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Tree-Ring Analysis of Timbers from 158-160 High Street, Newton-le-Willows, St Helens, Merseyside

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Summary

Nineteen samples were obtained from these two buildings with analysis producing a single site chronology. This comprises eight samples and is 158 rings long overall. It is dated as spanning AD 1470 - AD 1627.

Interpretation of the sapwood indicates the earliest phase is represented by a ridge beam in number 158 and a purlin in number 160. These have a felling date, it is suggested, in the range AD 1570 - 1605.

A second phase is represented by a timber from number 160 felled in AD 1615.

A third felling, possibly related to that of AD 1615, is represented by two samples from number 158. These have a felling date in the range AD 1596-1631.

Another phase is represented by a single sample from number 158 with a felling date of AD 1642-77.

The felling dates of two other samples cannot be determined with accuracy, but are unlikely to be before the late sixteenth century.

Multi period felling, intimated by archaeological survey, is also detected by dendrochronology. Number 158 retains the majority of older timbers, with the analysis showing construction activity from the late sixteenth century. The possible primary phase, represented by the crucks, cannot be dated.

Keywords

Dendrochronology
Standing Building

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Introduction

158 - 160 High Street, Newton-Le-Willows comprises two simple houses on the north side of the road at its junction with Crow Lane (TF 454759; Figs 1 and 2). The buildings are listed Grade II on the basis of their historic merit, it being believed that the site is at the western limits of the medieval burgage plots, rather than for their architectural interest. The axis of number 158 shows that it lay parallel to the street and not at right angles on a narrow plot. Until recently, AD 1990, they were attached to the Legh estates, the Lords of which had held Newton since the mid-fifteenth century.

Number 158 is of one-and-a-half storeys, while number 160, standing to the west, is of two storeys. It has rooms set in the roof space and is a slightly bigger building. A drawing of the front elevation is given in Figure 3. On structural evidence it is believed that number 160 was built as an addition to, or an extension of, number 158. It is further believed that the two properties may have been held by a single tenant at one time, but have certainly been occupied separately since AD 1839.

Within number 158 lies a substantial amount of timber framing, particularly from the floors and roofs, including the partial remains of a single cruck truss. The surviving cruck truss originally supported two pairs of purlins, of which the upper pair, and a single windbrace, survived *in-situ* until recently. A wide trench with five peg holes suggests the existence of a former tiebeam, or possibly cruck spurs. The former position of at least two other cruck trusses may be indicated by sandstone pads. Until recently many of the smaller timbers were concealed behind hardboard cladding, plasterboard, and within the sealed roof. Number 160 is entirely brick-built.

The listing description of AD 1978 describes the site as being of seventeenth-century date with an eighteenth-century extension. Over the gable was formerly the date AD 1622. The listing description also suggests that the east wall of number 158, the party wall to number 160, was possibly jettied. There is evidence for a series of major alterations and several phases of minor repair over, it is estimated on stylistic and structural grounds, the last 300 years or so. It has been suggested that some timbers from earlier phases of the building have been reused, perhaps several times.

The house has been the subject of a full survey (Lewis and Sayer 1990) in which report several phases are recognised. Phase 1 consists of the original cruck-framed open hall building, probably of three bays, but possibly of four. In phase 2 an upper floor was created by the resetting of a tiebeam and the removal of the lower purlins. Phases 3 and 4 consist of internal alterations, with phase 5 seeing the replacement of the timber-framed skin in brick. Phase 6 sees further minor developments with phase 7 seeing the construction in brick of number 160.

The Laboratory would like to take this opportunity to thank the owners of numbers 158 - 60, Mr and Mrs Smith, for providing access to the site and for providing help in locating the original positions of the timbers. We would also like to thank Jenny Lewis and Arthur Sayer for the use of their report in producing the introductory details above.

Sampling

Sampling and analysis by tree-ring dating of timbers at the site were commissioned by English Heritage. The purpose of this was to establish a construction date for the original cruck framed building and to better understand the subsequent development of the site. Current renovations to the property allowed excellent access to the timber framing, particularly to parts of the roof which had previously been hidden.

At the time of sampling virtually all the timbers, excepting the remains of the cruck truss and a few other timbers, had been removed from their original positions within the building and stored in assorted stacks in the yard to the rear. These timbers had been removed due to their poor and unsound condition and were unlikely to be used in the renovation. Prior to removal most of, but not all, the timbers had been numbered and their original locations recorded. Also prior to removal an attempt had been made to ascribe a possible construction phase to each timber on the basis of its situation within, and by comparisons to other timbers in, the building.

Having been removed from the building it was possible to clearly see the growth pattern of most of the timbers. It was observed that many of them came from very fast-grown trees with wide, and thus few, rings. It was possible to see that a number of timbers, particularly the smaller ones such as the common rafters and some of the floor joists, had too few rings, that is fewer than 54, for satisfactory analysis. Unfortunately so too did some of the larger timbers including subsidiary members of the cruck truss. However, other timbers did appear to have sufficient rings, and from these a total of nineteen samples was obtained.

Each sample was given the code NLW-A (for Newton-Le-Willows, site "A") and numbered 01 - 19. Seventeen samples were obtained by slicing the discarded timbers with a chain saw, with a further two samples, those from the cruck blades, being taken as cores.

The original position and/or use of each sampled timber was recorded at the time of sampling and, where available, the timber numbers noted. These details are given in Table 1. A note was also made of the supposed date or of the construction phase of the timber. Where possible the positions of the original timbers sampled are shown in drawings made by Jenny Lewis for the AD 1990 report and provided by English Heritage. These are reproduced here as Figures 4a-c. Not all timbers are shown in these drawings, with the dormer, for example, being undrawn.

Analysis

Each sample was prepared by sanding and polishing. At this stage it was seen that one sample, NLW-A07, had fewer than 54 annual rings, too few for satisfactory analysis, and this sample was rejected from the process. The rings widths of the remaining eighteen samples were measured (the resultant data being given at the end of this report) and compared with each other by the Litton/Zainodin grouping procedure (see appendix).

The usual minimum t-value for cross-matching used by the Nottingham Laboratory is 4.5, with a minimum overlap between individual samples of 54 rings. At a value of t=4.5 a group of four samples, NLW-A01, A03, A05 and A19 do cross-match with each other. These four samples were combined with each other at their relative offset positions and satisfactorily dated against a series of relevant reference chronologies for oak.

Each of the fourteen remaining measured but ungrouped samples was then compared individually with a series of relevant reference chronologies, the process indicated satisfactory cross-matching and dating for four such samples, NLW-A02, A06, A10, and A12. Although there is some tentative low-level cross-matching for some of the other samples it is not consistent nor satisfactory and all these others remain undated.

Three of these independently dated samples, NLW-A06, A10 and A12, do in fact cross-match with each other with a low, though maximum, value of *t*=3.7/3.5, at a relative positions consistent with their independent dating. For the purposes of analysis, because of this cross-matching and independent dating, these three samples, NLW-A06, A10 and A12, were combined at their relative off-set positions to form a second group.

The two groups thus formed, one of four samples, the other of three, were now found to cross-match with each other with a low, though maximum, value of *t*=3.9. This cross-match is found at a position consistent with the independent dating of the two groups. Because of this the seven samples they contain were combined at their indicated offsets to form a third group. It was then found that sample NWL-A02 cross-matches with this third group of seven samples at a position consistent with its independent dating against the reference chronologies.

Sample NWL-A02 was then combined with the group of seven to form a final site chronology, here described as NWLASQ01. The relative positions of the eight samples this 194 ring long site chronology contains are shown in the bar diagram, Figure 5. Site chronology NLWASQ01 was compared with a full series of relevant reference chronologies for oak, giving it a first ring date of AD 1434 and a last measured ring date of AD 1627. Evidence for this dating is given in the *t*-values of Table 2.

Two other samples, NLW-A14 and A15 from the cruck blades, were seen to cross-match with a satisfactory maximum value of *t*=6.7. At the relative position indicated for this, however, the overlap between them is only 50 years. Such a figure is below the Nottingham Laboratory's usual minimum. However, given that it is probable that they are from a single tree split in half, for the purposes of analysis the two samples were combined to form a short, 64 ring, chronology. Unfortunately this chronology could not be dated.

Interpretation

Unfortunately the analysis has not produced a clear-cut determination of the phases of timber used in the construction of this building. Only one sample, NLW-A19, retains complete sapwood, this having a last ring date of AD 1615. This is thus the felling date of the timber represented.

The other samples have either no heartwood/sapwood boundary, only the heartwood/sapwood boundary or only small amounts of sapwood. The estimated felling dates for such timbers are summarized over page.

Sample number	Sapwood	Last ring date	Estimated felling date range
NLW-A01	h/s	AD 1627	AD 1642 – 77
NLW-A02	h/s	AD 1582	AD 1597 – AD 1632
NLW-A03	no h/s	AD 1565	Not before AD 1580
NLW-A05	no h/s	AD 1561	Not before AD 1576
NLW-A06	h/s	AD 1557	AD 1572 – AD 1607
NLW-A10	7	AD 1555	AD 1563 – 98
NLW-A12	3	AD 1546	AD 1558 – 93

Estimated felling dates are based on the Laboratory's usual 95% confidence limit for the amount of sapwood on mature oaks from this part of England of 15 to 50 rings.

Conclusions

It would thus appear that the eight dated timbers represent at least three, or possibly four, different phases of felling. There is not, however, any clear-cut distinction in date between the two buildings. It does appear, though, as if number 158 retains the majority of dated timbers.

The earliest phase may be represented by samples NLW-A06, A10, and A12, a purlin from number 160 and a ridge beam and stair tread of number 158. These timbers may have been felled together in the late-sixteenth century, sometime, in round terms say, in the period AD 1565 – AD 1600.

The second phase of felling appears to be represented by sample NLW-A19, a bridging beam from number 160. This sample has a last measured complete sapwood ring date of AD 1615. This is thus the felling date of the timber.

A possible third phase of felling may be represented by sample NLW-A02, a dormer gable stud post from number 158. It is estimated that this timber was felled in the period AD 1597 – AD 1632. It is quite possible that this sample and sample NLW-A19 discussed above represent a single phase of felling, the timbers being cut at the same time in AD 1615.

The final certain phase of felling is represented by sample NLW-A01. The timber represented has an estimated felling date in the range AD 1642 – 77. Such a range is quite different to all those others discussed above.

The felling dates of the timbers represented by samples NLW-A03 and A05, from number 158, cannot be determined with certainty. It is, however, unlikely that there were felled before the late sixteenth century, and could belong to almost any of the phases discussed.

An attempt to show timbers grouped by possible felling phases is given below:

Sample number	Location	Felling date, actual or estimated
NLW-A06	160	
NLW-A10	158	AD 1565 – AD 1600
NLW-A12	158	
NWL-A19	160	AD 1615
NLW-A02	158	AD 1597 – AD 1632
NLW-A01	158	AD 1642 – 77
NLW-A03	158	Not before AD 1580
NLW-A05	158	Not before AD 1576

Tree-ring analysis has thus identified several possible phases of felling. The relationship between these and the development of the structure is not straight-forward. The variation in element type, the low number of samples dated combined with the multiple felling phases identified, and the possible reuse of material pose problems for the interpretation.

The signs of multi-period timbers and phases of construction detected by the archaeological survey do appear to be correct. In this case, assuming that the earliest dated timbers belong to this building and are not reused from elsewhere, its developmental history is perhaps slightly longer than expected, as they indicate construction activity in the late-sixteenth century rather than the seventeenth century. There are, however, no dates for the cruck blades which are thought to belong to the primary phase of construction.

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Table 1: Details of samples from the 158 and 160 High Street, Newton-le-Willows, St Helens, Merseyside

Sample no	Sample location, timber number, and house number	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
NLW-A01	Dormer gable, bottom rail (158)	120	h/s	AD 1508	AD 1627	AD 1627
NLW-A02	Dormer gable, stud post (158)	80	h/s	AD 1503	AD 1582	AD 1582
NLW-A03	Dormer gable, rafter (158)	55	no h/s	AD 1511	------	AD 1565
NLW-A04	Dormer gable, king post (158)	57	no h/s	------	------	------
NLW-A05	Dormer gable, rafter (158)	56	no h/s	AD 1506	------	AD 1561
NLW-A06	North purlin, timber 80 (160)	54	h/s	AD 1504	AD 1557	AD 1557
NLW-A07	Ridge beam, timber 78 (160)	nm	h/s	------	------	------
NLW-A08	South purlin, timber 2 (158)	71	23C	------	-----	-----
NLW-A09	Fireplace bressummer, timber 4 (158)	72	2	------	------	------
NLW-A10	Ridge beam, timber 1 (158)	66	7	AD 1490	AD 1548	AD 1555
NLW-A11	Floor joist, timber 110 (160)	125	28C	------	------	------
NLW-A12	Stair tread (158)	113	3	AD 1434	AD 1543	AD 1546
NLW-A13	Dormer stud piece (158)	61	17C	------	------	------
NLW-A14	South cruck blade, timber 66 (158)	54	h/s	------	------	------
NLW-A15	North cruck blade, timber 65 (158)	60	h/s	------	------	------
NLW-A16	Unknown beam	55	h/s	------	------	------
NLW-A17	North wall plate, timber 109 (158)	54	20C	------	------	------
NLW-A18	Eastern bridging beam (158)	80	16C	------	------	------
NLW-A19	West bridging beam (160)	142	22C	AD 1474	AD 1593	AD 1615

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

Table 2: Results of the cross-matching of site chronology NLWASQ01 and relevant reference chronologies when first ring date is AD 1434 and last ring date is AD 1627

Reference chronology	Span of chronology	*t*-value	
Bolsover Castle, Derbys	AD 1494 - 1744	6.4	(Howard *et al* forthcoming)
Dimple Farm, Matlock, Derbys	AD 1497 - 1593	6.3	(Howard *et al* 1996)
East Midlands	AD 882 - 1981	6.2	(Laxton and Litton 1988)
Staircase House, Stockport	AD 1489 - 1656	6.0	(Howard *et al* 2003)
Speke Hall, Merseyside	AD 1387 - 1598	6.0	(Howard *et al* 1992)
England	AD 401 - 1981	5.7	(Baillie and Pilcher 1982 unpubl)
Frith Hall Farm, Brampton, Derbys	AD 1480 - 1602	5.5	(Howard *et al* 1993)

Figure 1: Map to show general location of Newton-le-Willows

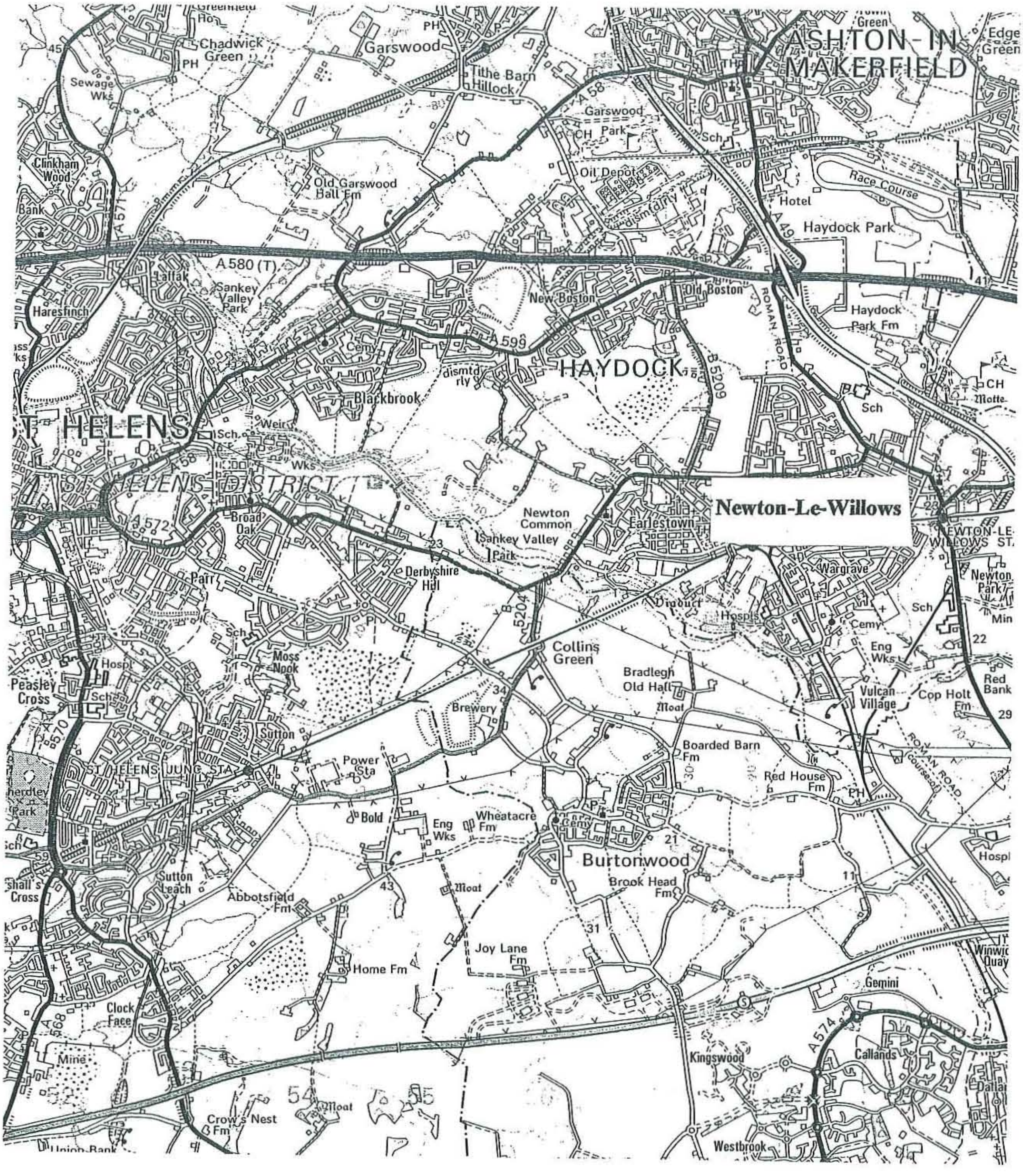


Figure 2: Map to show location of 158 – 160, High Street

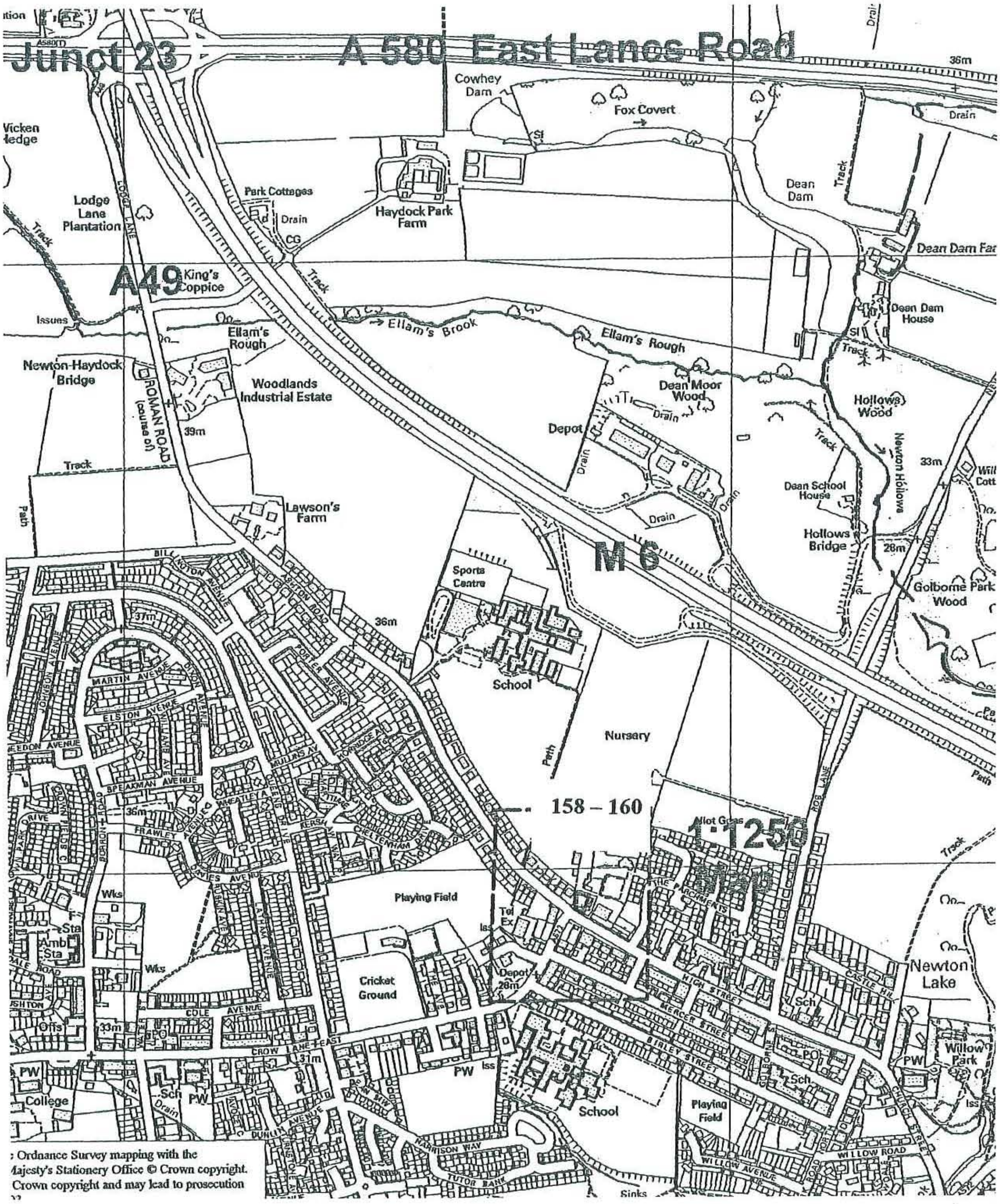


Figure 3: Drawing to show front, or south, elevation of 158 – 160, High Street

Figure 4a: Plan at ground-floor level to show timbers sampled (not all sampled timbers shown)

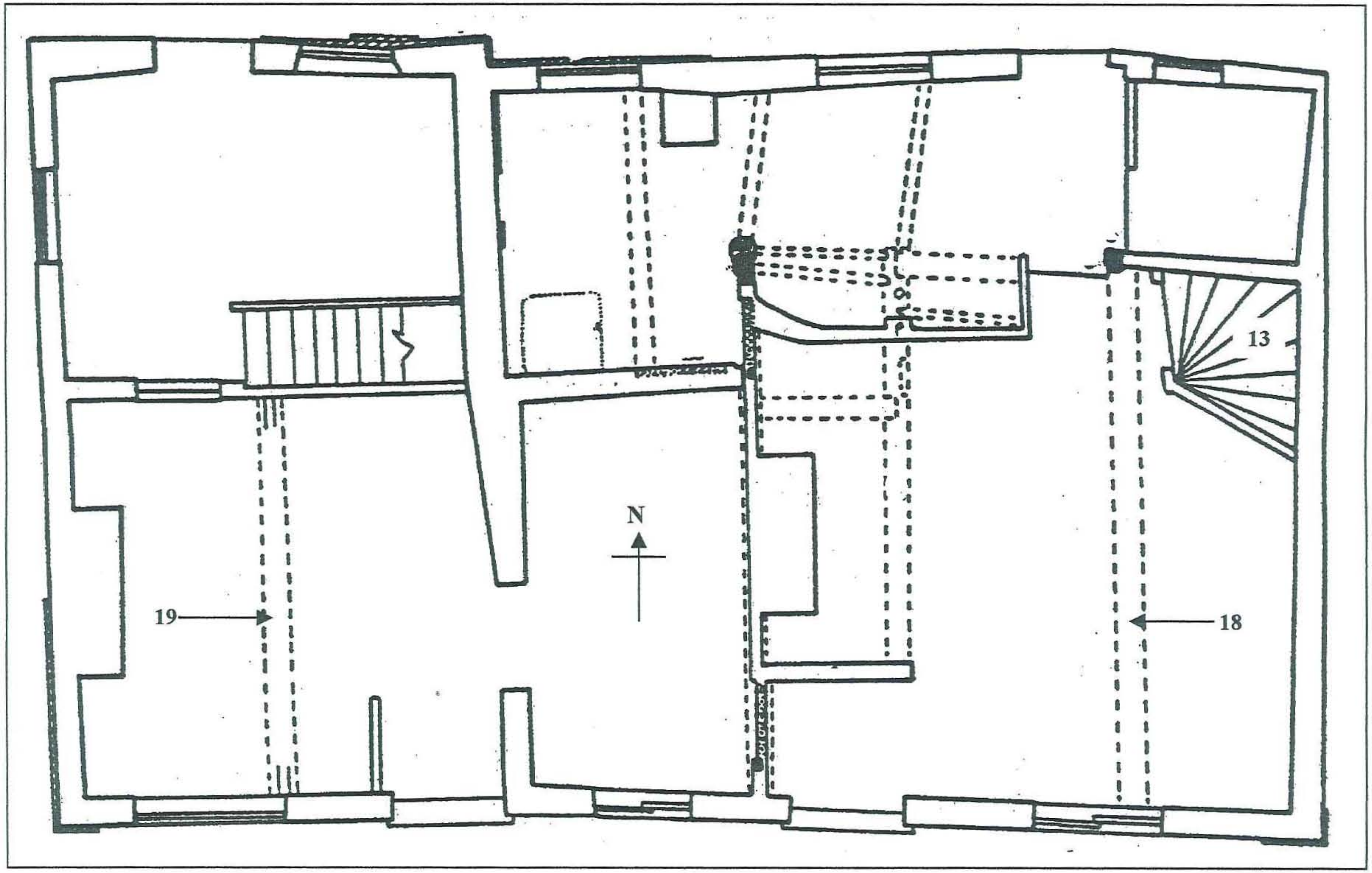


Figure 4b: Plan at first-floor level to show timbers sampled (not all sampled timbers shown)

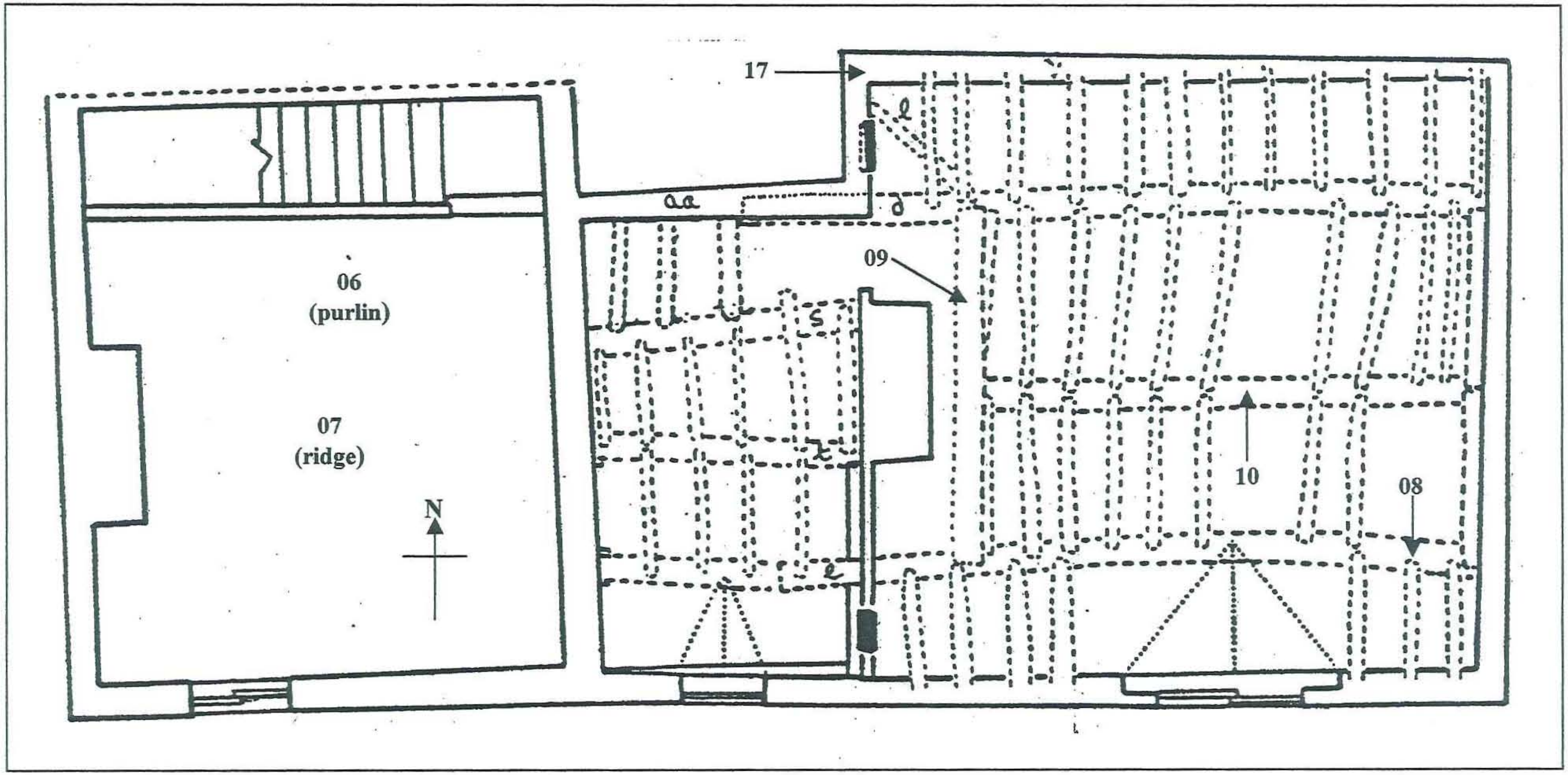


Figure 4c: Drawing of the cruck truss to show timbers sampled (viewed from the east looking west)

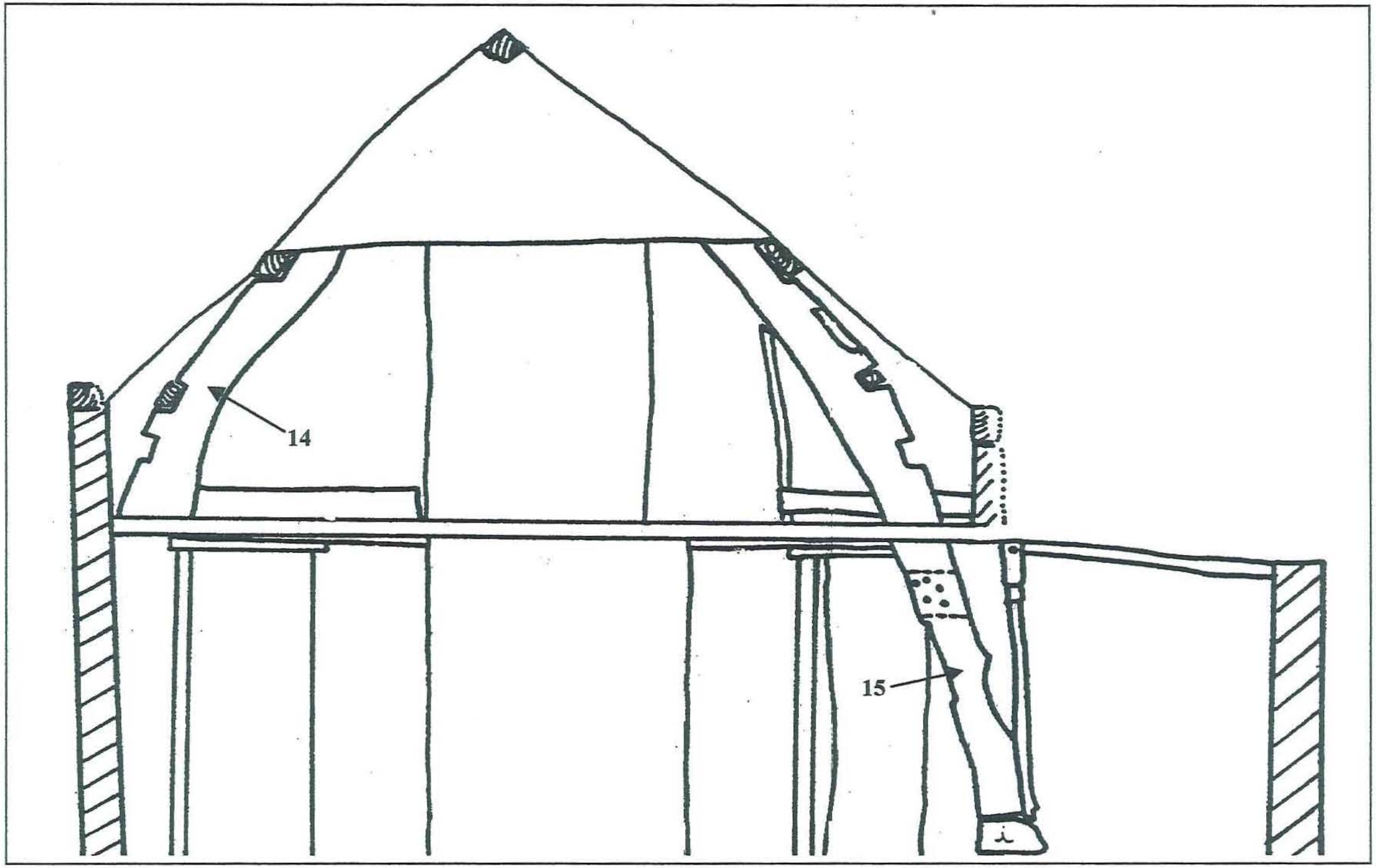
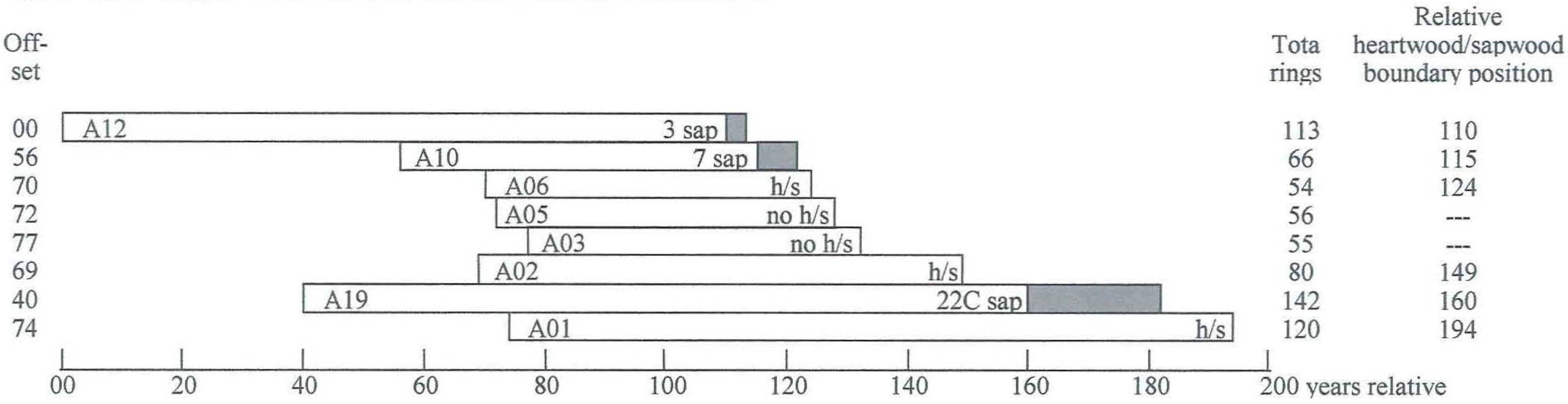


Figure 5: Bar diagram of the samples in site chronology NLWASQ01



white bars = heartwood rings, shaded area = sapwood rings
h/s = heartwood/sapwood boundary is last ring on sample
C = complete sapwood retained on sample

Data of measured samples – measurements in 0.01 mm units

NLW-A01A 120
139 210 195 188 181 167 112 92 119 101 105 148 174 179 212 187 170 95 151 202
194 159 123 166 138 175 158 197 229 175 180 150 159 119 73 69 110 130 114 132
174 194 222 206 158 169 150 203 119 101 127 190 220 212 242 199 199 201 122 170
170 163 204 185 179 158 101 106 75 82 59 104 127 106 106 117 115 116 123 118
95 90 69 73 61 102 119 103 83 54 71 50 40 36 40 41 49 58 60 55
66 51 48 51 49 60 59 52 32 36 38 44 36 57 70 51 56 61 47 75
NLW-A01B 120
131 215 196 182 182 168 110 92 126 98 93 161 168 177 210 201 159 102 148 196
201 154 120 176 135 173 165 187 229 174 183 152 149 119 80 80 107 141 109 129
187 177 216 208 169 162 147 203 130 85 106 199 227 209 223 198 205 208 125 170
182 169 204 181 181 150 108 102 82 82 75 119 124 107 106 115 118 117 126 115
109 97 67 74 67 94 126 114 70 54 57 46 49 31 45 31 49 57 69 56
69 49 51 47 56 51 59 57 36 33 37 25 51 52 54 41 43 45 52 59
NLW-A02A 80
99 103 118 162 95 121 144 121 175 223 168 138 141 135 112 120 103 120 127 145
127 126 98 90 101 113 129 84 118 112 123 112 152 174 192 183 138 176 129 100
116 100 109 151 149 190 278 238 191 147 120 128 121 78 70 79 105 84 115 107
131 128 112 70 69 96 119 113 140 95 88 71 66 54 54 46 74 74 78 86
NLW-A02B 80
68 108 117 151 105 115 143 115 197 218 172 148 119 142 116 126 106 108 132 144
132 134 105 89 85 118 122 95 106 113 124 104 149 160 175 187 150 170 133 114
104 102 109 151 150 193 265 232 214 144 117 117 119 73 78 67 110 78 121 112
146 127 105 73 74 92 114 112 132 101 102 74 55 53 54 50 88 64 72 107
NLW-A03A 55
87 137 169 135 81 123 94 100 176 169 197 167 173 149 89 183 203 194 115 123
160 131 151 163 145 206 111 126 118 127 118 57 70 88 125 90 84 116 172 222
259 266 248 209 221 189 85 187 321 197 79 43 47 65 82
NLW-A03B 54
112 136 176 143 79 122 88 100 186 174 157 153 168 152 85 176 220 191 128 125
167 123 142 148 153 188 116 132 105 139 116 66 59 87 124 90 95 113 162 230
246 263 255 196 220 180 106 172 307 231 67 57 56 101
NLW-A04A 57
567 316 293 352 311 338 296 327 345 385 451 360 566 283 326 315 216 344 279 341
343 486 255 400 444 381 546 329 328 377 352 225 341 296 331 349 378 354 313 355
315 424 328 273 288 295 291 263 228 160 153 310 235 169 157 140 152
NLW-A04B 57
584 312 306 346 324 342 298 350 330 384 384 355 567 287 279 333 222 342 284 337
352 443 289 424 427 390 542 304 298 352 354 240 325 295 326 351 382 345 318 375
274 396 339 307 279 306 275 266 212 161 155 307 217 173 172 151 121
NLW-A05A 56
106 223 208 234 225 218 190 124 94 43 104 54 53 120 131 205 142 181 137 76
147 228 240 167 127 165 132 144 178 179 217 150 155 120 151 123 62 57 104 143
99 113 151 121 167 135 143 122 107 139 114 64 93 206 170 222
NLW-A05B 56
114 225 205 248 228 221 185 128 99 50 87 63 55 130 124 209 150 183 135 72
144 233 238 165 135 162 135 138 174 185 212 168 154 120 155 122 63 62 85 149
100 114 120 126 175 135 146 122 106 146 113 80 98 188 174 181

NLW-A06A 54
461 490 441 486 352 392 498 520 486 511 352 266 176 113 196 201 223 340 420 404
306 286 366 388 424 340 282 324 362 355 382 513 469 411 376 358 349 190 71 88
120 181 163 192 236 326 254 270 196 123 83 83 100 100
NLW-A06B 54
441 488 436 505 358 399 504 506 501 509 327 283 175 123 170 262 277 352 417 387
300 299 356 391 423 342 269 324 347 337 375 472 464 422 373 339 354 184 62 91
139 181 161 195 237 322 242 265 184 119 78 94 95 110
NLW-A07A 42
189 125 487 363 285 295 293 152 377 235 302 285 350 173 380 390 283 227 280 239
260 225 178 190 230 229 232 179 240 225 225 219 233 246 126 66 122 126 112 110
156 169
NLW-A07B 42
185 120 494 358 278 276 315 153 390 239 273 291 346 172 387 393 281 210 285 237
239 217 161 184 219 253 239 146 224 196 223 224 203 254 139 59 127 131 113 119
143 190
NLW-A08A 71
233 416 485 357 393 394 538 637 741 524 412 440 339 379 484 358 296 374 181 146
203 298 416 313 420 383 276 289 240 161 122 141 186 199 220 298 333 138 71 67
55 72 75 66 57 63 79 123 122 145 181 160 114 167 161 269 312 255 177 137
173 127 146 113 78 53 52 63 77 121 129
NLW-A08B 71
223 419 499 342 394 400 561 685 742 538 420 453 309 355 470 366 303 381 184 135
244 319 452 291 431 355 258 270 237 164 117 132 190 199 225 311 320 137 73 56
60 76 67 65 59 68 75 113 135 123 170 165 117 151 182 268 295 229 206 137
170 140 136 124 65 53 57 53 81 121 142
NLW-A09A 72
196 167 299 177 189 96 86 98 272 228 342 313 281 418 399 365 193 274 234 286
244 203 240 191 208 225 282 286 232 227 168 126 144 113 119 95 97 71 60 120
117 56 56 62 60 43 45 26 38 41 45 43 46 50 59 98 70 72 52 47
47 52 71 63 59 64 68 66 78 68 58 68
NLW-A09B 72
186 166 289 177 184 108 71 107 276 235 314 319 276 426 378 375 198 288 232 273
244 205 242 198 216 226 280 294 240 203 158 129 142 116 118 106 89 63 74 106
117 51 62 59 60 49 38 30 33 41 47 41 44 51 60 98 73 72 56 42
52 54 70 66 56 66 64 79 73 68 60 71
NLW-A10A 66
216 116 93 84 100 89 173 152 93 143 218 241 198 268 428 354 298 312 212 349
383 451 320 234 199 233 248 230 184 188 131 134 219 167 121 116 125 167 225 178
94 113 96 104 127 289 362 354 338 209 236 177 126 188 243 151 108 149 253 297
196 222 236 161 136 242
NLW-A10B 66
243 110 84 59 83 85 150 148 97 132 227 240 197 274 417 359 307 276 219 336
357 456 307 227 199 221 258 234 177 183 128 125 234 152 123 116 119 170 221 165
103 102 98 116 145 318 360 343 350 177 224 183 112 198 243 153 112 145 250 294
182 251 179 206 165 162
NLW-A11A 125
102 84 135 141 160 125 134 95 82 141 155 135 154 137 127 162 160 168 122 208
268 228 195 195 280 257 338 101 48 50 72 87 80 66 46 39 60 62 106 52
58 81 129 133 85 59 88 97 98 93 163 259 223 182 140 132 88 52 79 74
48 83 161 178 63 85 110 68 80 52 91 53 49 49 64 54 76 123 103 205

100 84 71 97 158 150 272 92 49 43 44 52 58 58 85 102 103 62 47 45
75 68 64 61 77 69 69 56 84 75 78 117 58 73 83 68 114 89 136 162
136 197 229 212 186
NLW-A11B 125
109 106 123 133 162 124 133 96 93 145 152 142 149 138 132 157 157 174 112 207
271 221 177 190 308 274 311 120 67 61 79 89 76 67 54 52 61 67 93 68
45 71 114 125 87 64 77 97 93 102 160 282 222 199 136 142 80 66 69 70
49 79 163 165 73 91 108 75 81 50 97 46 43 44 68 56 83 129 107 190
113 75 65 102 151 157 272 98 40 42 44 54 57 58 91 96 101 70 46 46
70 67 65 58 74 78 64 61 95 65 80 112 83 83 74 58 90 109 146 166
125 202 236 207 193
NLW-A12A 113
299 304 187 241 183 158 169 173 152 176 132 110 110 124 123 193 81 107 111 141
151 92 137 125 151 139 226 332 254 258 210 199 225 173 178 206 222 195 169 271
239 297 278 173 127 114 144 145 93 151 156 113 148 100 58 40 45 37 35 32
26 30 36 33 29 36 32 25 38 39 63 61 68 54 87 95 129 167 151 115
102 96 120 109 84 113 156 149 147 136 93 83 67 88 154 117 123 184 224 211
270 336 399 313 259 277 367 237 119 147 178 195 197
NLW-A12B 113
322 303 187 239 179 162 172 172 154 176 127 113 110 129 131 176 94 104 111 134
142 107 143 130 153 147 241 322 259 245 210 211 222 172 171 197 204 184 172 238
233 298 261 209 142 113 132 123 109 147 159 108 146 98 59 46 41 40 30 31
23 31 38 33 34 37 25 28 35 42 66 58 68 58 89 113 104 176 154 124
100 94 110 88 72 104 149 162 165 120 104 91 82 104 166 141 125 165 239 204
281 334 411 310 271 262 355 214 124 150 180 188 208
NLW-A13A 61
64 93 104 75 79 80 120 147 122 131 148 165 115 128 127 112 158 133 186 93
111 144 207 193 246 267 190 176 139 169 192 143 209 193 154 175 163 134 175 98
114 134 111 185 214 195 275 113 136 212 189 252 215 180 179 155 127 244 304 307
246
NLW-A13B 61
69 97 95 89 69 82 124 146 110 136 162 149 125 120 128 111 164 136 162 112
94 163 200 183 220 247 196 191 146 163 177 153 208 185 158 163 178 130 168 103
113 134 117 186 207 197 244 145 128 201 212 256 193 184 165 154 142 183 316 268
282
NLW-A14A 54
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NLW-A18B 80
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84 77 104 162 219 292 205 214 186 146 116 123 120 204 297 278 336 350 277 263
NLW-A19A 142
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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.

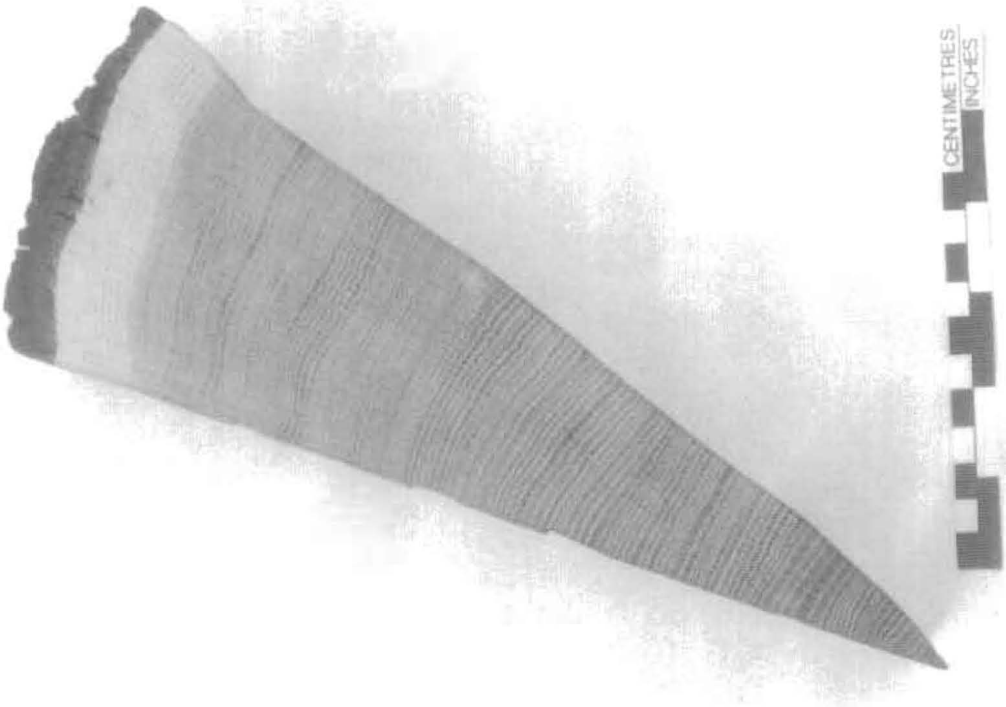

Fig 1. A wedge of oak from a tree felled in 1976. It shows the annual growth rings, one for each year from the innermost ring to the last ring on the outside just inside the bark. The year of each ring can be determined by counting back from the outside ring, which grew in 1976.

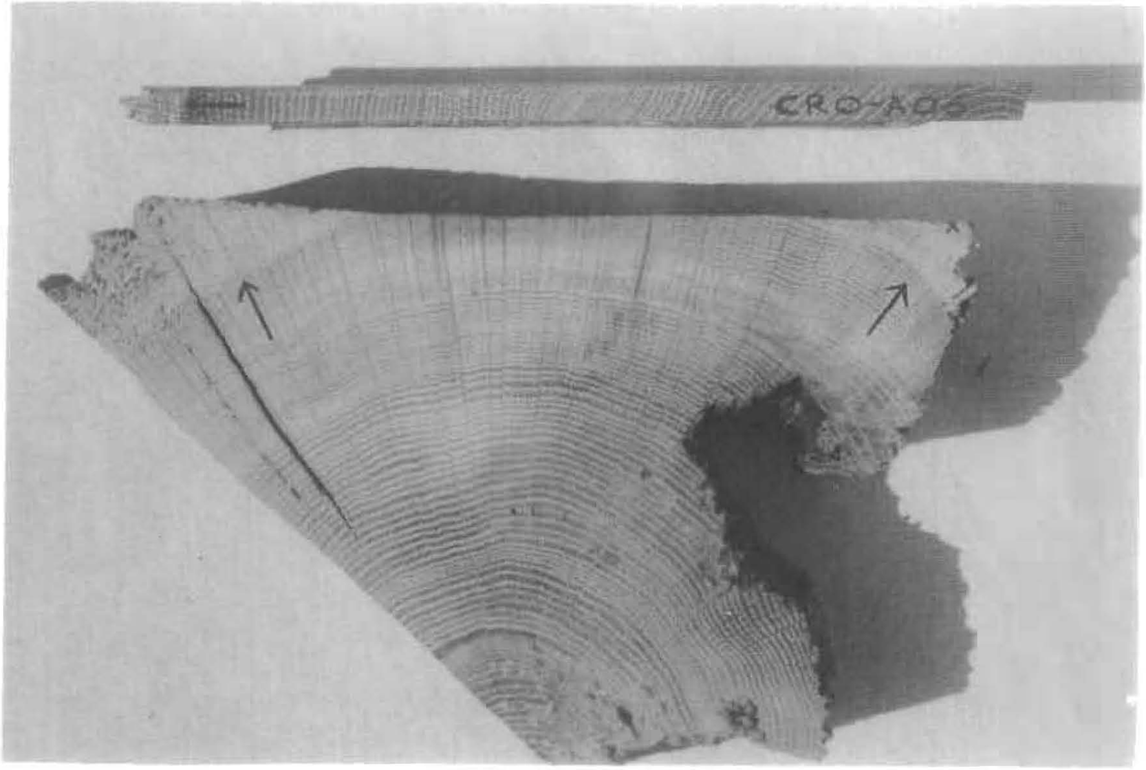

Fig 2. Cross-section of a rafter showing the presence of sapwood rings in the corners, the arrow is pointing to the heartwood/sapwood boundary (H/S). Also a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil.

Fig 3. 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.

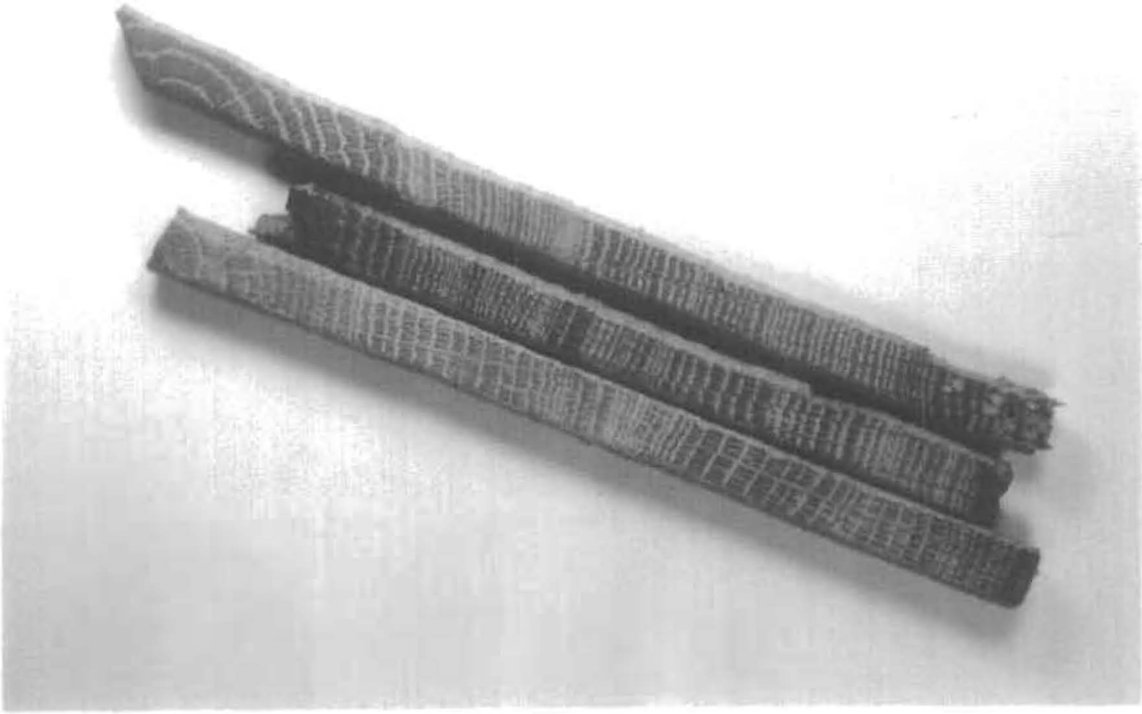

Fig 4. Three cores from timbers in a building. They come from trees growing at the same time. Notice that, although the sequences of widths look similar, they are not identical. This is typical.

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

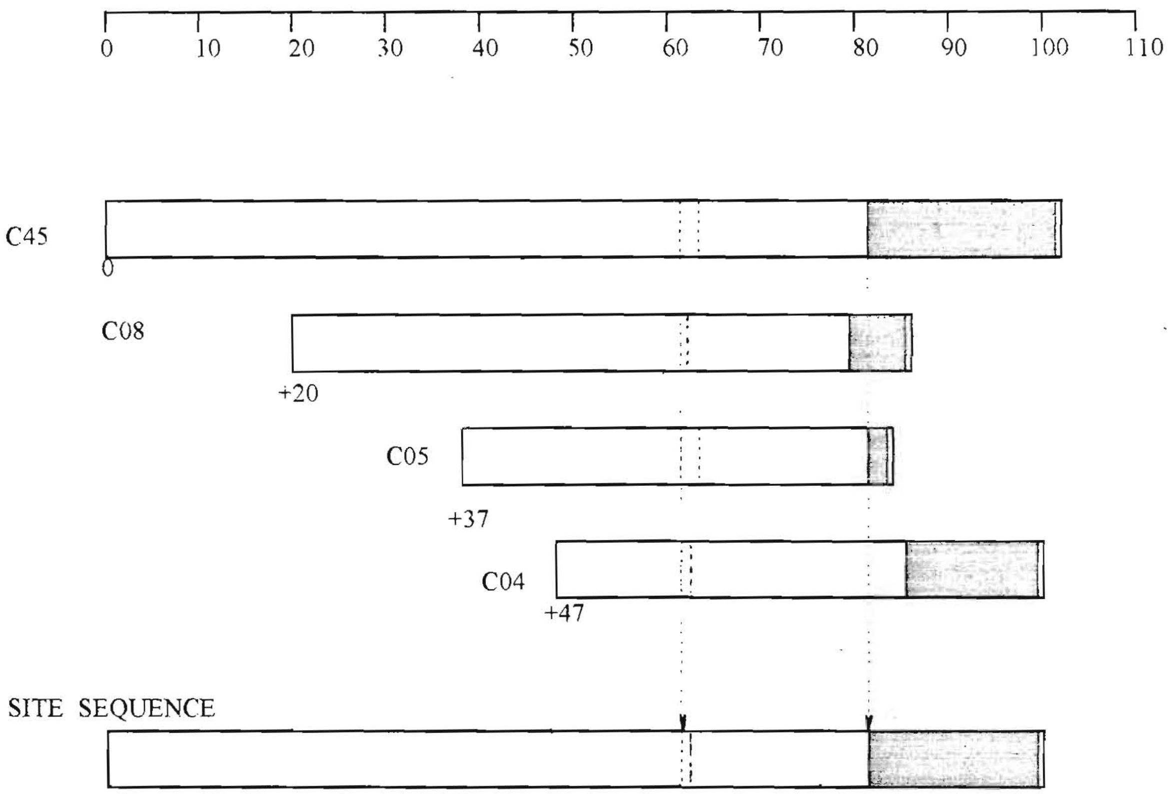

Fig 5. Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them.
The *bar diagram* represents these sequences without the rings themselves. The length of the bar is proportional to the number of rings in the sequence. Here the four sequences are set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

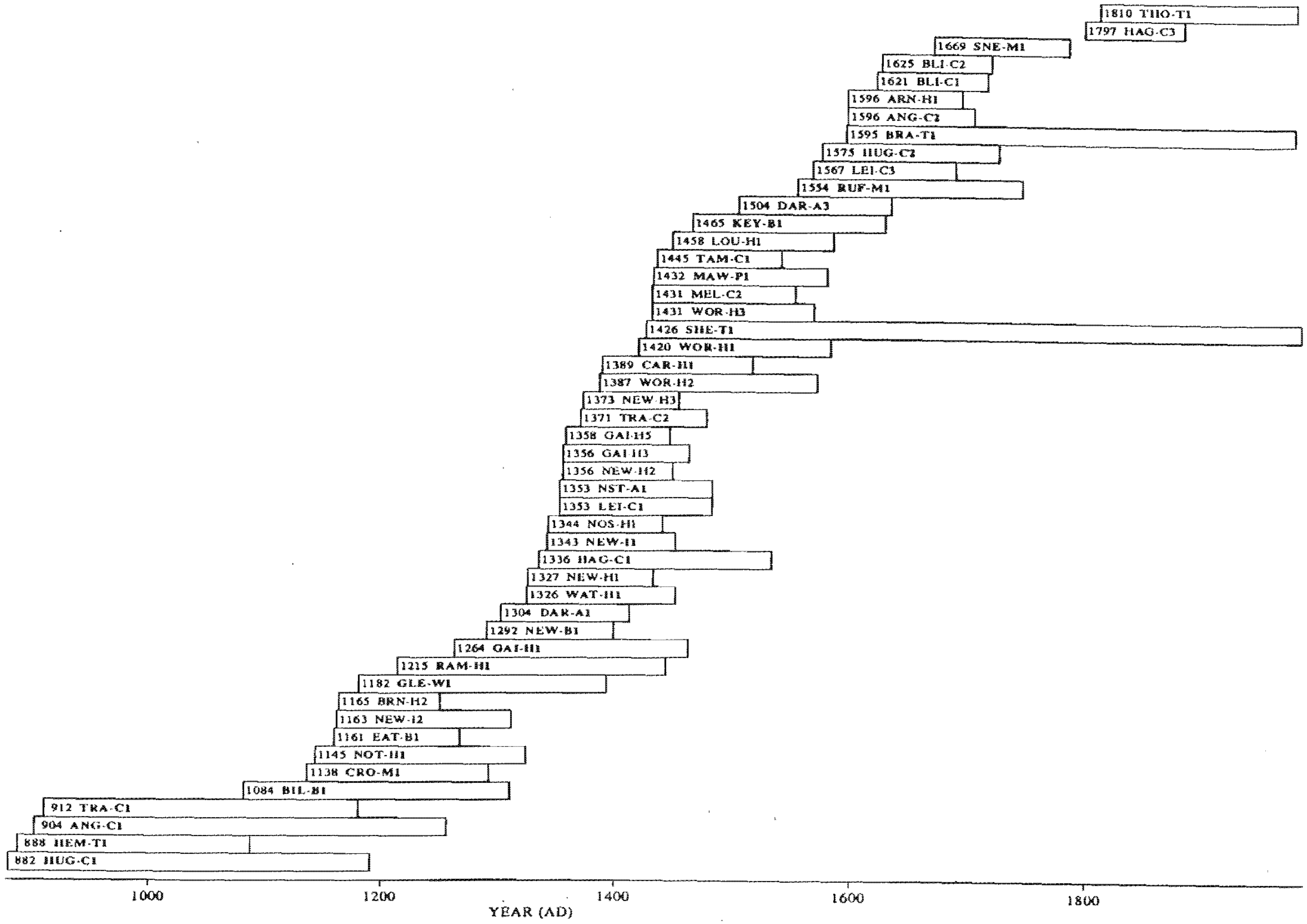

Fig 6. Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87.

(a)

(b)

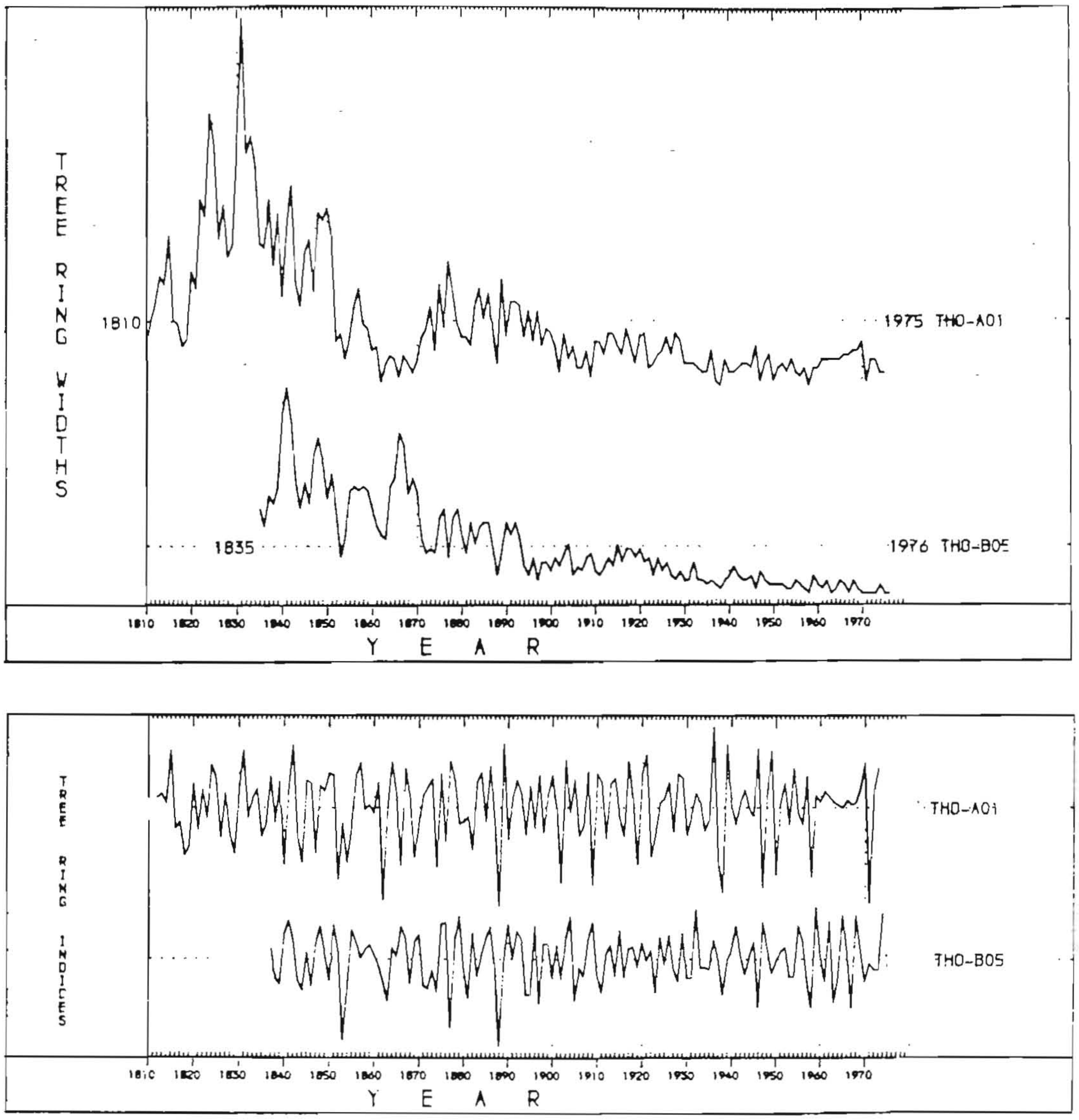

Fig 7. (a) The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known. Here the ring widths are plotted vertically, one for each year, so that peaks represent wide rings and troughs narrow ones. Notice the growth-trends in each; on average the earlier rings of the young tree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