Centre for Archaeology Report 87/2003

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With a contribution by Richard Bond

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Summary

Although Clothall Bury Farmhouse contains a large number of timbers, many of the oak beams had too few rings for satisfactory analysis. Other timbers were of elm which were not sampled.

Thus from the available material only seven samples were obtained. Tree-ring analysis produced a single site chronology of four samples from a wall apparently constructed of reused timbers. This site chronology is 118 rings long and dated as spanning AD 1636 to AD 1753.

The four dated samples probably represent three phases of felling. The earliest is probably represented by samples CLB-B05 and B06 these having an estimated felling date in the range AD 1727 - 52. It is possible that the two timbers represented were felled at slightly different times.

The next phase is probably represented by samples CLB-B07. This sample retains complete sapwood, the last ring being dated to AD 1747. Given the overlap in the estimated felling date range it is possible that samples CLB-B05 and B06 were felled at this time too.

The final phase of felling detected is represented by sample CLB-B03. This sample also retains complete sapwood, this last ring being dated to AD 1753.

Keywords

Dendrochronology
Standing Building

Author's address

University of Nottingham, University Park, Nottingham, NG7 2RD

Introduction

Clothall Bury farmhouse near Baldock, in the parish of Clothall, Hertfordshire (TL 289320; Figs 1 and 2), comprises what is believed to be a fifteenth-century former manor house, which has been altered and extended in the seventeenth and nineteenth centuries. Plans and illustrations of the house, as existing and as originally built, are given in Figures 3 and 4.

The house is of two timber-framed storeys with roughcast walls beneath a plain tile roof, and is divided into five bays internally. It is currently listed grade II and described as being a former manor house dating from the fifteenth century. The building was altered and extended in the middle of the seventeenth century and again in AD 1868. Behind the porch façade is a fifteenth century cross-wing. A crown post roof is partly exposed in one of the upper rooms with the top parts of it visible in the attic. The front elevation of *c.* AD 1868 has six sash windows with vertical glazing bars.

At the core of the present building is the original medieval open hall, divided into two bays and spanned by a central open roof truss. The current listing describes the hall as having an 'unusual upper cruck roof" with a central truss comprising 'two narrow blades forming a depressed arch'. Whilst the arched timbers are certainly curved and might justifiably be described as 'cruck-like' in their appearance, they are in fact not blades but arch braces. What other evidence there may be to show that the central hall truss is an 'upper cruck' truss (as opposed to, say, an arch-braced collar truss with its collar and upper parts of the principal rafters removed) is not stated in the listing description. The present roof frame over what was the original medieval hall is of tenoned-purlin construction. Many of the common rafters are reused timbers, presumably rafters salvaged from the original roof of the hall. The reused rafters are smoke-blackened and have a halving near to the apex for a scissor-brace. The hall was floored over in the seventeenth century and the former open hearth replaced by a brick chimney.

Adjoining the central hall on the east side is a timber-framed cross wing. This is also of medieval date and probably represents the 'solar' or 'upper end' cross wing of the original house. It has a crown-post roof, and the exposed timbers of the central roof truss have traces of smoke blackening (presumably either from a former fireplace heating the first floor chamber, or from smoke reaching the cross wing from the open hearth that heated the hall). Adjoining the east side of the medieval cross wing is a second, parallel, cross wing, probably dating from the seventeenth century.

Adjacent to the farmhouse is a particularly large and impressive aisled barn. This has already been the subject of tree-ring sampling, the analysis of which produced an unexpectedly early date (Arnold *et al* 2003).

Sampling

Sampling and analysis by tree-ring dating of timbers from the open hall cross-wing were commissioned by English Heritage. The purpose of this was to provide a precise date for its construction and to inform a potential listing upgrade.

The timbers of the roof of the hall and cross-wing, consisting mainly of common rafters, were examined as to their suitability for tree-ring dating. Although of only very modest dimensions, about 7cm square, the timbers were of a size that might normally provide sufficient rings, i.e. more than 54, for satisfactory analysis. However, in this case, not only were the timbers of modest size but they had been cut from very fast grown trees, and thus had too few rings. The only suitable timbers for tree-ring analysis were two beams of a primary truss visible in the first-floor chamber of the cross-wing, the other timbers of this truss being fast grown elm. Such fast grown timbers generally do not have sufficient rings, ie more than 54, for satisfactory analysis.

Although there were other timbers in the wall-framing of the ground-floor rooms of the cross-wing, most of them were of fast grown elm too, and those that were of oak showed evidence, by way of empty mortices and peg-holes, of being reused.

Thus, after on-site discussions with Richard Bond, and in conjunction with the English Heritage brief, the two oak timbers available from the primary truss of the cross-wing, which showed no evidence of reuse, were sampled. A further five reused oak timbers from a wall-frame on the ground floor of the cross-wing were also sampled. This was done in the hope that the reused oak timbers might be of the same, or similar date, and thus provide sufficient samples with suitable data to date the two primary timbers, which were less likely to date on their own.

The fast-grown elm timbers were not sampled. This was because while it has previously occasionally proved possible to date elm this has only been satisfactorily accomplished where there are numerous elm timbers to be sampled and the elm timbers are contemporaneous with oak from the same structure. There were insufficient elm timbers at Clothall Bury, and it was not at all certain that they were contemporary with any of the oak timbers.

Each sample was given the code CLB-B (for Clothall Bury, site "B"), and numbered 01 – 07. The positions of the timbers sampled are shown on the plans made by Richard Bond and provided by English Heritage, and on sketch drawings made at the time of sampling. These are reproduced here as Figures 5 and 6. Details of the samples are given in Table 1. In this report the individual timbers are described on a north - south, or east - west basis, as appropriate.

The Laboratory would like to take this opportunity of thanking the owners of the barn, Mr and Mrs Haltom, for allowing sampling, for being so enthusiastic about the project, and for the hospitality during a few cold days sampling in December. The Laboratory would also like to thank Richard Bond for not only providing the introductory paragraph above, but also for his clear advice and discussion about the possible phasing of the timbers.

The Laboratory would also like to thank Cathy Groves of the University of Sheffield Dendrochronology Laboratory for her considerable help in dating these samples.

Analysis

Each of seven samples was prepared by sanding and polishing and their annual growth-ring widths were measured. The data of these measurements are given at the end of the report. These data were then compared with each other by the Litton/Zainodin grouping procedure (see appendix). Unfortunately, although there was cross-matching between some of the samples, this was with lower *t*-values than is usually accepted, and with short, though just acceptable overlaps between some of the samples. The Litton/Zainodin grouping procedure would not automatically allow the formation of a group at the usual minimum value of t=4.5.

Each sample was then compared individually with a full range of reference chronologies for oak, including reference data held at the University of Sheffield Dendrochronology Laboratory. This indicated satisfactory cross-matches for four of the samples, CLB-B03, B05, B06, and B07, at consistently repeated dates. The dates obtained for each of these four samples were consistent with the low-level relative cross-matching between them.

Because of this low-level cross-matching, and particularly because of the satisfactory individual dating, the four samples were combined at their indicated relative off-sets to form a single site chronology CLBBSQ01, having a combined overall length of 118 rings. Site chronology CLBBSQ01 was compared to a full range of reference chronologies indicating a consistent satisfactory cross-match when the date of its first ring is AD 1636 and the date of its last measured ring is AD 1753. Evidence for this dating is given in the *t*-values of Table 2.

Interpretation

Analysis by dendrochronology has produced a single site chronology comprised of material obtained from a wall apparently made of reused timbers. This site chronology consists of only four samples, a relatively small number, but it is 118 rings long. This chronology has been satisfactorily dated as spanning the period AD 1636 to AD 1753.

The four dated samples certainly represent at least two or, more probably, three phases of felling. The earliest is probably represented by samples CLB-B05 and B06. These two samples have a variation in the relative position of the heartwood/sapwood boundary of only two years, a variation highly indicative of timbers having a single felling date. The average last heartwood ring date of samples CLB-B05 and B06 is AD 1712. The usual 95% confidence limit for the amount of sapwood on mature oaks from this part of England is 15 - 40 rings and such a limit would give the timbers represented an estimated felling date in the range AD 1727 – 52. However, given that the two samples do not match each other very well, it is likely that they have come from different sources and may not have been felled at exactly the same time.

The next phase of felling is probably represented by sample CLB-B07. This sample retains complete sapwood, that is, it has the last ring produced by the tree before it was felled. This last ring is dated to AD 1747. However, given that the estimated felling date range of samples CLB-B05 and B06 (up to AD 1752) overlaps with the felling date of sample CLB-B07, it is possible that the three timbers represented were all felled at the same time in AD 1747.

The probable third phase of felling detected is represented by sample CLB-B03. This sample also retains complete sapwood, this last ring being dated to AD 1753.

Conclusion

The mid-eighteenth century felling dates produced by the dated samples relate to their primary use and not their reuse in the wall of the cross-wing. This does, however, suggest that major alterations were made to the medieval cross-wing after the mid-eighteenth century. However, tree-ring dating has unfortunately not produced a date for the felling of the timbers used in the original medieval construction of the building.

Three samples remain ungrouped and undated. This is possibly due to each sample representing a timber of a different date. Singletons often remain undated despite their having sufficient rings, even where, as in this case, the rings show no sign of distortion, stress, or complacency.

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Table 1: Details of samples from Clothall Bury Farmhouse, Clothall, near Baldock, Hertfordshire

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
CLB-B01	East wall post of cross-wing truss	55	h/s	------	------	------
CLB-B02	Tiebeam of cross-wing truss	77	23C	------	------	------
CLB-B03	South main post to east wall	71	18C	AD 1683	AD 1735	AD 1753
CLB-B04	South stud post to east wall	50	29C	------	------	------
CLB-B05	North stud post to east wall	88	10	AD 1636	AD 1713	AD 1723
CLB-B06	Top rail to north end, east wall	58	6	AD 1660	AD 1711	AD 1717
CLB-B07	North main post to east wall	81	20C	AD 1667	AD 1727	AD 1747

*h/s = the heartwood/sapwood boundary is the last ring on the sample
C = complete sapwood retained on sample, last measured ring date is the felling date of the timber

Table 2: Results of the cross-matching of site chronology CLBBSQ01 and relevant reference chronologies when first ring date is AD 1636 and last ring date is AD 1753

Reference chronology	Span of chronology	*t*-value	
East Anglia	AD 781 – 1899	10.7	(Tyers and Groves pers comm 2001)
Chicksands Priory, Beds	AD 1670 – 1814	9.0	(Howard *et al* 1998)
Claydon House, Bucks	AD 1613 – 1756	8.2	(Tyers 1995)
South-east England	AD 435 – 1811	7.7	(Tyers and Groves pers comm 2001)
Thaxted Church, Essex	AD 1644 – 1813	6.8	(Tyers 1990)
Ely Cathedral	AD 1592 – 1736	6.6	(Howard *et al* 1992 unpubl)
Royal Arsenal, Woolwich	AD 1617 – 1782	6.1	(Tyers 2000)
East Midlands	AD 882 – 1981	5.6	(Laxton and Litton 1988)

Figure 1: Map to show general location of Clothall Bury

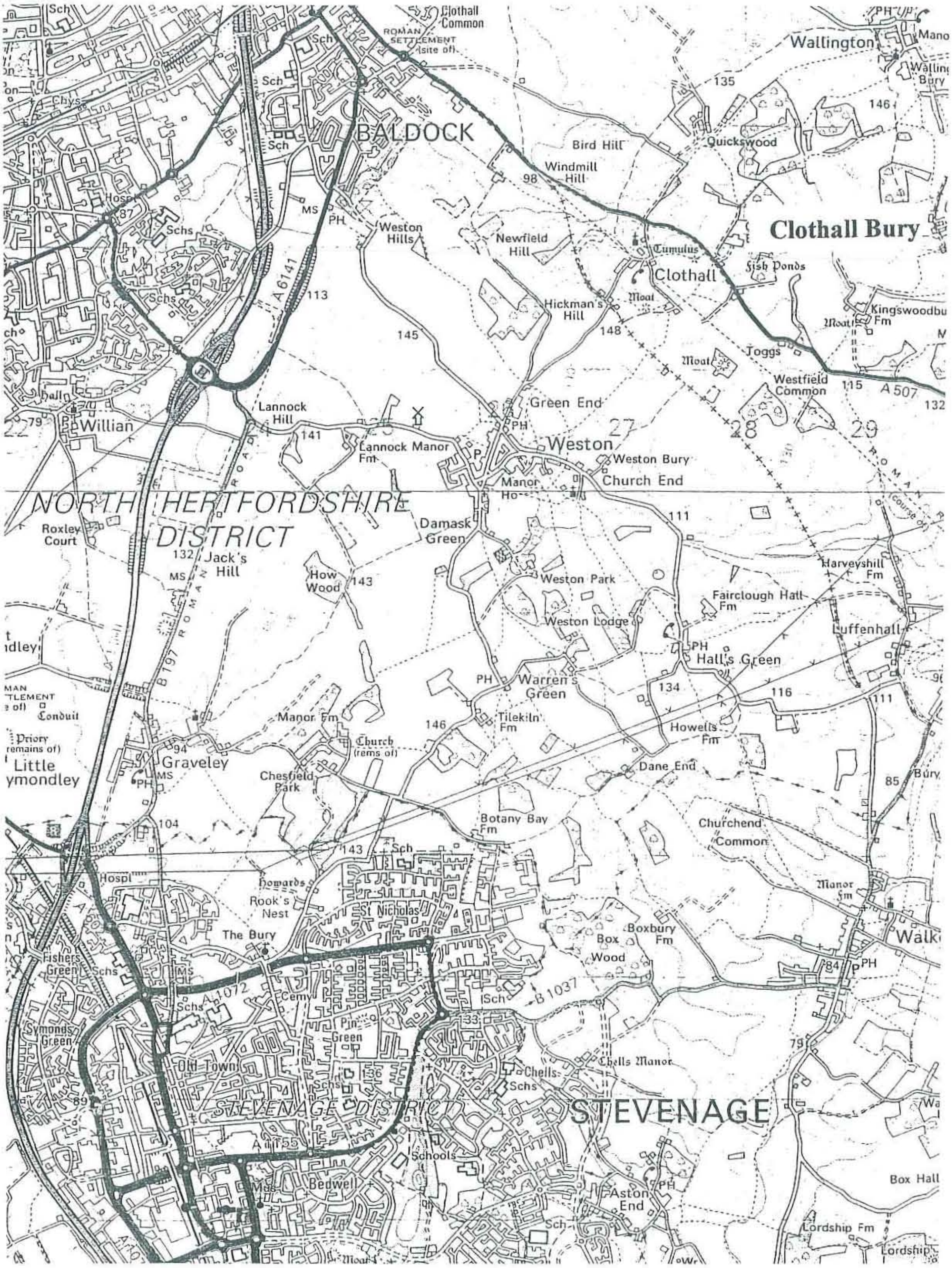

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Figure 2: Map to show location of Clothall Bury farmhouse

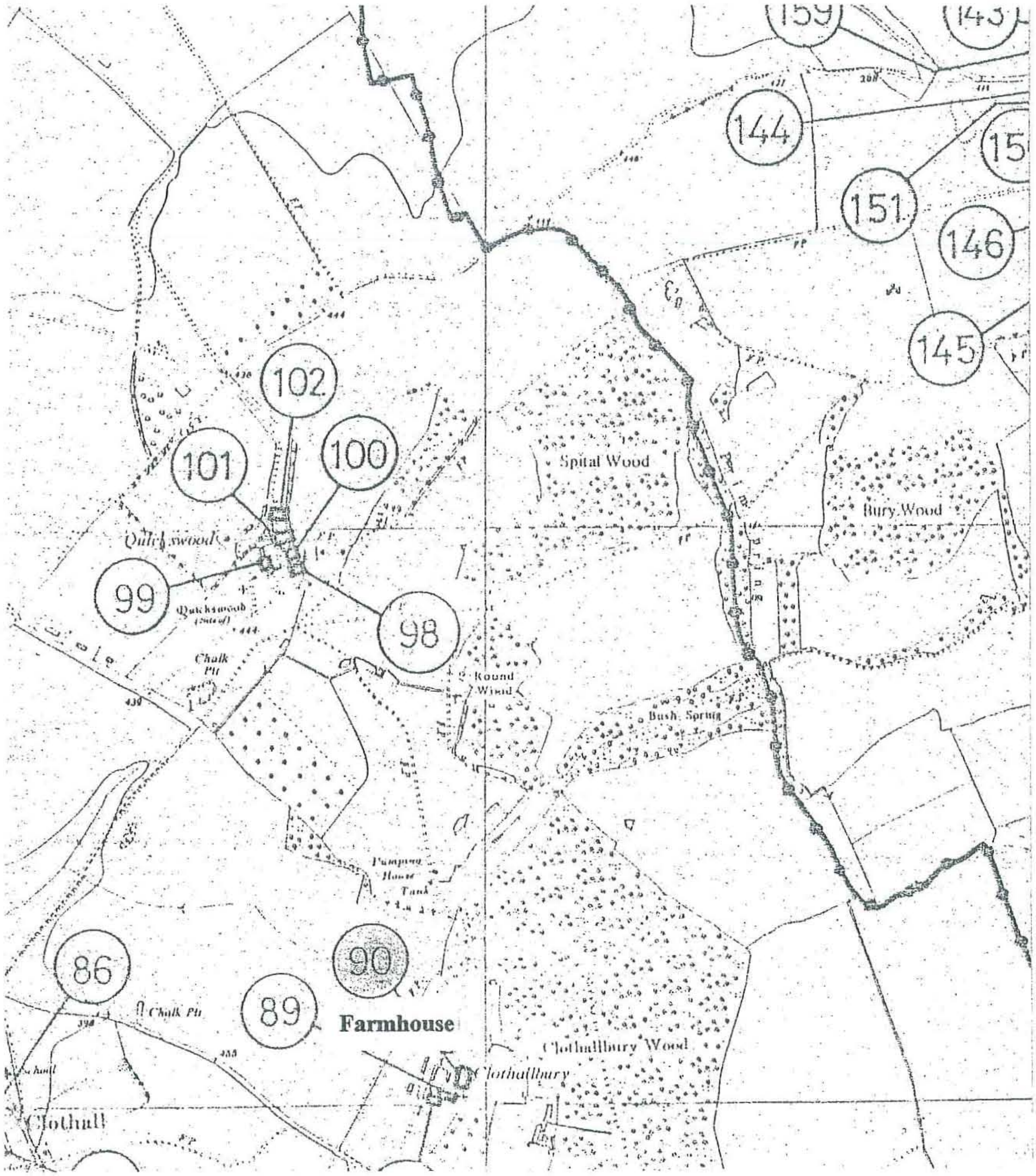
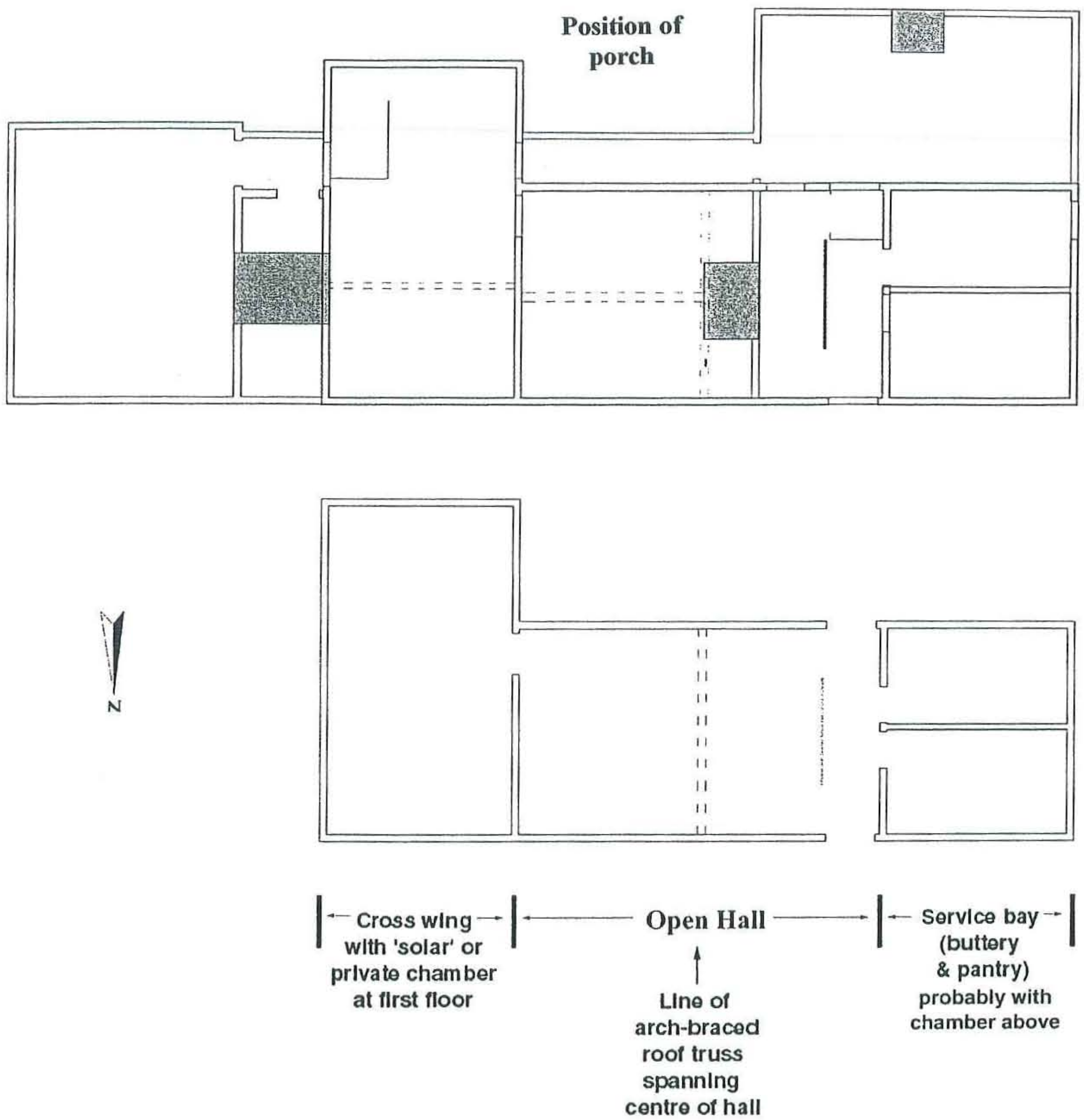


Figure 3: Plan of Clothall Bury Farmhouse

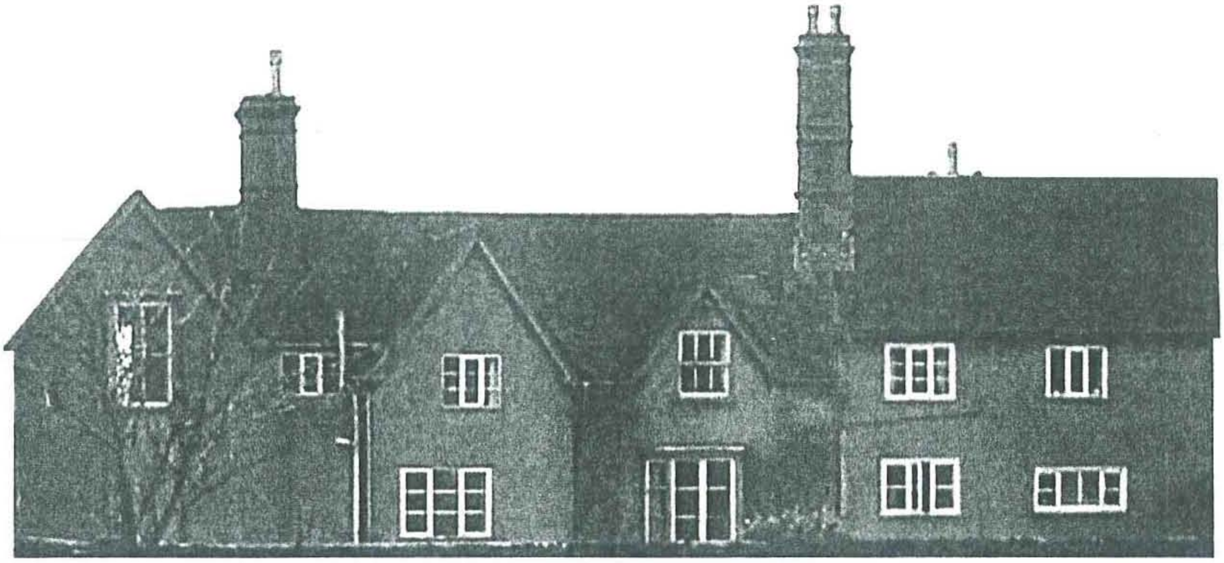


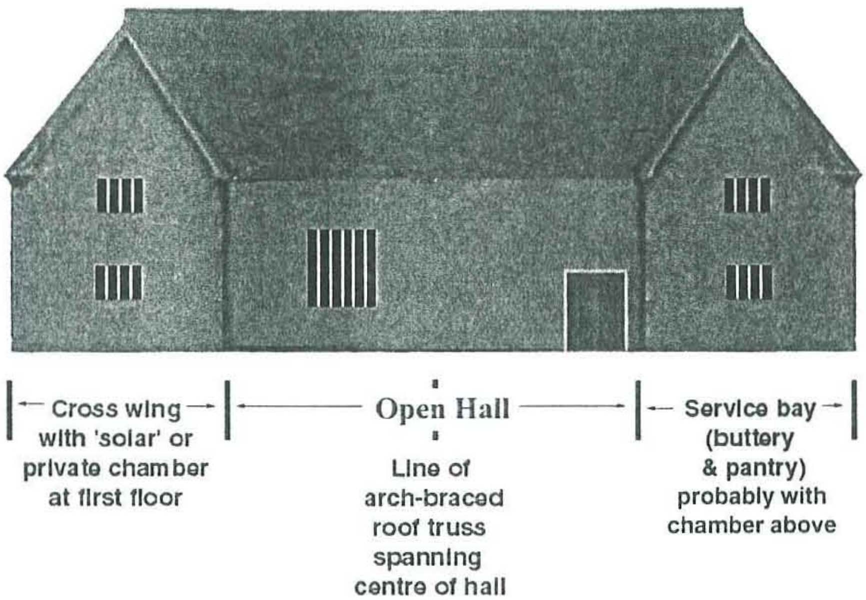
Clothall Bury Farmhouse

Diagrammatic plan of house as existing and as it may have appeared when first built

Richard Bond, English Heritage December 2002 **Drawing not to scale**

Figure 4: Reconstruction of Clothall Bury Farmhouse





Clothall Bury Farmhouse

Photo-reconstruction showing house as existing and as it may have appeared when first built

Richard Bond, English Heritage December 2002

Figure 5: plan to show location of samples
(01 / 02 from the primary truss at first –floor level,
03 – 07 from the timber framed wall at ground-floor level)

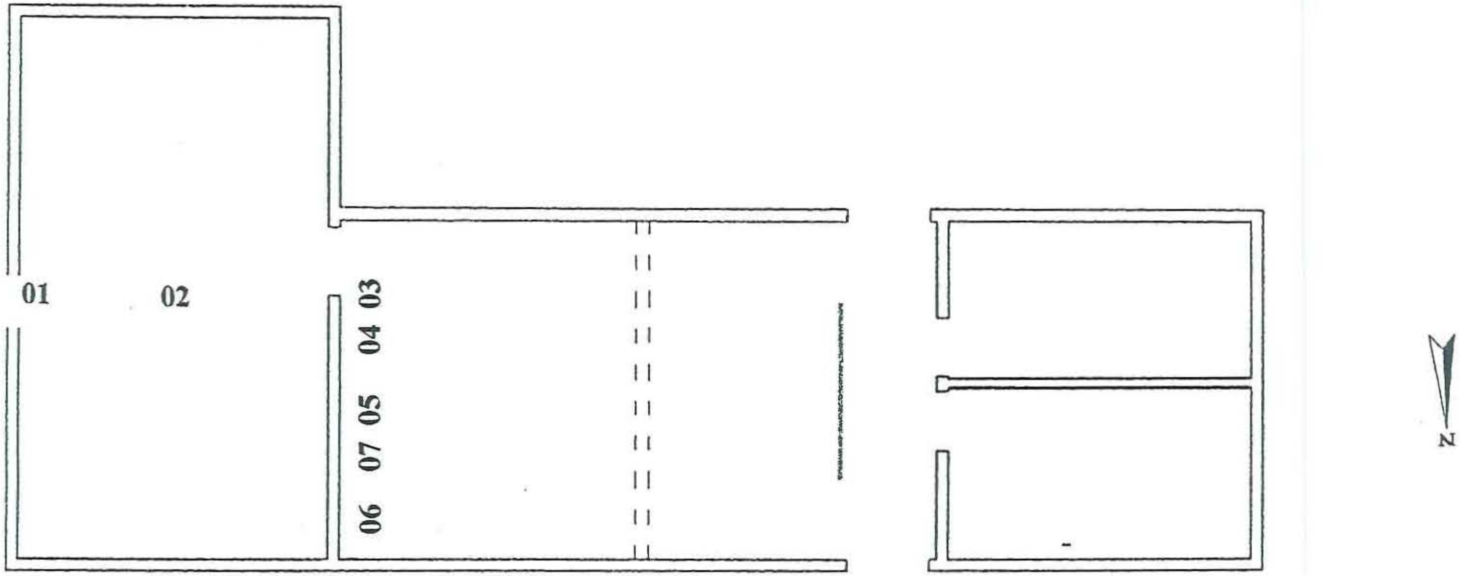


Figure 6: Sketch to show location of samples from the east wall of the open hall at ground-floor level (viewed from the west looking east)

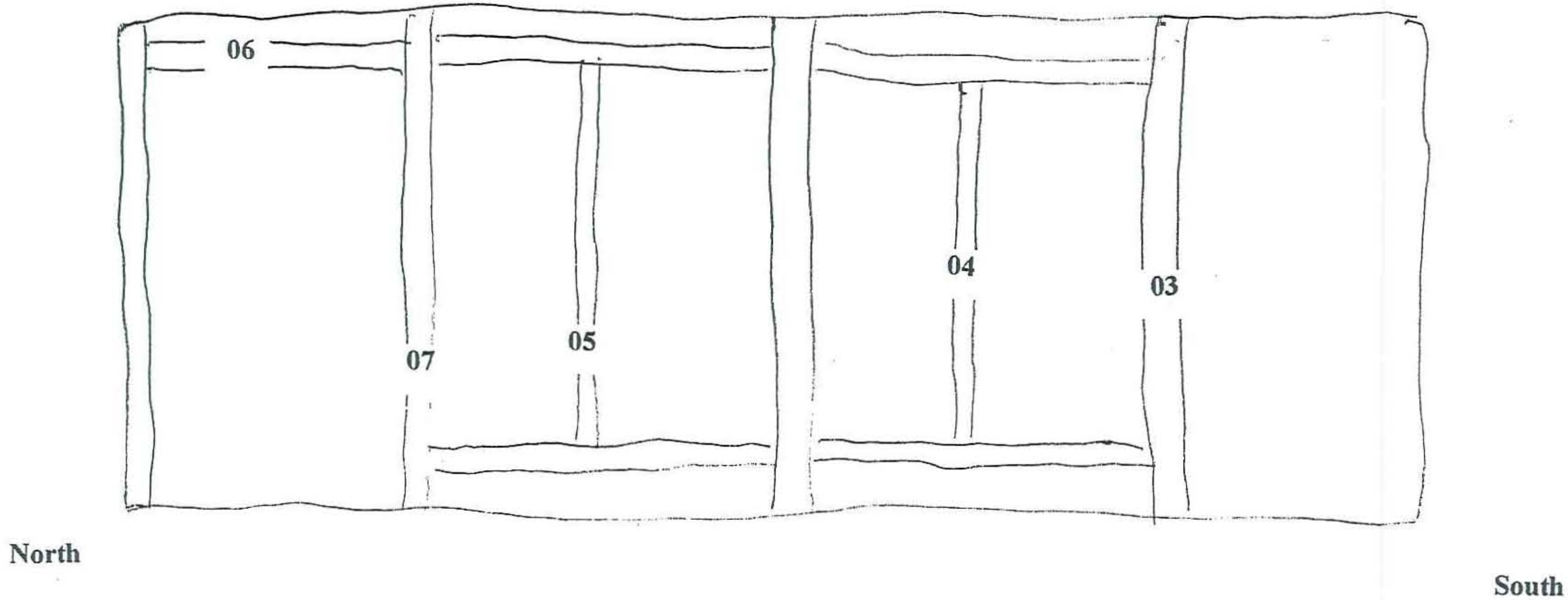
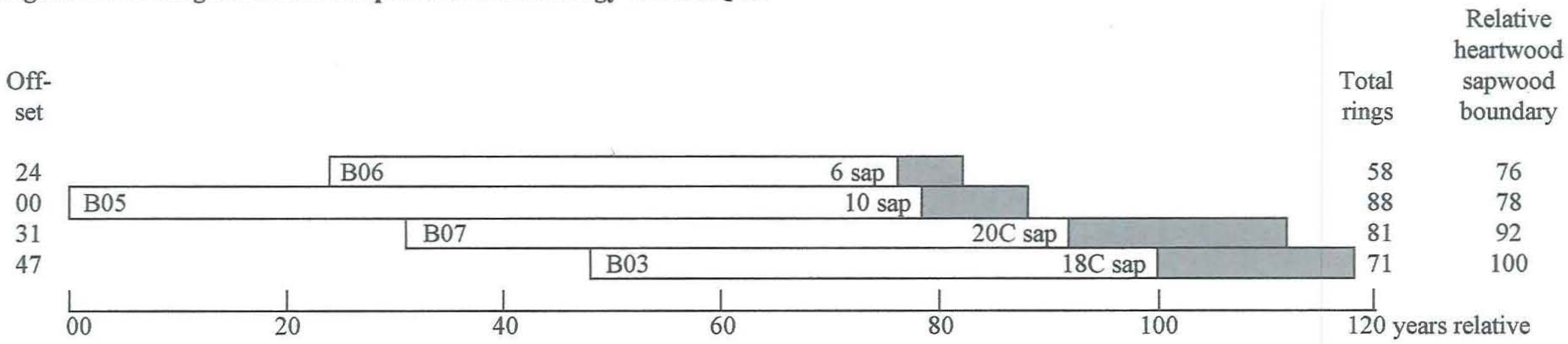


Figure 7: Bar diagram of the samples in site chronology CLBBSQO1



white bars = heartwood rings, shaded area = sapwood rings
C = complete sapwood retained on sample, the last measured ring date is the felling date of the tree

Data of measured samples – measurements in 0.01 mm units

CLB-B01A 55
147 288 241 186 183 162 166 188 258 196 190 237 181 324 333 262 215 252 300 317
242 281 204 287 222 182 188 127 126 223 227 203 206 166 119 89 114 119 169 332
219 238 212 136 123 163 197 278 239 241 170 129 144 141 155
CLB-B01B 55
158 280 239 203 189 166 186 196 245 217 201 236 190 304 320 259 236 234 299 356
197 273 208 295 220 184 188 135 121 225 245 188 181 151 128 82 125 124 151 335
219 251 208 132 121 166 193 282 226 237 170 148 190 103 152
CLB-B02A 77
439 378 501 453 430 453 585 290 329 290 229 276 321 193 263 241 137 245 332 237
201 119 113 48 71 77 75 92 104 152 118 134 153 212 126 245 194 231 188 103
171 206 121 107 63 105 82 129 85 158 133 165 135 321 280 258 179 141 102 128
108 98 76 83 101 75 74 94 72 67 97 102 114 83 79 113 84
CLB-B02B 77
455 294 333 428 441 491 566 305 320 284 214 263 326 187 244 254 129 245 338 225
204 108 106 66 66 87 60 102 88 153 123 129 147 227 107 239 186 219 197 114
177 200 123 113 66 101 83 124 89 158 142 164 136 349 250 215 250 165 111 137
103 112 84 97 87 87 75 81 79 69 92 109 117 85 82 104 80
CLB-B03A 71
336 200 179 255 185 250 220 172 207 194 242 180 218 412 343 337 272 201 222 227
327 321 183 268 201 170 221 168 184 206 203 118 169 161 140 122 93 153 186 215
145 150 108 133 165 234 186 124 103 135 124 120 176 100 83 137 142 72 62 82
68 103 156 150 130 81 66 89 112 152 130
CLB-B03B 71
146 191 210 241 180 227 215 184 237 214 213 172 258 405 309 346 261 193 222 222
312 325 179 253 202 172 212 164 194 189 212 119 157 158 154 128 75 154 196 209
123 162 119 132 165 218 190 124 104 133 131 114 192 91 80 135 130 70 69 73
75 95 156 158 124 76 56 97 122 147 142
CLB-B04A 50
118 162 191 185 159 111 135 75 61 106 131 158 114 98 115 159 131 154 83 108
84 122 105 138 154 98 108 96 88 102 77 64 96 88 110 141 158 150 128 108
158 122 176 143 201 151 111 122 173 154
CLB-B04B 48
120 158 169 175 142 114 160 83 65 121 153 162 129 99 122 128 134 175 107 118
97 145 111 138 175 89 111 116 124 116 81 86 141 104 118 158 172 188 163 124
179 143 214 170 235 185 136 148 176 164
CLB-B05A 88
52 41 117 108 98 90 120 165 137 189 267 201 251 134 166 189 133 173 318 369
195 198 249 212 318 252 298 288 228 200 208 212 266 167 231 217 167 207 163 123
171 192 168 142 183 175 195 181 144 107 193 152 179 176 148 164 165 166 122 152
185 191 173 216 201 157 193 220 222 189 175 184 195 246 225 231 226 275 141 284
202 221 177 157 265 253 194 196
CLB-B05A 88
57 41 127 99 92 100 114 156 144 188 250 206 253 140 164 193 134 170 302 369
186 206 255 225 317 250 299 275 228 203 192 200 249 170 222 202 166 206 147 119
181 213 183 154 178 173 183 192 118 97 163 145 168 171 151 180 165 164 109 148
158 196 170 222 208 151 174 210 211 174 178 179 179 252 222 229 215 277 145 296
213 231 162 179 254 261 192 200
CLB-B06A 58
230 274 311 243 195 226 260 299 280 392 312 420 290 434 333 179 276 407 306 375
569 471 482 281 257 202 247 216 220 186 211 313 253 237 210 139 148 192 249 157
203 194 154 245 348 207 246 195 220 274 284 315 354 266 139 144 153 214

CLB-B06B 58
219 281 295 249 182 210 271 288 284 387 366 441 277 427 333 177 309 453 352 344
560 464 493 283 253 214 281 231 255 202 226 319 267 257 204 122 154 191 242 157
200 197 170 251 344 208 240 198 221 243 328 306 282 263 178 187 154 197
CLB-B07A 81
254 307 205 142 179 127 270 426 231 231 541 376 350 372 336 508 444 242 250 379
243 241 201 206 333 240 313 247 148 262 369 277 168 153 111 127 225 154 114 224
130 111 105 124 157 154 119 72 92 122 91 66 73 71 131 209 114 160 155 161
184 123 91 94 104 125 113 80 94 87 75 92 72 62 65 62 74 65 90 114
74
CLB-B07B 81
236 356 225 117 157 128 315 380 219 235 547 350 359 368 338 496 440 213 264 372
243 238 197 204 332 240 321 250 160 271 347 275 169 148 114 134 222 153 114 220
142 98 104 119 156 154 116 71 85 137 85 65 78 73 128 215 109 157 162 150
187 123 97 85 105 128 108 84 93 80 84 84 75 62 67 66 66 57 110 98
100

of widths of this site sequence is stored on the computer. The reason for creating site sequences is that it is usually easier to date an average sequence of ring widths with a master sequence than it is to date the individual component sample sequences separately.

The straightforward method of cross-matching several sample sequences with each other one at a time is called the 'maximal *t*-value' method. The actual method of cross-matching a group of sequences of ring-widths used in the Laboratory involves grouping and averaging the ring-width sequences and is called the 'Litton-Zainodin Grouping Procedure'. It is a modification of the straight forward method and was successfully developed and tested in the Laboratory and has been published (Litton and Zainodin 1991; Laxton *et al* 1988).

4. ***Estimating the Felling Date***. As mentioned above, if the bark is present on a sample, then the date of its last ring is the date of the felling of its tree. 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, sapwood can be seen in the corner of the rafter and at the outer end of the core in Figure 2, both indicated by arrows. More importantly for dendrochronology, the sapwood is relatively soft and so liable to insect attack and wear and tear. The builder, therefore, may remove some of the sapwood for precisely these reasons. Nevertheless, if at least some of the sapwood rings are left on a sample, we will know that not too many rings have been lost since felling so that the date of the last ring on the sample is only a few years before the date of the original last ring on the tree, and so to the date of felling.

Various estimates have been made and used for the average number of sapwood rings in mature oak trees (English Heritage 1998). A fairly conservative range is between 15 and 50 and that this holds for 95% of mature oaks. This means, of course, that in a small number of cases there could be fewer than 15 and more than 50 sapwood rings. For example, the core CRO-A06 has only 9 sapwood rings and some have obviously been lost over time – either they were removed originally by the carpenter and/or they rotted away in the building and/or they were lost in the coring. It is not known exactly how many sapwood rings are missing, but using the above range the Laboratory would estimate between a minimum of 6 (=15-9) and a maximum of 41 (=50-9). If the last ring of CRO-A06 has been dated to 1500, say, then the estimated felling-date range for the tree from which it came originally would be between 1506 and 1541. The Laboratory uses this estimate for sapwood in areas of England where it has no prior information. It also uses it when dealing with samples with very many rings, about 120 to the last heartwood ring. But in other areas of England where the Laboratory has accumulated a number of samples with complete sapwood, that is, no sapwood lost since felling, other estimates in place of the conservative range of 15 to 50 are used. In the East Midlands (Laxton *et al* 2001) and the east to the south down to Kent (Pearson 1995) where it has sampled extensively in the past, the Laboratory uses the shorter estimate of 15 to 35 sapwood rings in 95% of mature oaks growing in these parts. Since the sample CRO-A06 comes from a house in Cropwell Bishop in the East Midlands, a better estimate of sapwood rings lost since felling is between a minimum of 6 (=15-9) and 26 (=35-9) and the felling would be estimated to have taken place between 1506 and 1526, a shorter period than before. (Oak boards quite often come from the Baltic and in these cases the 95% confidence limits for sapwood are 9 to 36 (Howard *et al* 1992, 56)).

Even more precise estimates of the felling date and range can often be obtained using knowledge of a particular case and information gathered at the time of sampling. For example, at the time of sampling the dendrochronologist may have noted that the timber from which the core of Figure 2 was taken still had complete sapwood but that none of the soft sapwood rings were lost in coring. By measuring into the timber the depth of sapwood lost, say 2 cm, a reasonable estimate can be made of the number of sapwood rings lost, say 12 to 15 rings in this case. By adding on 12 to 15 years to the date of the last ring on the sample a good tight estimate for the range of the felling date can be obtained, which is often better than the 15 to 35 years later we would have estimated without this observation. In the example, the felling is now estimated to *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

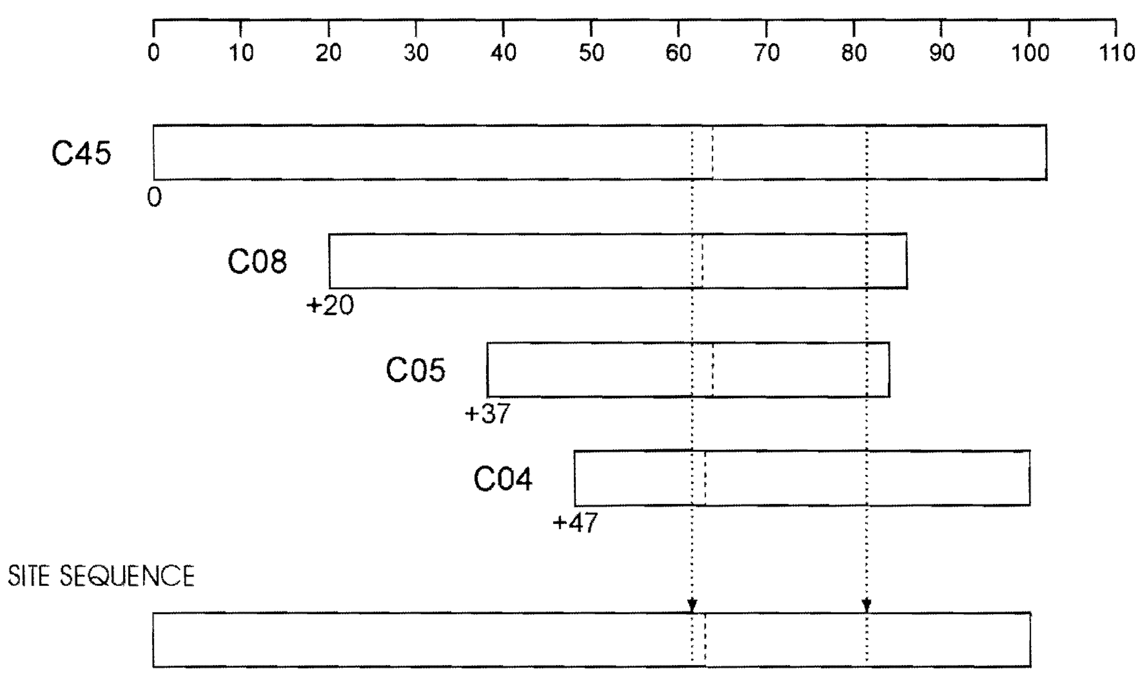


Fig 5. Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them.

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.

have taken place between AD 1512 and 1515, which is much more precise than without this extra information.

Even if all the sapwood rings are missing on a sample, but none of the heartwood rings are, then an estimate of the felling-date range is possible by adding on the full compliment of, say, 15 to 35 years to the date of the last heartwood ring (called the heartwood/sapwood boundary or transition ring and denoted H/S). Fortunately it is often easy for a trained dendrochronologist to identify this boundary on a timber. If a timber does not have its heartwood/sapwood boundary, then only a *post quem* date for felling is possible.

5. ***Estimating the Date of Construction***. There is a considerable body of evidence collected by dendrochronologists over the years that oak timbers used in buildings were not seasoned in medieval or early modern times (English Heritage 1998 and Miles 1997, 50-55). Hence provided all the samples in a building have estimated felling-date ranges broadly in agreement with each other, so that they appear to have been felled as a group, then this should give an accurate estimate of the period when the structure was built, or soon after (Laxton *et al* 2001, figure 8 and pages 34-5 where 'associated groups of fellings' are discussed in detail). However, if there is any evidence of storing before use or if there is evidence the oak came from abroad (eg Baltic boards), then some allowance has to be made for this.

6. ***Master Chronological Sequences***. Ultimately, to date a sequence of ring widths, or a site sequence, we need a master sequence of dated ring widths with which to cross-match it, a Master Chronology. To construct such a sequence we have to start with a sequence of widths whose dates are known and this means beginning with a sequence from an oak tree whose date of felling is known. In 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 (1988), but the components it contains are shown here in the form of a bar diagram. As can be seen, it is well replicated in that for each year in this period there are several sample sequences having widths for that year. The master is the average of these. This master can now be used to date oak from this area and from the surrounding areas where the climate is very similar to that in the East Midlands. The Laboratory has also constructed a master for Kent (Laxton and Litton 1989). The method the Laboratory uses to construct a master sequence, such as the East Midlands and Kent, is completely objective and uses the Litton-Zainodin grouping procedure (Laxton *et al* 1988). Other laboratories and individuals have constructed masters for other areas and have made them available. As well as these masters, local (dated) site chronologies can be used to date other buildings from nearby. The Laboratory has hundreds of these site sequences from many parts of England and Wales covering many short periods.

7. ***Ring-width Indices***. Tree-ring dating can be done by cross-matching the ring widths themselves, as described above. However, it is advantageous to modify the widths first. Because different trees grow at different rates and because a young oak grows in a different way from an older oak, irrespective of the climate, the widths are first standardized before any matching between them is attempted. These standard widths are known as ring-width indices and were first used in dendrochronology by Baillie and Pilcher (1973). The exact form they take is explained in this paper and in the appendix of Laxton and Litton (1988) and is illustrated in the graphs in Fig 7. Here ring-widths are plotted vertically, one for each year of growth. In the upper sequence of (a), the generally large early growth after 1810 is very apparent as is the smaller later growth from about 1900 onwards when the tree is maturing. A similar phenomena can be observed in the lower sequence of (a) starting in 1835. In both the widths are also changing rapidly from year to year. The peaks are the wide rings and the troughs are the narrow rings corresponding to good and poor growing seasons, respectively. The two corresponding sequence of Baillie-Pilcher indices are plotted in (b) where the differences in the immature and mature growths have been removed and only the rapidly changing peaks and troughs remain, that are associated with the common climatic signal. This makes cross-matching easier.

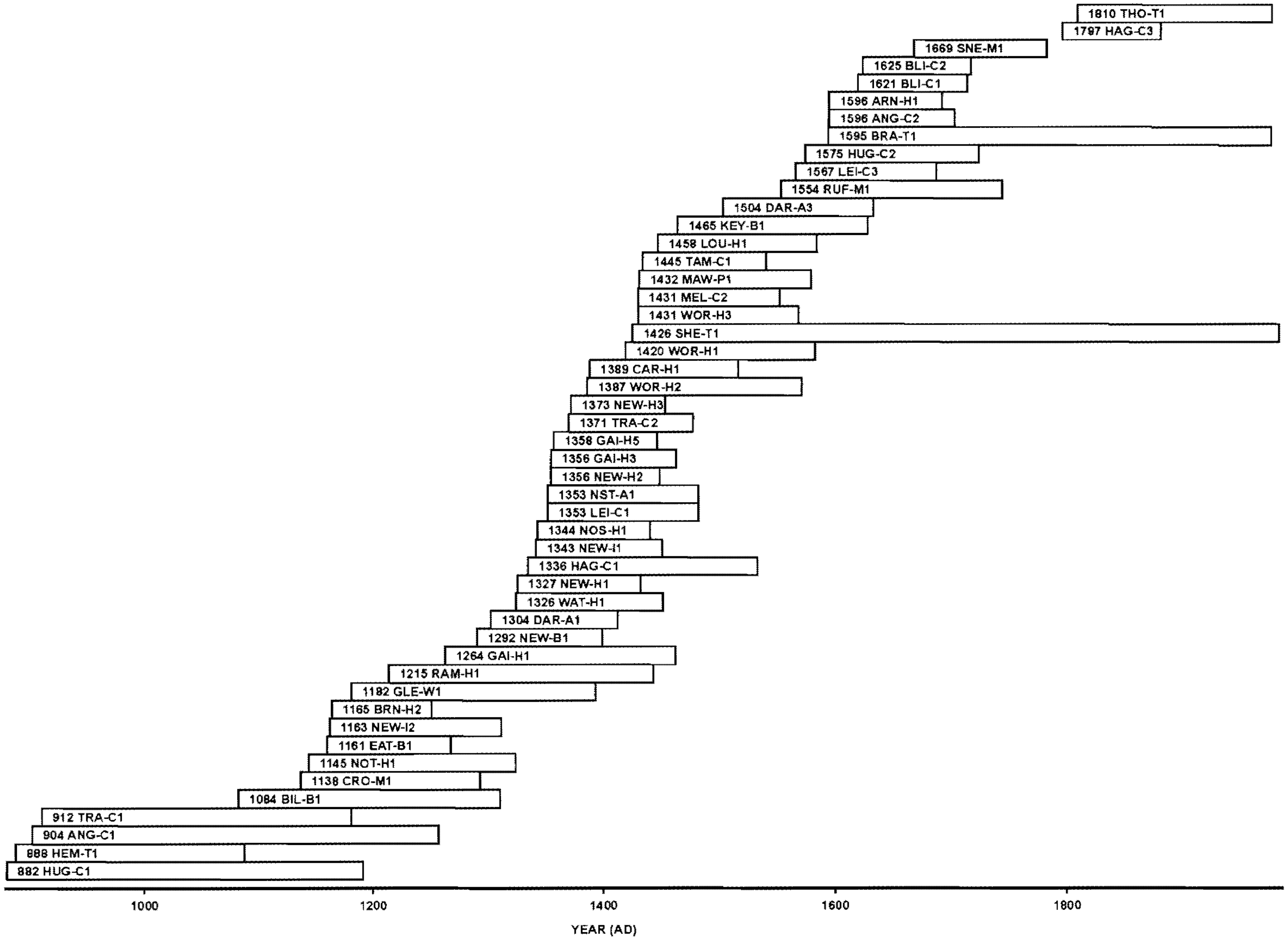
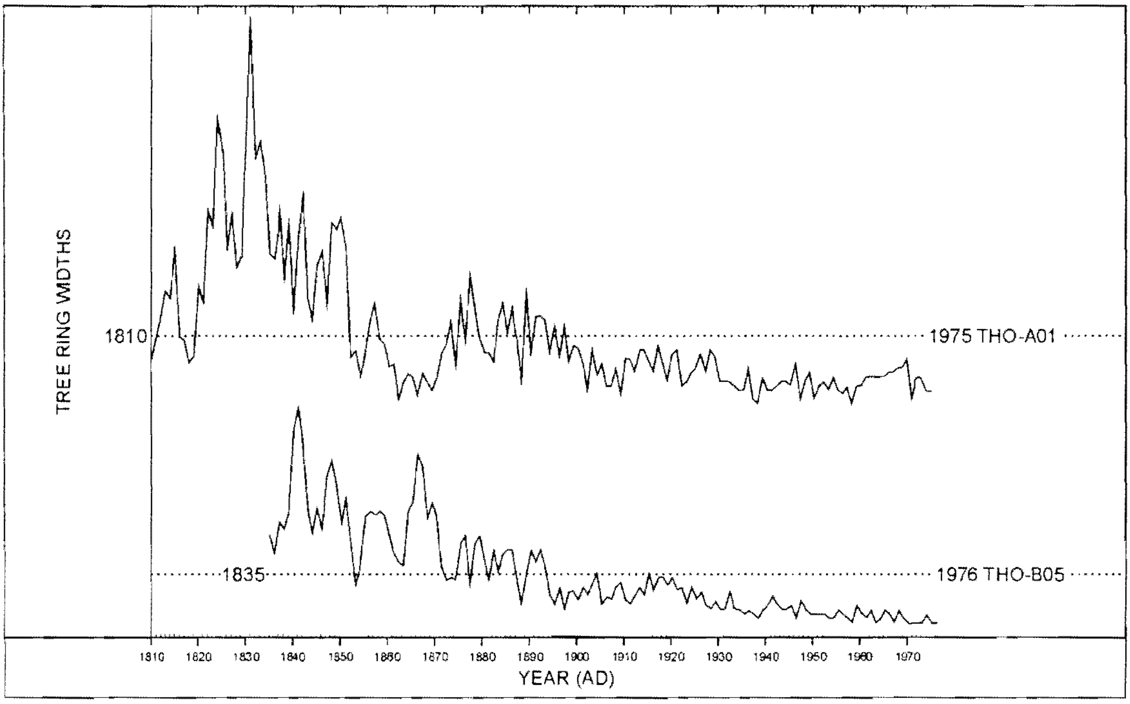


Fig. 6 Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

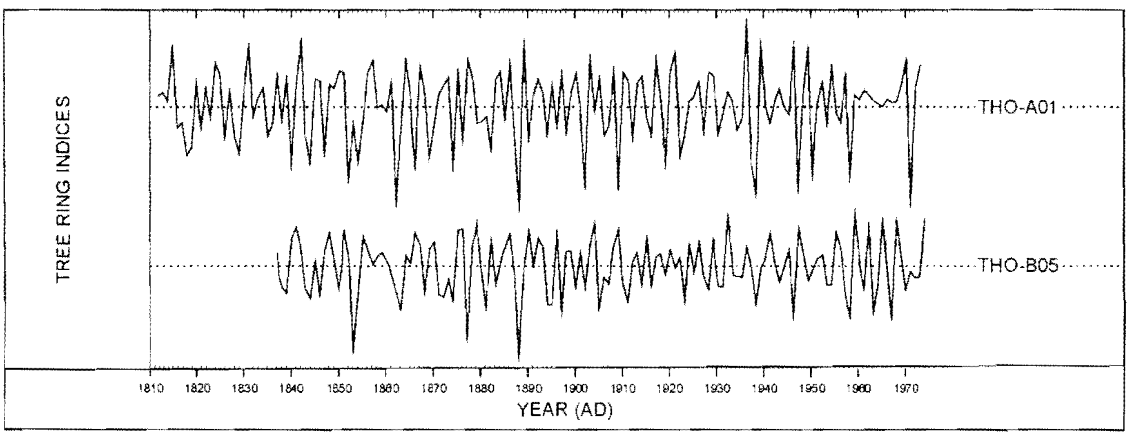


Fig 7. (a) The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known. Here the ring widths are plotted vertically, one for each year, so that peaks represent wide rings and troughs narrow ones. Notice the growth-trends in each; on average the earlier rings of the young tree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

Fig 7. (b) The *Baillie-Pilcher* indices of the above widths. The growth-trends have been removed completely.

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