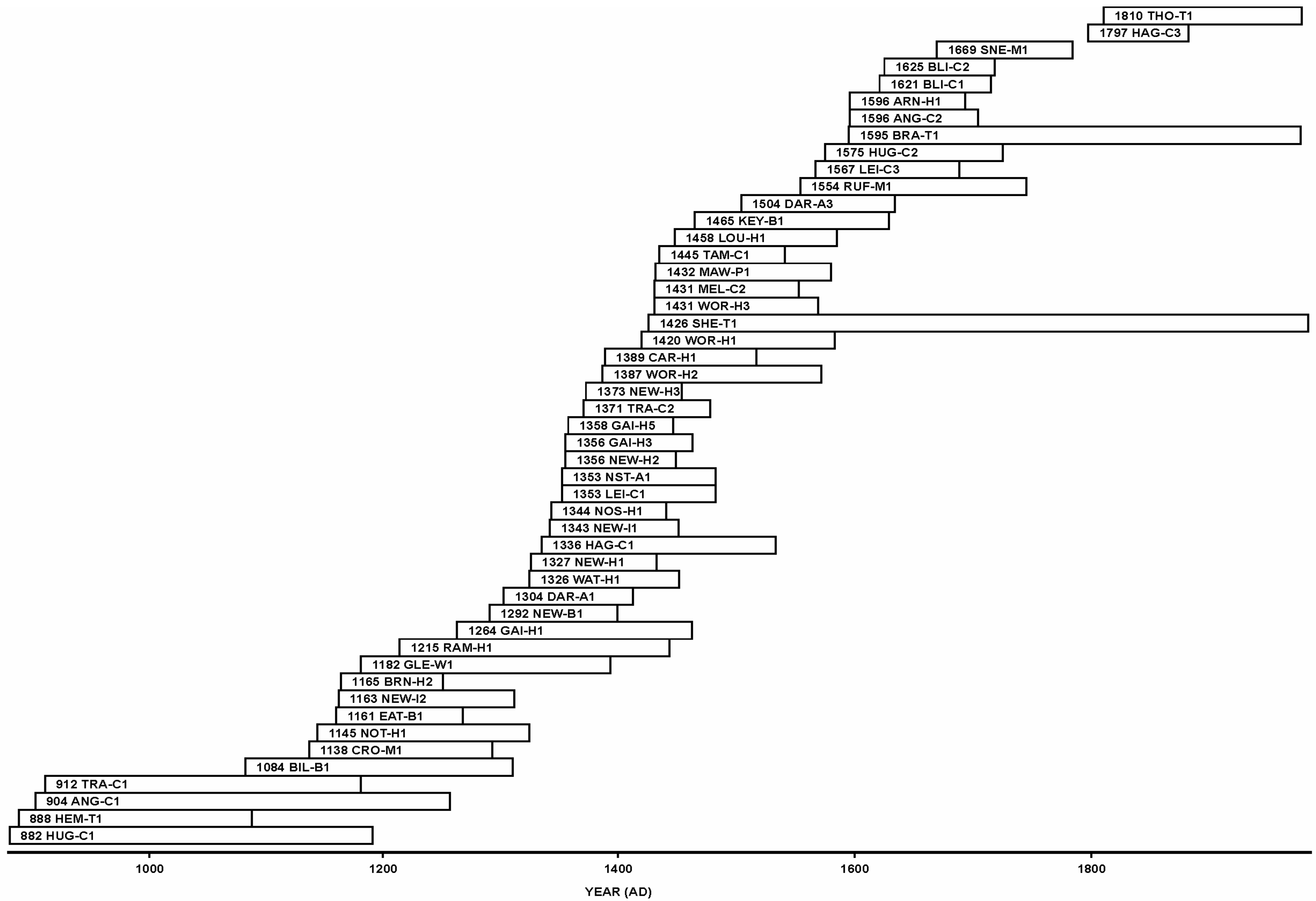
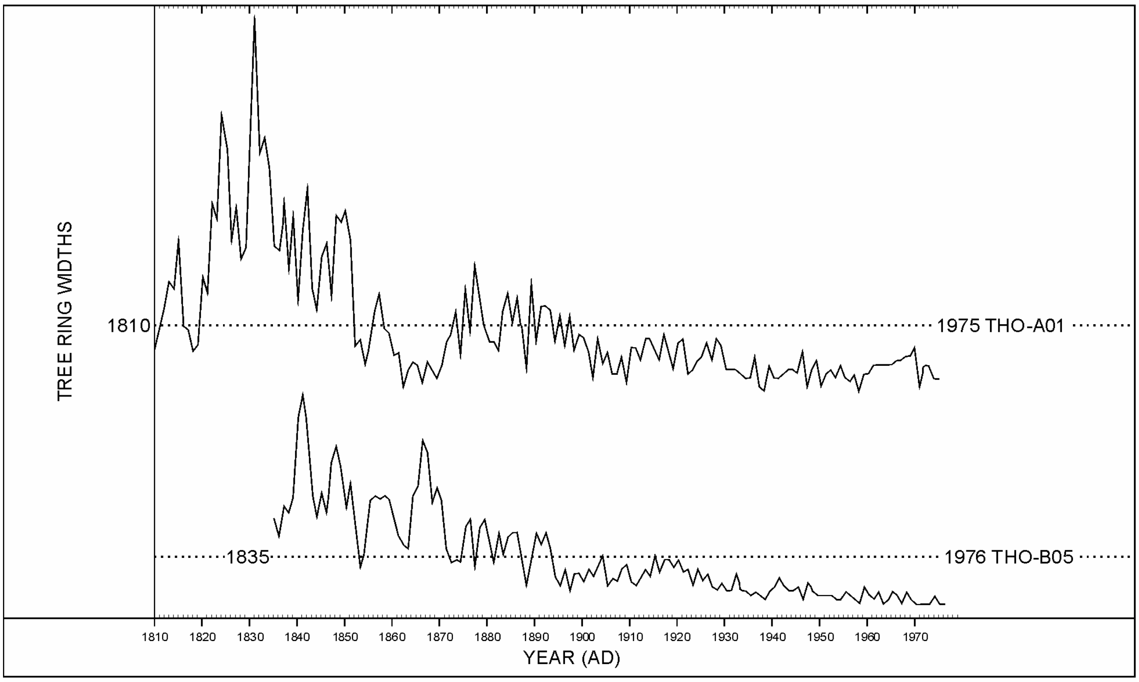


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

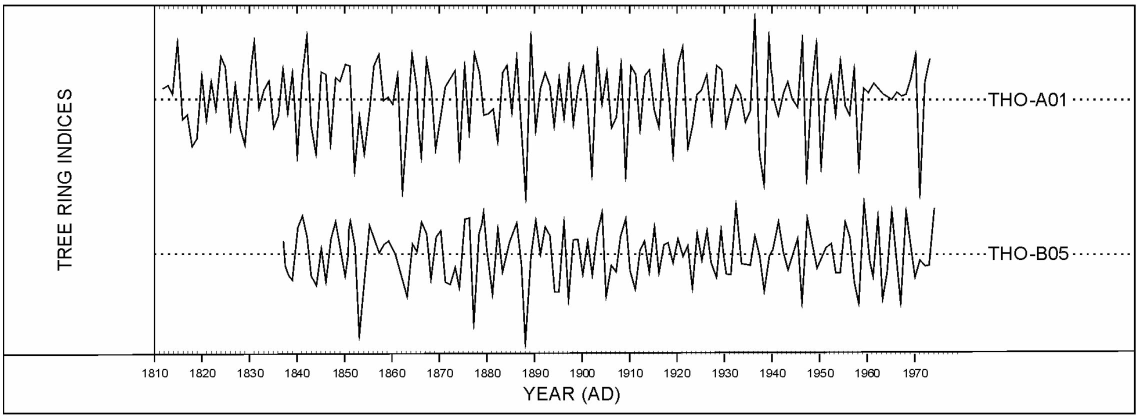


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

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

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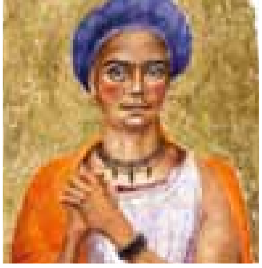


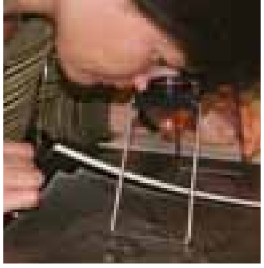


ENGLISH HERITAGE RESEARCH AND THE HISTORIC ENVIRONMENT

English Heritage undertakes and commissions research into the historic environment, and the issues that affect its condition and survival, in order to provide the understanding necessary for informed policy and decision making, for the protection and sustainable management of the resource, and to promote the widest access, appreciation and enjoyment of our heritage. Much of this work is conceived and implemented in the context of the National Heritage Protection Plan. For more information on the NHPP please go to http://www.english-heritage.org.uk/professional/protection/national-heritage-protection-plan/.

The Heritage Protection Department provides English Heritage with this capacity in the fields of building history, archaeology, archaeological science, imaging and visualisation, landscape history, and remote sensing. It brings together four teams with complementary investigative, analytical and technical skills to provide integrated applied research expertise across the range of the historic environment. These are:

- Intervention and Analysis (including Archaeology Projects, Archives, Environmental Studies, Archaeological Conservation and Technology, and Scientific Dating)
- Assessment (including Archaeological and Architectural Investigation, the Blue Plaques Team and the Survey of London)
- Imaging and Visualisation (including Technical Survey, Graphics and Photography)
- Remote Sensing (including Mapping, Photogrammetry and Geophysics)

The Heritage Protection Department undertakes a wide range of investigative and analytical projects, and provides quality assurance and management support for externally-commissioned research. We aim for innovative work of the highest quality which will set agendas and standards for the historic environment sector. In support of this, and to build capacity and promote best practice in the sector, we also publish guidance and provide advice and training. We support community engagement and build this in to our projects and programmes wherever possible.

We make the results of our work available through the Research Report Series, and through journal publications and monographs. Our newsletter *Research News*, which appears twice a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities.

A full list of Research Reports, with abstracts and information on how to obtain copies, may be found on www.english-heritage.org.uk/researchreports

For further information visit www.english-heritage.org.uk

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