RESEARCH DEPARTMENT REPORT SERIES no. 34-2008 ISSN 1749-8775

ST SWITHUN'S CHURCH, WOODBOROUGH, NOTTINGHAMSHIRE
TREE-RING ANALYSIS OF TIMBERS FROM THE BELLFRAME AND BELFRY FLOOR

SCIENTIFIC DATING REPORT

Alison Arnold and Robert Howard

ARCHAEOLOGICAL SCIENCE

ENGLISH HERITAGE

Research Department Report Series 34-2008

ST SWITHUN'S CHURCH, WOODBOROUGH, NOTTINGHAMSHIRE
TREE-RING ANALYSIS OF TIMBERS FROM THE BELLFRAME AND BELFRY FLOOR

A J Arnold and R H Howard

NGR SK632 477

ISSN 1749-8775

Requests for further hard copies, after the initial print run, can be made by emailing: Res.reports@english-heritage.org.uk.
or by writing to English Heritage, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD
Please note that a charge will be made to cover printing and postage.

SUMMARY

Dendrochronological analysis undertaken on samples taken from the belfry floor and bellframe at this church has resulted in the construction and dating of two site sequences.

The first, WDBASQ01, contains two samples, both from the bellframe, and spans the period AD 1530–1619. The second, WDBASQ02, contains ten samples, two from the belfry floor and eight from the bellframe, and spans the period AD 1529–1650. Interpretation of the heartwood/sapwood boundary ring date of the dated samples suggests they were all felled sometime within the range AD 1651–64.

Tree-ring analysis has shown the belfry floor and bellframe are likely to be contemporary, with both structures dating to the mid-seventeenth century.

CONTRIBUTORS

Alison Arnold, Robert Howard

ACKNOWLEDGEMENTS

The Laboratory would like to thank Mr Paul Sail, churchwarden, for arranging access. The plan of the belfry floor (Fig 7) was provided by English Heritage. Mr George Dawson kindly provided his illustrations of the bellframe for reproduction here (Figs 8–15) as well as allowing us to see his description of the frame. Thanks are also given to the English Heritage Scientific Dating Section and Cathy Tyers of Sheffield University Dendrochronology Laboratory for their advice and assistance throughout the production of this report.

ARCHIVE LOCATION

NTRDL

DATE OF INVESTIGATION

2008

CONTACT DETAILS

Alison Arnold and Robert Howard
Nottingham Tree-ring Dating Laboratory
20 Hillcrest Grove
Sherwood
Nottingham NG5 1FT

CONTENTS

INTRODUCTION

The Grade-II* listed parish church of St Swithun is located on the south side of Main Street, in the village of Woodborough, Nottinghamshire (Figs 1–3; SK632 477). The church plan is one of west tower, nave, north and south aisles, chancel, and south porch, with some of these elements thought to date from the twelfth century. The church underwent a scheme of restoration in AD 1891–7.

The two-stage west tower (Fig 4) is thought to date to the thirteenth and fifteenth centuries. This contains an oak bellframe (Fig 5). This frame was originally built to hold four bells, although at some later date it has been altered to hold a fifth bell. This has necessitated both end-gates being cut away and new beams being inserted, thereby allowing the treble pit to hold two bells. It is of jack-braced design of Pickford type 6.B (Pickford 1993), and it is thought likely that construction of the bellframe occurred in AD 1680, when a new tenor bell was provided (George Dawson *pers comm*). The floor on which the frame sits is supported by four large north-south beams built into the tower walls (Figs 6 and 7).

AIMS AND OBJECTIVES

Sampling and analysis by tree-ring dating was commissioned and funded by English Heritage. It was requested by Mr Graham Pledger and Dr Valerie Scott to assist with discussions regarding the repairs currently being undertaken to the Tower. It was hoped that successful tree-ring analysis would provide dating evidence for the belfry floor and bellframe, thereby demonstrating their relationship to each other.

SAMPLING

A total of 14 timbers was sampled from the belfry floor and from the bellframe itself. Each sample was given the code WDB-A (for Woodborough) and numbered 01–14. Samples WDB-A01–04 are from the belfry floor beams and samples WDB-A05–14 from the bellframe. The position of samples was noted at the time of sampling and has been marked on Figures 7–15. Further details relating to the samples can be found in Table 1. The belfry floor beams have been numbered from east to west.

ANALYSIS, RESULTS, AND INTERPRETATION

At this stage it was noticed that one of the samples taken from the belfry floor (WDB-A01) had too few rings to make secure dating a possibility and this sample was rejected prior to measurement. The remaining 13 samples were prepared by sanding and polishing and their growth-ring widths measured; the data of these measurements is given at the end of the report. All 13 samples were compared with each other by the Litton/Zainodin grouping procedure (*see* Appendix), resulting in 12 samples forming two groups.

Firstly, two samples, both from bellframe timbers, matched each other and were combined at the relevant offset positions to form WDBASQ01, a site sequence of 90 rings (Fig 16). This site sequence was then compared with a large number of relevant reference chronologies for oak where it was found to match at a first-ring date of AD

1530 and a last-measured ring date of AD 1619. The evidence for this dating is given by the *t*-values in Table 2.

Secondly, ten samples, seven from the bellframe and three from floor beams, matched each other and were combined at the relevant offset positions to form WDBASQ02, a site sequence of 122 rings (Fig 16). Attempts to date this site sequence by comparing it against the reference material resulted in a consistent match where the first ring date is AD 1529 and the last-ring date is AD 1650 (Table 3).

Eleven of the dated samples from these two site sequences retain the heartwood/sapwood boundary ring. In all cases this can be seen to be broadly contemporary and therefore suggestive of a single felling. The average heartwood/sapwood boundary ring date of these samples is AD 1629, which allows an estimated felling date to be calculated for the 11 timbers represented to within the range AD 1651–64. This allows for sample WDB-A05 having the last-measured ring date of AD 1650 with incomplete sapwood.

Attempts were then made to date sample WDB-A06 by comparing it against the reference material, but this proved unsuccessful and this sample, taken from a jack-brace, remains undated

DISCUSSION AND CONCLUSION

Prior to tree-ring analysis being undertaken, it had been suggested that the bellframe dated to the provision of the tenor bell in AD 1680. It is now known that nine of the bellframe timbers and three of the belfry floor beams were felled in AD 1651–64. Additionally, the similarity in end dates for the samples suggests that actual felling probably occurred in the early part of this range.

It can be seen that there is no obvious difference in the heartwood/sapwood boundary ring position of those samples taken from the floor beams and those from the bellframe (Fig 17), which suggests that the timbers utilised in the construction of the belfry floor and the bellframe are contemporary, with both structures dating to AD 1651–64.

The high level of matching seen, not only between samples of the same structure (ie, floor beams 3 and 4 match each other at t=10.8 and several of the bellframe timbers match each other at levels of more than t=7.0), but perhaps more interestingly between bellframe elements and floor beams, such as beam 4 matching a brace from the bellframe at t=14.7, suggests that a single source of timber was utilised for both structures, thereby adding further support that they are contemporary. This degree of matching also indicates the possibility that some of the timbers may have been derived from the same tree.

The only measured sample that could not be dated is WDB-A06, taken from a jack brace. Looking at the sample, the ring pattern is quite distorted, which might have inhibited it from matching against the other samples from this site and against the reference material.

BIBLIOGRAPHY

Arnold, A J and Howard, R E, 2007 unpubl Tree-ring analysis of timbers from Cromford Bridge Hall, Cromford, Derbyshire – Nottingham Tree-ring Dating Laboratory unpubl computer file CRMBSQ01/3/4

Baillie, M G L, and Pilcher, J R, 1982 unpubl A master tree-ring chronology for England, unpubl computer file MGB-EOI, Queens Univ, Belfast

Howard, R E, Laxton, R R, Litton, C D, Morrison A, Sewell, J, and Hook, R, 1993 Nottingham University Tree-Ring Dating Laboratory: Derbyshire, Peak Park and RCHME dendrochronological Survey 1991–92, *Vernacular Architect*, 24, 43–4

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

Howard, R E, Laxton, R R, Litton, C D, Morrison A, Sewell, J, and Hook, R, 1995 Nottingham University Tree-Ring Dating Laboratory: Derbyshire, Peak Park and RCHME dendrochronological Survey 1994–95, *Vernacular Architect*, 26, 53– 4

Howard, R E, Laxton, R R, and Litton, C D, 2003 *Tree-ring analysis of timbers from Staircase House (30A & 31 Market Place), Stockport, Greater Manchester*, Centre for Archaeol Rep, 12/2003

Howard, R E, 2005 unpubl Tree-ring analysis of timbers from Aston Hall, Aston, Birmingham – unpubl computer file ASTHSQ01, NottinghamTree-Ring Dating Laboratory

Howard, R E, Laxton, R R, and Litton, C D, 2005 *Tree-ring analysis of timbers from the Riding School, Bolsover Castle, Bolsover, Derbyshire*, Centre for Archaeol Rep, 40/2005

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

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

Pickford, C, 1993 *Bellframes: A practical guide to inspection and recording*, Bedford

TABLES

Table 1: Details of tree-ring samples from the belfry floor and bellframe of St Swithun's Church, Woodborough, Nottinghamshire

Sample number	Sample location	Total rings*	Sapwood rings**	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
WDB-A01	Beam 1	NM	--	----	----	----
WDB-A02	Beam 2	64	17	1583	1629	1646
WDB-A03	Beam 3	106	16	1543	1632	1648
WDB-A04	Beam 4	93	13	1555	1634	1647
WDB-A05	West brace, truss A–A	48	19	1603	1631	1650
WDB-A06	North jack brace, F–F	56	11	----	----	----
WDB-A07	West brace, truss B–B	66	18	1581	1628	1646
WDB-A08	Top cill, truss B–B	97	h/s	1529	1625	1625
WDB-A09	Top cill, F–F	68	--	1541	----	1608
WDB-A10	Top cill, truss C–C	108	18	1542	1631	1649
WDB-A11	South brace, H–H	56	18	1594	1631	1649
WDB-A12	East brace, truss A–A	70	20	1579	1628	1648
WDB-A13	East jack brace, truss A–A	96	21	1553	1627	1648
WDB-A14	Top cill, truss H–H	90	h/s	1530	1619	1619

*NM = not measured
**h/s = the heartwood/sapwood ring is the last ring on the sample

Table 2: Results of the cross-matching of site sequence WDBASQ01 and relevant reference chronologies when the first-ring date is AD 1530 and the last-ring date is AD 1619

Reference chronology	*t*-value	Span of chronology	Reference
England	6.5	AD 401–1981	Baillie and Pilcher 1982 unpubl
Kirk Ireton Church, Derbys	7.7	AD 1512–1601	Howard *et al* 1995
Aston Hall, Aston, Birminghm	7.0	AD 1457–1624	Howard 2005 unpubl
Frith Hall, Brampton, Derbys	7.0	AD 1480–1602	Howard *et al* 1993
Bolsover Castle (Riding house), Derbys	6.5	AD 1494–1744	Howard *et al* 2005
Staircase House, Stockport, Greater Manchester	6.4	AD 1489–1656	Howard *et al* 2003
Aisled barn, Yew Tree Farm, North Leverton, Notts	6.4	AD 1476–1618	Arnold and Howard 2007 unpubl

Table 3: Results of the cross-matching of site sequence WDBASQ02 and relevant reference chronologies when the first-ring date is AD 1529 and the last-ring date is AD 1650

Reference chronology	*t*-value	Span of chronology	Reference
East Midlands	5.8	AD 882–1981	Laxton and Litton 1988
Brewhouse Yard Museum, Notts	8.1	AD 1544–1701	Howard *et al* 1994
Bolsover Castle (Riding house), Derbys	7.6	AD 1494–1744	Howard *et al* 2005
Cromford Bridge House, Derbys	7.3	AD 1550–1662	Arnold and Howard 2007 unpubl
Rufford Mill, Notts	7.1	AD 1571–1727	Laxton *et al* 1984
Staircase House, Stockport, Greater Manchester	6.8	AD 1489–1656	Howard *et al* 2003
15/17 St John's St, Wirksworth, Derbys	6.4	AD 1586–1676	Howard *et al* 1995

FIGURES

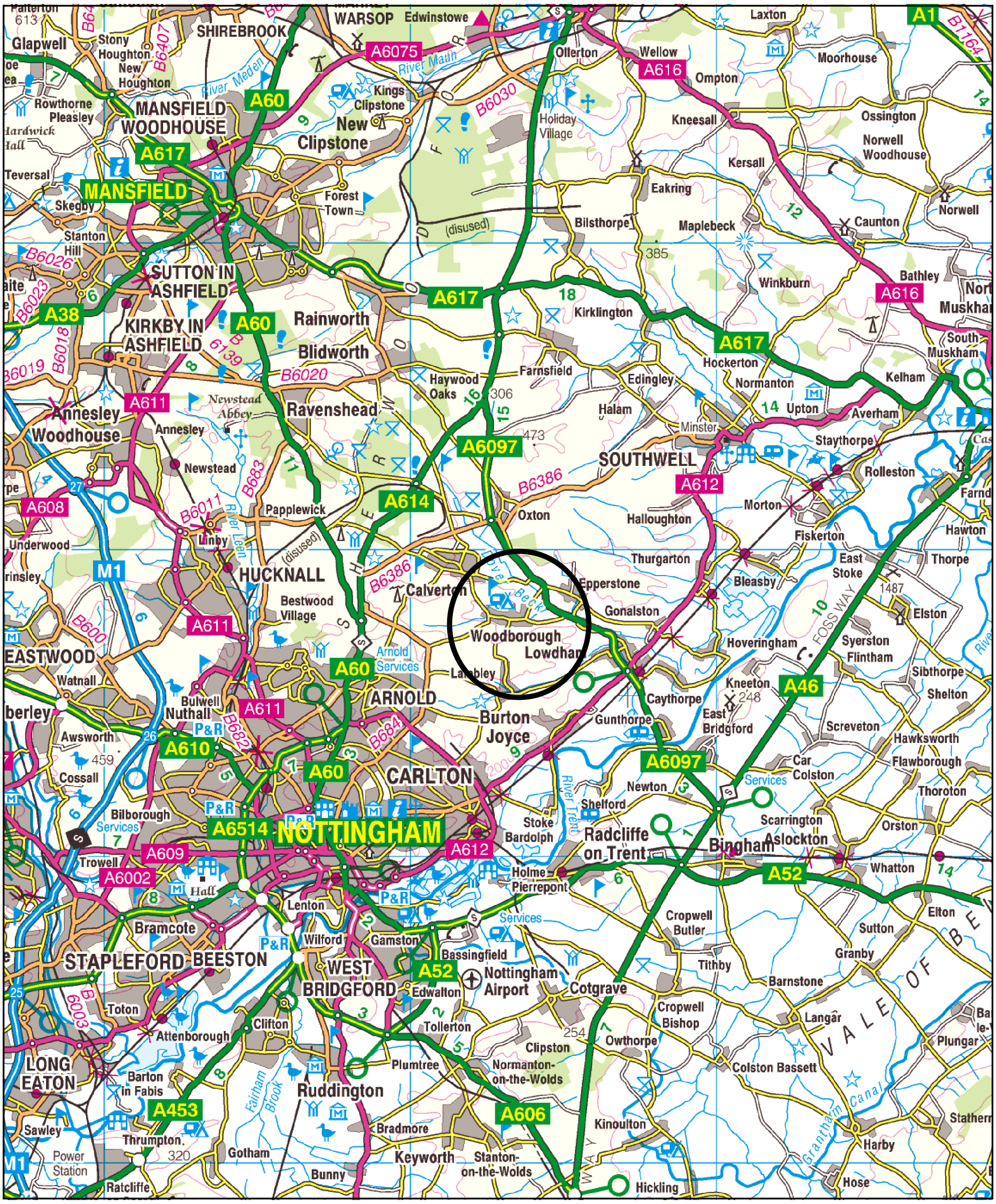


Figure 1: Map to show the general location of Woodborough, Nottinghamshire

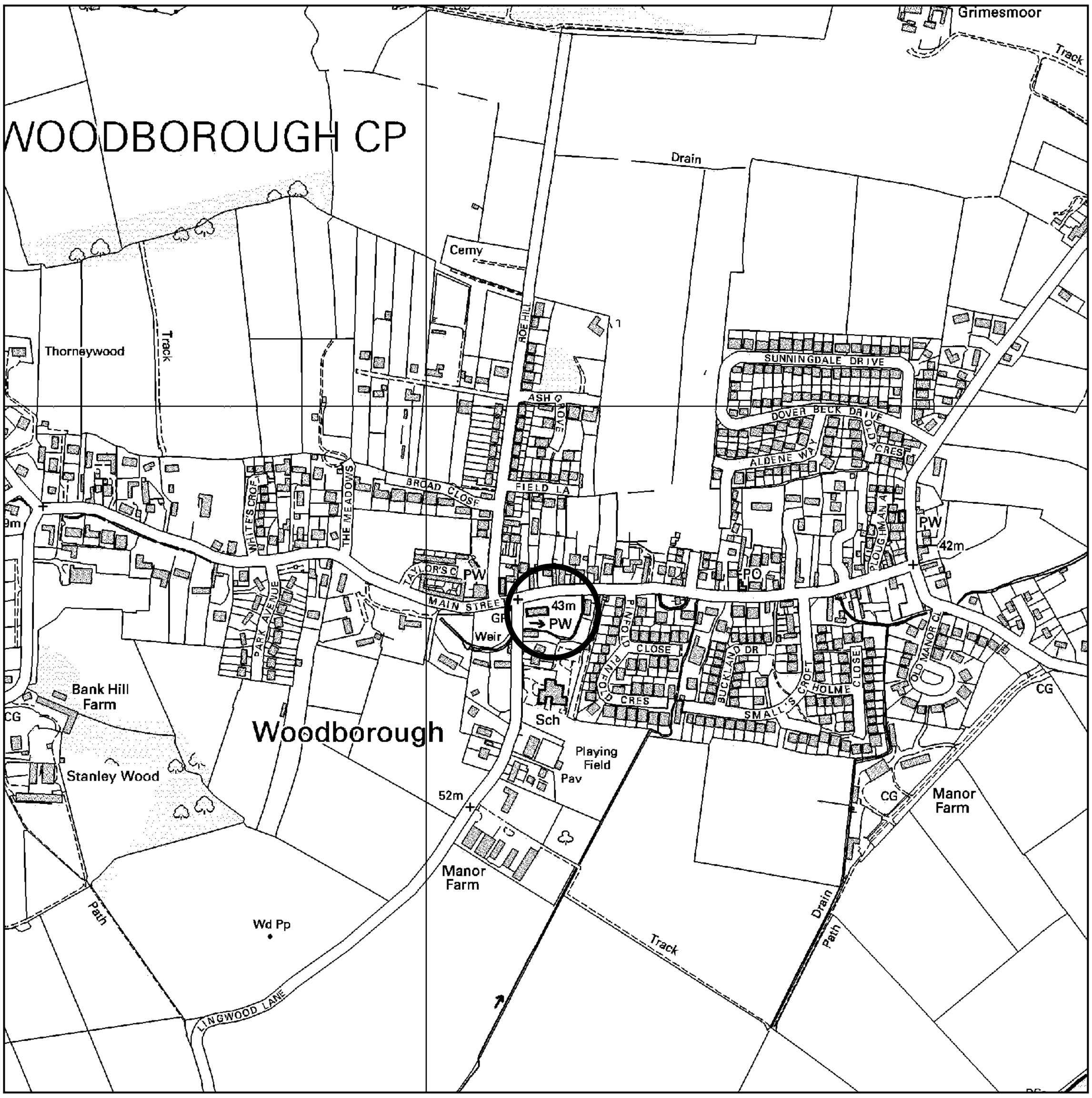


Figure 2: Map of Woodborough, with the general location of St Swithun's Church circled

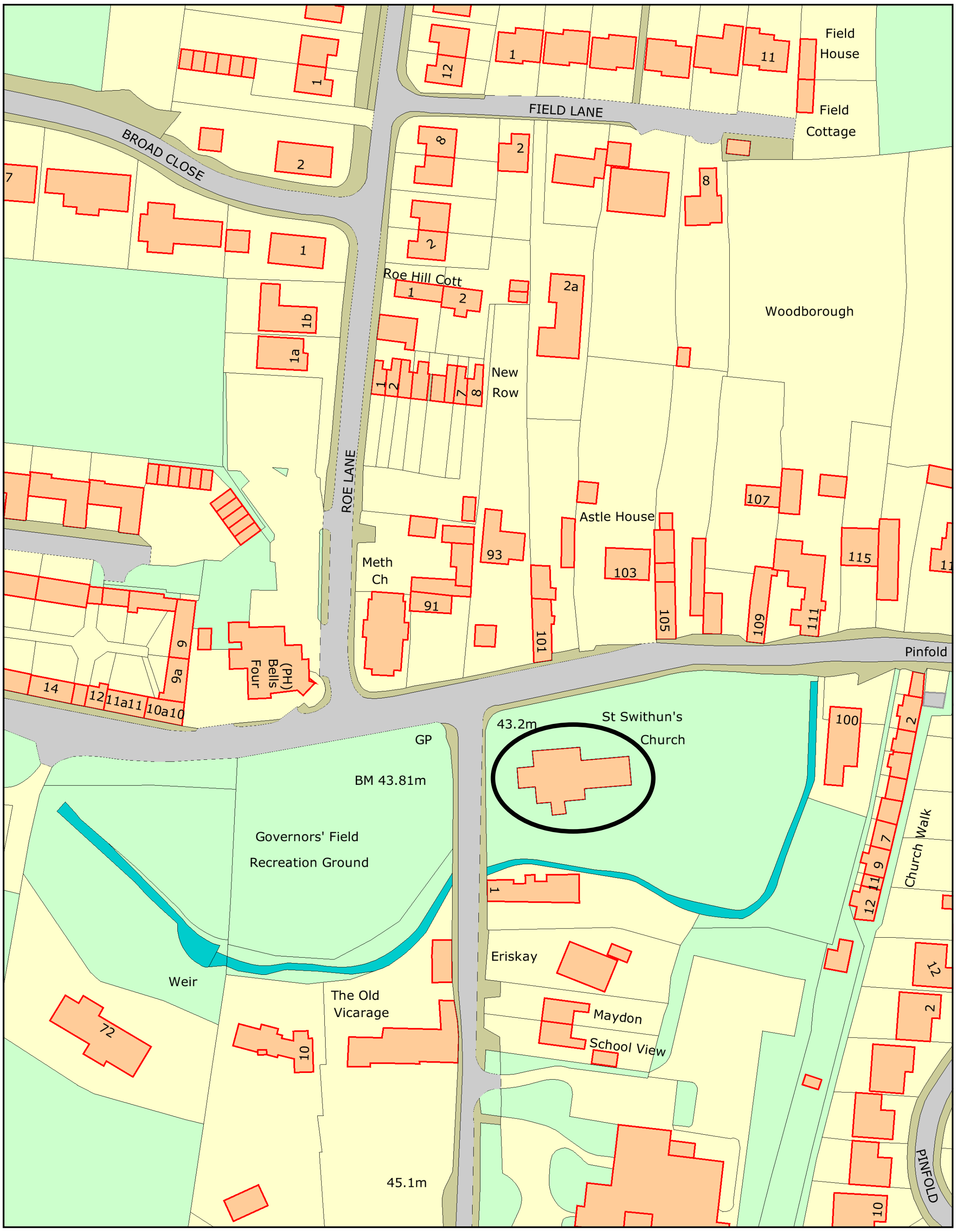
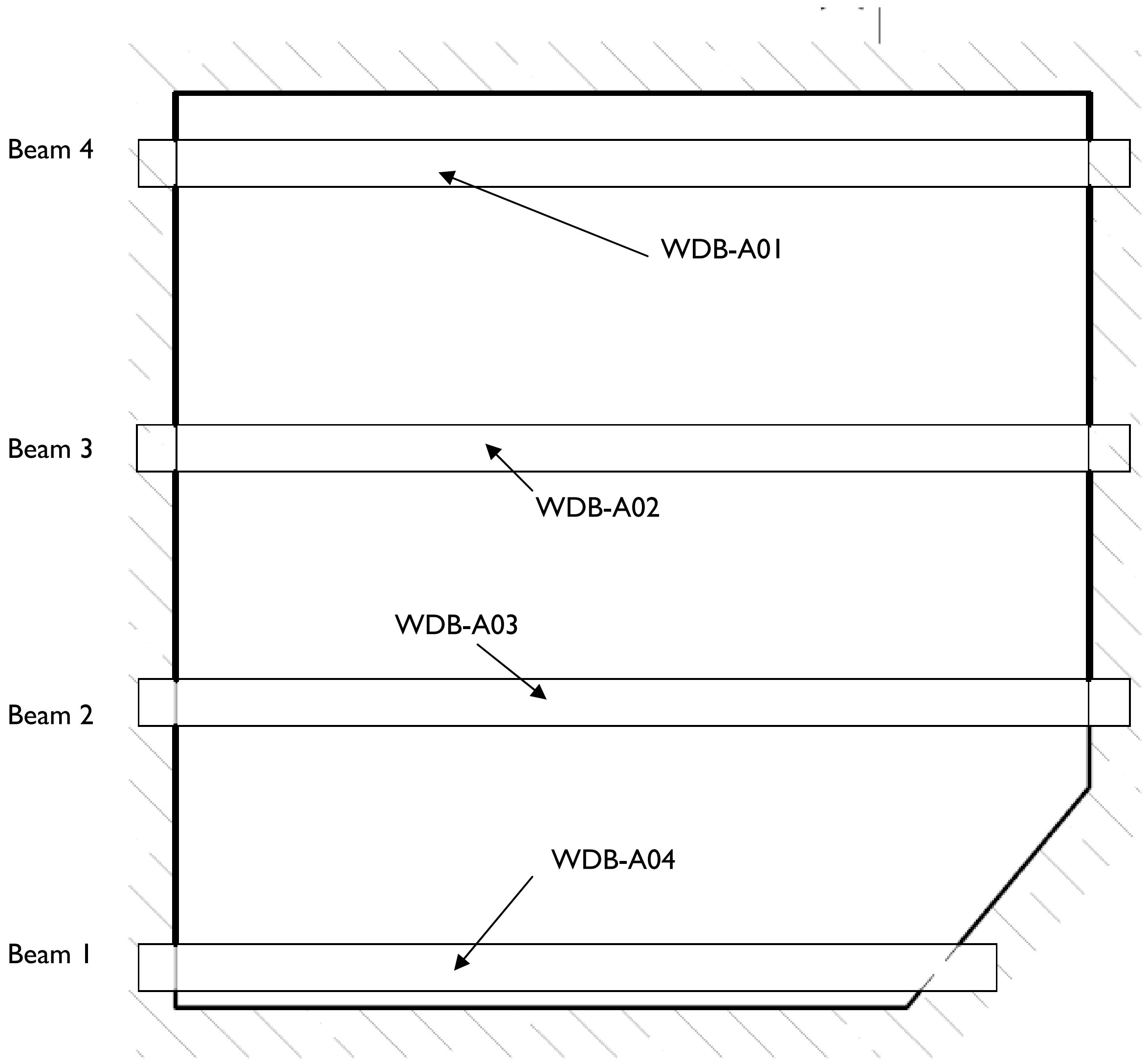


Figure 3: Map to show the location of St Swithun's Church (

Figure 4: St Swithun's Church, west tower

Figure 5: St Swithun's Church, bellframe

Figure 6: St Swithun's Church, belfry floor, beam 4 to the far left (as viewed from below)



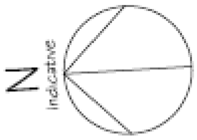


Figure 7: St Swithun's Church, sketch plan of belfry floor, showing the location of samples WDB-A01–04 (English Heritage)

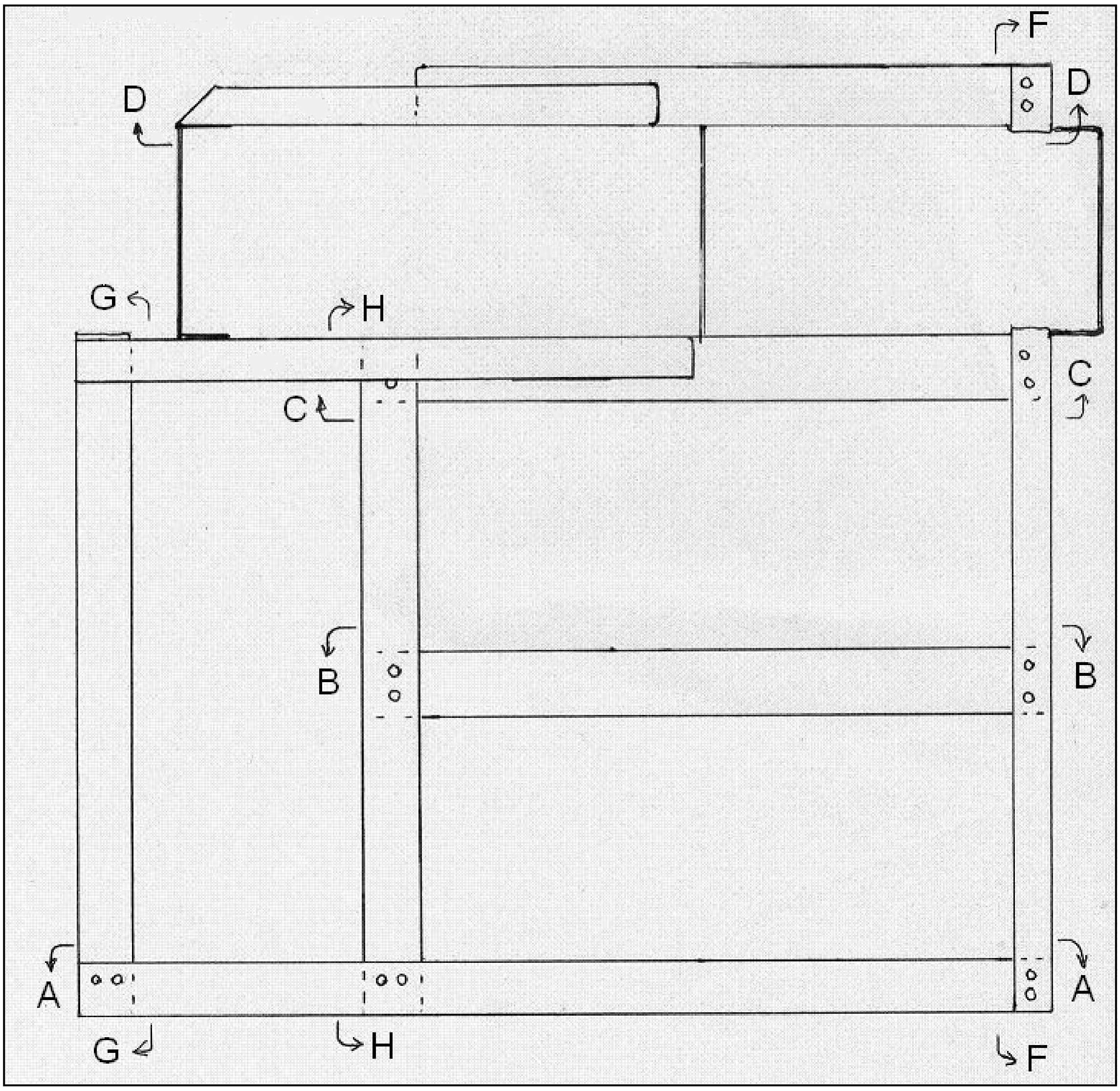


Figure 8: Plan at top cill level, indicating the locations of the trusses shown in Figures 9–15 (George Dawson)

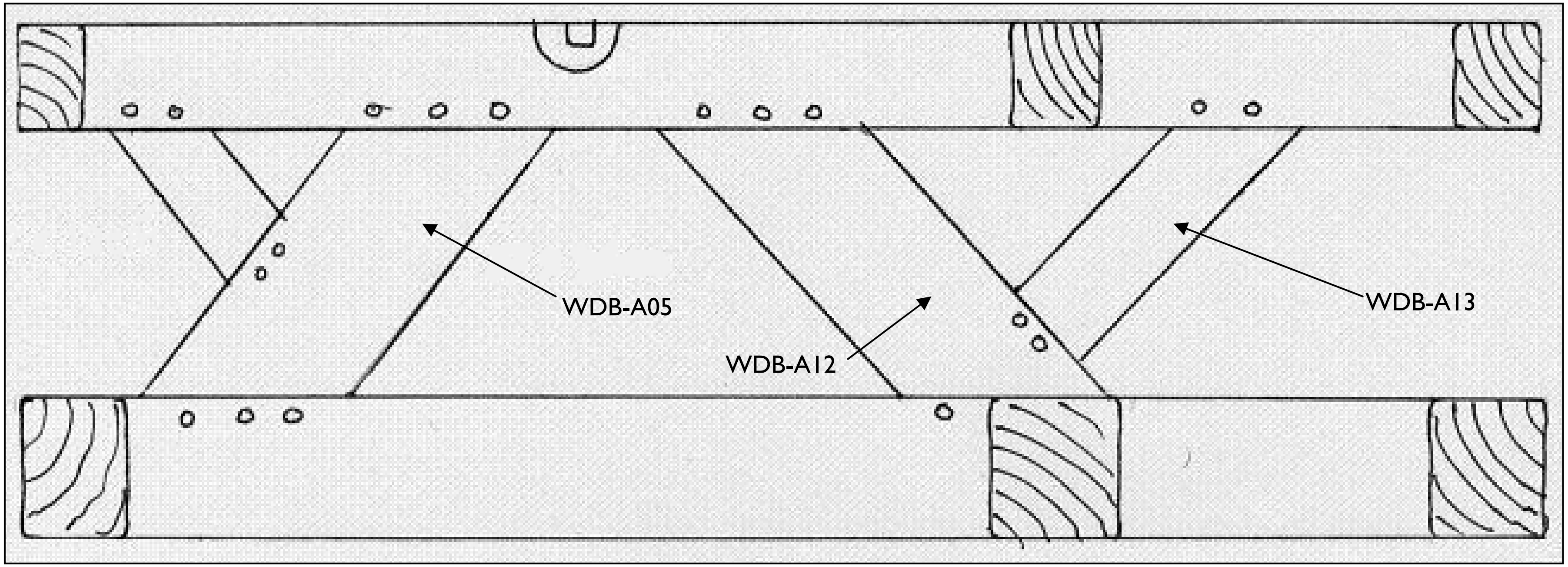


Figure 9: Truss A–A (south face), showing the location of samples WDB-A05, WDB-A12, and WDB-A13 (George Dawson)

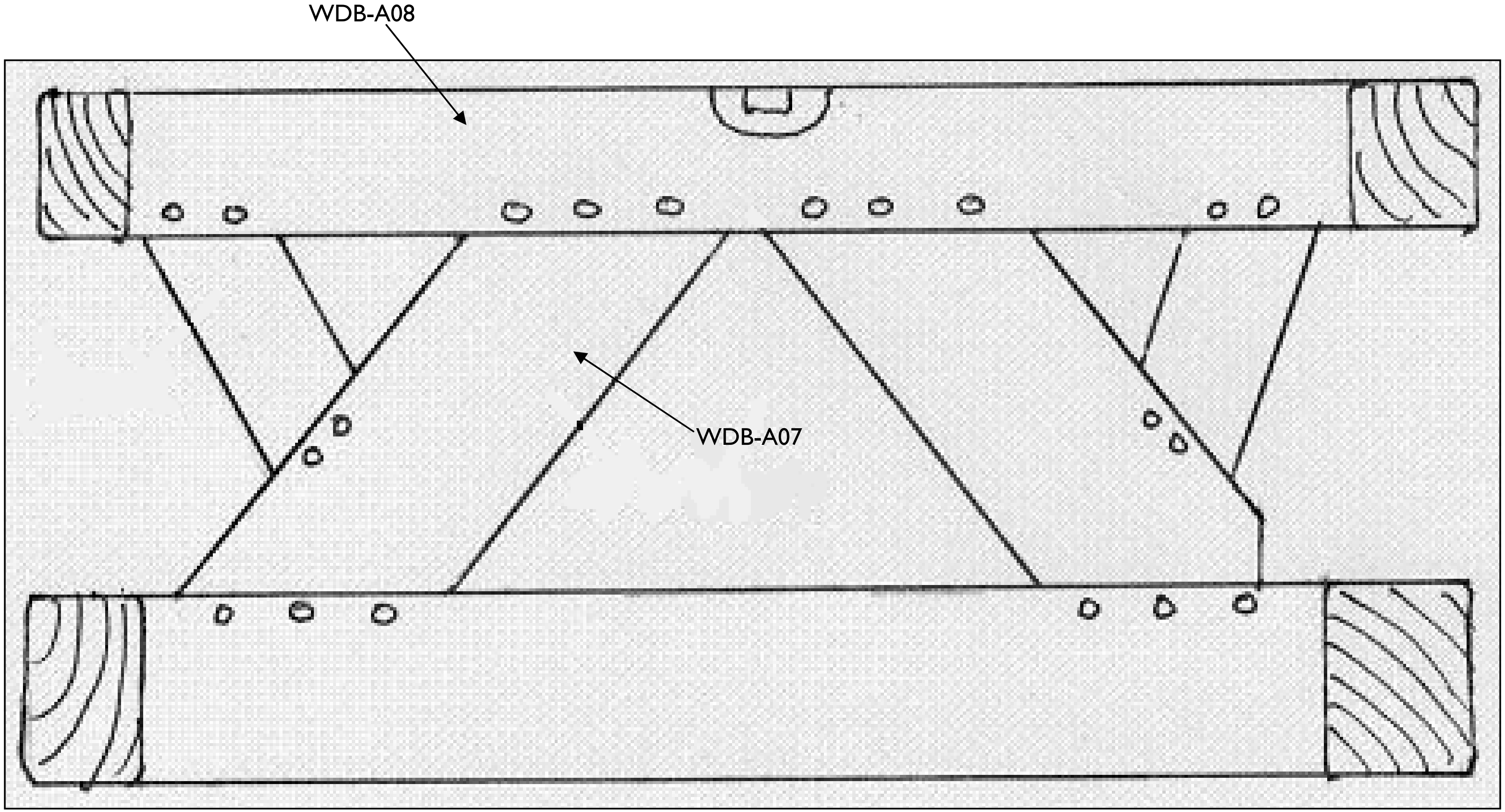


Figure 10: Truss B–B (south face), showing the location of samples WDB-A07 and WDB-A08 (George Dawson)

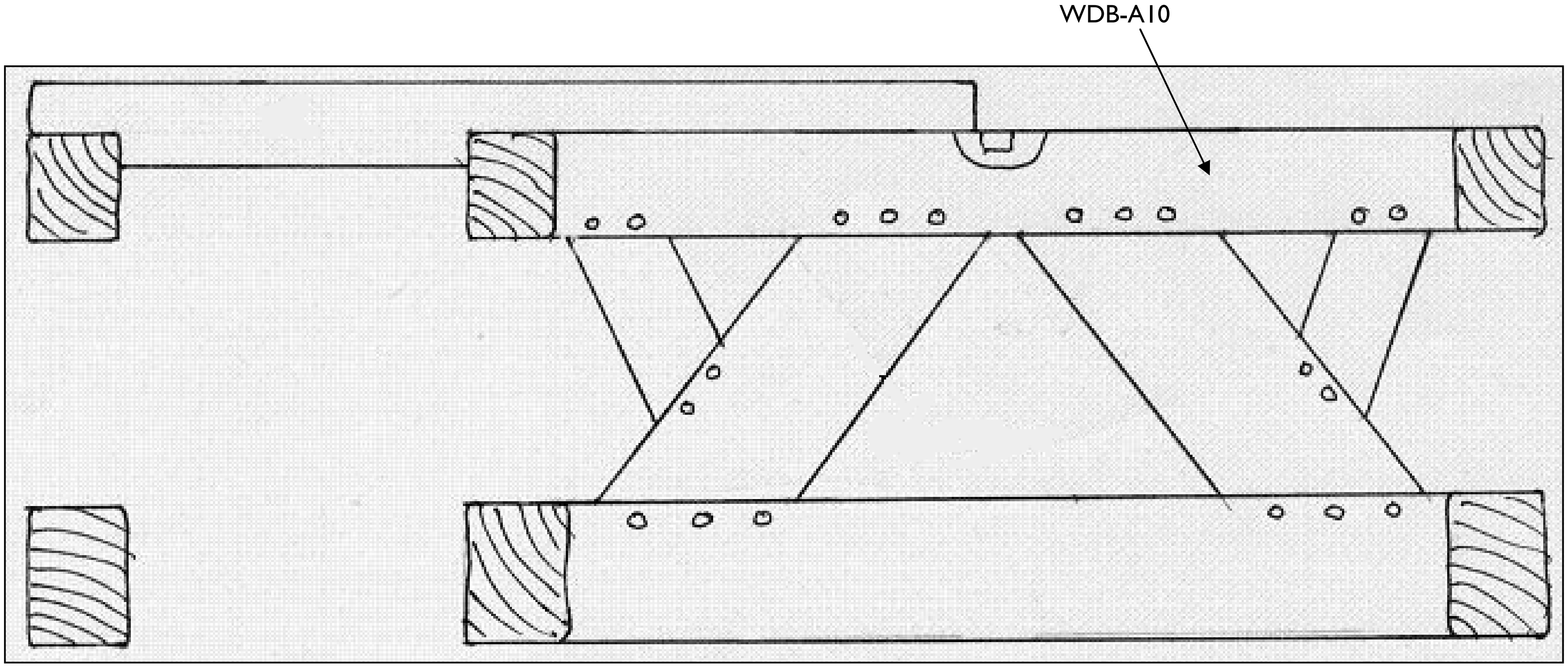


Figure 11: Truss C–C (north face), showing the location of sample WDB-A10 (George Dawson)

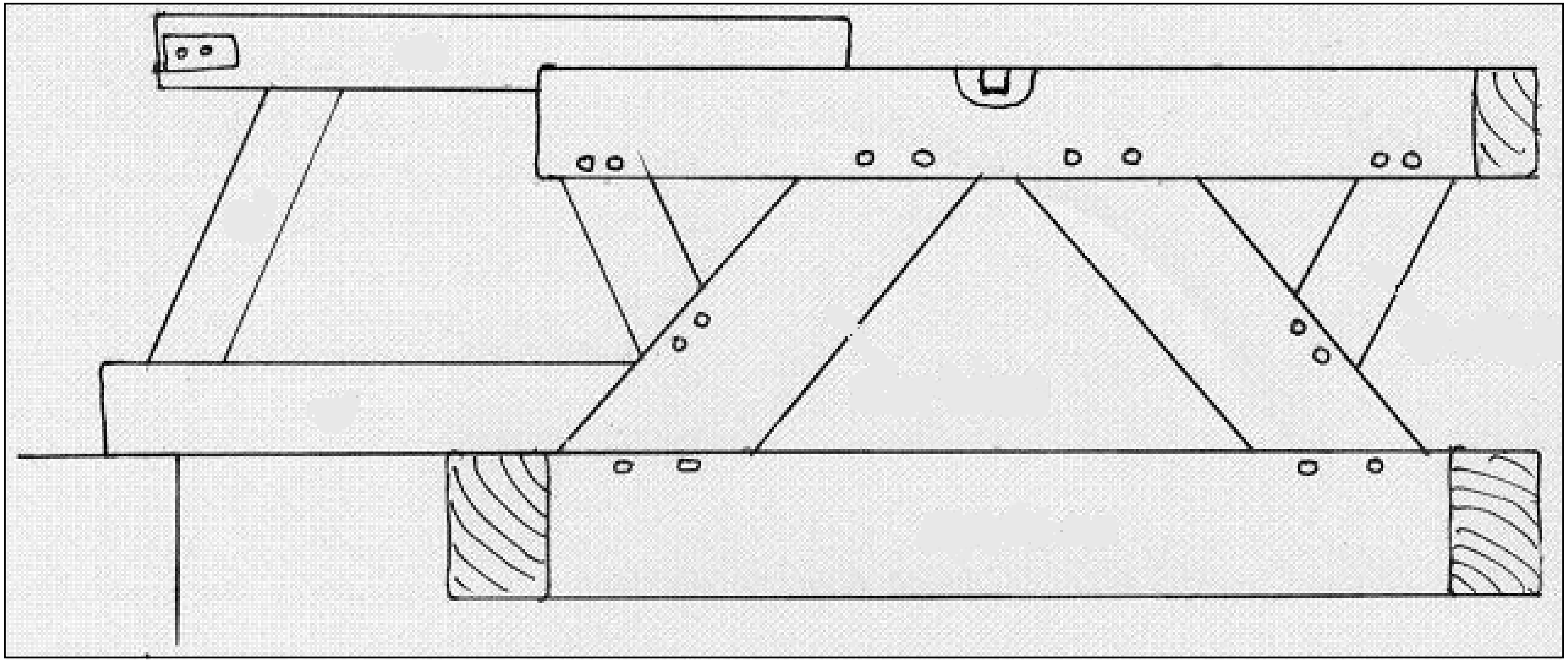


Figure 12: Truss D–D (north face) (George Dawson)

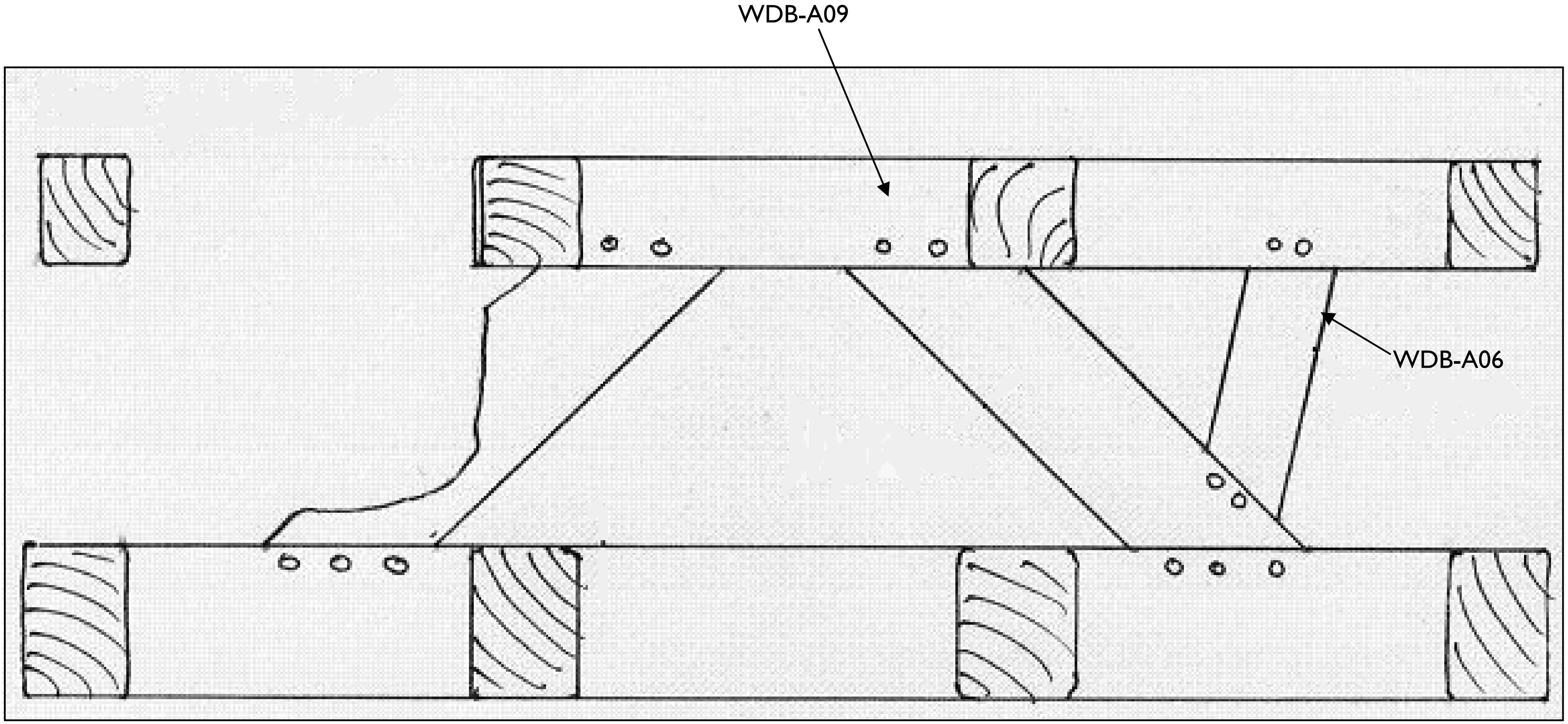


Figure 13: End gate F–F (east face), showing the location of samples WDB-A06 and WDB-A09 (George Dawson)

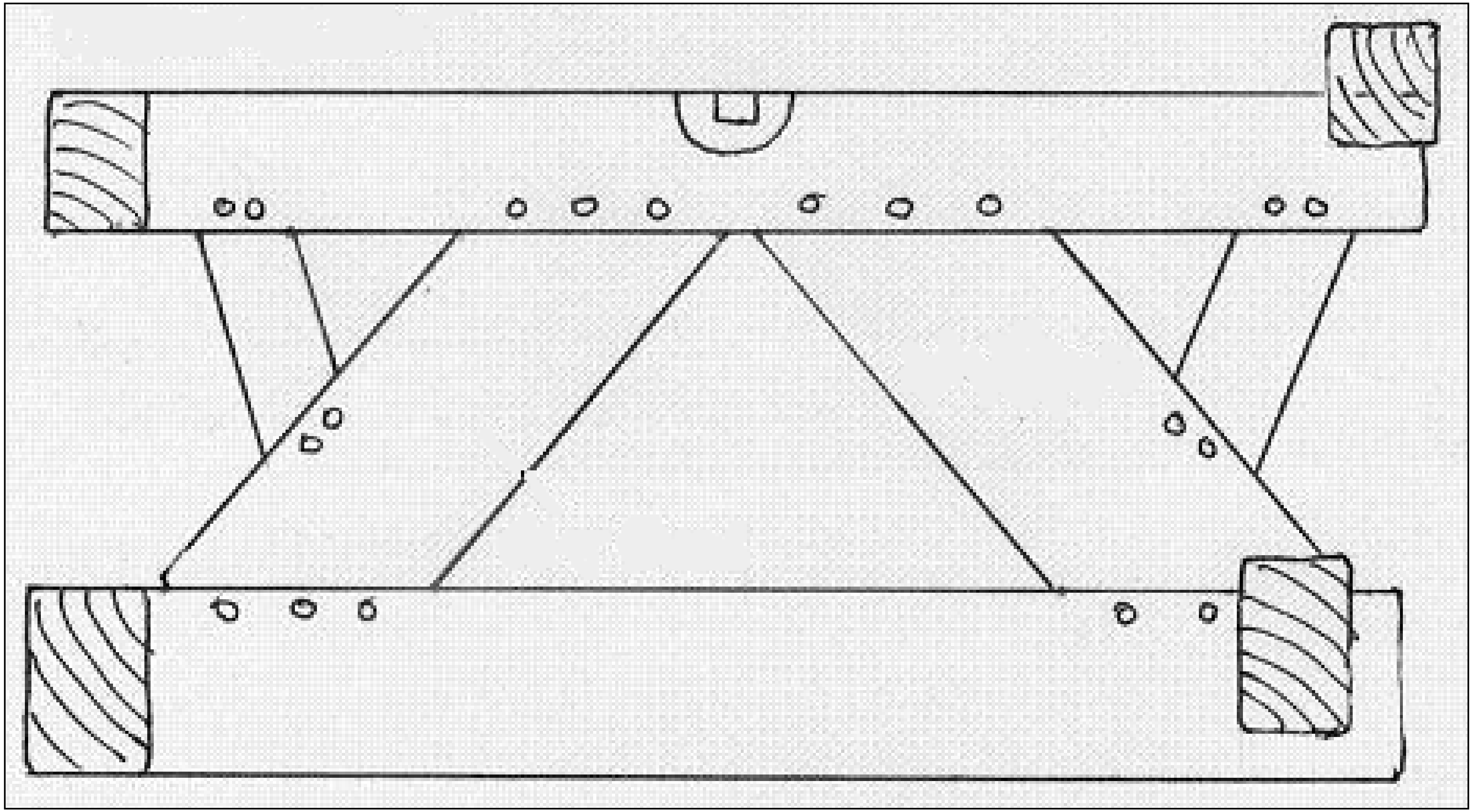


Figure 14: End gate G–G (west face) (George Dawson)

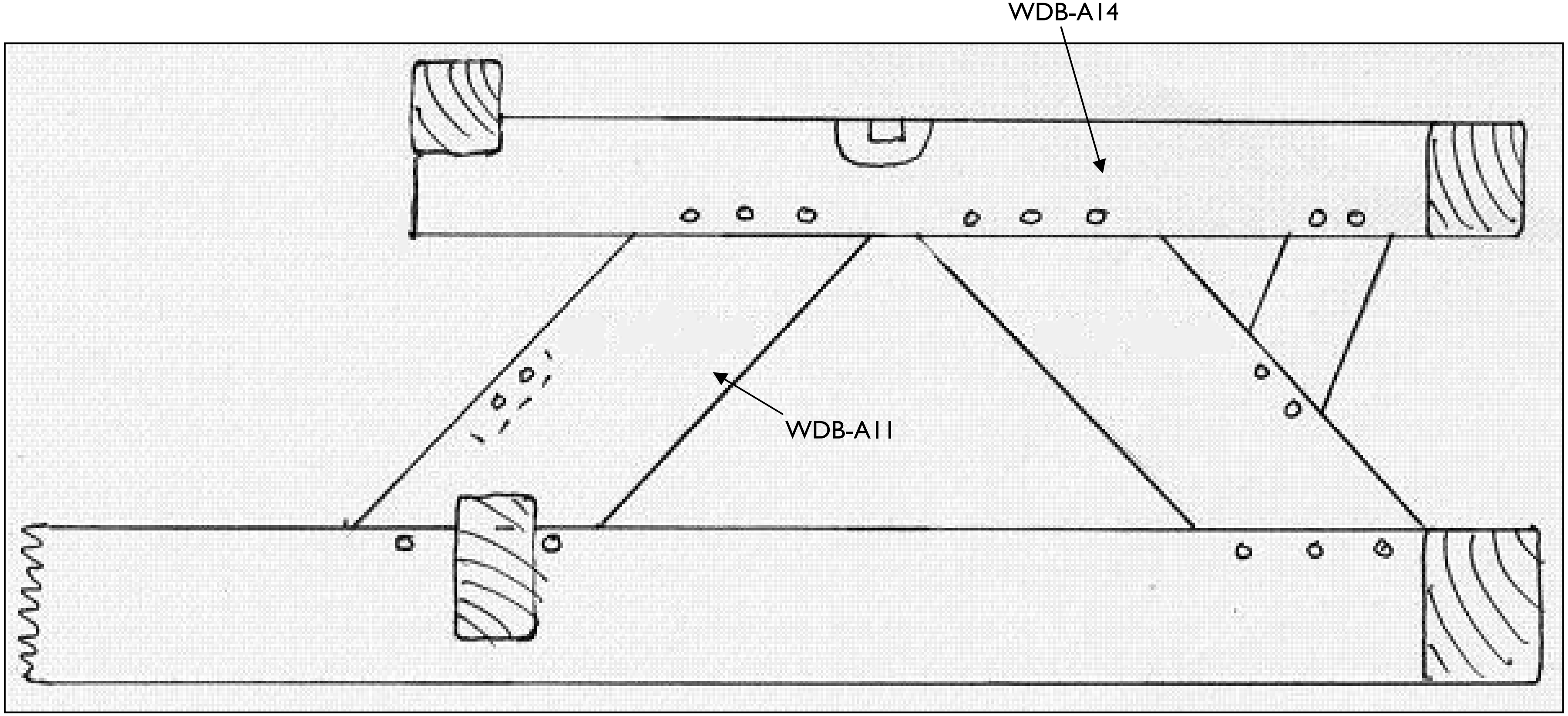
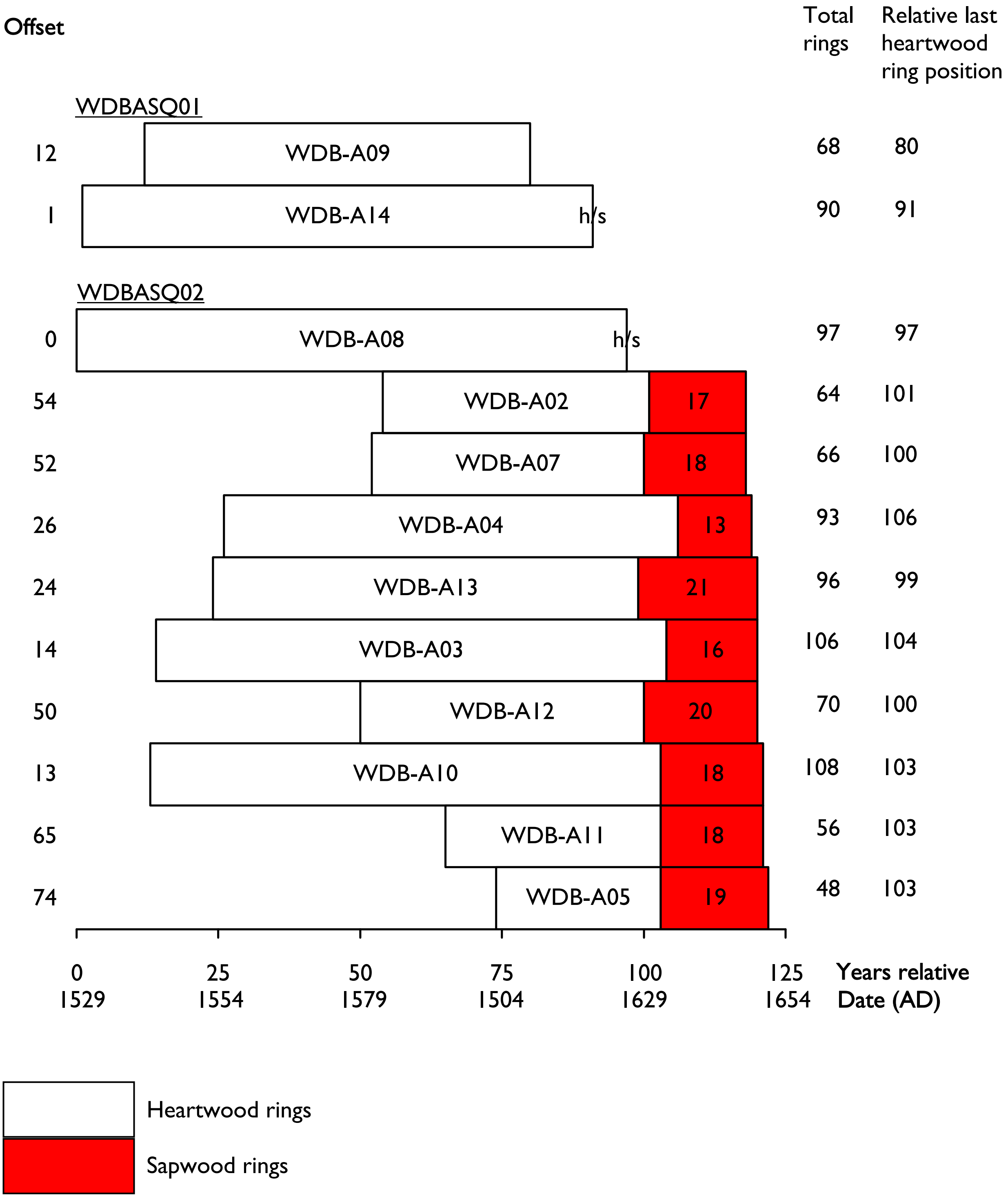


Figure 15: Truss H–H (east face) (George Dawson)



h/s = the heartwoods/sapwood boundary ring is the last ring on the sample

Figure 16: Bar diagram of samples in site sequences WDBASQ01 and WDBASQ02

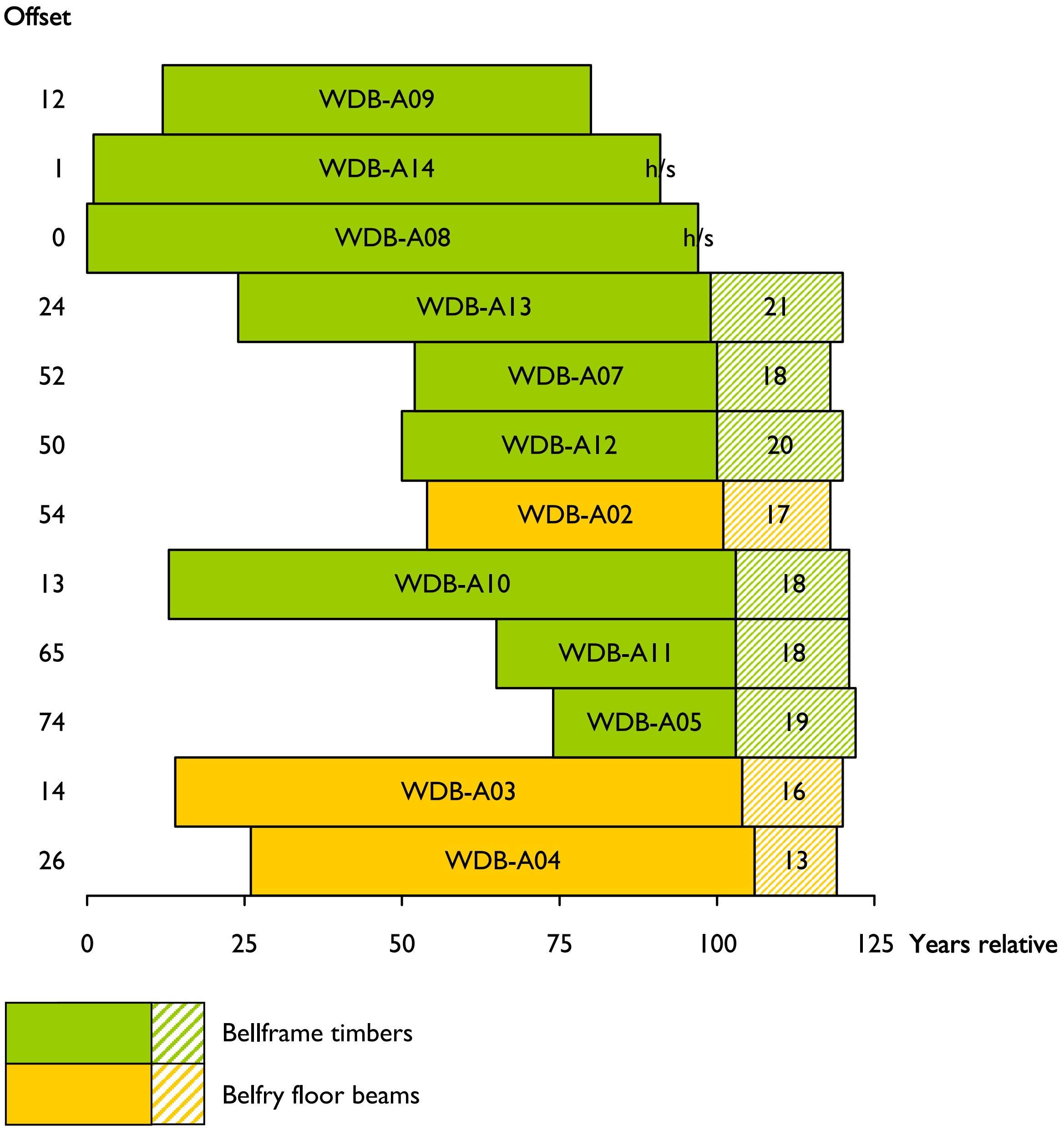


Figure 17: Bar diagram of all dated samples, sorted by heartwood/sapwood boundary ring position

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

```
WDB-A02A 64
 401 622 535 400 361 328 336 340 358 355 508 341 431 180 165 217 281 223 143 189
 250 231 248 256 195 285 304 189 259 240 214 216 232 249 279 261 284 315 270 358
 311 324 211 270 209 303 284 262 239 258 202 206 346 193 304 412 332 327 371 158
 190 233 213 273
WDB-A02B 64
 381 636 528 405 353 335 338 340 349 357 507 340 432 182 160 218 278 227 135 194
 254 229 244 259 208 271 311 194 255 240 218 215 225 255 271 268 278 313 268 352
 306 337 212 271 242 266 290 260 233 267 197 197 358 190 313 408 324 329 402 178
 206 246 199 270
WDB-A03A 106
 170 262 209 218 181 281 232 269 211 168 211 125 133  99 113 121 148 124 165 164
 141 105  84 129 171 229 225 318 391 353 266 281 138 124 176 175 290 440 223 261
 273 330 275 285 227 139 191 199 318 255 398 302 425 169 124 150 182 161 142 171
 225 213 183 229 157 247 247 158 206 213 191 194 200 162 270 250 244 309 222 245
 171 204 126 189 155 303 299 246 301 250 158 184 315 159 212 308 168 236 292 162
 150 196 249 273 226 173
WDB-A03B 106
 169 254 214 220 191 277 228 278 195 169 237 121 168 134 114 109 144 134 162 176
 134 104  96 102 169 232 228 342 389 332 289 294 149 124 171 176 281 449 219 266
 271 333 274 282 235 137 194 201 323 261 392 312 414 164 146 129 187 168 139 167
 231 221 192 224 159 246 249 162 207 224 179 200 201 165 268 257 241 304 224 253
 183 195 142 205 154 305 313 229 299 238 157 205 314 162 229 285 190 206 297 151
 181 196 228 273 210 217
WDB-A04A 93
 209 265 210 326 562 685 886 1011 913 539 298 387 384 441 438 321 484 369 296 207
 154 151 189 166 320 436 206 251 259 423 307 296 231 144 164 196 294 267 459 306
 366 168 178 212 210 171 130 159 222 308 332 330 239 298 256 148 239 245 208 261
 262 211 331 325 299 328 212 272 302 274 158 267 263 349 323 345 405 293 255 248
 307 126 256 274 253 283 249 156 220 178 228 295 179
WDB-A04B 93
 235 269 214 335 572 689 929 991 910 529 299 378 383 435 439 324 489 383 292 209
 150 148 195 164 326 430 204 247 266 413 301 313 221 133 176 188 297 268 454 317
 364 167 176 217 205 168 136 152 224 314 346 314 237 302 264 155 230 250 202 260
 267 198 334 321 295 336 209 274 310 267 155 278 253 352 323 342 407 310 241 248
 311 128 219 329 249 269 245 189 210 170 247 269 181
WDB-A05A 34
 288 406 227 262 382 194 229 207 216 433 517 360 539 274 337 252 347 217 426 256
 391 374 244 271 235 180 251 194 131 261 286 281 258 359
WDB-A05B 48
 326 213 305 411 252 273 300 221 256 263 224 238 229 161 293 302 237 289 213 283
 273 279 180 245 230 252 300 280 332 295 247 201 240 115 177 219 208 219 321 113
 153 135 135 201 187 233 243 171
WDB-A06A 56
 311 676 478 542 291 307 255 271 258 145 172 305 279 257 312 230 245 290 322 292
 253 275 189 156 246 132 265 300 219 330 251 288 365 252 205 204 272 239 406 303
 229 213 195 171 224 148 160 163 153 227 368 164 203 141 274 112
WDB-A06B 56
 325 703 480 539 297 307 251 255 268 135 173 303 273 263 209 247 250 301 341 341
 285 289 141 186 231 119 257 285 308 347 234 293 357 321 216 200 253 245 399 315
 226 208 200 168 234 147 154 173 158 238 363 174 203 164 200 173
WDB-A07A 66
 154 218 233 273 251 250 221 197 225 208 205 235 261 223 249 205 216 300 243 245
 197 190 183 215 209 221 227 233 228 254 231 230 228 189 165 181 171 227 173 195
 157 192 182 165 162 145 166 174 208 182 172 185 173 139 165 125 132 153 131 144
 194 116 144 122 125 120
WDB-A07B 66
 154 233 239 261 256 264 226 195 230 192 182 222 238 214 270 205 225 295 244 248
 194 177 185 210 227 229 237 236 221 242 224 248 215 195 151 177 184 216 156 196
 142 190 194 161 163 151 176 186 238 165 187 200 175 136 164 134 128 154 119 154
 195 122 148 109 122 150
WDB-A08A 97
 437 356 571 393 327 310 330 420 529 638 529 573 443 323 447 479 405 491 395 389
 318 334 354 275 348 274 285 148 164 231 267 215 213 226 221 193  95 113 110 124
 140 147 220 190 183 218 185 145 119 104 165 165 140 108 137 185 202 196 197 182
 196 188 210 225 262 249 276 207 190 206 178 170 141 111 101 134 113 160 162 128
 111 131 140 168 195 175 161 113 151 164 173 175 148 122 120 107 127
```

```
WDB-A08B 97
 418 359 471 383 333 320 324 420 512 684 545 547 444 347 427 506 390 497 377 384
 273 360 341 264 328 262 301 148 159 222 282 228 196 218 219 205 111 111 109 126
 143 143 222 167 198 207 191 145 125 109 146 172 148 107 139 215 205 188 197 178
 211 181 207 225 271 248 276 214 187 218 185 172 135 110 108 125 133 161 166 128
 116 131 142 163 207 176 157 122 150 161 162 187 138 115 126 118 117
WDB-A09A 68
 410 295 330 322 356 332 278 374 428 500 489 436 487 440 460 435 279 384 396 340
 372 311 336 302 261 244 229 367 237 331 197 285 229 212 167 180 227 199 215 247
 225 162 213 243 246 254 164 180 192 219 182 256 273 280 362 281 286 344 324 307
 194 237 249 261 247 307 209 265
WDB-A09B 68
 434 272 331 317 346 324 272 382 422 483 475 442 484 436 461 432 284 383 395 341
 368 298 339 316 269 252 229 366 231 329 197 304 234 205 158 184 229 195 211 247
 218 169 221 233 249 241 171 155 208 213 206 256 267 278 359 289 290 334 330 294
 192 234 249 273 234 287 214 269
WDB-A10A 92
 323 435 461 322 433 361 435 393 317 345 357 425 283 312 245 226 214 313 273 293
 319 245 257 156 172 189 233 157 184 289 245 213 268 196 159 168 132 195 236 176
 135 182 207 236 225 186 181 204 207 225 219 271 266 260 164 190 199 202 169 167
 146 164 204 154 165 225 172 136 169 199 140 172 158 178 164 165 208 178 179 142
 129 142 126 127 158 135 141 167 131 173 143 135
WDB-A10B 57
 181 248 206 165 149 182 190 195 169 148 167 220 176 192 235 171 163 166 168 163
 200 167 198 160 122 179 152 156 115  97 118 101  96 106 109 102 132  94 112 109
  63  70 100  88 105 135 135 131 163  91 102  96  96 131 104 109  51
WDB-A11A 56
 233 388 180 182 267 254 163 127 151 189 264 251 328 236 287 295 171 270 284 177
 255 242 156 287 219 269 287 219 324 288 280 196 318 329 372 302 310 440 312 239
 228 280 118 195 263 236 244 332 127 199 172 210 252 182 294 165
WDB-A11B 56
 254 366 163 191 261 256 164 125 146 176 247 276 321 229 286 278 170 233 265 203
 234 224 164 296 310 263 284 222 315 281 297 198 319 316 377 306 299 443 317 235
 220 288 116 194 262 230 253 342 149 182 159 224 252 196 294 204
WDB-A12A 70
 706 913 348 530 506 676 479 314 317 278 308 341 472 324 426 405 450 217 241 324
 357 226 145 201 360 264 236 245 211 264 393 214 243 287 201 217 195 169 319 240
 237 297 220 201 187 201 145 208 158 216 230 223 295 249 196 169 292 154 158 198
 200 231 245  81  97 182 240 245 241 166
WDB-A12B 70
 754 921 347 481 509 657 467 317 319 278 301 355 452 316 421 394 458 211 254 328
 360 240 140 212 352 262 244 232 220 273 396 213 244 283 205 221 192 171 319 242
 234 297 221 199 193 201 147 199 167 216 227 233 292 260 192 161 309 145 168 198
 208 222 252  80 113 172 243 233 233 177
WDB-A13A 96
 404 263 226 172 134 192 260 238 305 309 284 198 109 109 127 159 160 184 311 178
 187 187 195 137 137 112 138 177 160 132 153 223 222 212 260 225 234 255 280 215
 321 249 338 241 230 211 205 165 130 103  79  94  94 139 146 138 103 120 118 128
 139 155 165 112 120 146 154 144 112 102 106 100  74  94 107  86 100  99 117  89
  70  81  83  84 115 154  90 104  99  90 100  80 111 122  86  98
WDB-A13B 96
 390 268 206 163 143 183 274 245 313 311 255 218 105 121 119 156 154 193 320 179
 176 196 199 135 138 112 135 176 148 133 160 217 215 223 259 230 233 251 276 269
 337 263 343 229 236 207 214 179 124 101  82 100  93 139 152 139 119 124 114 125
 143 160 164 113 105 137 159 147 110  95 109  99  81  89 106 105  85  95 110  87
  65  72  82  80 125 144 121  84  99  83  94  91 113 104 104  83
WDB-A14A 90
 400 395 354 329 327 380 353 405 366 368 481 410 226 346 313 359 330 300 440 453
 448 392 331 370 339 334 326 304 335 358 316 308 313 302 318 238 286 272 320 258
 353 253 281 321 206 210 232 247 231 249 283 249 229 243 281 257 256 248 203 238
 236 199 242 249 213 316 231 275 327 269 275 208 199 231 277 260 310 277 259 237
 293 265 245 241 213 220 235 216 286 183
WDB-A14B 90
 391 406 344 342 324 384 347 406 371 371 475 425 224 342 319 351 333 313 428 449
 450 418 351 357 334 343 324 302 333 373 320 327 320 302 319 242 275 287 300 261
 335 260 282 322 224 186 233 250 220 251 279 255 217 245 289 265 257 236 213 226
 225 195 256 244 229 311 242 272 317 283 276 210 206 219 281 263 307 281 258 228
 300 260 250 237 221 215 228 216 285 204
```

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,

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

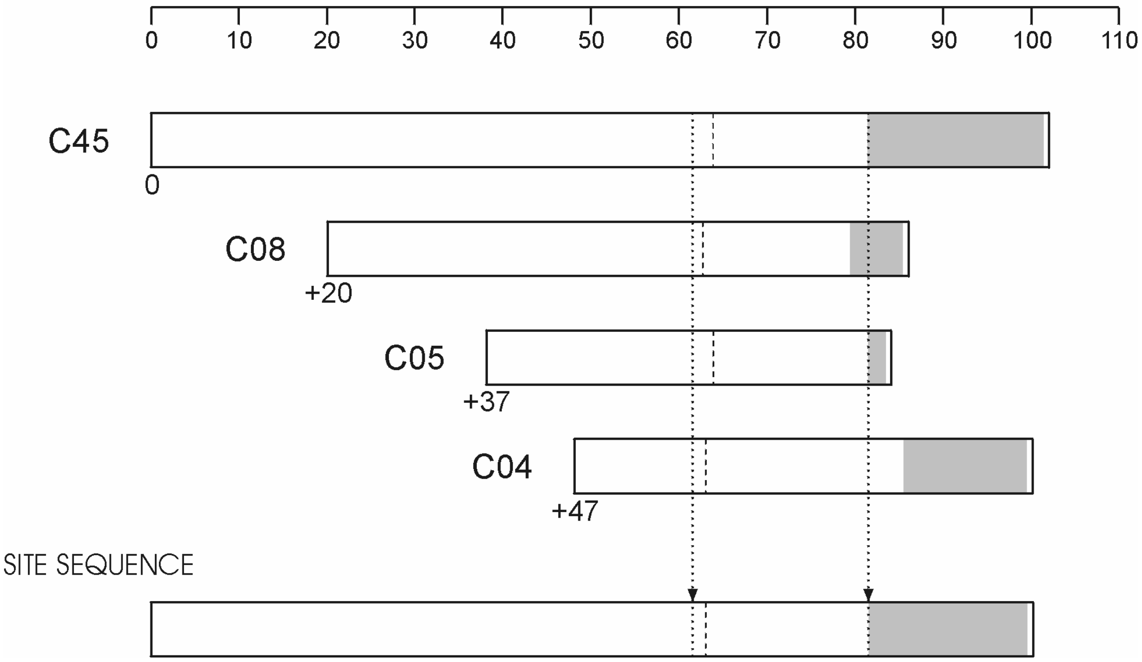


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

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

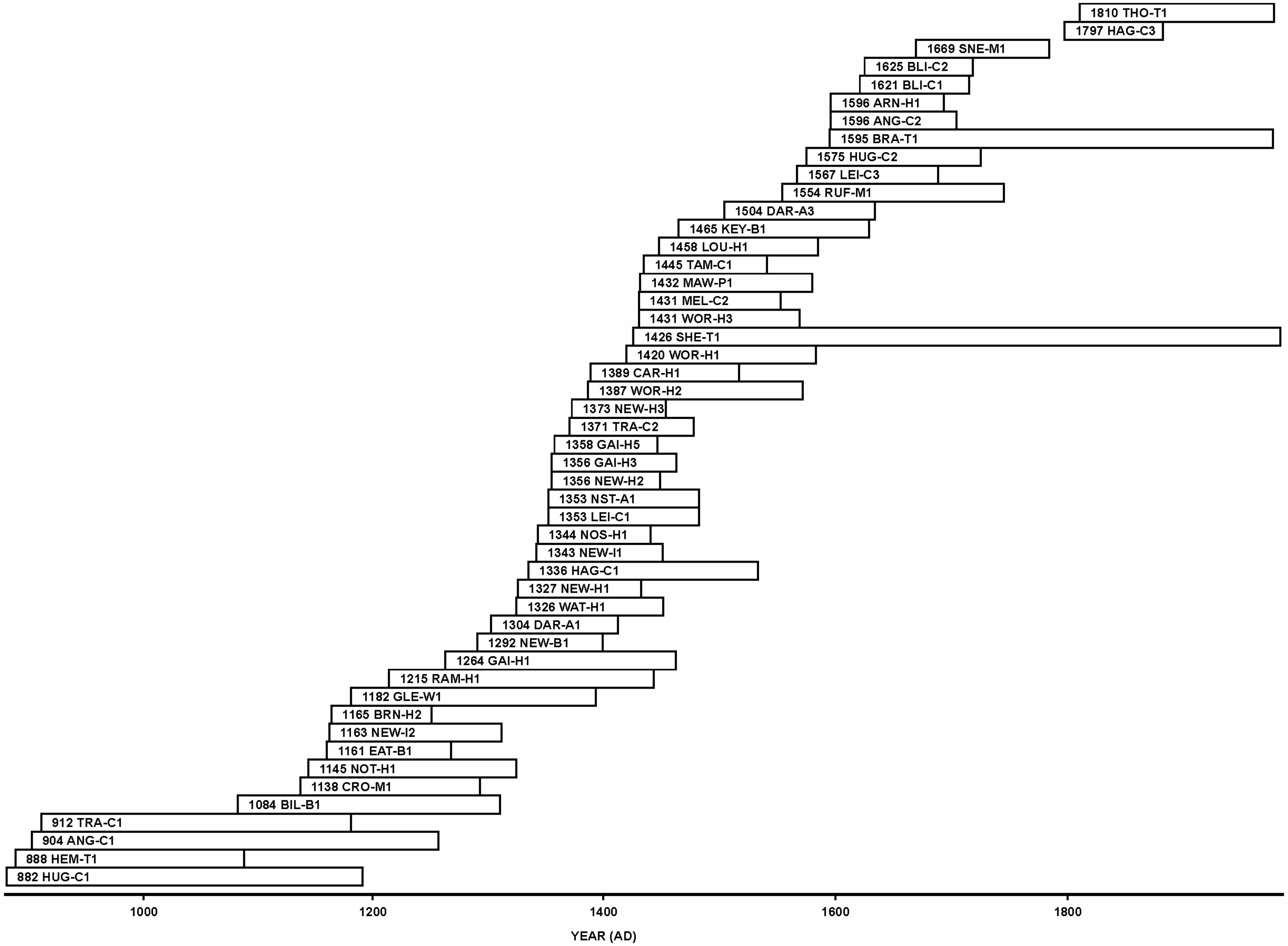
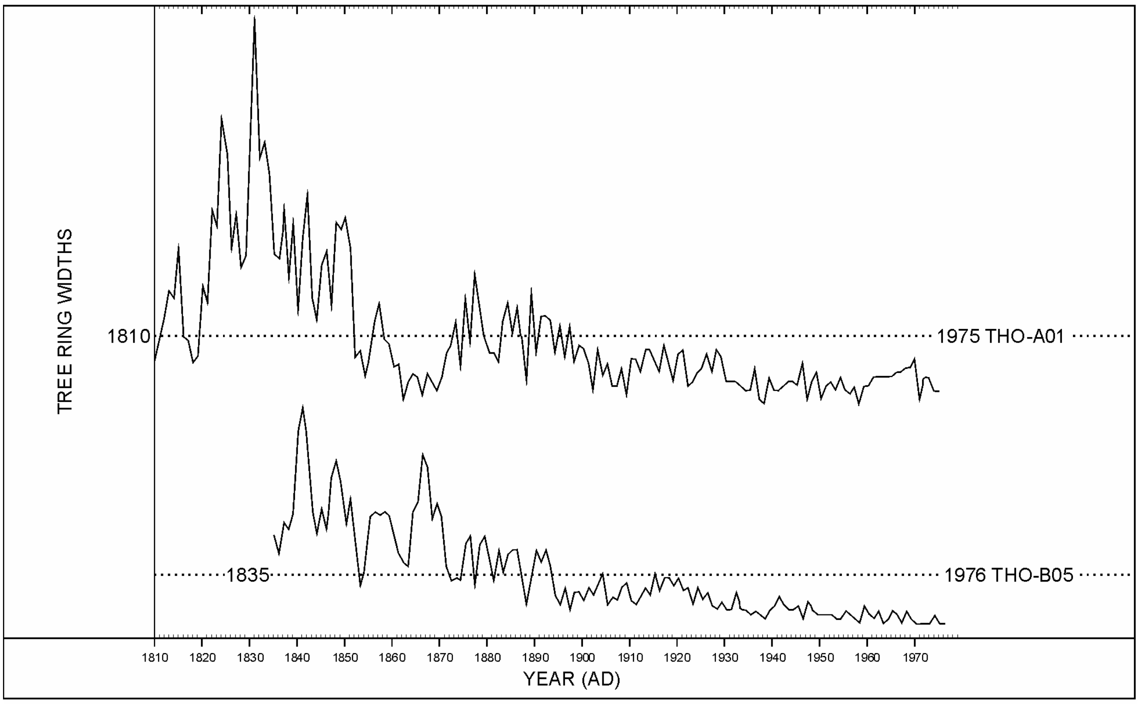


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

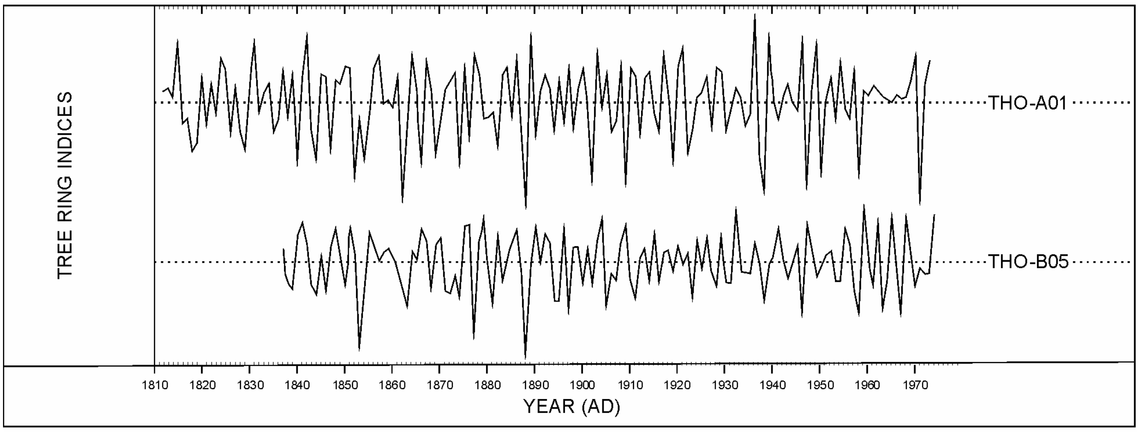


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

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

(i)

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

Laxon, 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