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Summary

Twenty samples from various parts of Maison Dieu, Ospringe, were analysed by tree-ring dating. This analysis produced two site chronologies. The first, consisting of eight samples, has 89 rings but it did not cross-match with any reference chronologies. Although it is undated, the cross-matching of the samples, and the relative positions of the heartwood/sapwood boundaries on the samples within it strongly suggest that the timbers they represent are all of a single felling phase.

The second site chronology, composed of four samples, has 65 rings, and is dated as spanning the period AD 1388-1452. Interpretation of the sapwood boundary on the samples in this site chronology gives an estimated felling date in the range AD 1462-1482.

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Introduction

Maison Dieu at Ospringe lies alongside the main A2 trunk-road running from London to Canterbury (TR 003608; Fig 1). The house incorporates parts of a building formerly belonging to the Hospital of Blessed Mary of Ospringe, commonly known from its earliest days as God's House, hence its name, Maison Dieu. It was one of a particular concentration of such medieval establishments along Watling Street, in Kent. These catered for pilgrims traveling to and from the shrine of St Thomas a Becket at Canterbury, an activity that grew after his re-enshrinement in AD 1220. The establishment at Ospringe was staffed by Brethren of the Holy Cross, living under the rule of the Augustinian order. Whilst their duties were mainly spiritual they did also attend to medical needs as well as providing general hospitality to pilgrims.

The earliest record of Maison Dieu is for grants of corn and building materials by Henry III in AD 1234. A charter was granted in AD 1246 and there are a dozen or so other thirteenth-century references to the site. At its height it comprised a substantial collection of buildings on both side of Watling Street. A plan of the site, taken from the English Heritage guide (Rigold *et al* 1985), is given in Figure 2. The fourteenth century, however, saw a gradual decline of the establishment, with high costs and expensive maintenance, bad stewardship and the demands made on it by various monarchs. A number of commissions of inquiry made investigation of the running of the house, but no practical change was made and when the last brethren died in AD 1470 he was not replaced. In AD 1516 the Bishop of Rochester obtained the dissolution of the hospital and its revenues were added to the newly founded St John's College, Cambridge. To this day the College owns part of the hospital lands and the patronage of its living at Headcorn, Kent.

Some time after AD 1547 the site was leased to Robert Streynsham. Some of the buildings were demolished about this time, their materials being used to build a new house. Part of the existing structure was turned into a shop in AD 1894. In 1947 the building passed to the State and then into the care of the Historic Buildings and Monuments Commission for England.

Only the two substantial fragments of the hospital remain, on the south side of the A2, these being subsidiary buildings of the main complex which was on the north side of the road. Only the building to the west of Water Lane is in custodianship, being grade II* listed and a scheduled ancient monument, and it is this portion which is the subject of the current dendrochronological investigation.

The house is jettied on two sides, the north and the east. Within are two halls, one on the ground floor, the other upstairs. The upper hall has a good example of a king-post roof, a type widely used in south-eastern England from the early-fourteenth century until the middle of the sixteenth century. The coupled rafters are each joined by short collars toward the top and the collars of each couple are linked by a collar purlin. Plans of the building are provided in Figure 3

Sampling and analysis by tree-ring dating of timbers from Maison Dieu was commissioned by English Heritage. The purpose of sampling was to establish the construction date of the main building and to establish the date of fireplaces, which were believed to be insertions of the sixteenth century. A further purpose of analysis was to establish or confirm the date of a southern wing of the building and to confirm the dating of work currently believed to be of seventeenth-century date.

The Laboratory would like to take this opportunity to thank all those who assisted with the sampling of the timbers. In particular thanks are due to Mr and Mrs Friar, custodians of the site, who were most helpful and hospitable during sampling. We would also like to thank Paul Roberts of English Heritage who is recording this building and who assisted with the interpretation of the site prior to sampling.

Sampling

The timbers within this site were initially assessed with Mr Paul Roberts as to their suitability for tree-ring analysis in relation the phases of construction for which dating was required. All the timbers of the southern wing were quite unsuitable, having very wide, and thus relatively few, growth-rings. The timbers of the main part of Maison Dieu also had slightly wide rings but enough timbers had sufficient rings to make sampling worthwhile. Within the main part of the building various fireplace timbers were also available for sampling.

A total of twenty different oak timbers were sampled by coring. Each sample was given the code OSP-A (for Ospringe, site "A") and numbered 01–20. Five samples, OSP-A02-5 and OSP-A17, were obtained from timbers of fireplaces believed to have been inserted in the sixteenth century or to belong to seventeenth-century repairs. Fourteen samples, OSP-A06-16 and OSP-A18-20, were obtained from timbers that were believed to date from the original building. The date of the timber of the undercroft, sampled as OSP-A01, was uncertain.

The positions of these cores were recorded at the time of sampling on plans provided by English Heritage. The are reproduced here as Figure 4a/b. Details of the samples are given in Table 1. In this table the timbers have been identified and numbered from either east to west, or from north to south.

Analysis

Each sample was prepared by sanding and polishing. One sample, OSP-A19 was found to have too few rings for satisfactory analysis and it was not measured. The growth-ring widths of the remaining nineteen samples were measured (data provided at the end of this report) and compared with each other by the Litton/Zainodin grouping procedure (see appendix). At a minimum t-value of 4.5 two groups of samples formed.

The eight samples of the first group cross-matched with each other at relative positions as shown in the bar diagram Figure 5. The growth-ring widths of the nine samples were combined at these relative off-set positions to form OSPASQ01, a site chronology of 89 rings. Site chronology OSPASQ01 was compared with a series of relevant reference chronologies for oak, but there was no satisfactory cross-matching

The four samples of the second group cross-matched with each other at relative positions as shown in the bar diagram Figure 6. The growth-ring widths of these four samples were combined at these relative off-set positions to form OSPASQ02, a site chronology of 65 rings. Site chronology OSPASQ02 was compared with a series of relevant reference chronologies giving it a first ring date of AD 1388 and a last measured ring date of AD 1452. Evidence for this dating is given in the t-values of Table 2.

The two site chronologies were compared with each other, and with the remaining ungrouped samples. In neither case was there any satisfactory cross-matching. Each of the six remaining ungrouped samples was compared individually with a full range of reference chronologies, but again there was no satisfactory cross-matching.

Interpretation

Due to the lack of cross-matching it is not possible to give an estimated felling date range for the timbers represented by site chronology OSPASQ01. However, the cross-matching between the individual samples, and the relative position of the heartwood/sapwood boundary would suggest that all the timbers are of a single felling phase.

The average last heartwood ring date of the samples in site chronology OSPASQ02 is AD 1447. The usual 95% confidence limits for the amount of sapwood on mature oaks from Kent is in the range 15 - 35 rings. This would give this group of timbers estimated felling dates in the range AD 1462-1482.

The timbers in site chronology OSPASQ01 are mostly joist timbers. Not all these timbers are visible for their entire length, though those which are do not show any signs of reuse by way of redundant mortises etc. Two samples in this site chronology, OSP-A02 and A03, are from lintels. While not showing any evidence for reuse, it is quite possible that they are in secondary positions.

The timbers represented by site chronology OSPASQ02 are joists, a lintel and a doorpost. Again there is no evidence for reuse in any of these timbers, although in each case this is a possibility.

The lack of cross-matching between the two site chronologies might suggest that the timbers represented came from different sources. It is also possible that the timbers were felled at different times. It is possible the undated samples are from an area unrepresented by the existing reference chronologies for Kent.

Conclusion

In this instance tree-ring analysis has failed to achieve most of its stated purposes. It was not possible to analyse timbers from the southern gallery, nor to date a large number of samples from the main phase of construction, nor confirm or disprove the date of the supposed seventeenth-century work.

However, it is possible to show that one, undated, group of timbers are contemporaneous with each other, all of them probably being felled at the same time. This is the case with some of the jetty joists from the north and east sides and two of the fireplace lintels.

A second, dated, group of timbers, two other jetty joists from the north side, a doorpost and a fireplace lintel, are also contemporary with each other. These timbers have an estimated felling in the later fifteenth century, a date slightly at odds with that expected on stylistic and documentary ground.

It is impossible to say whether or not the two groups of timbers are contemporary with each other. The lack of cross-matching between the two groups does not necessarily mean that the timbers are of different dates.

The lack of dating for site chronology OSPASQ01may in part be due to the fact that the sampled timbers have relatively few rings and show a rather erratic growth pattern. It is also a possibility that *if* the timbers were felled from the mid-sixteenth century onwards, there is very little reference material from Kent available for that time.

The cross-matching and dating for the samples of site chronology OSPASQ02 is highly localised; all the satisfactory cross-matches are against reference chronologies from Kent. The t-values dating the four samples are relatively low and may be due to the site chronology having only 65 rings.

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Table 1: Details of samples from Maison Dieu, Ospringe, Kent

Sample no	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
OSP-A01	Undercroft bridging beam	76	21C	------	------	------
OSP-A02	Lintel to ground floor fireplace	67	h/s	------	------	------
OSP-A03	Lintel to first floor fireplace	85	h/s	------	------	------
OSP-A04	Lintel to Great Chamber fireplace	61	5	AD 1388	1443	1448
OSP-A05	Lintel to stairs/parlour door	71	h/s	------	------	------
OSP-A06	Doorpost by ground floor fireplace	57	h/s	AD 1392	1448	1448
OSP-A07	North jetty joist 6	54	2	------	------	------
OSP-A08	North jetty joist 8	54	h/s	------	------	------
OSP-A09	North jetty joist 11	84	h/s	------	------	------
OSP-A10	North jetty joist 12	65	5	AD 1388	1447	1452
OSP-A11	North jetty joist 13	55	no h/s	------	------	------
OSP-A12	North jetty joist 14	58	2	AD 1394	1449	1451
OSP-A13	North jetty joist 9	85	h/s	------	------	------
OSP-A14	North jetty joist 15	77	h/s	------	------	------
OSP-A15	East jetty joist 5	64	h/s	------	------	------
OSP-A16	North jetty joist 18	54	3	------	------	------
OSP-A17	North sidebeam to grnd floor hall fireplace	50	no h/s	------	------	------
OSP-A18	Tie to central truss, Great Chamber	52	2	------	------	------
OSP-A19	East jetty joist 2	nm	---	------	------	------
OSP-A20	North jetty joist 22	83	h/s	------	------	------

*h/s = the heartwood/sapwood boundary is the last ring on the sample
nm = sample not measured
C = complete sapwood retained on sample

Table 2: Results of the cross-matching of site chronology OSPASQ02 and relevant reference chronologies when first ring date is AD 1388 and last ring date is AD 1452

Reference chronology	Span of chronology	t-value	
East Midlands	AD 882 – 1981	3.0	(Laxton and Litton 1988)
Kent-88	AD 1158 – 1540	4.7	(Laxton and Litton 1989)
MC10---H	AD 1386 – 1585	3.6	(Fletcher 1978 unpubl)
Tower London	AD 1379 – 1534	3.9	(Bridge 1988)
Blue House, Kent	AD 1293 – 1461	3.5	(Howard *et al* 1988)
China Court, Kent	AD 1375 – 1491	5.3	(Howard *et al* 1988)
Ightham Mote, New Chapel	AD 1394 – 1465	3.8	(Howard *et al* 1994)
Ightham Mote, East range jetty	AD 1393 – 1468	4.5	(Howard *et al* 1995)
Ightham Mote, cottages and dovecote	AD 1392 – 1463	4.2	(Howard *et al* 1994)

Figure 1: Map to show general location of Maison Dieu

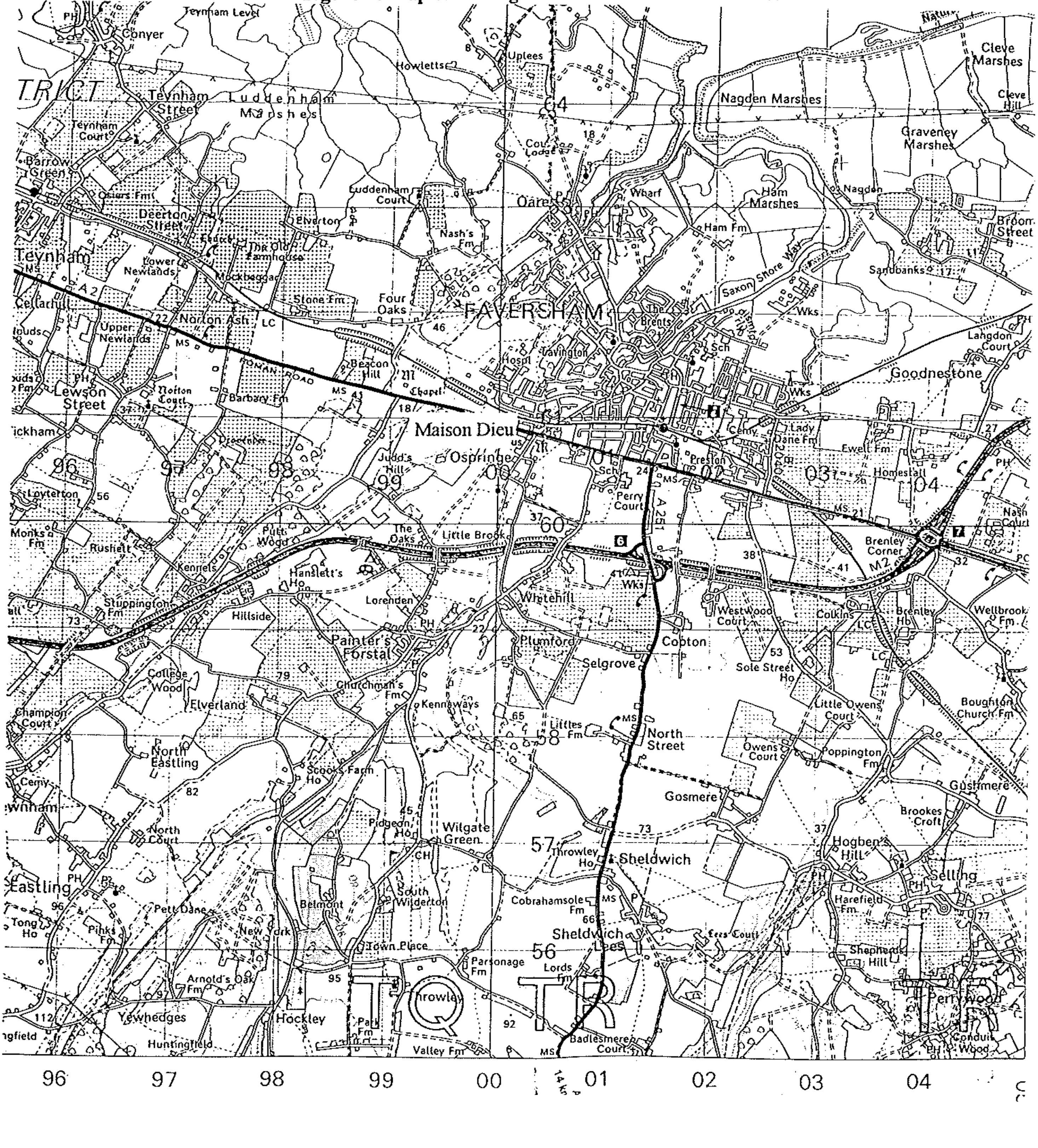


Figure 2: Maison Dieu site plan

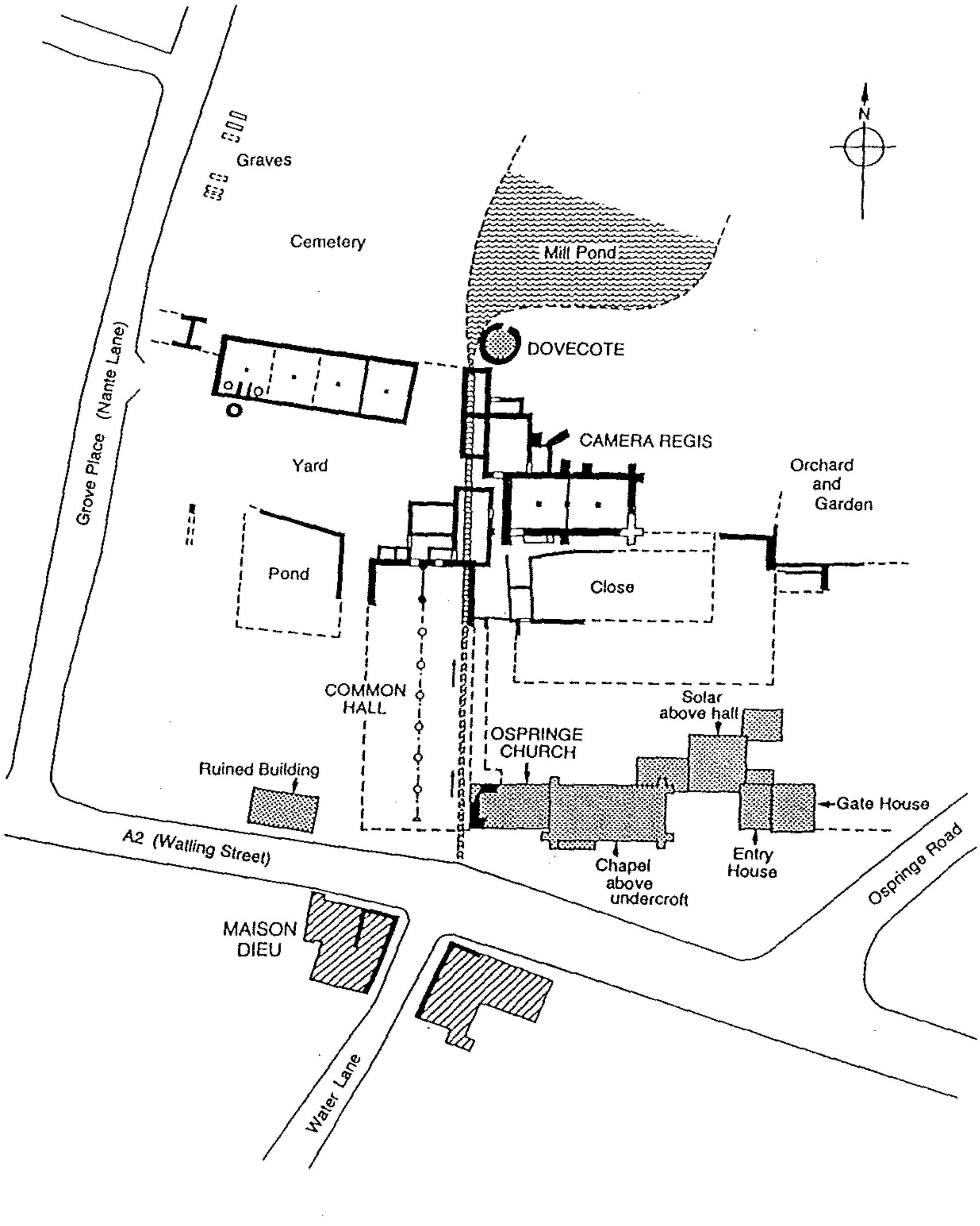
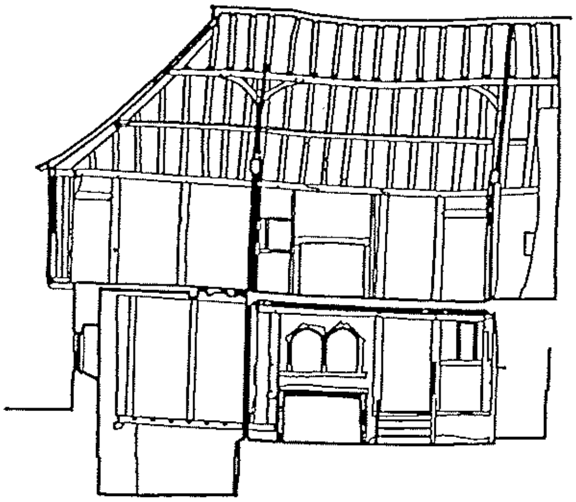
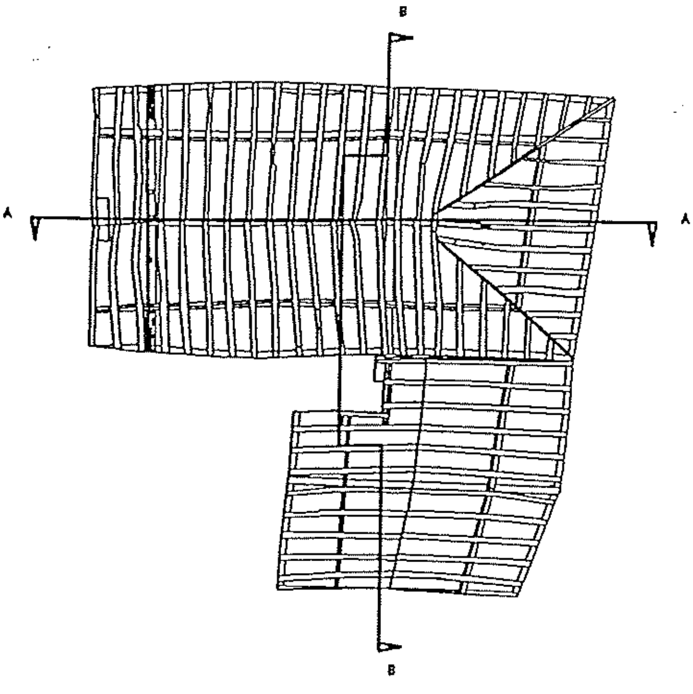


Figure 3: Plan and cross-sections of Maison Dieu



Section A–A

Section B–B



Roof Plan

Figure 4a: Plan of ground floor to show sample locations

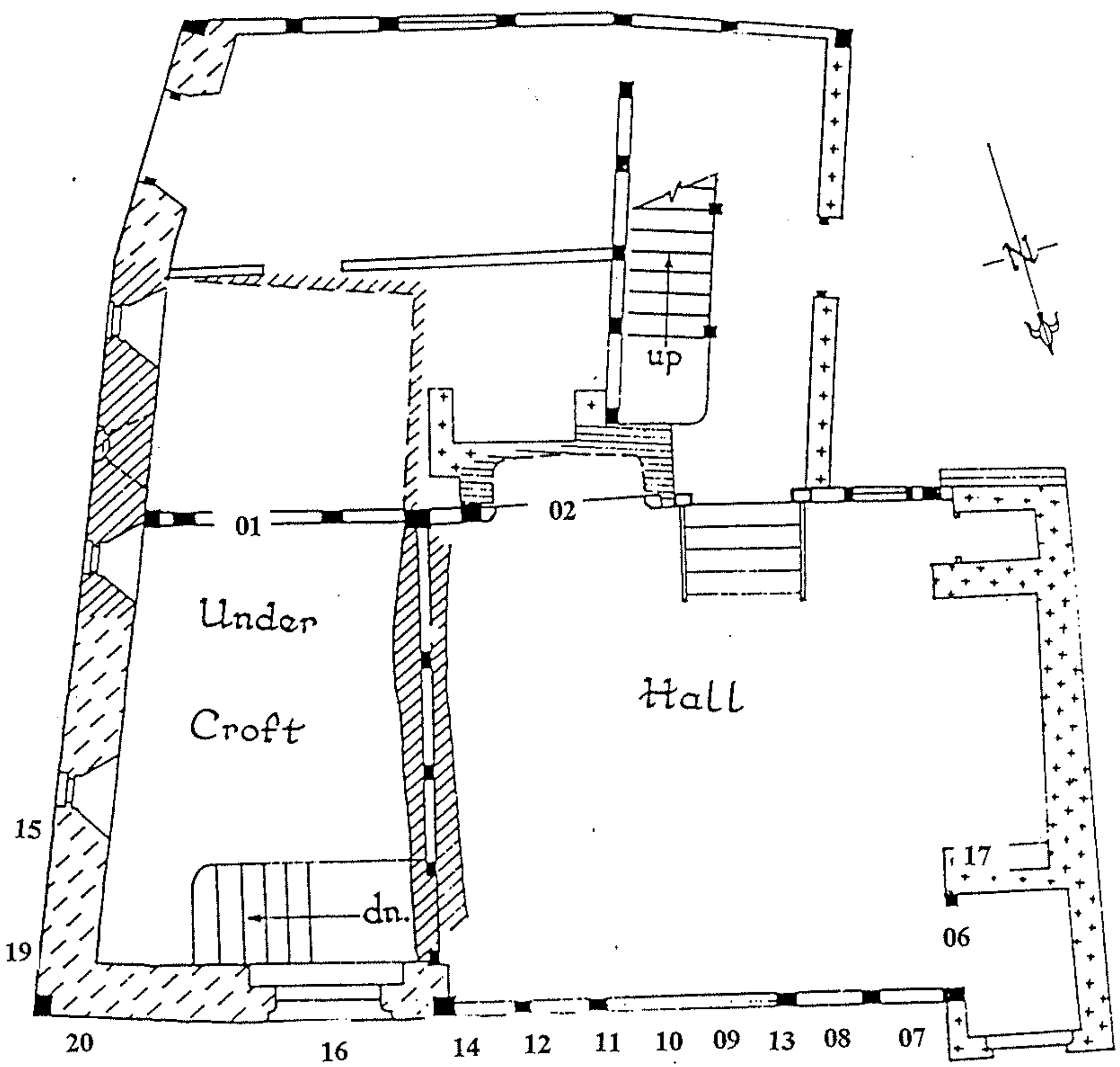


Figure 4b: Plan of first floor to show sample locations

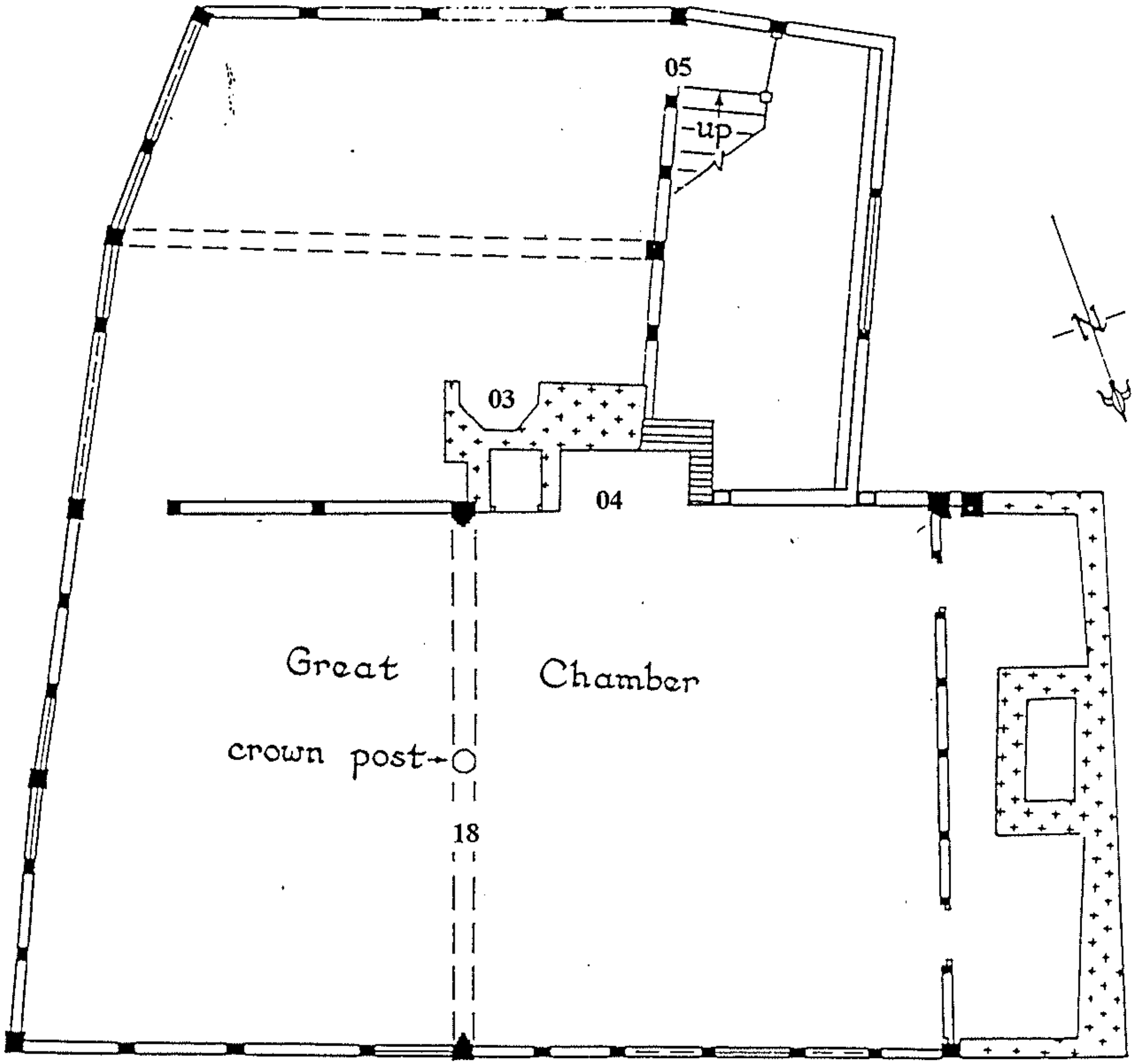


Figure 5: Bar diagram of samples in site chronology OSPASQ01

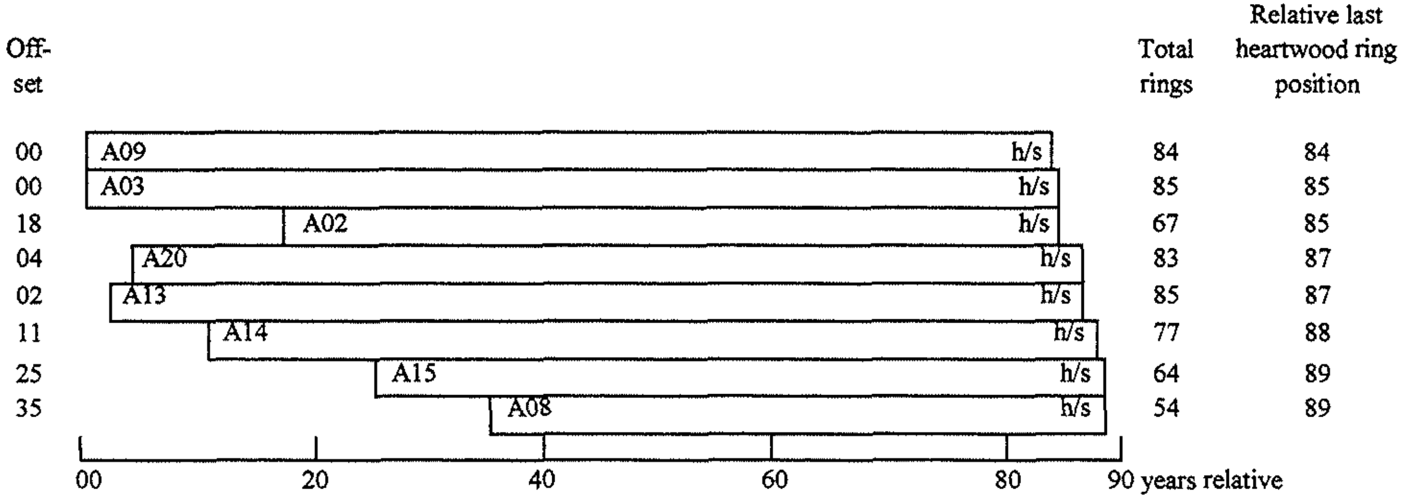
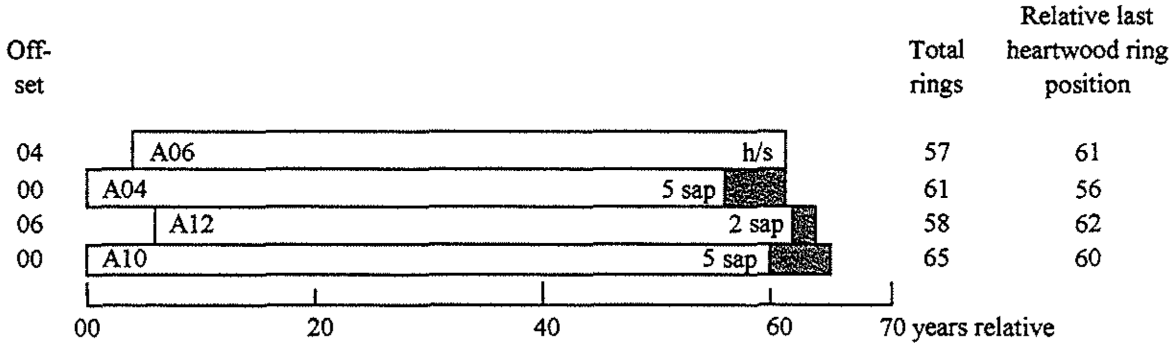


Figure 6: Bar diagram of samples in site chronology OSPASQ02



White bars = heartwood rings, shaded area = sapwood rings
h/s = heartwood/sapwood boundary is last ring on sample

Data of measured samples – measurements in 0.01mm units

OSP-A01A 76
183 155 164 208 116 231 411 274 308 374 298 283 246 449 500 252 273 356 214 191
261 309 365 207 221 335 244 276 276 273 226 270 305 256 241 208 266 409 205 246
174 163 144 191 213 193 210 195 198 374 269 240 328 200 222 185 183 193 132 140
143 108 163 134 158 123 158 131 120 151 142 213 199 105 103 164
OSP-A01B 76
149 104 168 237 138 246 425 295 324 339 286 281 248 445 491 262 267 354 209 202
265 323 346 207 232 353 246 275 276 271 220 276 306 252 248 204 266 410 204 240
186 153 149 183 214 197 208 194 200 378 273 238 332 206 205 179 187 188 145 138
141 114 158 137 156 122 152 131 120 161 136 214 189 122 99 157
OSP-A02A 67
45 92 139 137 72 45 51 29 20 40 57 54 58 67 55 223 224 120 90 74
100 98 179 100 106 153 101 124 175 122 149 116 116 108 151 154 174 172 216 282
189 123 147 142 188 193 162 144 200 248 200 203 219 129 179 148 185 120 139 161
181 164 170 125 251 199 132
OSP-A02B 67
38 91 144 136 75 47 43 20 28 35 61 51 56 65 77 202 223 124 88 81
106 104 179 99 98 145 112 119 167 114 148 120 122 96 156 158 164 164 210 300
197 153 149 129 169 194 154 143 200 245 189 200 217 120 187 143 188 112 140 171
187 165 163 132 290 152 162
OSP-A03A 85
268 242 199 97 118 80 74 80 81 127 157 221 167 180 146 107 83 107 443 465
380 221 159 138 93 94 77 73 81 84 92 66 48 204 245 174 101 66 68 76
82 76 83 79 62 80 99 100 88 63 48 50 63 68 100 207 359 332 204 188
188 149 218 167 142 137 152 168 107 114 129 113 107 133 169 113 110 161 121 221
222 162 231 190 155
OSP-A03B 85
291 264 201 107 106 85 78 67 93 145 158 207 163 172 150 112 82 96 436 446
380 228 155 142 106 96 77 77 83 107 89 66 58 205 235 161 99 56 60 74
73 65 84 78 61 59 88 112 84 64 66 55 80 71 96 176 334 319 216 195
207 148 210 180 135 148 156 152 119 108 104 113 108 145 164 121 103 157 111 229
218 156 241 176 162
OSP-A04A 61
245 205 196 235 135 104 71 56 44 46 52 55 54 92 49 61 105 93 105 88
87 161 347 577 485 386 356 345 272 221 236 190 310 264 240 247 272 262 224 249
236 199 275 227 293 205 213 259 246 215 231 152 145 125 127 102 156 143 149 178
449
OSP-A04B 61
231 218 199 231 133 105 72 48 47 41 60 51 42 89 41 67 100 102 105 81
94 150 356 571 490 386 354 334 271 222 245 189 316 273 232 256 263 264 221 254
232 195 275 236 296 207 210 252 250 213 236 145 155 130 112 103 147 129 157 130
256
OSP-A05A 71
189 220 204 127 265 254 268 197 177 185 222 294 259 406 593 343 318 155 139 130
156 170 187 134 226 240 279 265 365 200 308 401 235 281 196 146 254 270 256 204
184 175 207 257 222 256 251 162 213 242 219 256 185 177 194 178 320 276 305 280
409 228 243 260 298 206 143 103 195 179 195

OSP-A05B 71
202 215 205 137 258 257 252 201 175 192 226 285 274 418 602 330 331 161 123 131
142 182 188 128 222 246 269 263 368 210 312 395 232 286 200 132 258 260 276 199
170 192 206 256 212 262 245 173 209 276 234 245 211 143 212 176 312 274 263 315
405 233 230 258 296 205 150 98 211 175 191
OSP-A06A 57
132 133 200 218 153 155 154 166 152 177 153 171 207 197 208 114 123 206 463 379
287 246 197 199 130 147 220 177 235 183 158 185 220 210 154 126 163 166 243 177
195 138 157 192 218 186 179 117 179 162 188 176 157 141 135 179 292
OSP-A06B 57
96 117 186 194 162 157 155 159 147 176 150 166 212 187 199 123 130 206 471 361
295 252 203 215 128 150 219 165 263 176 171 177 213 210 151 131 157 178 244 174
205 153 164 201 229 203 179 120 167 166 186 177 155 134 136 196 302
OSP-A07A 54
156 295 309 315 416 348 320 260 301 215 239 237 304 245 230 207 223 212 185 168
290 204 213 260 212 227 207 215 200 240 297 229 211 158 170 228 196 181 168 126
135 177 154 140 128 166 184 180 184 203 198 235 165 161
OSP-A07B 54
162 287 328 320 424 319 324 273 301 210 248 255 291 246 221 217 220 216 173 170
282 214 240 255 198 236 204 217 198 238 298 229 210 163 171 221 204 178 163 128
144 160 160 146 129 162 185 180 186 216 176 148 174 160
OSP-A08A 54
110 196 145 196 208 282 190 156 185 110 143 213 142 148 135 126 123 169 202 185
387 457 369 265 213 267 200 225 211 170 158 179 173 178 180 243 172 227 210 212
217 258 246 212 240 140 152 131 116 102 147 141 166 170
OSP-A08B 54
145 196 149 195 202 286 170 183 150 120 134 195 123 161 135 128 112 182 198 217
385 458 386 257 196 252 201 236 210 179 154 166 187 179 189 237 177 236 189 203
215 258 242 212 242 142 156 127 112 99 151 149 148 180
OSP-A09A 84
391 274 218 82 127 123 58 76 77 94 148 221 173 178 158 114 83 110 427 496
410 240 156 160 102 104 82 57 94 91 93 80 51 200 234 165 89 61 55 69
86 69 86 81 65 63 76 109 89 73 69 54 63 70 110 222 388 347 204 212
188 155 208 159 155 139 158 145 98 110 114 108 104 135 174 117 114 161 128 263
253 176 240 196
OSP-A09B 84
393 278 217 76 129 113 68 79 63 106 153 212 177 183 160 107 82 110 428 483
391 236 156 165 102 97 75 68 92 88 83 75 53 189 238 173 96 67 62 78
80 72 83 69 59 81 87 103 95 60 55 54 69 69 108 242 398 343 208 173
189 152 198 168 152 151 159 149 127 127 111 110 110 133 178 110 114 161 126 271
247 183 233 193
OSP-A10A 65
139 216 204 250 161 95 58 34 46 37 69 72 66 101 62 71 103 121 119 81
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212 204 246 228 214 202 176 261 246 233 190 129 136 136 153 183 192 169 173 216
233 258 196 236 302
OSP-A10B 65
176 221 199 252 136 97 54 35 46 41 64 72 63 110 58 67 105 124 117 85
86 135 277 428 409 295 357 345 271 239 251 201 371 271 219 276 228 228 235 243
241 201 236 228 203 182 179 242 240 221 197 123 144 129 142 198 181 176 171 254
176 249 181 232 330

OSP-A11A 55
230 304 247 324 390 352 315 161 154 168 196 194 174 128 214 205 267 237 314 182
243 318 283 306 199 163 246 252 254 184 220 185 193 250 217 237 248 217 223 295
240 275 204 191 208 200 306 235 298 301 387 232 232 269 311
OSP-A11B 55
204 299 238 340 414 338 309 180 131 170 181 189 186 141 241 223 257 224 314 182
221 295 260 338 197 149 285 223 262 181 208 182 187 251 217 251 226 164 237 294
236 251 221 194 181 203 324 268 296 268 391 236 228 268 336
OSP-A12A 58
242 232 162 163 216 134 117 164 154 176 209 187 215 107 131 204 483 379 308 263
226 221 158 179 220 174 236 173 155 163 211 201 157 138 184 192 245 159 163 132
146 192 221 246 205 145 171 170 176 147 167 137 139 187 285 426 321 289
OSP-A12B 58
220 228 158 204 153 142 122 176 150 181 214 187 216 117 128 205 480 385 302 259
233 227 144 183 217 170 222 193 148 156 213 211 160 130 190 185 239 152 148 145
147 194 225 242 208 138 199 179 179 151 170 137 135 205 291 414 307 254
OSP-A13A 85
74 95 209 200 92 141 195 189 181 294 272 172 154 98 99 134 272 268 288 196
145 134 106 81 86 50 63 76 94 78 82 159 187 131 80 54 41 59 58 58
69 61 54 71 79 85 69 84 52 60 50 65 63 94 128 176 158 142 141 124
115 117 111 133 118 127 104 95 96 87 97 109 120 108 94 120 97 163 176 148
182 136 134 125 150
OSP-A13B 85
51 90 207 210 90 131 183 198 163 292 263 167 154 91 92 136 275 267 289 181
141 130 96 87 79 57 65 82 81 85 80 164 202 131 70 59 39 50 62 61
72 56 61 72 71 88 75 80 51 53 60 62 60 93 135 169 163 139 146 119
117 116 118 126 122 120 104 99 98 86 91 102 128 104 95 116 102 157 173 146
181 143 132 131 138
OSP-A14A 77
106 117 197 247 124 153 147 220 127 104 93 125 130 176 165 210 167 268 230 236
198 244 318 383 148 77 50 90 106 151 164 215 237 164 251 257 254 258 185 209
182 167 155 176 290 305 280 292 187 236 197 209 176 182 231 174 166 171 173 187
151 155 143 174 112 80 93 77 118 111 82 105 85 91 105 108 112
OSP-A14B 77
141 119 187 250 114 140 130 219 135 112 85 122 142 159 182 199 176 269 243 272
189 244 322 380 148 79 51 91 105 143 167 221 240 159 250 257 254 259 191 203
178 172 155 180 278 279 277 293 185 248 201 214 180 191 241 180 161 169 184 175
161 149 148 174 108 98 81 77 110 109 84 102 86 89 102 106 133
OSP-A15A 64
129 361 226 258 238 229 216 160 185 241 184 177 183 160 141 196 132 107 113 63
102 145 133 129 121 139 139 210 206 265 619 804 646 458 457 308 175 205 189 143
193 182 246 225 238 233 185 276 225 286 160 221 258 229 213 168 136 177 188 170
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OSP-A15B 64
121 354 252 255 229 226 198 165 175 249 186 174 181 163 143 219 143 104 111 67
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208 168 242 225 236 241 185 280 226 285 148 229 246 242 224 161 137 181 184 175
255 309 262 198

OSP-A16A 54
84 69 60 77 81 73 79 77 63 70 86 102 95 60 53 62 64 64 115 216
368 293 208 145 142 168 104 80 86 63 65 63 54 52 53 60 58 79 103 91
73 78 102 89 257 235 201 224 197 181 84 117 120 133
OSP-A16B 54
89 68 59 75 80 71 78 78 57 78 88 95 104 55 55 53 61 76 110 249
367 281 212 157 151 218 91 81 84 56 69 73 50 51 49 60 64 83 99 89
80 87 109 99 266 258 206 237 193 154 102 93 123 165
OSP-A17A 50
194 224 195 188 193 207 362 381 421 319 248 173 257 283 344 356 284 309 300 247
282 344 382 789 676 613 454 138 121 202 250 358 232 236 231 268 222 255 272 190
264 284 267 260 212 225 278 271 242 287
OSP-A17B 50
208 234 189 191 194 206 366 359 420 326 248 173 256 278 349 363 274 311 306 254
280 352 371 790 674 607 451 138 123 206 252 360 237 229 228 277 239 255 272 183
253 287 262 253 201 252 267 272 252 255
OSP-A18A 52
520 501 494 325 229 242 214 320 263 233 229 153 273 287 368 302 228 334 334 482
363 367 248 322 293 251 276 224 171 273 199 216 154 161 118 75 50 44 35 42
22 55 90 150 142 166 135 118 122 85 96 150
OSP-A18B 52
656 509 486 314 217 220 260 295 260 247 229 153 258 257 376 295 293 299 338 473
325 358 270 307 287 250 293 264 169 280 228 217 145 162 134 72 47 38 39 27
39 55 89 163 144 171 138 108 114 92 103 161
OSP-A20A 83
194 236 118 121 159 145 144 235 241 151 146 99 72 98 243 284 275 146 100 104
81 85 60 56 64 69 80 76 78 160 207 147 81 43 45 47 55 51 68 50
46 51 66 91 74 64 55 44 48 69 52 108 149 184 162 155 130 118 105 104
115 122 133 116 117 109 90 88 98 102 107 110 98 125 101 175 205 148 177 150
115 138 126
OSP-A20B 83
242 280 123 142 164 144 144 246 217 137 138 91 71 97 226 285 280 147 102 101
75 76 58 52 58 79 71 59 67 167 207 144 75 50 40 40 57 65 63 58
33 56 66 81 77 64 52 56 49 55 49 110 149 205 177 133 123 117 119 103
105 130 126 133 112 103 101 83 85 114 101 104 110 110 98 159 202 139 173 142
135 123 125
OSP-A21A 87
282 322 215 204 196 179 129 132 88 117 132 197 140 188 148 179 178 212 277 161
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APPENDIX

Tree-Ring Dating

The Principles of Tree-Ring Dating

Tree-ring dating, or *dendrochronology* as it is known, is discussed in some detail in the Laboratory's Monograph, '*An East Midlands Master Tree-Ring Chronology and its uses for dating Vernacular Buildings*' (Laxton and Litton 1988b) and, for example, in *Tree-Ring Dating and Archaeology* (Baillie 1982) or *A Slice Through Time* (Baillie 1995). 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 Figure1 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, 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 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 1, 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. 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 University of Nottingham Tree-Ring dating Laboratory

1. ***Inspecting the Building and Sampling the Timbers.*** Together with a building historian we inspect the timbers in a building 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 2 has about 120 rings; about 20 of which are sapwood rings. Similarly the core has just over 100 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 to 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.

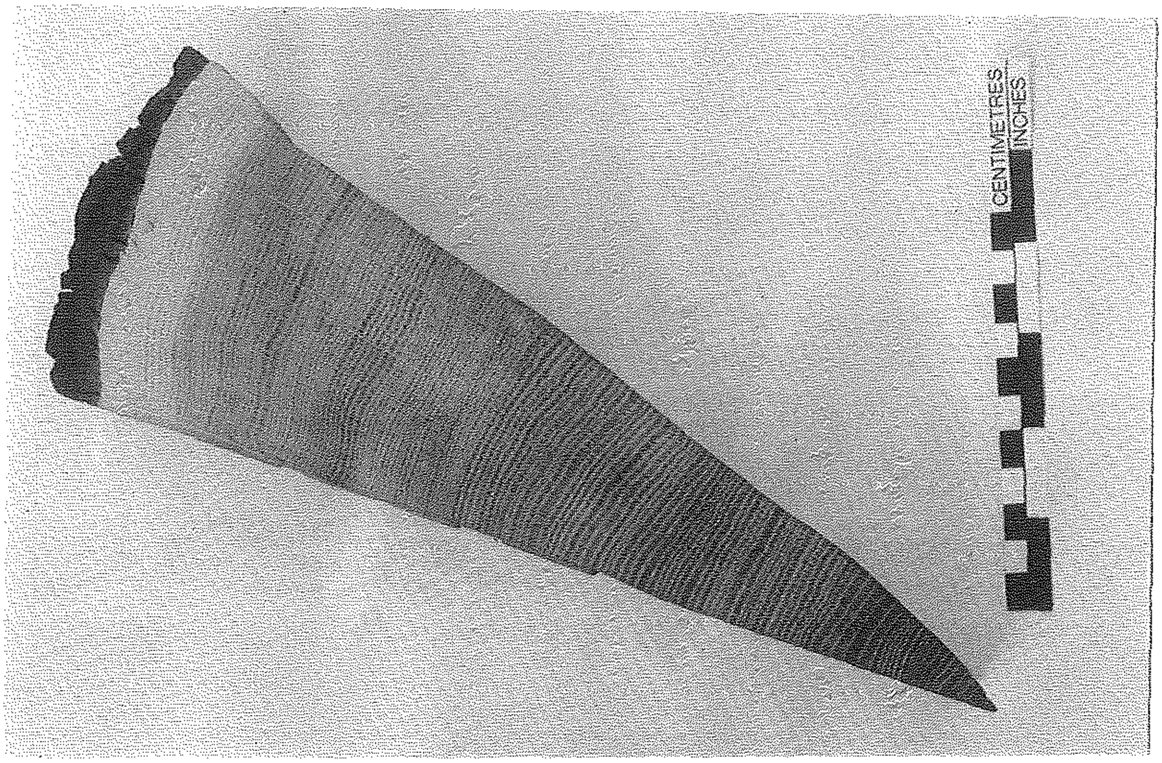

Fig 1. A wedge of oak from a tree felled in 1976. It shows the annual growth rings, one for each year from the innermost ring to the last ring on the outside just inside the bark. The year of each ring can be determined by counting back from the outside ring, which grew in 1976.

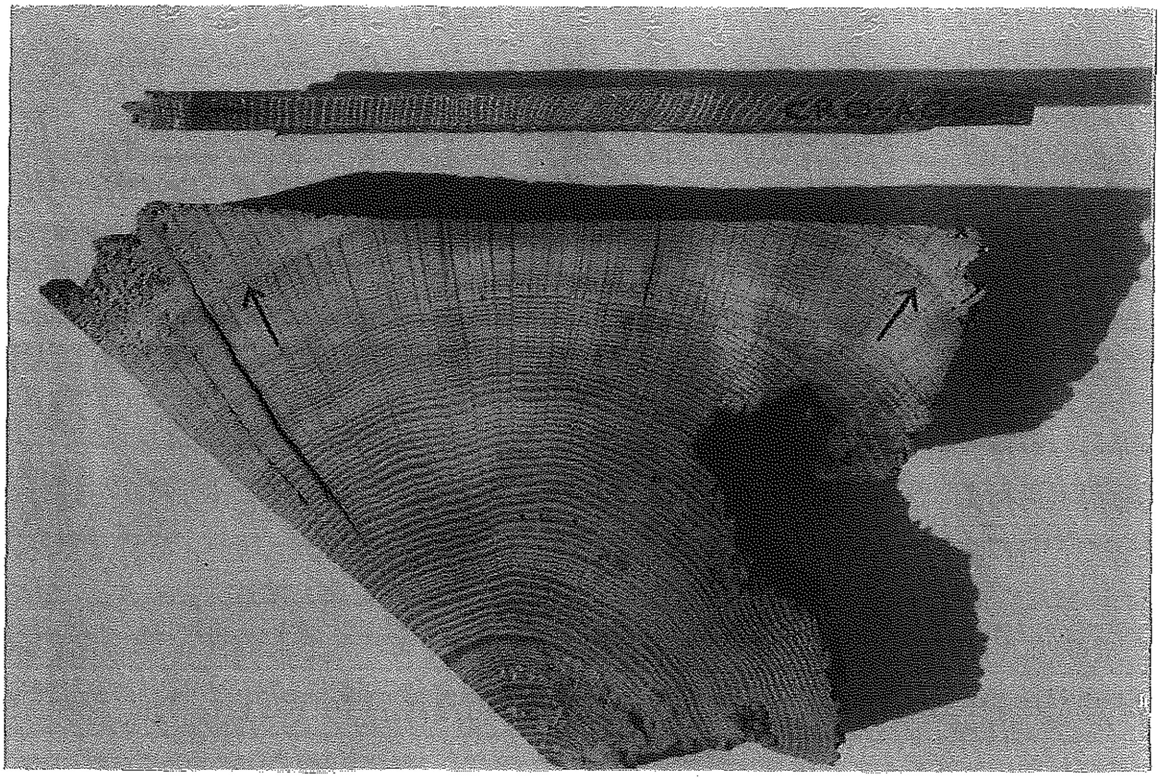

Fig 2. Cross-section of a rafter showing the presence of sapwood rings in the corners; the arrow is pointing to the heartwood/sapwood boundary (H/S). Also a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil.

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 2; it is about 15cm long and 1cm diameter. Great care has to be taken to ensure that as few as possible of the outer rings are lost. 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 inspecton 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 is insured with the CBA.

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 2. 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 3).

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 4). 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 5.0, is usually adequate for the dating to be accepted with reasonable confidence (Laxton *et al* 1988a,b; Howard *et al* 1984 - 1995).

   This is illustrated in Fig 5 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. C08 matches C45 best when it is at a position starting 20 rings after the first ring of 45, 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 between these two whatever the position of one sequence relative to the other.

   It is standard practice in our Laboratory first to cross-match as many as possible of the 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 Fig 5. The fifth bar at the bottom is a site sequence for a roof at Lincoln Cathedral and is constructed from the matching sequences from 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. 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.

average sequence of ring widths with a master sequence than it is to date the individual component sample sequences separately.

This 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'. This was developed and tested in the Laboratory and has been published (Litton and Zainodin 1991; Laxton *et al* 1988a). To illustrate the difference between the two approaches with the above example, consider sequences C08 and C05. They are the most similar pair with a t-value of 10.4. Therefore, these two are first averaged with the first ring of C05 at +17 rings relative to C08 (the offset at which they match each other). This average sequence is then used in place of the individual sequences C08 and C05. The cross-matching continues in this way gradually building up averages at each stage eventually to form the site sequence.

4. ***Estimating the Felling Date.*** If the bark is present on a sample, then the date of its last ring is the date of the felling of its tree. Actually it could be the year after if it had been felled in the first three months 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, they can be seen in two upper corners of the rafter and at the outer end of the core in Figure 2. 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 for 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. Thus in these circumstances the date of the present last ring is at least close to the date of the original last ring on the tree, and so to the date of felling.

   Various estimates have been made for the average number of sapwood rings in a mature oak. One estimate is 30 rings, based on data from living oaks. So, in the case of the core in Figure 2 where 9 sapwood rings remain, this would give an estimate for the felling date of 21 (= 30 - 9) years later than of the date of the last ring on the core. Actually, it is better in these situations to give an estimated range for the felling date. Another estimate is that in 95% of mature oaks there are between 15 and 50 sapwood rings. So in this example this would mean that the felling took place between 6 (= 15 - 9) and 41 (= 50 - 9) years after the date of the last ring on the core and is expected to be right in at least 95% of the cases (Hughes *et al* 1981; see also Hillam *et al* 1987).

   Data from the Laboratory has shown that when sequences are considered together in groups, rather than separately, the estimates for the number of sapwood can be put at between 15 and 40 rings in 95% of the cases with the expected number being 25 rings. We would use these estimates, for example, in calculating the range for the common felling date of the four sequences from Lincoln Cathedral using the average position of the heartwood/sapwood boundary (Fig 5). These new estimates are now used by us in all our publications except for timbers from Kent and Nottinghamshire where 25 and between 15 to 35 sapwood rings, respectively, is used instead (Pearson 1995).

   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 2 was taken still had complete sapwood. Sapwood rings were only lost in coring, because of their softness. By measuring in the timber the depth of sapwood lost, say 2 cm., a reasonable estimate can be made of the number of sapwood rings missing from the core, 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 40 years later we would have estimated without this observation.

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

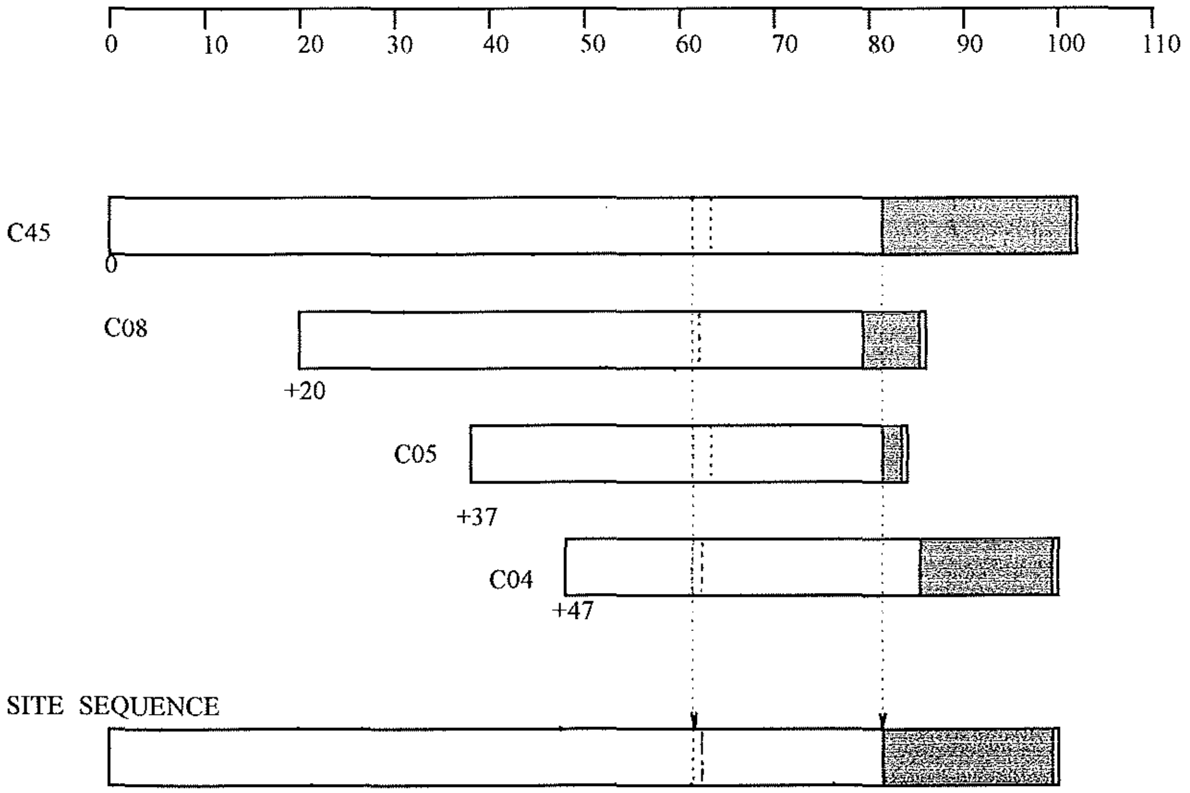

Fig 5. Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them.
The *bar diagram* represents these sequences without the rings themselves. The length of the bar is proportional to the number of rings in the sequence. Here the four sequences are set 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.

Even if all the sapwood rings are missing on all the timbers sampled, an estimate of the felling date is still possible in certain cases. For provided the original last heartwood ring of the tree, called the heartwood/sapwood boundary (H/S), is still on some of the samples, an estimate for the felling date of the group of trees can be obtained by adding on the full 25 years, or 15 to 40 for the range of felling dates.

If none of the timbers have their heartwood/sapwood boundaries, then only a *post quem* date for felling is possible.

5. ***Estimating the Date of Construction.*** There is a considerable body of evidence in the data collected by the Laboratory that the oak timbers used in vernacular buildings, at least, were used 'green' (see also Rackham (1976)). Hence provided the samples are taken *in situ,* and several dated with the same estimated common felling date, then this felling date will give an estimated date for the construction of the building, or for the phase of construction. If for some reason or other we are rather restricted in what samples we can take, then an estimated common felling date may not be such a precise estimate of the date of construction. More sampling may be needed 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 Fig 6 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 Fig 6. 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 1988b, 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* 1988a). 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 (1988b) and is illustrated in the graphs in Fig 7. Here ring-widths are plotted vertically, one for each year of growth. In the upper sequence (a), the generally large early growth after 1810 is very apparent as is the smaller generally later growth from about 1900 onwards. A similar difference can be observed in the lower sequence 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, hopefully corresponding to good and poor growing seasons, respectively. The two corresponding sequences of Baillie-Pilcher indices are plotted in (b) where the differences in the early and late growths have been removed and only the rapidly changing peaks and troughs remain. only associated with the common climatic signal and so make cross-matching easier.

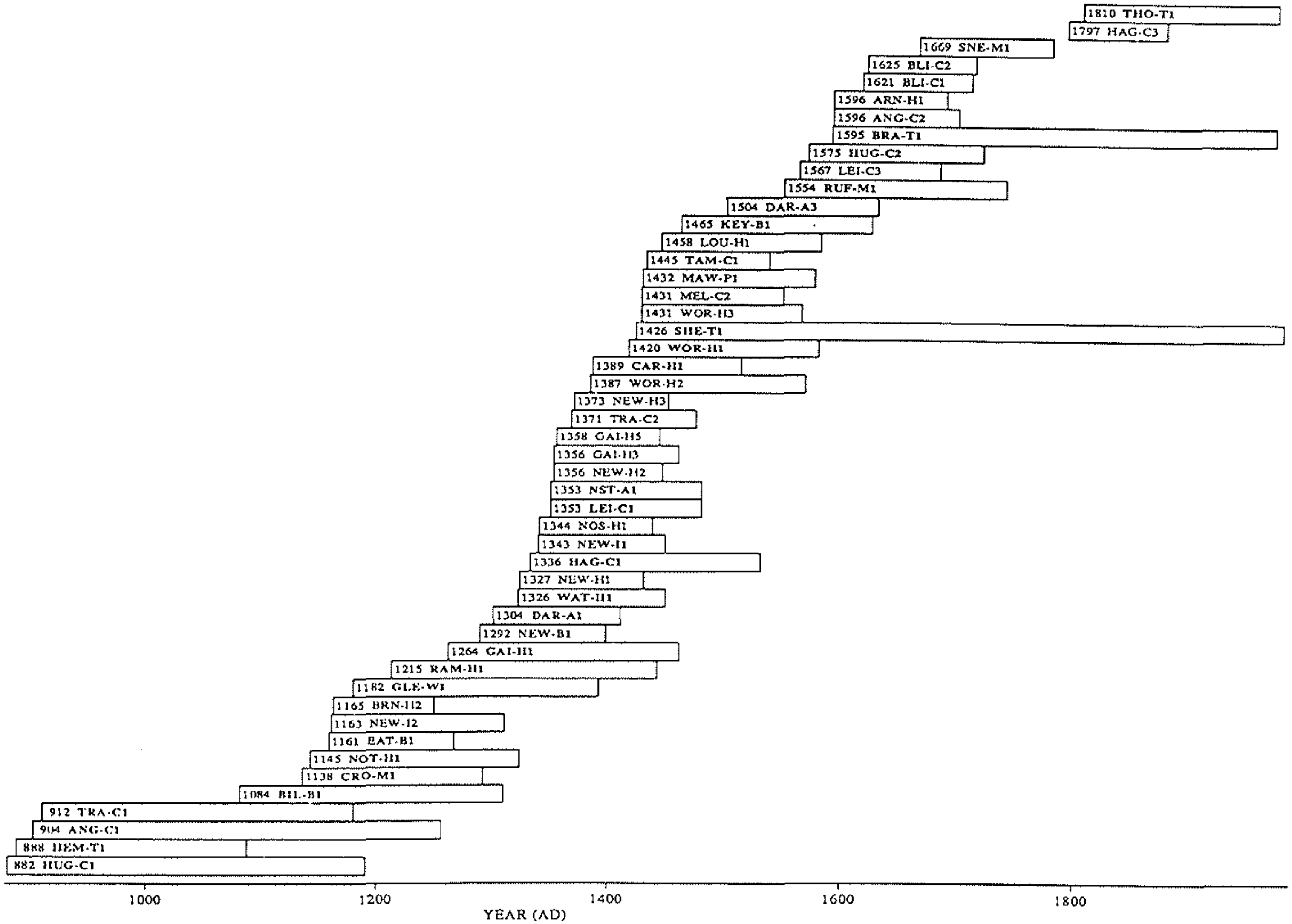

Fig 6. Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87.

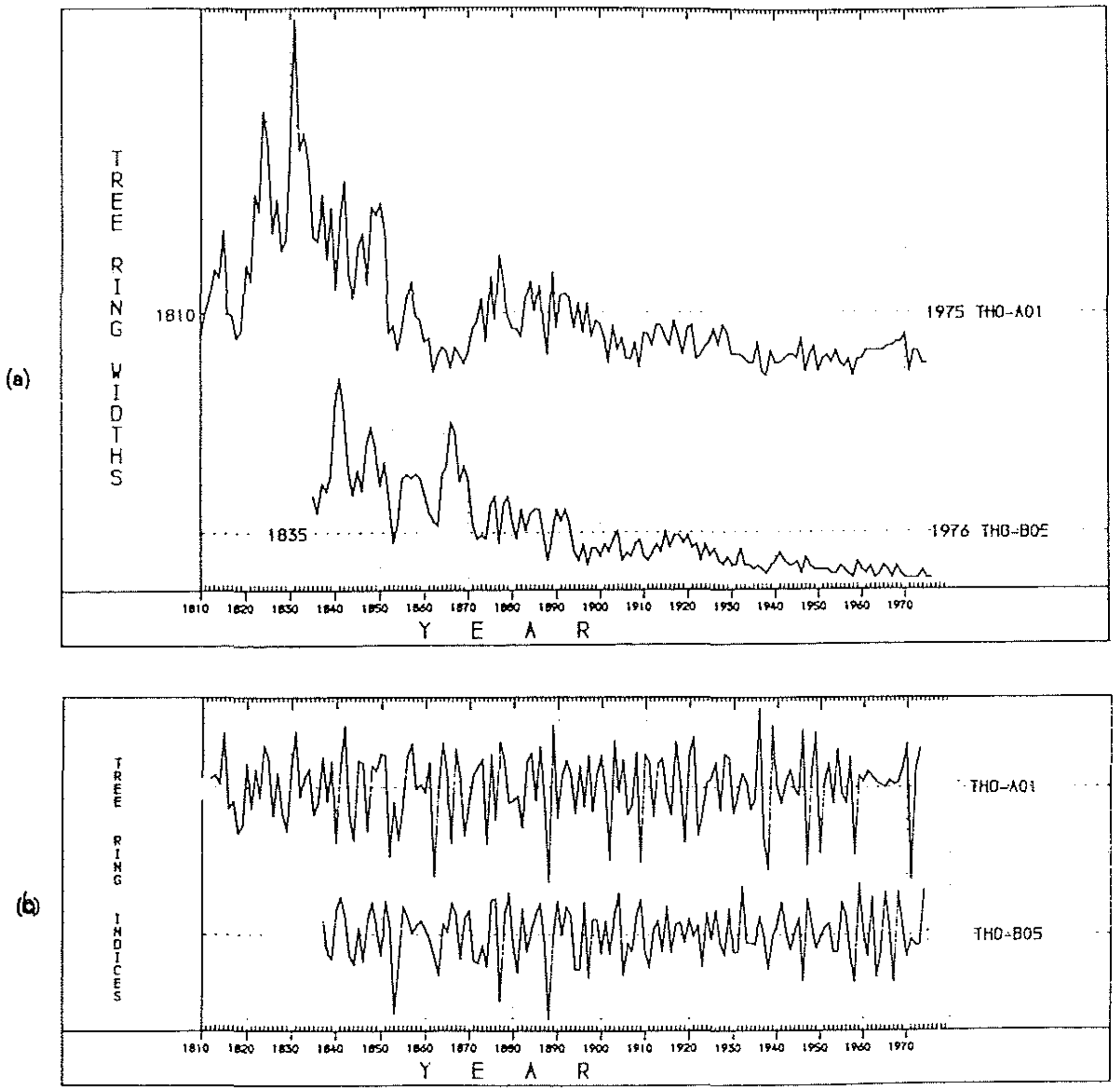

Fig 7. (a) The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known. Here the ring widths are plotted vertically, one for each year, so that peaks represent wide rings and troughs narrow ones. Notice the growth-trends in each; on average the earlier rings of the young tree are wider than the later ones of the older tree in both sequences.

(b) The *Baillie-Pilcher indices* of the above widths. The growth-trends have been removed completely.

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