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**Tree-Ring Analysis of Timbers from 16-17 West Street,  
Faversham, Kent**

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### **Summary**

Dendrochronology analysis was undertaken on eight samples from oak timbers at these premises, FAV-C01-04 from 17 West Street and FAV-C05-08 from 16 West Street.

No cross-matching occurred between the samples and attempts to date them individually were unsuccessful.

The poor results are most likely to be due to the short ring-width sequences of these samples and the lack of a Kent chronology covering this period.

### **Keywords**

Dendrochronology  
Standing Buildings

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## TREE-RING ANALYSIS OF TIMBERS FROM 16-17 WEST STREET, FAVERSHAM, KENT

### Introduction

These properties are located on West Street, Faversham (TR 01456142; Figs 1, 2a, 2b, and 2c). The following description is taken from a report into the buildings written by Sarah Pearson (pers comm). These two properties encompass two separate structures, both thought, on the evidence of style and structure, to date from the late-sixteenth or early seventeenth centuries. Both are of two storeys jettied out over the street front, now with attics and partly with cellars. The earlier of the two structures, encompasses 17 West Street and the western half of 16 West Street. Its patterned external framing originally suggesting a date between about AD 1580 and AD 1620, probably towards the earlier end of this period (Fig 2c). The second range, to the east, being the remainder of 16 West Street, was added, or more probably rebuilt, not long afterwards. This has been placed some time in the first half of the seventeenth century.

The Laboratory would like to thank John and Carol Stockley of 16 West Street and Pam Kingsnorth from 17 West Street for allowing us access to their premises for both the initial survey and sampling. We also thank Sarah Pearson for all her assistance in locating the properties and arranging access, and for providing the building description above, and the drawings and photographs, which are reproduced with her kind permission (Figs 2a, 2b, 2c, 3, and 4).

### Sampling

A total of eight samples were taken from oak timbers at these premises, four from 16 West Street (rafter, tiebeams, and crossbeam) and four from 17 West Street (purlins, corner post, and tiebeam) with each sample being given the code FAV-C (for Faversham, site "C"). The positions of these samples were recorded at the time of sampling and have been marked on Figures 3 and 4. Further details relating to the samples are recorded in Table 1.

### Analysis and Results

Each sample was prepared by sanding and polishing and the growth-ring widths of all eight were measured; the data of these measurements are given at the end of the report. The growth-ring widths of the samples were compared with each other by the Litton/Zainodin grouping procedure (see appendix). No grouping between the samples occurred and attempts to date the samples individually, by cross-matching against relevant reference chronologies for oak, were unsuccessful. Therefore, all eight samples must remain undated.

## Discussion

Dendrochronological analysis in this case has been unsuccessful in dating timbers at these premises. This is most likely due to the short ring width sequences of the samples and the fact that the Kent chronology does not, at present, cover this period. Therefore, dating of these houses, must remain on stylistic grounds only, that is the earlier phase, which spans the western part of 16 West Street and 17 West Street, to AD 1580-1620, and the second phase, forming the eastern half of number 16, to the first half of the seventeenth century.

Figure 1: Street plan of Faversham to show the location of 16-17 West Street

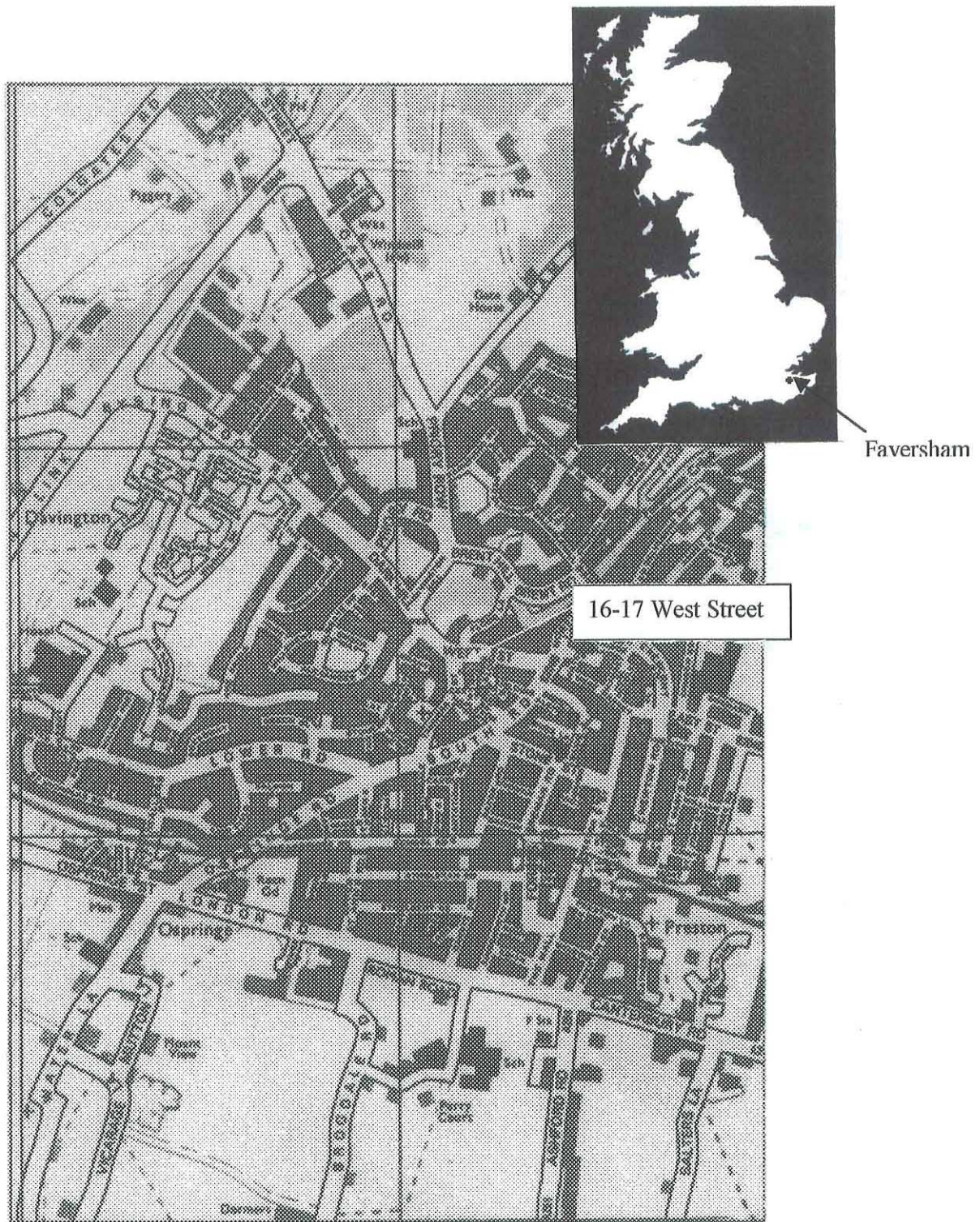


Figure 2a: 16 West Street, the eastern half (later phase) closest to the camera; photograph provided by Sarah Pearson



Figure 2b: 16-17 West Street, 16 West Street closest to the camera; photograph provided by Sarah Pearson



Figure 2c: 16-17 West Street, the distinctive ornamental framing can be seen on number 17 and on the western half of number 16; photograph provided by Sarah Pearson





Figure 3: Ground-floor plan of 16-17 West Street, Faversham, showing the location of samples FAV-C05-08, drawn by Sarah Pearson

*Ground floor*

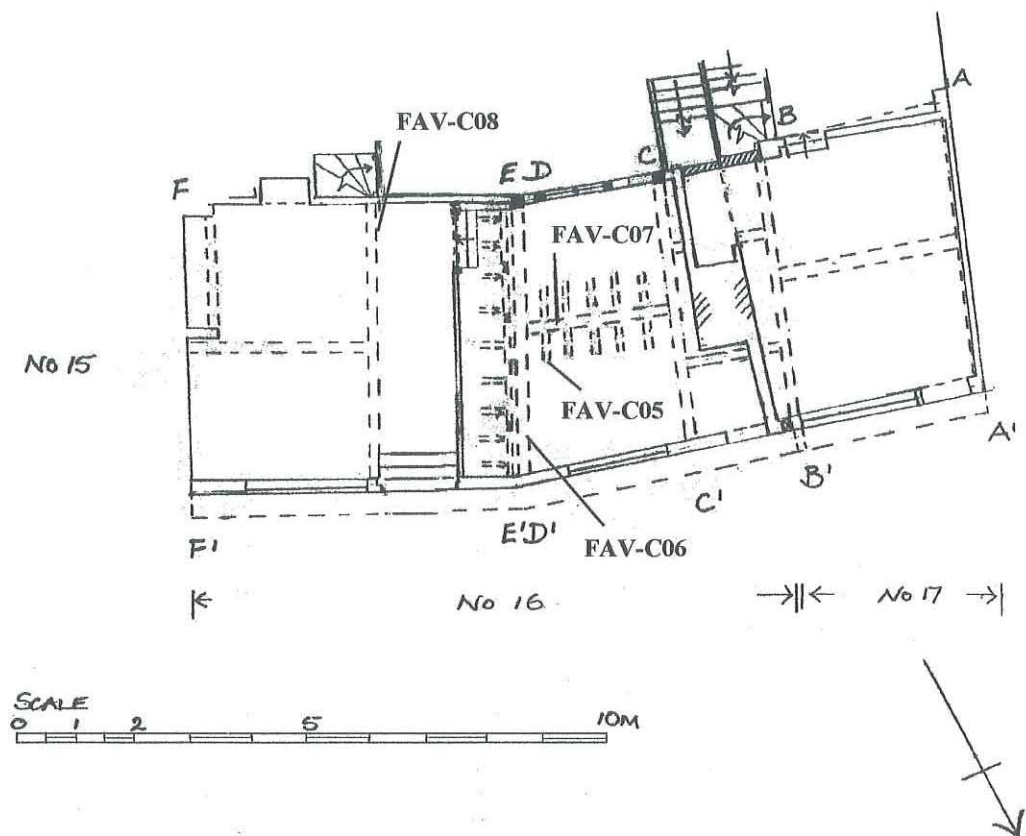
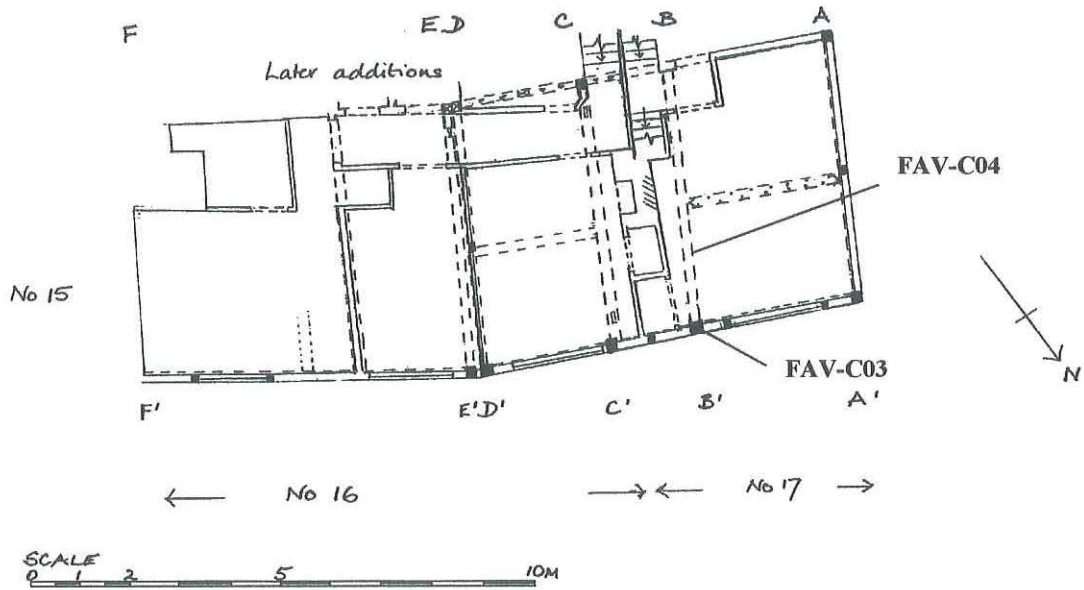


Figure 4: First-floor plan of 16-17 West Street, Faversham, showing the location of samples FAV-C03-04, drawn by Sarah Pearson; sketch plan of attic and the location of samples FAV-C01-02 (not to scale)

*First floor*



*The Attic, 17 West Street*

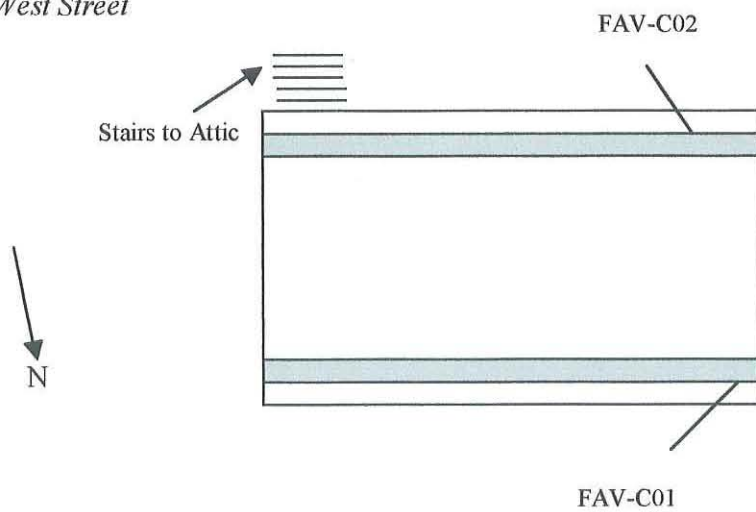


Table 1: Details of tree-ring samples from 16-17 West Street, Faversham, Kent

Sample number	Sample location	Total rings	Sapwood rings*	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
FAV-C01	North purlin (attic), number 17	59	15	----	----	----
FAV-C02	South purlin, (attic), number 17	49	30	----	----	----
FAV-C03	Corner post B <sup>1</sup> , (first floor), number 17	64	15	----	----	----
FAV-C04	Tiebeam B-B <sup>1</sup> , (first floor), number 17	65	13	----	----	----
FAV-C05	North joist, fifth from west (ground floor), number 16	57	05	----	----	----
FAV-C06	Crossbeam D- D <sup>1</sup> , (ground floor), number 16	43	h/s	----	----	----
FAV-C07	Spinebeam between C & D (ground floor), number 16	50	--	----	----	----
FAV-C08	Crossbeam, centre of bay E-F (ground floor), number 16	66	20	----	----	----

\*h/s = the heartwood/sapwood boundary is the last ring on sample

Data of measured samples – measurements in 0.01 mm units

FAV-C01A 59

156 248 216 304 270 288 267 163 212 197 110 48 69 55 58 106 120 174 151 144  
166 190 313 282 219 285 270 225 290 233 244 182 205 171 144 238 224 196 161  
132 147 160 156 150 224 169 97 130 104 80 103 90 89 81 117 111 109 165 108

FAV-C01B 59

146 249 197 287 261 279 280 166 205 186 119 44 75 61 56 111 113 173 148 146  
168 187 311 276 219 297 252 222 298 235 238 172 207 175 143 240 206 197 158 128  
136 161 151 150 268 142 103 106 114 80 113 75 104 94 130 114 121 141 90

FAV-C02A 49

206 317 294 376 275 252 275 219 180 246 252 266 202 243 212 162 318 306 248 266  
194 221 253 185 187 223 150 114 89 147 124 75 149 133 154 125 166 176 132 128  
171 124 125 138 158 158 136 150 107

FAV-C02B 49

218 322 305 373 299 228 264 242 166 249 246 258 206 244 223 161 314 288 251 248  
180 222 263 204 181 230 162 112 129 107 124 82 144 129 154 126 168 179 131 127  
169 125 127 159 131 161 139 170 74

FAV-C03A 64

521 521 315 245 206 533 249 599 355 276 57 51 90 108 95 74 87 127 206 176  
91 113 111 131 128 78 51 64 113 100 185 253 273 137 99 60 130 107 244 139  
107 54 57 55 48 48 43 34 78 56 113 74 85 127 168 78 91 72 78 111  
121 109 160 77

FAV-C03B 64

509 520 328 251 207 545 247 599 351 271 54 71 77 103 90 71 94 147 193 147  
93 114 107 142 120 76 52 66 112 109 180 256 278 141 99 66 104 101 217 137  
95 60 57 49 51 40 38 39 70 86 92 94 85 117 159 79 91 73 91 92  
109 135 139 78

FAV-C04A 65

285 190 126 185 136 218 209 163 156 185 159 147 121 89 157 132 109 167 138 172  
157 125 199 206 131 199 256 303 162 214 166 61 228 168 203 166 217 239 224 258  
150 207 143 124 85 40 42 55 94 120 76 107 98 87 97 82 71 192 95 112 88  
150 115 140 78

FAV-C04B 65

276 184 129 183 148 221 204 167 155 168 168 155 120 87 157 120 118 178 143 169  
156 115 201 203 145 191 246 305 159 202 161 69 238 165 197 169 209 244 235 254  
174 213 144 117 80 40 47 54 92 101 89 113 89 91 107 88 78 176 91 121  
86 148 116 139 74

FAV-C05A 57

131 72 114 64 48 53 81 98 107 126 122 97 128 135 118 193 184 199 238 222  
237 204 234 197 129 199 228 195 201 220 214 215 227 213 214 187 109 280 209 246  
256 182 205 144 156 131 182 217 227 263 274 247 192 171 187 179 147

FAV-C05B 57

101 74 97 75 48 59 89 115 119 135 122 96 130 131 120 174 186 201 233 217  
227 194 217 184 142 207 231 209 186 236 215 207 215 199 215 177 109 258 216 230  
272 178 204 145 169 127 184 220 242 241 277 250 179 185 170 176 140

FAV-C06A 43

152 287 228 315 314 422 329 257 479 368 430 363 358 319 211 150 278 318 214 197

280 240 207 202 208 168 336 396 327 371 329 337 372 332 233 348 219 155 175 161  
233 370 233

FAV-C06B 43

128 271 245 342 296 412 344 237 475 369 415 352 346 299 222 150 288 301 209 202  
279 245 206 196 208 176 327 376 336 377 336 340 371 322 237 340 218 152 181 161  
232 365 229

FAV-C07A 50

152 365 365 301 292 187 151 114 102 56 43 120 152 126 152 170 140 240 308 254  
275 331 431 506 363 432 485 404 229 226 207 133 293 168 281 162 280 239 507 487  
391 374 376 346 361 353 415 390 364 374

FAV-C07B 50

153 362 366 301 291 201 149 111 105 54 45 118 147 125 160 162 130 280 330 253  
244 373 422 518 362 403 492 386 244 231 189 130 295 174 276 174 278 240 509 489  
386 351 404 374 388 349 440 392 374 335

FAV-C08A 66

408 327 538 406 510 701 584 480 598 525 490 469 409 378 389 394 301 299 328 392  
294 335 247 302 312 327 145 174 171 207 99 134 145 207 124 136 142 175 200 198  
150 141 145 141 190 131 165 108 127 90 79 143 184 145 123 128 136 164 154 113  
115 126 112 139 162 98

FAV-C08B 66

272 345 506 415 536 674 579 485 602 515 495 459 416 378 384 403 298 302 322 392  
292 336 250 316 303 332 140 182 168 211 101 123 145 201 126 125 147 167 205 184  
166 136 147 143 182 147 135 106 122 91 80 143 181 143 125 129 147 153 149 119  
115 125 113 139 164 87

## 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 Figure 1 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.

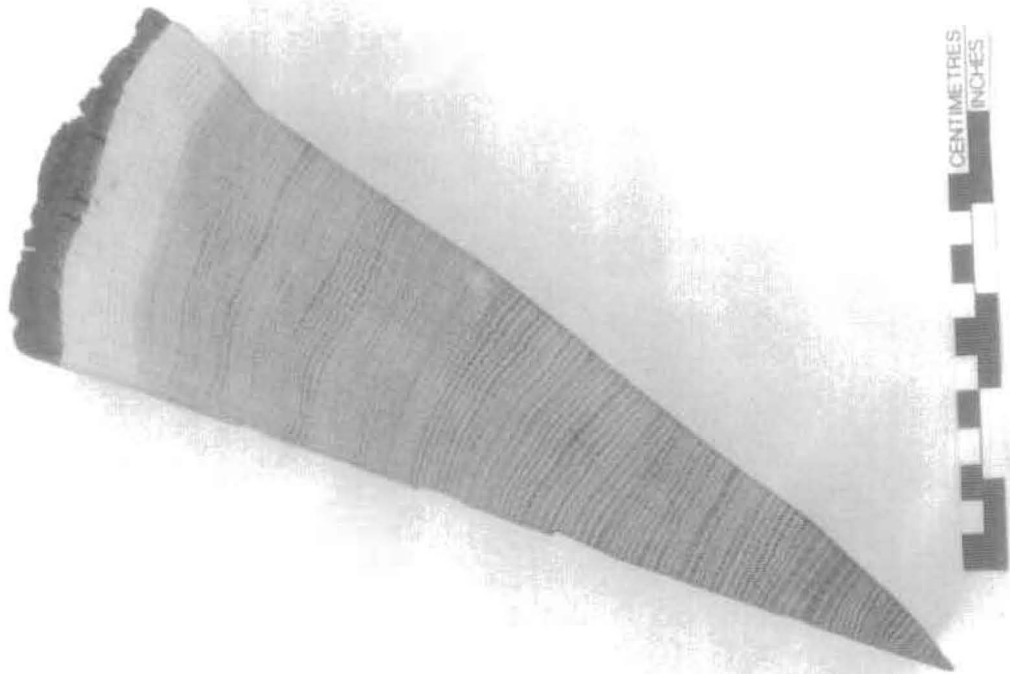


Fig 1. A wedge of oak from a tree felled in 1976. It shows the annual growth rings, one for each year from the innermost ring to the last ring on the outside just inside the bark. The year of each ring can be determined by counting back from the outside ring, which grew in 1976.

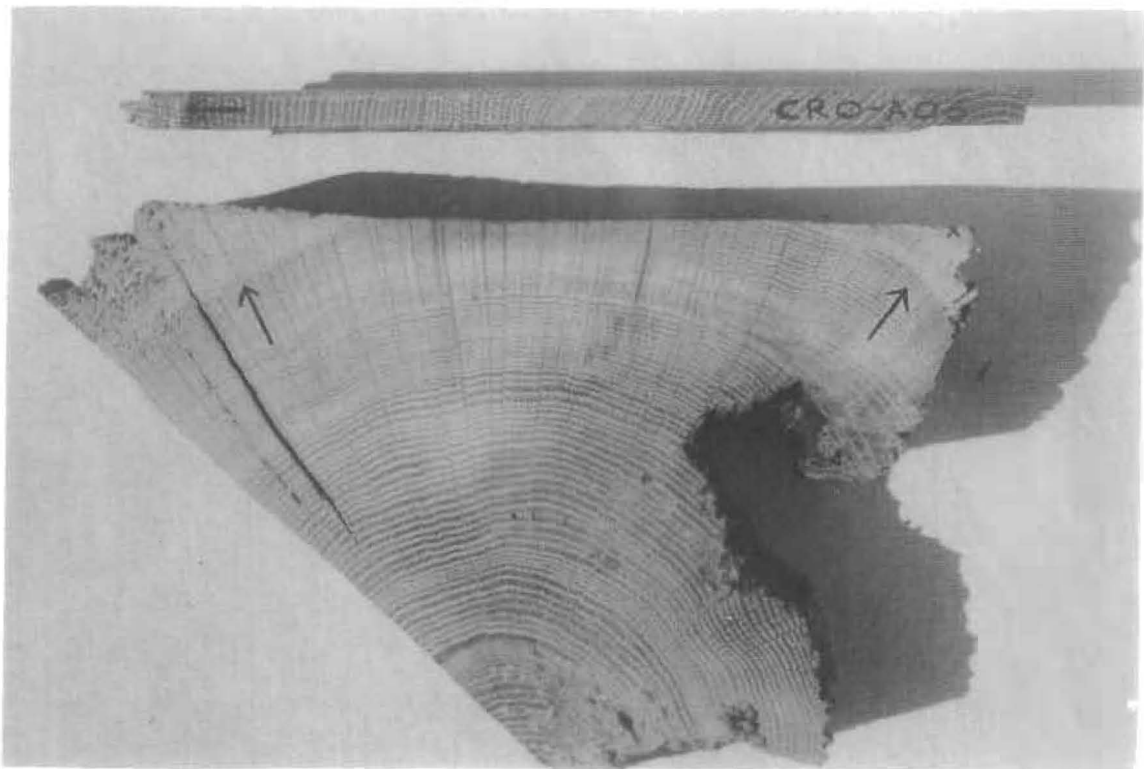


Fig 2. Cross-section of a rafter showing the presence of sapwood rings in the corners, the arrow is pointing to the heartwood/sapwood boundary (H/S). Also a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil.



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.

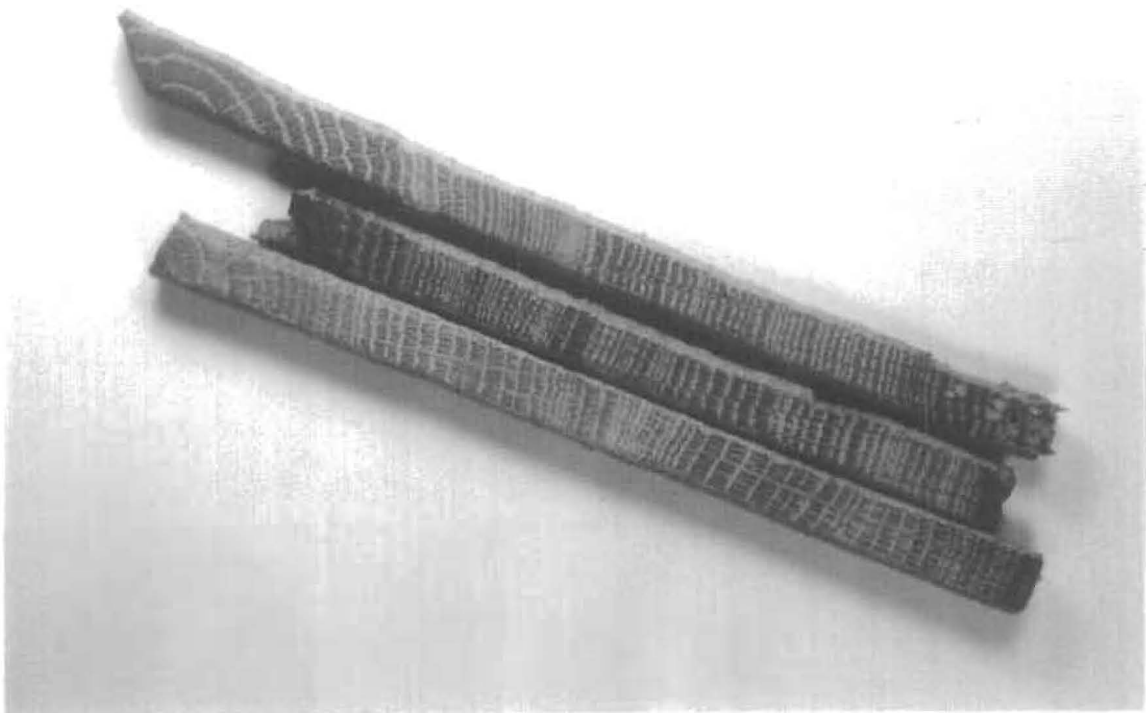


Fig 4. Three cores from timbers in a building. They come from trees growing at the same time. Notice that, although the sequences of widths look similar, they are not identical. This is typical.



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 inspection of the building and its timbers the dendrochronologist may come to the conclusion that, as far as can be judged, none of the timbers have sufficient rings in them for dating purposes and may advise against sampling to save further unwarranted expense.

All sampling by the Laboratory is undertaken according to current Health and Safety Standards. The Laboratory 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**

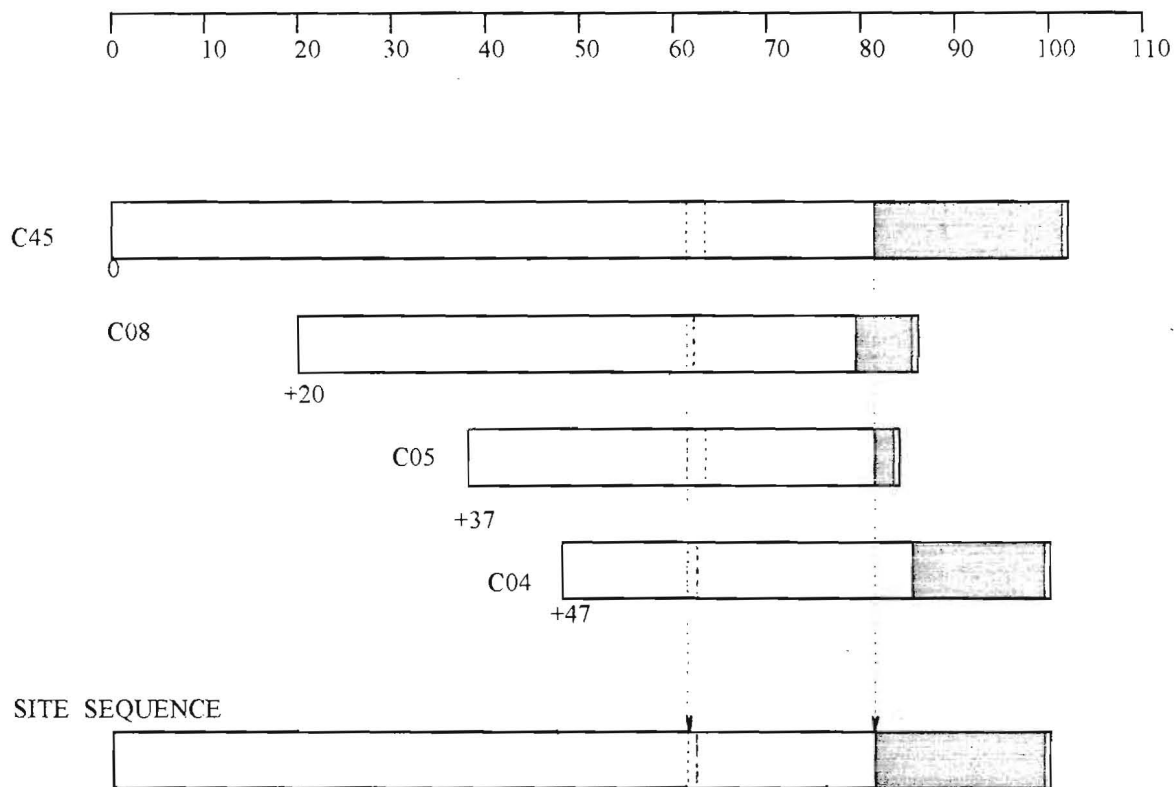


Fig 5. Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them.

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.

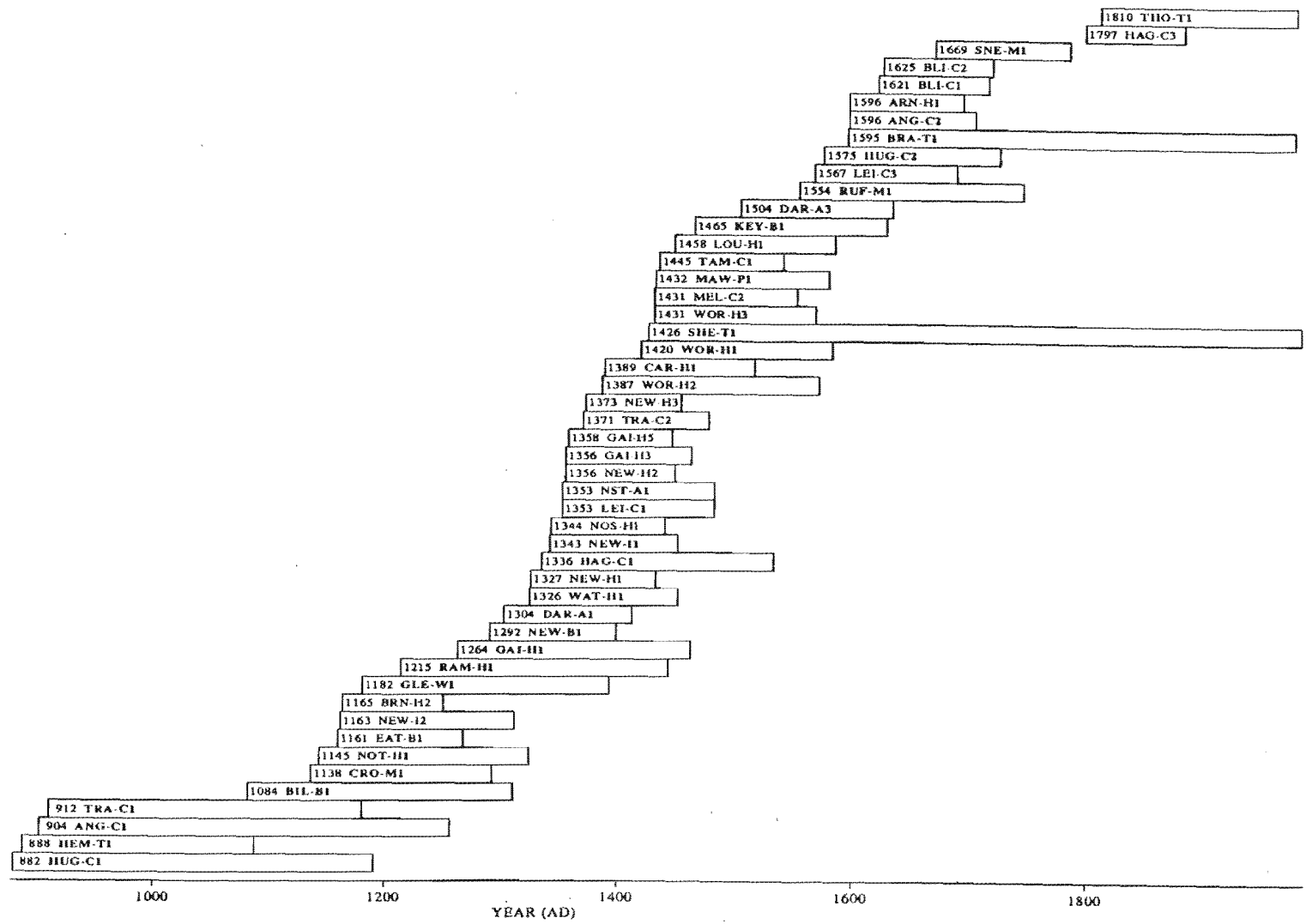


Fig 6. Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87.

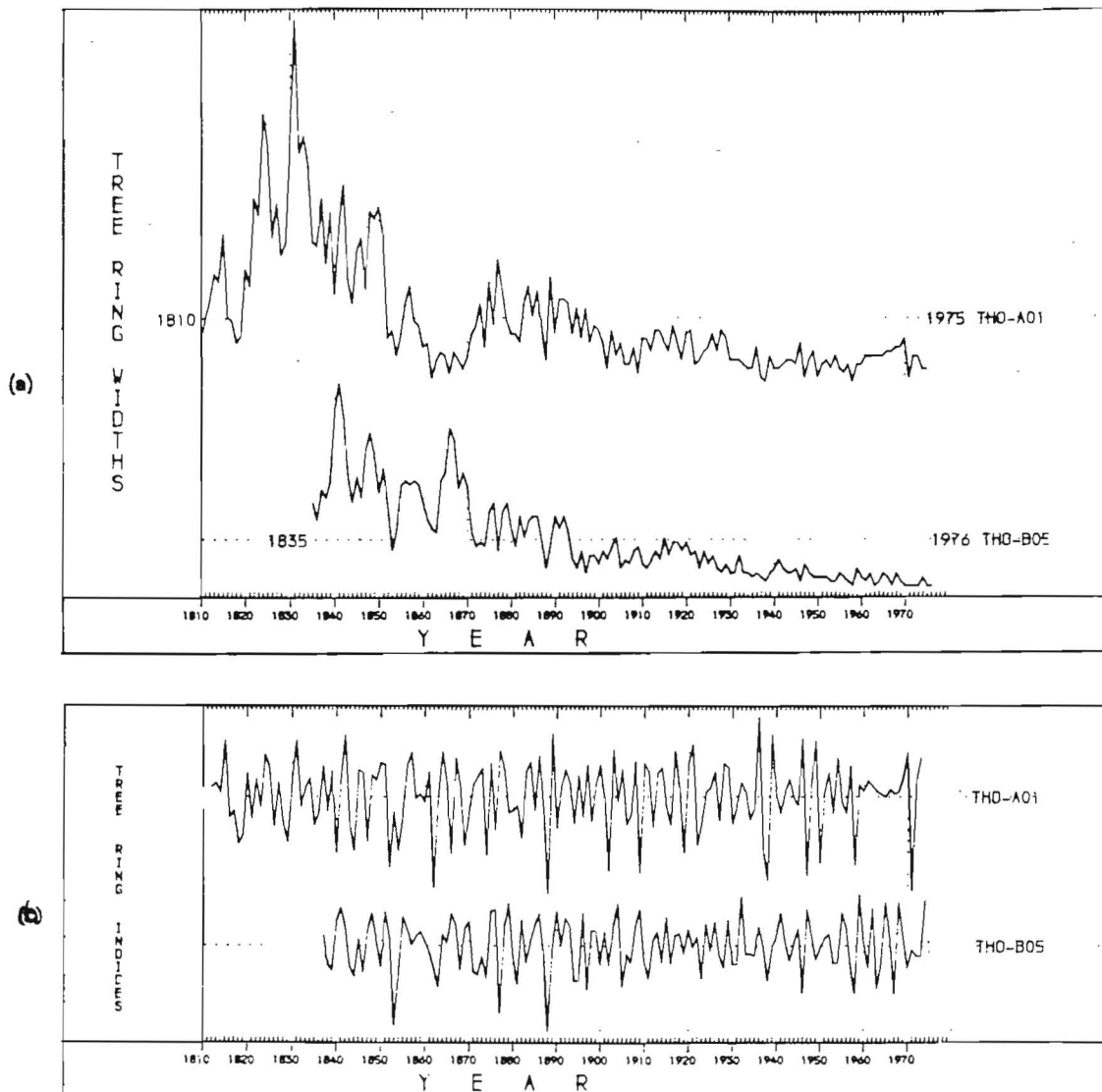


Fig 7. (a) The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known. Here the ring widths are plotted vertically, one for each year, so that peaks represent wide rings and troughs narrow ones. Notice the growth-trends in each; on average the earlier rings of the young tree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

## REFERENCES

- Baillie, M G L, 1982 *Tree-Ring Dating and Archaeology*, London.
- Baillie, M G L, 1995 *A Slice Through Time*, London
- Baillie, M G L, and Pilcher, J R, 1973, A simple cross-dating program for tree-ring research, *Tree-Ring Bulletin*, **33**, 7-14
- Hillam, J, Morgan, R A, and Tyers, I, 1987, Sapwood estimates and the dating of short ring sequences, *Applications of tree-ring studies*, BAR Int Ser, **3**, 165-85
- Howard, R E, Laxton, R R, Litton, C D, and Simpson, W G, 1984-95, Nottingham University Tree-Ring Dating Laboratory Results, *Vernacular Architecture*, **15 - 26**
- Hughes, M K, Milson, S J, and Legett, P A, 1981 Sapwood estimates in the interpretation of tree-ring dates, *J Archaeol Sci*, **8**, 381-90
- Laxton, R R, Litton, R R, and Zainodin, H J, 1988a An objective method for forming a master ring-width sequence, *P A C T*, **22**, 25-35
- Laxton, R R, and Litton, C D, 1988b *An East Midlands Master Chronology and its use for dating vernacular buildings*, University of Nottingham, Department of Archaeology Publication, Monograph Series III
- Laxton, R R, and Litton, C D, 1989 Construction of a Kent Master Dendrochronological Sequence for Oak, A.D. 1158 to 1540, *Medieval Archaeol*, **33**, 90-8
- Litton, C D, and Zainodin, H J, 1991 Statistical models of Dendrochronology, *J Archaeol Sci*, **18**, 429-40
- Pearson, S, 1995 *The Medieval Houses of Kent, An Historical Analysis*, London
- Rackham, O, 1976 *Trees and Woodland in the British Landscape*, London