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Scientific Dating

Ruins of Catchfrench Old House and Screen Wall
Catchfrench Manor
St Germans
Cornwall

Tree-ring Analysis of Oak Timbers

Alison Arnold, Robert Howard, and Cathy Tyers

Discovery, Innovation and Science in the Historic Environment

Research Report Series no. 36-2021

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RUINS OF CATCHFRENCH OLD HOUSE AND SCREEN WALL CATCHFRENCH MANOR ST GERMANS CORNWALL

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NGR: SX 30745 59574

ISSN 2059-4453 (Online)

SUMMARY
Dendrochronological analysis was undertaken on two core and three sliced samples obtained from both *in situ* and *ex situ* timbers at this site. This analysis produced a single site chronology comprising two samples, this being 77 rings long overall. Although this site chronology could not be dated, the grouping of the two samples would suggest that the two timbers represented, a wall beam and a lintel to the doorway/entrance tower, are coeval. The three remaining ungrouped individual samples are also undated.

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ACKNOWLEDGEMENTS
We would firstly like to thank Stephen Swinbank, Project Engineer for Mann Williams Consulting Civil & Structural Engineers, and Richard Burrows of Williams & Burrows Heritage Repair Ltd, for their unstinting help and cooperation in accessing this site. We are very grateful to Eric Berry for use of the front cover image of this report. We would also like to acknowledge the considerable help and assistance provided by the on-site contractors at the time of sampling. Thanks to Catherine Marlow and Hayley McParland of Historic England for their help too. Finally, we would like to thank Shahina Farid, Historic England Scientific Dating Coordinator, for commissioning and facilitating this programme of tree-ring analysis.

ARCHIVE LOCATION
Historic England Archive
The Engine House
Firefly Avenue
Swindon SN2 2EH

HISTORIC ENVIRONMENT RECORD OFFICE
Cornwall and Isles of Scilly Historic Environment Record
Kresen Kernow
Little Vauxhall
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DATE OF INVESTIGATION
2020–21

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INTRODUCTION

Catchfrench Old House stands just to the south of the Grade II listed Catchfrench Manor (Fig 1). It is a two-storey range of late eighteenth-century construction with gothic windows and other decorative details (LEN 1329154). The Manor House was built *c* AD 1780 to the design of Charles Rawlinson of nearby Lostwithiel. The Manor was originally surmounted by a castellated parapet, but this was removed in the early nineteenth century.

Catchfrench Old House itself incorporates substantial remains of an earlier sixteenth-century house, this possibly being the replacement of a still earlier, medieval house, which had stood on the same footprint. The early/mid sixteenth-century replacement house was then remodelled and extended *c* AD 1580 following a fire and was probably extended again in the mid-seventeenth century (the house passing through several hands at this time).

Evidence in the fabric and in historic documents suggests that the part built by George Kekewich in *c* AD 1580 was a courtyard building, either as a U-plan, or as a fully enclosed courtyard with building ranges to each side. At the heart of this house it appears that the original hall-house was re-fronted and was provided with a three-storey porch tower plus a parlour and parlour chamber to the left, and a full-height open-hall to the right (Fig 2).

The Catchfrench estate was bought by the Glanville family in AD 1728. When the Manor House was built in *c* AD 1780, Humphrey Repton was invited to advise on the improvement of the grounds, and in due course the formal gardens and pleasure grounds with lawns, drives, shrubberies, and an ornamental quarry, laid out. During the nineteenth century the buildings fell into an increasing state of disrepair whilst still in ownership of the Glanvilles, until AD 1930. Subsequently passing through several hands again, it came into the possession of the present owners in AD 1987.

The present remains of the Old House comprise a roofless ruin (Fig 3a/b).

SAMPLING

Following a Heritage Statement and Heritage Impact assessment (Berry 2018), sampling and analysis by dendrochronology was requested by Catherine Marlow (Historic England Inspector of Historic Buildings and Areas) and Hayley McParland (Historic England Science Advisor) to provide independent dating evidence to inform a possible redesignation of this ‘at risk’ ruin. It was hoped that tree-ring dating would enhance the understanding of the overall development of the building and inform its significance.

Most timbers targeted for dendrochronological analysis were embedded in the fabric of the walls as lintels to doors and windows, or other elements of the ruins. Most of the timbers are in a much-deteriorated state; being fragile and barely held in place by loose and unstable masonry, or by creeping vegetation. As such, each timber had to be assessed for stability prior to any work being undertaken. From the few suitable timbers available therefore, a total of only five samples was obtained; three of these by slicing timbers removed from the walls, which were not considered structurally sound enough to be conserved and reinstated, and two by coring timber *in situ*. Each sample was given the code CAT-F (for 'Catchfrench') and numbered 01–05 (Table 1). The sampled timbers are identified on photographs taken at the time of sampling shown in Figures 4a–e.

ANALYSIS AND RESULTS

Each of the five samples obtained was prepared by sanding and polishing and its annual growth ring widths were measured; these data being given at the end of this report. The five measured series were then compared with each other by the Litton/Zainodin grouping procedure (see Appendix).

This comparative process resulted in the production of a single group comprising two samples; these cross-matching with each other at a value of t=4.6 as shown in Figure 5. The two cross-matching series were combined at their indicated offset positions to form site chronology CATFSQ01, this having an overall length of 77 rings. This site chronology was then compared to an extensive corpus of reference chronologies for oak, but there was no reliable repeated cross-dating at any position and these two samples must, therefore, remain undated.

The three remaining ungrouped series were then also compared individually with the full corpus of reference chronologies for oak, but again there was no cross-matching and these samples must also remain undated.

INTERPRETATION AND CONCLUSION

Analysis of data from the small number of samples obtained at this site has failed to produce any conclusive dating evidence, although it is likely that two timbers, a wall beam and a lintel to the doorway/entrance tower (represented by samples CAT-F01 and CAT-F03 respectively), are coeval. Such lack of dating might perhaps be considered slightly unusual in that, although they do not have particularly high numbers of rings, all the samples do have more than the minimum of 54 rings required, and none of them show any signs of compression or distortion, which might make cross-matching and dating, difficult.

It is possible, although this cannot be proven by tree-ring dating, that the lack of cross-matching between a few samples is caused by the sampled timbers, with the exception of the two cross-matched ones, being associated with different phases of construction, or modification, or repair and therefore, of different dates; with the growth rings they contain sharing no, or insufficient, overlap. Such a phenomenon would in effect make each sample a 'singleton' and while such samples can sometimes be dated, particularly where they have high numbers of rings, this is often much more difficult than with well-replicated data from several cross-matching samples. This might particularly be the case here, where, with only five timbers being available, the number of samples is a little below the 8–10 usually considered the minimum for successful dating.

It is also possible too that the timbers used at Catchfrench are from an area, and/or a time period, for which there is presently little reference material available with which the samples can be compared, although this seems relatively unlikely. It may only be when further samples and data is obtained from this locality that the Catchfrench samples might eventually be dated.

REFERENCES

Berry, E, 2018 *Catchfrench Manor*: *Heritage Statement* + *Heritage Impact Assessment* unpubl

TABLES

Table 1: Details of tree-ring samples from the ruins of Catchfrench Old House and Screen Wall, St Germans, Cornwall

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
	Doorway/Entrance Tower					
CAT-F01	South wall, upper level wall beam	71	h/s			
CAT-F02	South wall, window lintel	72	h/s			
CAT-F03	North wall 1st floor window lintel	77	h/s	------	------	------
CAT-F04	North doorway lintel	59	no h/s	------	------	------
	Parlour					
CAT-F05	Parlour, West wall Ground Floor door lintel	57	h/s	------	------	------

Key:
h/s = the heartwood/sapwood ring is the last ring on the sample

FIGURES

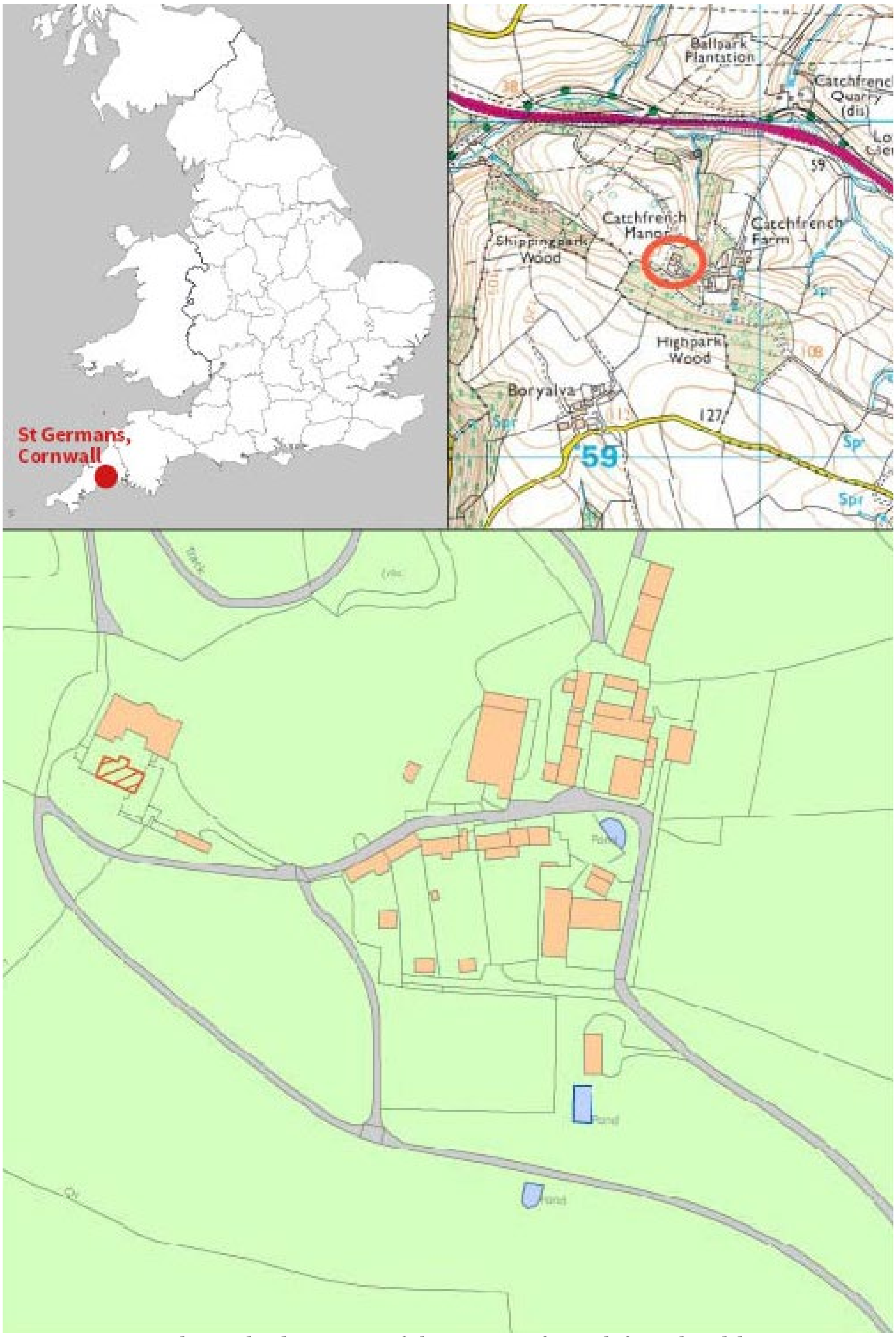


Figure 1: Maps to show the location of the ruins of Catchfrench Old House, St Germans in Cornwall, marked in red. Scale: top right 1:15000; bottom 1:2000.

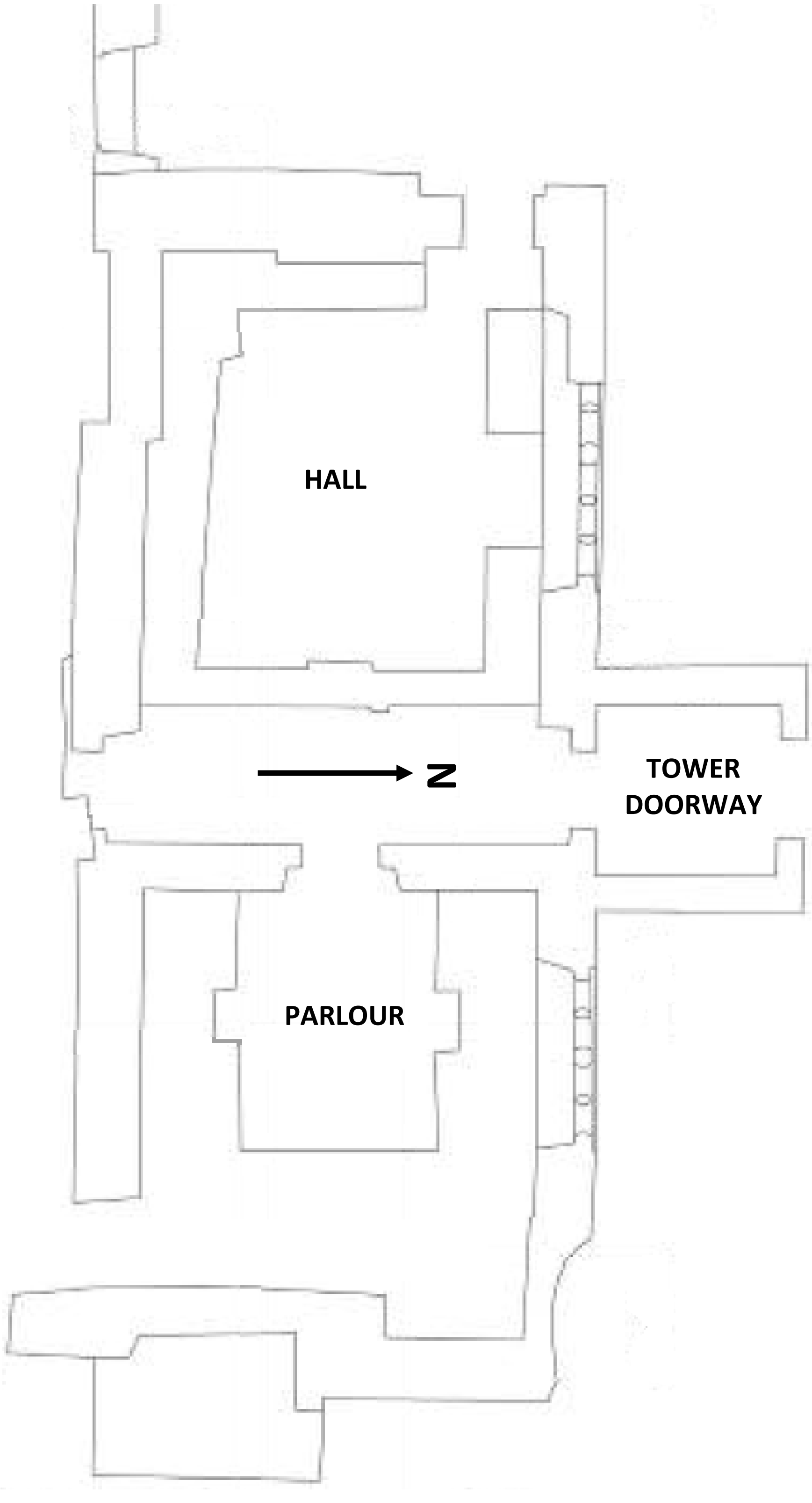


Figure 2: Plan to show the layout and arrangement of the rooms at Catchfrench Old House (after Berry 2013 unpubl*)*

Figure 3a/b: External elevation of the north wall (top), with internal elevation of the same (bottom) (after Berry 2013 unpubl*)*

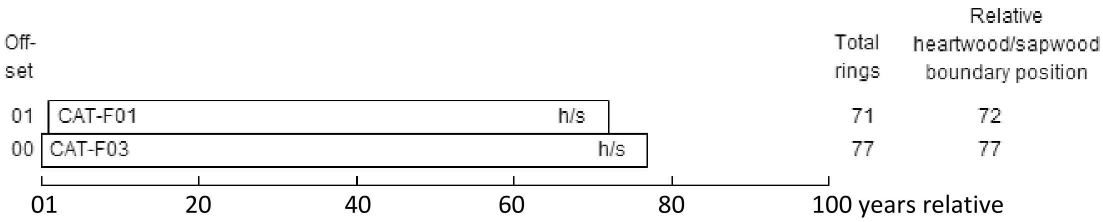

Figure 4a: Tower, south wall upper level wall beam (photograph Robert Howard)


Figure 4b: Tower, south wall window lintel (photograph Robert Howard)

Figure 4c: Tower, north wall, first floor window lintel (photograph Robert Howard)

Figure 4d: Tower, north doorway lintel (photograph Robert Howard)

Figure 4e: Parlour, west wall, ground floor door lintel (photograph Robert Howard)



White bars = heartwood rings;
Shaded bars = sapwood rings
h/s = heartwood/sapwood boundary

Figure 5: Bar diagram of the samples in site chronology CATFSQ01

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units
CAT-F01A 71
167 463 369 241 156 234 123 146 169 269 248 250 168 207 217 124 117 155 123 114
160 74 82 113 99 127 157 66 121 121 139 138 104 117 121 150 143 96 142 125
117 109 159 125 117 143 146 112 140 156 158 91 105 133 137 101 107 114 89 110
95 65 93 120 96 125 101 110 85 157 100
CAT-F01B 71
169 459 365 229 155 247 176 203 177 250 265 232 171 205 214 126 121 153 116 120
182 83 82 98 89 131 148 82 122 123 132 138 106 123 112 155 140 110 127 126
126 110 151 126 118 146 156 115 139 176 157 100 109 132 159 110 114 119 90 112
99 67 89 114 96 129 103 106 90 161 100
CAT-F02A 72
264 280 238 216 274 214 186 282 128 167 184 248 268 164 279 264 330 254 232 151
200 174 165 181 303 527 350 259 100 186 165 223 222 224 344 159 101 212 181 221
353 231 178 227 420 281 265 218 153 207 93 79 75 160 153 193 127 100 125 101
67 89 107 109 234 140 102 215 156 115 122 173
CAT-F02B 72
258 276 249 236 259 240 147 266 128 182 176 253 277 153 282 270 332 253 251 143
187 173 174 189 310 507 358 267 112 206 157 221 212 220 334 167 112 201 180 204
364 230 180 226 407 287 292 207 148 220 89 84 70 151 164 189 128 99 132 92
76 81 110 115 234 134 105 209 156 113 120 175
CAT-F03A 77
173 273 229 166 135 125 166 111 96 100 67 103 94 60 61 87 71 160 401 398
176 201 165 183 357 282 378 360 305 336 364 264 335 292 263 172 248 210 164 190
251 246 268 179 218 161 280 282 248 259 253 250 201 176 289 265 242 139 204 120
158 96 123 84 195 107 130 110 118 117 100 78 75 92 69 77 62
CAT-F03B 77
181 270 235 176 142 116 153 109 93 95 67 101 91 59 81 79 69 137 415 375
198 210 178 178 357 280 385 410 293 308 335 257 340 282 270 167 259 209 156 190
208 225 211 204 209 159 276 313 225 259 250 260 189 187 274 269 245 146 211 121
159 93 118 93 198 97 131 118 118 108 106 65 75 93 62 71 64
CAT-F04A 59
433 493 552 321 371 375 495 504 389 510 698 618 536 340 330 275 223 446 340 342
249 135 139 213 206 210 305 269 306 223 254 304 325 393 383 235 159 168 142 171
161 189 129 189 116 201 149 140 151 146 90 106 105 68 65 100 94 120 103
CAT-F04B 59
451 455 552 318 353 376 478 507 361 485 694 625 529 336 348 264 215 434 346 335
257 133 145 214 204 218 300 278 298 214 223 309 339 407 367 240 149 174 140 168
167 179 140 184 134 195 163 137 162 140 93 113 98 62 56 96 96 122 103
CAT-F05A 57
186 201 153 242 328 299 316 141 253 173 180 232 269 294 237 201 260 253 327 376
461 354 315 398 495 440 452 476 501 343 370 435 417 321 315 334 498 489 428 428
453 377 456 381 402 413 267 303 275 262 290 233 322 296 123 157 128
CAT-F05B 57
200 196 154 227 330 313 304 146 246 180 169 236 267 300 235 207 250 250 325 389
454 362 303 385 490 417 429 492 532 354 354 407 393 317 326 323 476 506 432 420
431 376 476 391 425 350 265 275 274 252 262 228 322 290 123 153 126

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 Nottingham Tree-ring Dating Laboratory's Monograph, *An East Midlands Master Tree-Ring Chronology and its uses for dating Vernacular Buildings* (Laxton and Litton 1988) and *Dendrochronology: Guidelines on Producing and Interpreting Dendrochronological Dates* (English Heritage 1998). Here we will give the bare outlines. Each year an oak tree grows an extra ring on the outside of its trunk and all its branches just inside its bark. The width of this annual ring depends largely on the weather during the growing season, about April to October, and possibly also on the weather during the previous year. Good growing seasons give rise to relatively wide rings, poor ones to very narrow rings and average ones to relatively average ring widths. Since the climate is so variable from year to year, almost random-like, the widths of these rings will also appear random-like in sequence, reflecting the seasons. This is illustrated in Figure A1 where, for example, the widest rings appear at irregular intervals. This is the key to dating by tree rings, or rather, by their widths. Records of the average ring widths for oaks, one for each year for the last 1000 years or more, are available for different areas. These are called master chronologies. Because of the random-like nature of these sequences of widths, there is usually only one position at which a sequence of ring widths from a sample of oak timber with at least 70 rings will match a master. This will date the timber and, in particular, the last ring.

If the bark is still on the sample, as in Figure A1, then the date of the last ring will be the date of felling of the oak from which it was cut. There is much evidence that in medieval times oaks cut down for building purposes were used almost immediately, usually within the year or so (Rackham 1976). Hence if bark is present on several main timbers in a building, none of which appear reused or are later insertions, and if they all have the same date for their last ring, then we can be quite confident that this is the date of construction or soon after. If there is no bark on the sample, then we have to make an estimate of the felling date; how this is done is explained below.

The Practice of Tree-Ring Dating at the Nottingham Tree-Ring Dating Laboratory

1. Inspecting the Building and Sampling the Timbers

Together with a building historian the timbers in a building are inspected to try to ensure that those sampled are not reused or later insertions. Sampling is almost always done by coring into the timber, which has the great advantage that we can sample *in situ* timbers and those judged best to give the date of construction, or phase of construction if there is more than one in the building. The timbers to be sampled are also inspected to see how many rings they have. We normally look for timbers with at least 70 rings, and preferably more. With fewer rings than this, 50 for example, sequences of widths become difficult to match to a unique position within a master sequence of ring widths and so are difficult to date (Litton and Zainodin 1991). The cross-section of the rafter shown in Figure A2 has about 120 rings; about 20 of which are sapwood rings – the lighter rings on the outside. Similarly the core has just over 100 rings with a few sapwood rings.

To ensure that we are getting the date of the building as a whole, or the whole of a phase of construction if there is more than one, about 8–10 samples per phase are usually taken. Sometimes we take many more, especially if the construction is complicated. One reason for taking so many samples is that, in general, some will fail to give a date. There may be many reasons why a particular sequence of ring widths from a sample of timber fails to give a date even though others from the same building do. For example, a particular tree may have grown in an odd ecological niche, so odd indeed that the widths of its rings were determined by factors other than the local climate! In such circumstances it will be impossible to date a timber from this tree using the master sequence whose widths, we can assume, were predominantly determined by the local climate at the time.

Sampling is done by coring into the timber with a hollow corer attached to an electric drill and usually from its outer rings inwards towards where the centre of the tree, the pith, is judged to be. An illustration of a core is shown in Figure A2; it is about 150mm long and 10mm diameter. Great care has to be taken to ensure that as few as possible of the outer rings are lost in coring. This can be difficult as these outer rings are often very soft (see below on sapwood). Each sample is given a code which identifies uniquely which timber it comes from, which building it is from and where the building is located. For example, CRO-A06 is the sixth core taken from the first building (A) sampled by the Laboratory in Cropwell Bishop. Where it came from in that building will be shown in the sampling records and drawings. No structural damage is done to any timbers by coring, nor does it weaken them.

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

All sampling by the Laboratory is undertaken according to current Health and Safety Standards. The Laboratory's dendrochronologists are insured.

Figure A1: A wedge of oak from a tree felled in 1976. It shows the annual growth rings, one for each year from the innermost ring to the last ring on the outside just inside the bark. The year of each ring can be determined by counting back from the outside ring, which grew in 1976

Figure A2: Cross-section of a rafter, showing sapwood rings in the left-hand corner, the arrow points to the heartwood/sapwood boundary (H/S); and a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil

Figure A3: Measuring ring widths under a microscope. The microscope is fixed while the sample is on a moving platform. The total sequence of widths is measured twice to ensure that an error has not been made. This type of apparatus is needed to process a large number of samples on a regular basis

Figure A4: Three cores from timbers in a building. They come from trees growing at the same time. Notice that, although the sequences of widths look similar, they are not identical. This is typical

2. *Measuring Ring Widths*

Each core is sanded down with a belt sander using medium-grit paper and then finished by hand with flourgrade-grit paper. The rings are then clearly visible and differentiated from each other with a result very much like that shown in Figure A2. The core is then mounted on a movable table below a microscope and the ring-widths measured individually from the innermost ring to the outermost. The widths are automatically recorded in a computer file as they are measured (see Fig A3).

3. *Cross-Matching and Dating the Samples*

Because of the factors besides the local climate which may determine the annual widths of a tree's rings, no two sequences of ring widths from different oaks growing at the same time are exactly alike (Fig A4). Indeed, the sequences may not be exactly alike even when the trees are growing near to each other. Consequently, in the Laboratory we do not attempt to match two sequences of ring widths by eye, or graphically, or by any other subjective method. Instead, it is done objectively (ie statistically) on a computer by a process called cross-matching. The output from the computer tells us the extent of correlation between two sample sequences of widths or, if we are dating, between a sample sequence of widths and the master, at each relative position of one to the other (offsets). The extent of the correlation at an offset is determined by the *t*-value (defined in almost any introductory book on statistics). That offset with the maximum *t*-value among the *t*-values at all the offsets will be the best candidate for dating one sequence relative to the other. If one of these is a master chronology, then this will date the other. Experiments carried out in the past with sequences from oaks of known date suggest that a *t*-value of at least 4.5, and preferably at least 5.0, is usually adequate for the dating to be accepted with reasonable confidence (Laxton and Litton 1988; Laxton *et al* 1988; Howard *et al* 1984–1995).

This is illustrated in Figure A5 with timbers from one of the roofs of Lincoln Cathedral. Here four sequences of ring widths, LIN-C04, 05, 08, and 45, have been cross-matched with each other. The ring widths themselves have been omitted in the bar diagram, as is usual, but the offsets at which they best cross-match each other are shown; eg the sequence of ring widths of C08 matches the sequence of ring widths of C45 best when it is at a position starting 20 rings after the first ring of C45, and similarly for the others. The actual *t*-values between the four at these offsets of best correlations are in the matrix. Thus at the offset of +20 rings, the *t*-value between C45 and C08 is 5.6 and is the maximum found between these two among all the positions of one sequence relative to the other.

It is standard practice in our Laboratory first to cross-match as many as possible of the ring-width sequences of the samples in a building and then to form an average from them. This average is called a site sequence of the building being dated and is illustrated in Figure A5. The fifth bar at the bottom is a site sequence for a roof at Lincoln Cathedral and is constructed from the matching sequences of the four timbers. The site sequence width for each year is the average of the widths in each of the sample sequences which has a width for that year. Thus in Fig A5 if the widths shown are 0.8mm for C45, 0.2mm for C08, 0.7mm for C05, and 0.3mm for

C04, then the corresponding width of the site sequence is the average of these, 0.55mm. The actual sequence of widths of this site sequence is stored on the computer. The reason for creating site sequences is that it is usually easier to date an average sequence of ring widths with a master sequence than it is to date the individual component sample sequences separately.

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

4. Estimating the Felling Date

As mentioned above, if the bark is present on a sample, then the date of its last ring is the date of the felling of its tree (or the last full year before felling, if it was felled in the first three months of the following calendar year, before any new growth had started, but this is not too important a consideration in most cases). The actual bark may not be present on a timber in a building, though the dendrochronologist who is sampling can often see from its surface that only the bark is missing. In these cases the date of the last ring is still the date of felling.

Quite often some, though not all, of the original outer rings are missing on a timber. The outer rings on an oak, called sapwood rings, are usually lighter than the inner rings, the heartwood, and so are relatively easy to identify. For example, sapwood can be seen in the corner of the rafter and at the outer end of the core in Figure A2, both indicated by arrows. More importantly for dendrochronology, the sapwood is relatively soft and so liable to insect attack and wear and tear. The builder, therefore, may remove some of the sapwood for precisely these reasons. Nevertheless, if at least some of the sapwood rings are left on a sample, we will know that not too many rings have been lost since felling so that the date of the last ring on the sample is only a few years before the date of the original last ring on the tree, and so to the date of felling.

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

Even more precise estimates of the felling date and range can often be obtained using knowledge of a particular case and information gathered at the time of sampling. For example, at the time of sampling the dendrochronologist may have noted that the timber from which the core of Figure A2 was taken still had complete sapwood but that some of the soft sapwood rings were lost in coring. By measuring into the timber the depth of sapwood lost, say 20mm, a reasonable estimate can be made of the number of sapwood rings lost, say 12 to 15 rings in this case. By adding on 12 to 15 years to the date of the last ring on the sample a good tight estimate for the range of the felling date can be obtained, which is often better than the 15 to 35 years later we would have estimated without this observation. In the example, the felling is now estimated to have taken place between AD 1512 and 1515, which is much more precise than without this extra information.

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

5. Estimating the Date of Construction

There is a considerable body of evidence collected by dendrochronologists over the years that oak timbers used in buildings were not seasoned in medieval or early modern times (English Heritage 1998; Miles 1997, 50–5). Hence, provided that all the samples in a building have estimated felling-date ranges broadly in agreement with each other, so that they appear to have been felled as a group, then this should give an accurate estimate of the period when the structure was built, or soon after

(Laxton *et al* 2001, fig 8; 34–5, where 'associated groups of fellings' are discussed in detail). However, if there is any evidence of storage before use, or if there is evidence the oak came from abroad (eg Baltic boards), then some allowance has to be made for this.

6. Master Chronological Sequences

Ultimately, to date a sequence of ring widths, or a site sequence, we need a master sequence of dated ring widths with which to cross-match it, a Master Chronology. To construct such a sequence we have to start with a sequence of widths whose dates are known and this means beginning with a sequence from an oak tree whose date of felling is known. In Figure A6 such a sequence is SHE-T, which came from a tree in Sherwood Forest which was blown down in a recent gale. After this other sequences which cross-match with it are added and gradually the sequence is 'pushed back in time' as far as the age of samples will allow. This process is illustrated in Figure A6. We have a master chronological sequence of widths for Nottinghamshire and East Midlands oak for each year from AD 882 to 1981. It is described in great detail in Laxton and Litton (1988), but the components it contains are shown here in the form of a bar diagram. As can be seen, it is well replicated in that for each year in this period there are several sample sequences having widths for that year. The master is the average of these. This master can now be used to date oak from this area and from the surrounding areas where the climate is very similar to that in the East Midlands. The Laboratory has also constructed a master for Kent (Laxton and Litton 1989). The method the Laboratory uses to construct a master sequence, such as the East Midlands and Kent, is completely objective and uses the Litton-Zainodin grouping procedure (Laxton *et al* 1988). Other laboratories and individuals have constructed masters for other areas and have made them available. As well as these masters, local (dated) site chronologies can be used to date other buildings from nearby. The Laboratory has hundreds of these site sequences from many parts of England and Wales covering many short periods.

7. Ring-Width Indices

Tree-ring dating can be done by cross-matching the ring widths themselves, as described above. However, it is advantageous to modify the widths first. Because different trees grow at different rates and because a young oak grows in a different way from an older oak, irrespective of the climate, the widths are first standardized before any matching between them is attempted. These standard widths are known as ring-width indices and were first used in dendrochronology by Baillie and Pilcher (1973). The exact form they take is explained in this paper and in the appendix of Laxton and Litton (1988) and is illustrated in the graphs in Figure A7. Here ring-widths are plotted vertically, one for each year of growth. In the upper sequence of (a), the generally large early growth after 1810 is very apparent as is the smaller later growth from about 1900 onwards when the tree is maturing. A similar phenomenon can be observed in the lower sequence of (a) starting in 1835. In both the widths are also changing rapidly from year to year. The peaks are the wide rings and the troughs are the narrow rings corresponding to good and poor growing seasons, respectively. The two corresponding sequence of Baillie-Pilcher indices are plotted in (b) where the differences in the immature and mature growths have been removed and only the rapidly changing peaks and troughs remain, that are associated with the common climatic signal. This makes cross-matching easier.

t-value/offset Matrix

	C45	C08	C05	C04
C45		+20	+37	+47
C08	5.6		+17	+27
C05	5.2	10.4		+10
C04	5.9	3.7	5.1	

Bar Diagram

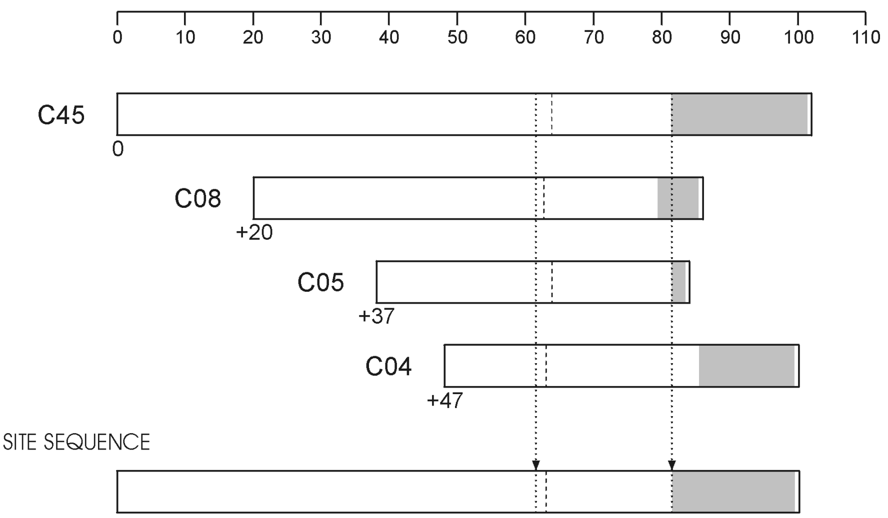


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

The bar diagram represents these sequences without the rings themselves. The length of the bar is proportional to the number of rings in the sequence. Here the four sequences are set at relative positions (offsets) to each other at which they have maximum correlation as measured by the *t*-values. The *t*-value/offset matrix contains the maximum *t*-values below the diagonal and the offsets above it. Thus, the maximum *t*-value between C08 and C45 occurs at the offset of +20 rings and the *t*-value is then 5.6. The site sequence is composed of the average of the corresponding widths, as illustrated with one width.

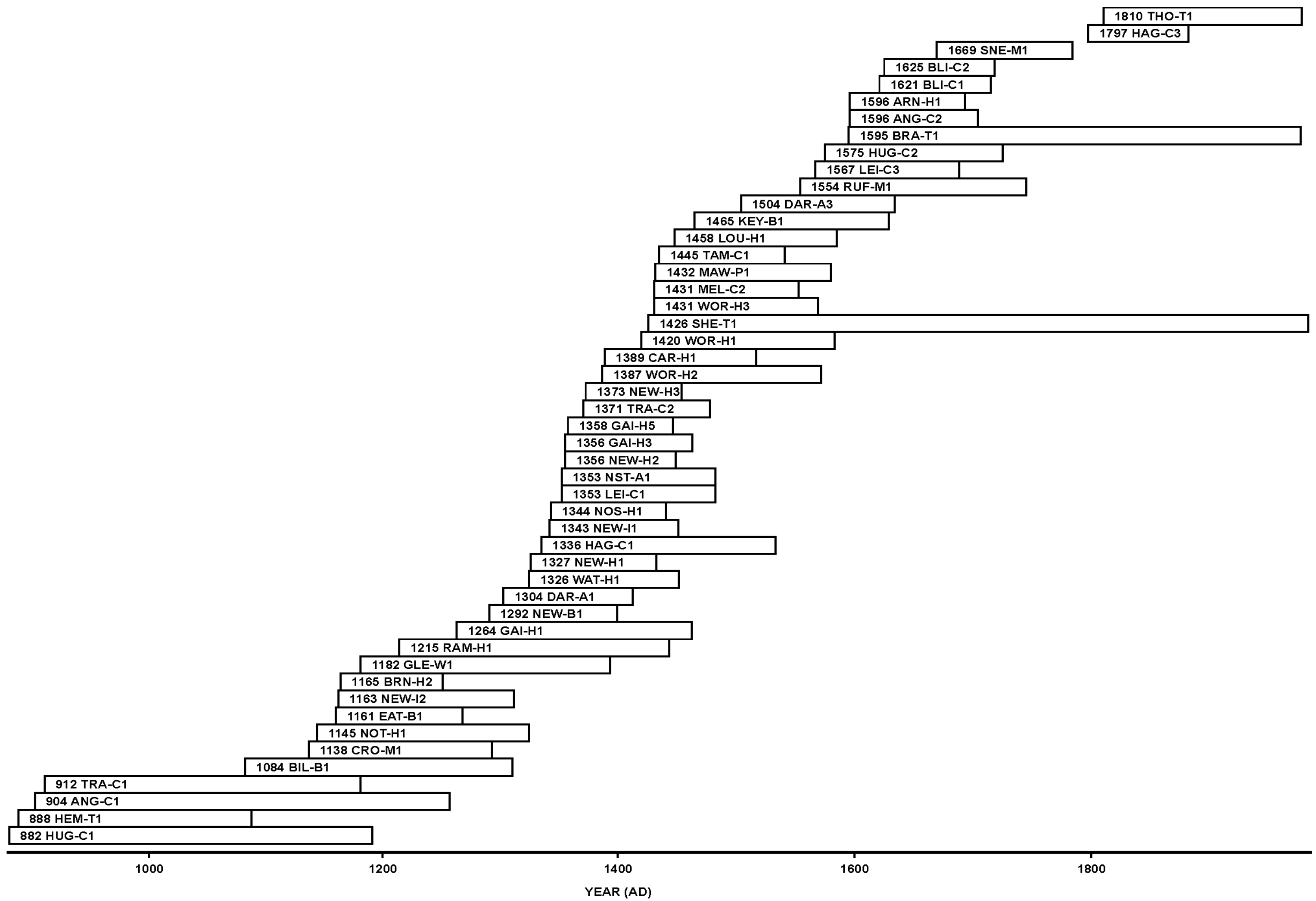
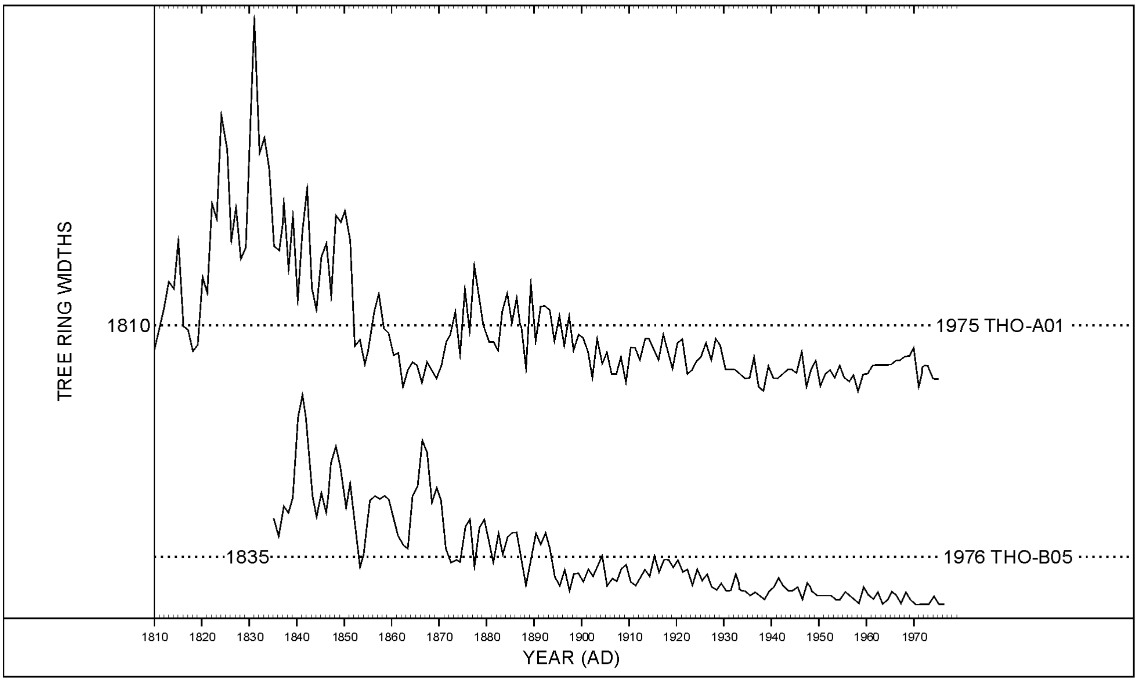


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

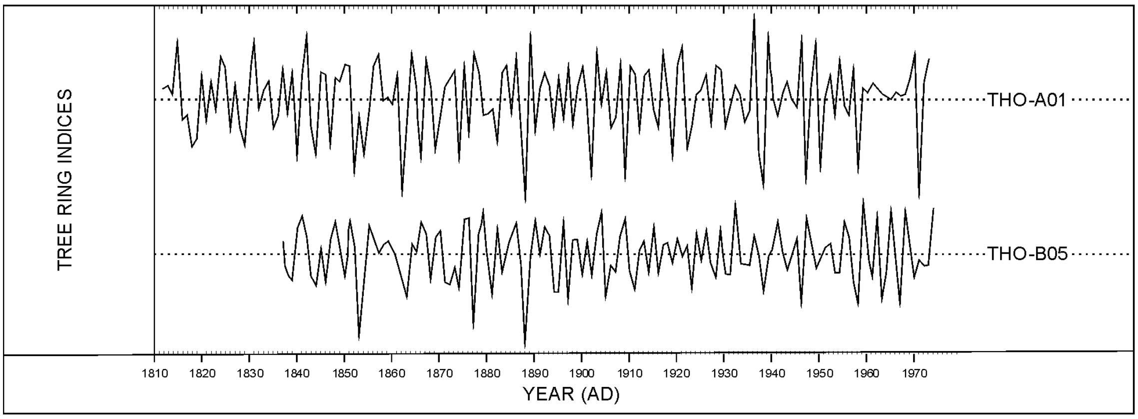


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

Here the ring widths are plotted vertically, one for each year, so that peaks represent wide rings and troughs narrow ones. Notice the growth-trends in each; on average the earlier rings of the young tree are wider than the later ones of the older tree in both sequences

Figure A7 (b): The Baillie-Pilcher indices of the above widths

The growth trends have been removed completely

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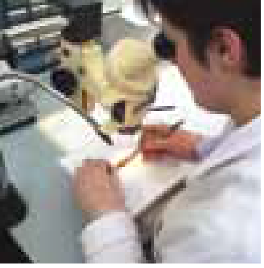
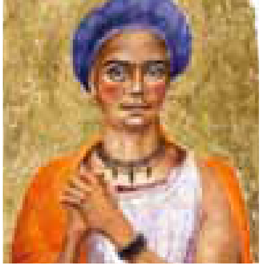


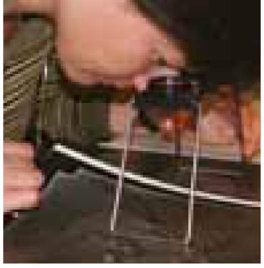


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ISSN 2059-4453 (Online)