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7–9 North Bar Within, Beverley East Riding of Yorkshire Tree-ring analysis of oak timbers

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7–9 NORTH BAR WITHIN
BEVERLEY
EAST RIDING OF YORKSHIRE

Tree-ring analysis of oak timbers

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SUMMARY
Tree-ring analysis was undertaken on samples taken from timbers of the west and middle range roofs of 7–9 North Bar Within, Beverley, resulting in the construction of a single site sequence. Site sequence BEVHSQ01 contains 20 samples and spans the period AD 1538–1674. Interpretation of the sapwood suggests felling of all timbers occurred in, or around, AD 1674 with construction of both roofs likely to have followed shortly after.

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INTRODUCTION

The *Early Fabric in Historic Towns: Voluntary Group Projects*, funded by Historic England, have been developed in the recognition and acknowledgement of the excellent work being undertaken by local vernacular groups in the study of local architectural trends and fabrics. The project's intention is to encourage this type of study through the provision of support and to facilitate training of more people in building analysis and recording. The local projects were coordinated by Rebecca Lane (Historic England South West Region: Senior Architectural Investigator).

Early Fabric in Beverley Project

Whilst there is a corpus of research on form and age of the town of Beverley, it does not cover detailed examination of early fabric or aspects of typology, with analysis and interpretation of existing buildings until now not having benefited from dendrochronology, with the exception of some limited work on the Minster.

Initially, 13 properties were identified that were thought to be key to understanding the town's architectural development for a programme of comprehensive investigation. These properties were assessed for their suitability for tree-ring dating and those found to contain timbers potentially suitable for analysis were sampled. As the project progressed and some of the original buildings identified were rejected as unsuitable for tree-ring dating, further candidates for tree-ring analysis were assessed and sampled if appropriate.

It was hoped that successful dating of these buildings would extend the knowledge of early fabric and selected buildings in the historic town of Beverley in support of Historic England's responsibility to identify and understand the urban vernacular and historic environment of this market town. The reports produced on the buildings recorded as part of this project by the Yorkshire Vernacular Buildings Study Group, led by David Cook, will be held in the YVBSG archive and will be available through their website (www.yvbsg.org.uk), whilst a summary of the project is presented in Vernacular Architecture (Cook and Neave 2018).

7–9 NORTH BAR WITHIN

The Grade II listed 7–9 North Bar Within, Beverley (List Entry No 1162330) is located at the south end of the street (Figs 1–3) as part of a row of shops and dwellings. It is aligned facing north-east (for simplicity east for the purpose of this report) and consists of three connected ranges (Fig 4). Although the outer walls are of brick construction, elements of timber framing survive within the building, such as in the north gable of the east range and the south gable of the west range, with it possible that further timber framing is masked by the later render.

All three ranges are of two storeys with lofts. The building is thought to date to the mid or late-seventeenth century but with alterations, such as rebuilding of front of the east range in brick and insertion of fireplaces, being undertaken in the early-eighteenth century.

East range

The east (or front) range is aligned north/south with the street frontage being divided into five bay, defined by five deep sash windows at first floor level. At the south end of the range there is a passageway which runs under the house. To the right (north) of the western part of the passage is the gabled stair turret.

The roof area over this range is divided into two by a thin stud partition. The roof overall consists of eight bays, separated by seven collared common rafter couples, between each are three ordinary common rafter couples. It is underdrawn at collar level and appears to be a relatively modern softwood replacement.

Middle range

Behind the northern half of the east range is the east/west aligned middle range, to the south of which is a small yard. The roof over this range is of common rafter and collar type, although the majority of the collars have been renewed, as have some of the common rafters (Fig 5).

West range

This range, situated behind (west of) the middle range, is aligned north/south; to the south end of the range is a passage leading to a large yard located beyond this range and containing a number of small detached buildings. The roof over this range consists of five collar trusses, between which are two or three pairs of common rafters (Fig 6).

SAMPLING

A total of 24 oak (*Quercus* sp.) timbers were sampled in this building, 12 from the middle range roof and 12 from the west range roof, those in the east range being considered unsuitable. Each sample was given the code BEV-H and numbered 01–24. Two separate cores were taken from timber BEV-H02, one with 66 and one with 64 rings, in order to maximise the ring sequence length; these two cores matched each other at t = 11.1 giving a combined ring sequence of 96 rings. The location of all samples was noted at the time of sampling and has been marked on Figure 7. Further details relating to the samples can be found in Table 1. During the sampling process and within the interim summary the middle range was referred to as the east range but following receipt of the description provided by the Yorkshire Vernacular Buildings Study Group this has now been altered to follow their nomenclature.

ANALYSIS AND RESULTS

The ring pattern of one of the samples from a purlin in the middle range (BEV-H11) could be seen to be severely distorted by a knot and so was rejected prior to measurement. The remaining 23 samples were prepared by sanding and polishing and their growth ring-widths measured; the data of these measurements are given at the end of the report. These samples were then compared with each other by the Litton/Zainodin grouping programme (see Appendix) resulting in 20 samples matching to form a single group at a minimum t-value of 5.3.

These 20 samples were combined at the relevant offset positions to form BEVHSQ01, a site sequence of 137 rings (Fig 8). This site sequence was compared against a series of relevant reference chronologies for oak where it was found to match securely and consistently at a first-ring date of AD 1538 and a last-measured ring date of AD 1674. The evidence for this dating is given in Table 2.

Attempts were then made to date the ungrouped samples by comparing them individually against the reference chronologies but no secure matches were noted and all three remain undated.

INTERPRETATION

Tree-ring analysis has resulted in the successful dating of 20 timbers taken from the two sampled roofs (Fig 8).

Middle range

Eight of the samples, representing six common rafters and two purlins from the roof of the middle range, have been successfully dated. Two of these, BEV-H03 and BEV-H05, have complete sapwood and the last-measured ring date of AD 1674, the felling date of the timbers represented. Another three samples have the heartwood/sapwood boundary ring which in all cases is broadly contemporary and suggestive of a single felling. The average of these is AD 1650 and using the estimate that 95% of mature oak trees in this region have 15–40 sapwood rings allows an estimated felling date to be calculated for the three timbers represented to within the range AD 1674–90 (allowing for sample BEV-H09 having the last-measured ring date of AD 1673 with incomplete sapwood), consistent with these timbers also having been felled in AD 1674. The remaining three dated samples do not have the heartwood/sapwood boundary but with last-measured ring dates of AD 1632 (BEV-H08), AD 1637 (BEV-H12), and AD 1644 (BEV-H10) these have *terminus post quem* dates for felling of AD 1647, AD 1652, and AD 1659, respectively. The overall level of matching within this group of timbers suggests that it is likely that all were felled as part of a single felling episode in, or around, AD 1674.

West range

All 12 of the samples, representing common rafters from the west range roof, have been successfully dated. One of these, BEV-H19, has complete sapwood and the last-measured ring date of AD 1674, the felling date of the timber represented. Another two samples, BEV-H17 and BEV-H22, had retained complete sapwood but in both instances the ring boundaries of the outermost rings were not clearly defined due to compaction and hence were not measured. In each case it was estimated that approximately 25-30 rings were not measured, thus allowing felling date ranges of *c* AD 1672–77 and *c* AD 1669–74 respectively to be obtained. Seven further samples have the heartwood/sapwood boundary which in all cases is broadly contemporary and suggestive of a single felling. The average of these is AD 1648, allowing an estimated felling date to be calculated for the timbers represented to within the range AD 1663–88, consistent with these timbers also having been felled in, or around, AD 1674. The final two dated samples, BEV-H14 and BEV-

H24 do not have the heartwood/sapwood boundary ring but with last-measured ring dates of AD 1593 and AD 1621 these have *terminus post quem* dates for felling of AD 1609 and AD 1637 respectively. Again the overall level of matching within this group of timbers suggests that it is likely that all were felled as part of a single felling episode in, or around, AD 1674.

DISCUSSION

Tree-ring analysis has demonstrated timber used in both the middle and west range roofs of 7–9 North Bar Within was felled in, or around, AD 1674, providing support for the mid/late-seventeenth century construction date previously assigned to the building on the basis of architectural features. Additionally, it can now be said that the middle and west ranges are contemporary. It is unfortunate that the timbers of the east range were unsuitable for dating and, therefore, whether this range is also coeval is still unclear.

A number of potential same tree matches were noted amongst the samples, not only between timbers from the same roof, such as BEV-H03 and BEV-H09 which match each other at a value of t=14.1) but also between different roofs; sample BEV-H04 (from the middle roof) matches samples BEV-H15 and BEV-H19 (both from the west roof) at values of t=12.9 and 11.0, respectively. These are high enough to suggest the timbers represented were cut from the same tree and provides further support for the timbers throughout these two roofs representing a single episode of felling.

Given the difficulties encountered in successfully dating timbers from this region, both previously and during this project, the production and dating of a well replicated and reasonably long site sequence is of great value and BEVHSQ01 is likely to be a useful reference chronology for future work in the East Riding of Yorkshire.

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TABLES

Table 1: Details of tree-ring samples from 7–9 North Bar Within, Beverley, Yorkshire

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
Middle range						
BEV-H01	North common rafter 3	46	15C	----	----	----
BEV-H02	North common rafter 4	96	23	----	----	----
BEV-H03	North common rafter 6	77	30C	1598	1644	1674
BEV-H04	North common rafter 9	64	22	1604	1645	1667
BEV-H05	North common rafter 11	94	22C	1581	1652	1674
BEV-H06	North purlin (east)	58	--	----	----	----
BEV-H07	North purlin (west)	101	10	1567	1657	1667
BEV-H08	South common rafter 14	79	--	1554	----	1632
BEV-H09	South common rafter 15	80	26	1594	1647	1673
BEV-H10	South common rafter 16	59	--	1586	----	1644
BEV-H11	South purlin (east)	NM	--	----	----	----
BEV-H12	South purlin (west)	79	--	1559	----	1637
West range						
BEV-H13	East common rafter 4	99	h/s	1557	1655	1655
BEV-H14	East common rafter 8	54	--	1540	----	1593
BEV-H15	East common rafter 11	72	12	1585	1644	1656
BEV-H16	East common rafter 12	109	h/s	1543	1651	1651
BEV-H17	East common rafter 13	84	06c (+*c*25-30nm)	1564	1641	1647
BEV-H18	East common rafter 16	75	13	1583	1644	1657
BEV-H19	West common rafter 3	89	18C	1586	1656	1674
BEV-H20	West common rafter 9	111	h/s	1538	1648	1648
BEV-H21	West common rafter 10	79	h/s	1565	1643	1643
BEV-H22	West common rafter 12	95	h/sc (+*c*25-30nm)	1550	1644	1644
BEV-H23	West common rafter 14	113	07	1549	1654	1661
BEV-H24	West common rafter 15	62	--	1560	----	1621

NM = not measured; h/s = heartwood/sapwood boundary is the last-measured ring; C = complete sapwood retained on sample, last measured ring is the felling date; c = complete sapwood present on the sample but outermost rings are unmeasurable

Table 2: Results of the cross-matching of site sequence BEVHSQ01 and reference chronologies when the first-ring date is AD 1538 and the last-measured ring date is AD 1674

Site reference	*t* – value	Span of chronology	Reference
Manor House, Nether Poppleton, North Yorkshire	9.1	AD 1494–1619	Howard 2004
Nun Appleton, Tadcaster, West Yorkshire	8.4	AD 1478–1657	Arnold *et al* 2008a
Lodge Farm, Staunton Harold, Leicestershire	8.3	AD 1533–1647	Arnold *et al* 2008b
Manor House, Sutton Scarsdale, Derbyshire	8.0	AD 1521–1658	Howard *et al* unpubl 1996
Bolsover Castle (Riding house), Bolsover, Derbyshire	7.6	AD 1494–1744	Howard *et al* 2005
Bolsover Little Castle, Bolsover, Derbyshire	7.4	AD 1532–1749	Arnold *et al* 2003
Ledston Hall, Leeds, West Yorkshire	7.2	AD 1424–1668	Arnold *et al* 2015
Pontefract Castle, Yorkshire	7.0	AD 1507–1656	Arnold and Howard 2005
The Cruck House, Glebe Farm, Octon, East Yorkshire	7.0	AD 1545–1670	Tyers 2008a
Stubley Farm barn, Morley, West Yorkshire	6.5	AD 1508–1662	Tyers 2008b
Church of St Martin (bellframe), North Leverton, Nottinghamshire	6.4	AD 1596–1710	Arnold *et al* 2016
Church of St Andrew, Welham, Leicestershire	6.3	AD 1443–1633	Arnold *et al* 2005

FIGURES

Figure 1: Map to show the general location of Beverley (red ellipse). © Crown Copyright and database right 2020. All rights reserved. Ordnance Survey Licence number 10002490

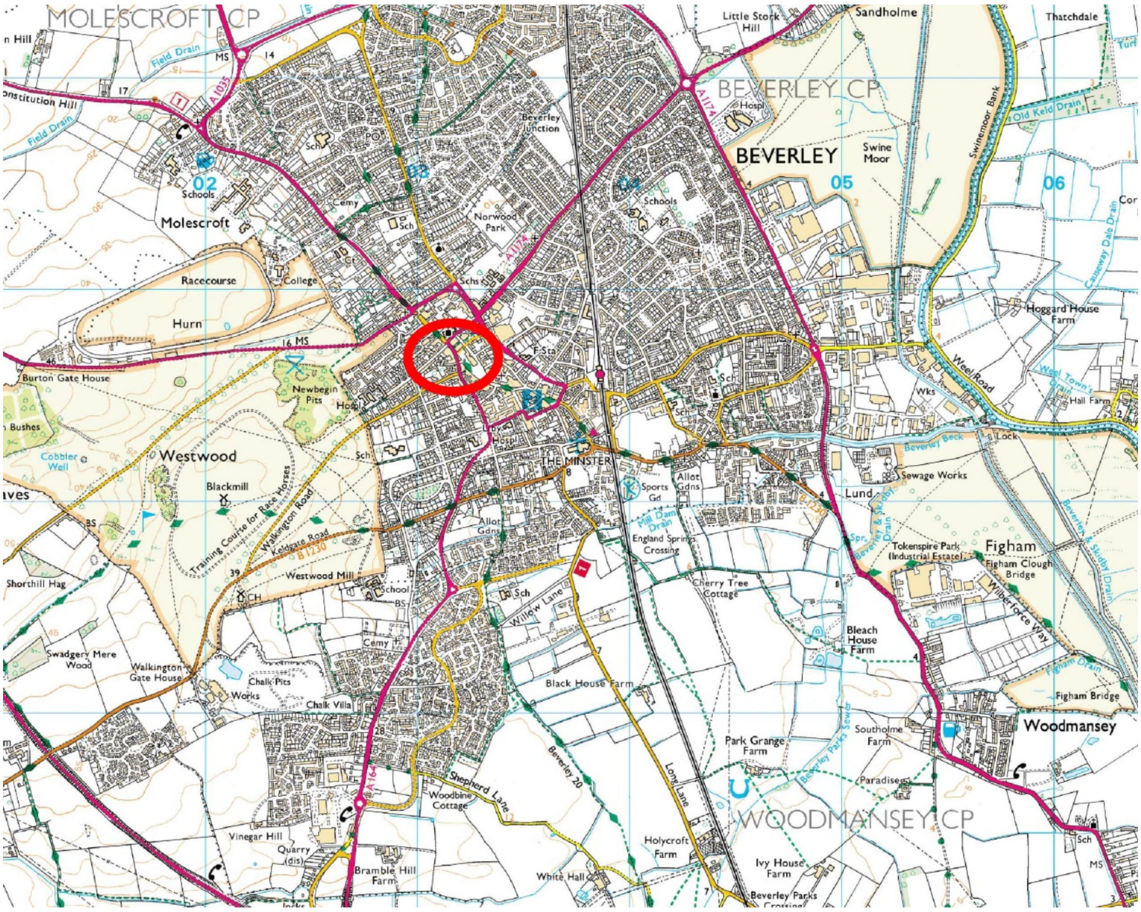

Figure 2: Map to show the general location of 7–9 North Bar Within in Beverley (red ellipse). © Crown Copyright and database right 2020. All rights reserved. Ordnance Survey Licence number 100024900

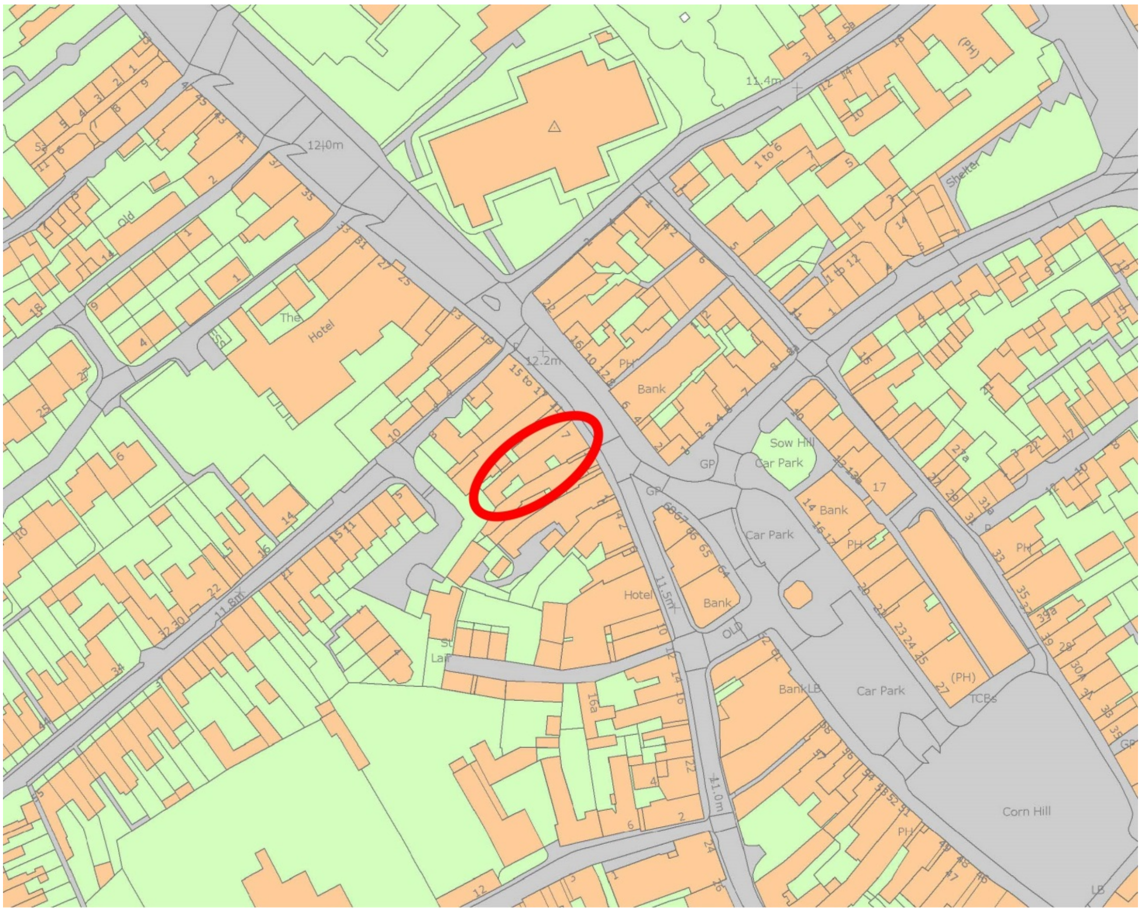

Figure 3: Map to show the location of 7–9 North Bar Within in Beverley (red ellipse). © Crown Copyright and database right 2020. All rights reserved. Ordnance Survey Licence number 100024900

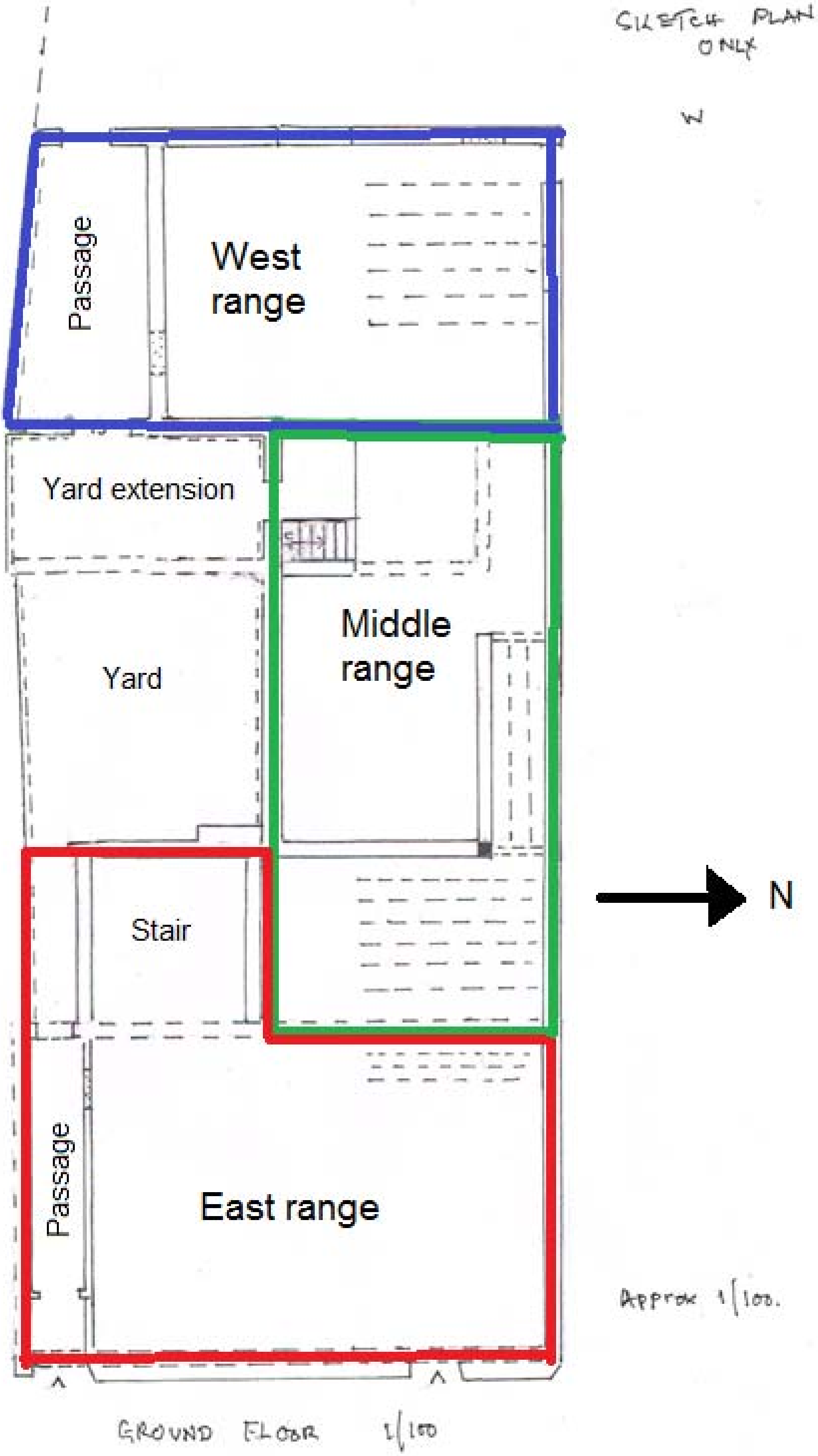

Figure 4: Ground-floor plan of 7–9 North Bar Within (YVBSG)

Figure 5: Middle range, photograph taken from the west (Alison Arnold)

Figure 6: West range, photograph taken from the north-east (Alison Arnold)

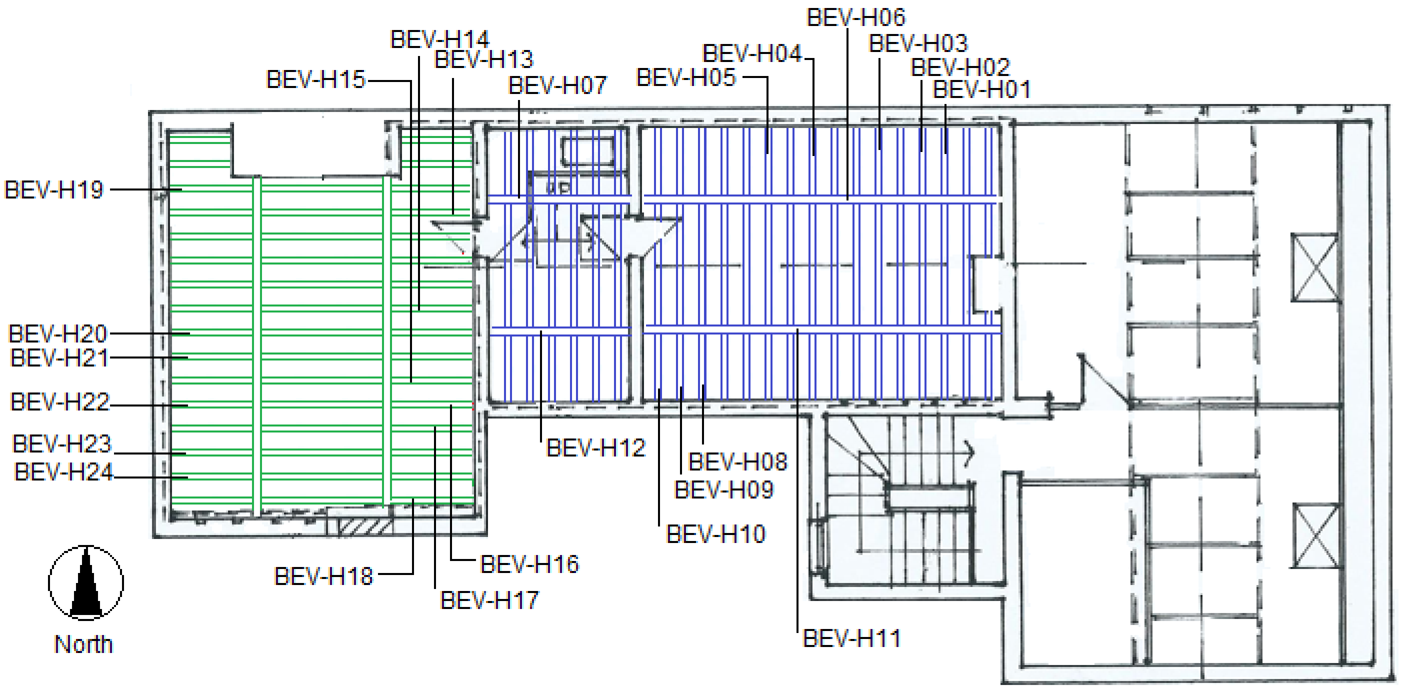

Figure 7: Roof plan, showing the location of sampled timbers BEV-H01–24 (after Chris Wooller)

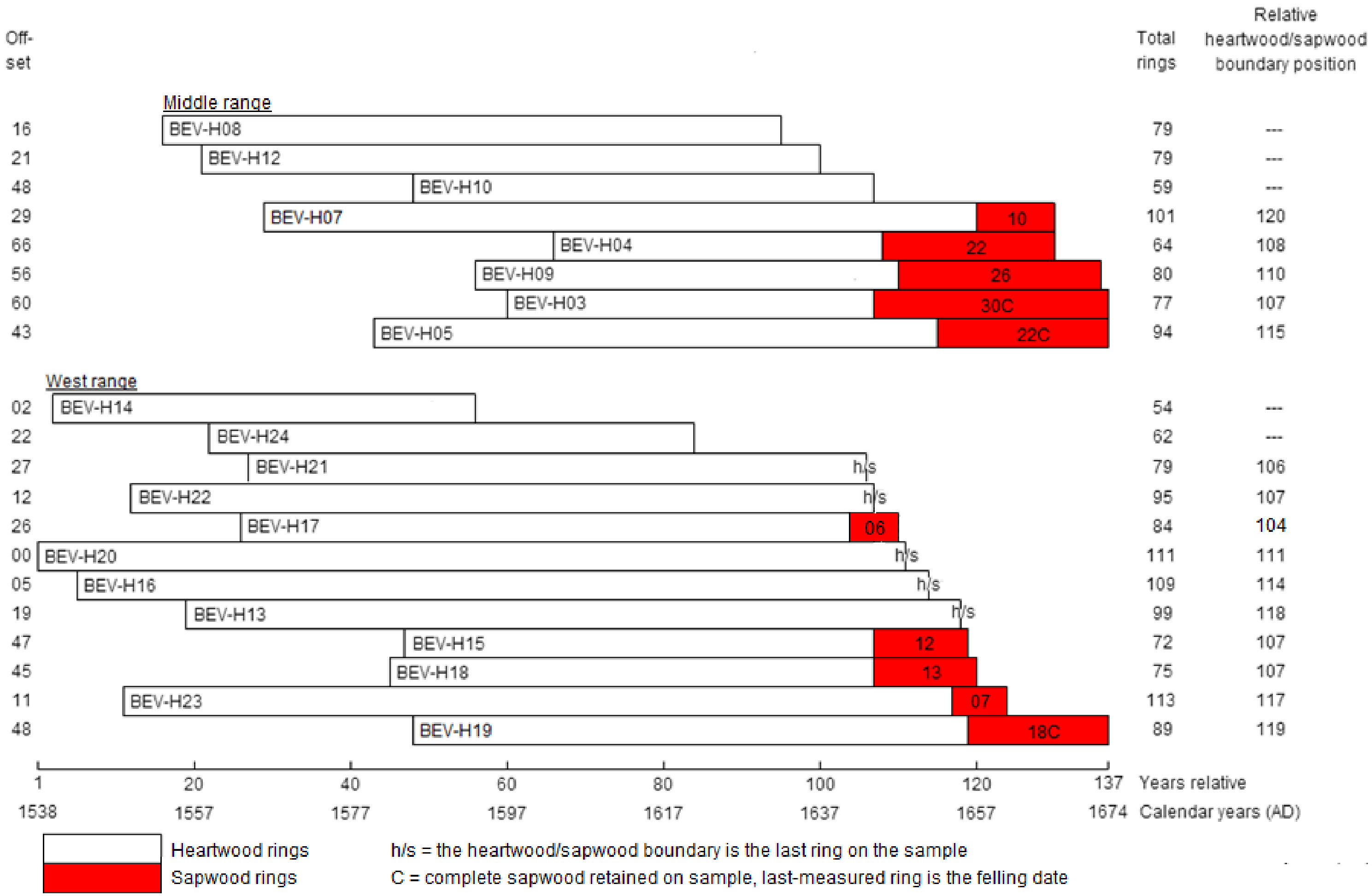

Figure 8: Bar diagram to show the position of samples in site sequence BEVHSQ01, sorted by area

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

BEV-H01A 46
503 333 205 226 410 282 169 177 219 198 190 246 153 137 119 58 65 132 103 141
159 224 120 59 74 129 226 229 231 146 74 77 109 118 154 139 126 90 61 112
158 158 99 126 190 84

BEV-H01B 46
469 325 196 199 364 281 169 204 191 175 189 235 163 134 114 64 59 136 91 152
155 218 119 55 83 130 225 223 262 143 75 80 107 125 142 132 126 89 65 103
162 156 102 122 176 93

BEV-H02A 66
85 85 96 98 90 122 110 133 125 146 152 145 111 139 123 113 138 142 198 222
234 142 139 225 202 177 180 142 51 59 53 46 43 58 57 62 67 79 77 75
53 36 25 32 40 114 110 80 46 29 32 34 29 23 22 24 50 38 35 38
33 41 40 34 41 51

BEV-H02B 64
315 290 368 347 339 316 386 274 296 292 304 313 308 281 311 301 295 339 332 251
307 301 352 274 193 140 190 80 49 51 62 77 98 79 87 101 90 122 109 121
125 116 93 115 121 109 147 155 185 225 236 164 143 227 235 229 213 172 73 63
54 51 50 49

BEV-H03A 77
213 275 257 282 320 436 210 167 258 235 220 57 113 73 114 71 56 75 124 118
147 140 116 79 201 125 121 70 123 143 214 268 213 102 176 154 170 106 75 138
127 105 143 143 47 118 145 102 101 59 87 69 54 75 65 55 98 88 93 72
53 58 83 70 51 93 42 40 109 67 60 57 65 80 81 113 148

BEV-H03B 77
188 273 251 283 326 431 208 155 284 228 221 90 89 85 106 69 56 78 113 119
152 129 114 90 196 133 111 87 110 142 222 270 210 107 177 151 175 107 71 149
119 111 142 132 55 109 139 106 98 65 80 66 63 72 74 49 98 87 94 70
49 63 82 64 58 90 36 48 107 72 57 53 71 79 82 101 143

BEV-H04A 64
76 61 85 175 190 51 55 53 69 56 40 71 85 113 153 99 95 61 121 157
133 81 96 83 124 136 123 84 104 104 101 78 43 84 206 104 102 52 54 92
112 101 113 51 51 50 61 102 87 75 166 253 202 104 103 100 133 143 130 106
57 76 87 110

BEV-H04B 64
93 39 115 175 191 56 52 48 67 63 47 51 99 102 160 112 106 49 115 164
136 94 98 102 116 148 154 74 103 99 97 93 47 70 223 105 103 40 46 96
109 103 119 47 49 62 64 94 88 80 163 239 200 115 81 84 140 127 121 117
55 56 105 102

BEV-H05A 94
203 150 173 205 144 177 126 89 127 137 106 111 153 154 153 87 119 121 144 142
121 108 123 68 55 99 115 145 171 160 144 147 106 63 147 109 100 110 61 56

48 69 70 65 66 55 73 68 87 46 38 74 67 58 92 98 77 79 83 96
101 45 88 61 64 76 51 42 51 61 112 83 54 55 64 56 34 70 74 63
56 40 53 34 36 53 48 49 59 69 61 55 58 72

BEV-H05B 94
196 161 173 198 150 178 116 103 126 131 113 111 149 159 149 93 106 135 137 150
120 104 133 74 62 89 121 152 171 158 141 141 114 61 149 112 93 106 51 74
50 55 73 68 73 57 61 72 85 45 43 72 62 61 86 100 94 80 78 98
99 62 89 65 75 74 64 45 49 67 111 85 49 61 57 59 44 74 72 67
49 42 47 35 46 46 42 51 56 65 62 63 53 83

BEV-H06A 58
344 322 314 270 168 172 205 218 251 263 229 167 231 243 272 245 142 218 259 303
218 216 330 361 321 357 211 145 205 115 135 165 198 179 203 144 139 160 157 192
180 205 241 126 145 109 176 156 157 191 67 55 46 53 45 71 91 102

BEV-H06B 58
351 320 316 267 163 178 211 213 241 266 224 161 205 226 289 246 140 209 249 272
231 205 323 337 332 351 214 147 201 112 137 160 196 184 204 146 142 163 161 183
186 203 248 133 113 153 173 175 163 189 69 49 54 45 46 72 88 100

BEV-H07A 101
191 200 270 253 217 138 166 145 132 146 113 127 166 142 140 116 124 135 169 178
123 128 88 135 127 125 170 159 171 148 118 100 104 60 55 71 55 57 47 41
42 59 49 62 81 100 126 69 74 80 100 112 129 113 149 180 150 129 99 87
107 106 133 113 85 99 89 75 75 58 50 73 52 88 59 53 45 50 58 73
75 74 67 58 63 59 57 54 53 75 66 109 89 136 108 71 110 72 85 112
98

BEV-H07B 101
187 196 259 268 217 132 176 138 121 143 119 136 160 136 142 123 128 135 166 176
120 130 88 130 134 129 178 164 170 141 111 111 96 63 60 63 62 56 37 49
40 63 45 66 80 104 125 59 54 86 100 113 128 114 146 181 148 126 98 83
111 103 129 109 82 96 83 73 68 50 59 74 53 84 59 48 52 45 61 72
79 76 59 57 61 59 51 40 59 67 70 103 95 120 115 84 102 61 81 107
95

BEV-H08A 79
278 393 223 302 282 425 416 326 307 315 232 128 125 119 143 230 196 139 73 47
56 43 51 51 71 95 72 69 69 82 101 110 158 176 78 66 91 87 145 163
216 162 153 128 163 71 53 43 49 62 59 54 65 61 74 75 87 87 78 115
80 82 112 81 87 85 80 81 67 59 26 48 39 53 43 50 57 38 42

BEV-H08B 79
261 399 234 304 297 419 426 334 304 315 234 129 125 123 138 228 196 137 77 44
60 45 46 50 74 93 80 64 69 87 102 115 162 173 80 69 91 89 146 167
208 160 156 127 159 72 47 48 50 57 67 51 62 66 75 76 89 82 84 116
78 87 100 85 85 91 78 78 67 49 36 51 41 51 42 55 57 38 44

BEV-H09A 80
286 294 236 232 218 212 221 282 331 366 300 215 297 277 301 117 118 129 115 118
72 81 118 113 121 123 117 95 159 149 118 88 126 105 173 223 155 87 142 139
161 86 88 108 117 102 140 121 59 104 125 94 118 85 111 76 70 83 79 54

105 121 86 86 69 61 96 105 82 96 44 71 112 114 111 86 116 81 98 97

BEV-H09B 80
290 288 241 227 225 217 226 280 329 370 309 215 296 276 300 122 120 126 115 128
61 87 115 115 127 118 122 95 156 147 123 91 122 111 176 216 158 86 143 137
162 97 82 110 111 108 135 130 47 109 134 91 115 88 124 81 64 88 72 63
101 116 91 93 63 71 88 109 78 94 50 72 104 112 114 97 115 83 103 90

BEV-H10A 59
217 69 44 32 70 119 157 268 411 347 330 337 271 283 251 245 369 527 384 277
275 272 313 95 71 104 125 149 67 88 131 122 142 138 115 120 137 144 114 89
123 136 157 204 113 85 96 93 73 58 51 73 47 53 130 116 54 87 115

BEV-H10B 59
215 68 46 34 63 117 153 266 409 338 336 303 284 262 257 236 376 529 389 279
273 270 315 100 68 105 125 147 69 87 131 131 143 135 119 128 123 141 111 82
125 125 155 190 117 83 92 85 80 57 48 76 54 42 137 117 47 97 108

BEV-H12A 79
370 478 410 336 298 266 202 173 177 228 214 233 215 142 143 97 105 135 111 141
156 163 183 124 207 203 217 214 114 137 95 139 144 139 187 193 210 211 166 174
177 105 80 57 86 62 49 52 55 71 73 89 117 124 107 70 70 76 95 150
127 109 143 144 152 119 118 87 138 140 125 123 117 127 139 106 82 56 57

BEV-H12B 79
379 482 405 349 304 261 208 170 177 237 226 256 229 132 143 94 107 137 115 139
160 159 185 130 214 200 216 207 131 140 92 124 137 149 181 187 203 208 176 179
163 103 71 61 86 64 52 48 56 79 63 96 112 123 113 70 68 84 91 147
134 111 145 139 155 128 102 97 147 133 122 119 116 123 142 113 77 51 63

BEV-H13A 99
156 166 320 281 255 229 147 120 107 120 128 101 104 87 80 55 114 101 111 123
117 126 103 123 123 117 87 81 47 63 39 38 40 45 38 46 41 54 58 60
40 57 49 47 52 55 69 43 37 62 55 50 95 127 111 103 98 95 104 109
96 80 33 47 46 47 41 42 40 33 29 29 38 31 19 28 31 30 28 35
34 29 26 53 48 34 30 33 38 39 32 32 29 30 38 39 19 29 50

BEV-H13B 99
150 166 322 276 261 226 148 129 100 127 130 100 101 92 80 53 123 108 107 133
116 112 105 126 117 107 88 86 40 53 39 35 35 51 50 43 38 54 73 57
42 54 44 54 55 60 66 49 34 51 50 56 92 132 101 103 99 94 103 107
96 86 30 44 45 51 39 46 38 32 40 33 29 32 19 38 38 21 40 28
36 35 29 46 47 31 30 35 35 44 47 43 28 29 39 41 23 29 45

BEV-H14A 54
312 229 273 250 315 313 193 179 130 122 120 221 225 223 196 302 193 113 144 307
322 385 229 200 132 160 158 296 231 232 236 215 145 201 255 219 196 208 221 226
272 187 173 174 157 107 76 50 47 53 41 57 94 97

BEV-H14B 54
308 240 269 250 345 327 198 176 126 113 111 237 228 218 207 305 198 117 130 312
325 393 238 194 139 168 162 296 262 230 241 215 145 203 255 216 200 203 234 220
275 188 170 177 167 105 79 48 45 53 44 54 94 98

BEV-H15A 72
340 246 156 79 66 88 116 153 275 366 217 170 70 81 67 152 191 248 234 103
50 114 206 221 60 82 65 101 51 45 56 117 121 204 155 119 71 164 273 187
114 163 140 196 338 214 118 91 121 141 88 34 55 230 158 174 76 56 146 195
268 129 79 54 56 73 44 62 54 166 250 177

BEV-H15B 72
336 260 149 71 72 89 119 145 264 361 217 170 73 83 64 152 188 246 241 99
50 112 206 222 58 79 62 100 53 32 63 117 122 200 167 117 62 159 271 182
112 154 156 200 329 222 114 91 120 139 81 34 66 244 161 185 75 53 162 199
274 134 72 56 58 63 47 56 63 161 250 185

BEV-H16A 109
269 356 267 167 144 93 105 110 179 181 189 170 307 182 114 147 315 294 258 184
128 122 112 119 230 165 205 237 210 121 183 223 197 196 178 163 145 169 119 131
97 111 61 51 38 29 33 31 33 40 50 70 68 55 61 62 65 56 60 81
81 42 50 54 80 118 90 99 142 139 125 67 149 175 142 139 93 85 63 72
62 69 71 39 59 63 57 30 32 41 36 23 41 33 36 34 26 54 47 37
40 38 41 51 36 33 31 55 58

BEV-H16B 109
251 359 277 159 144 99 95 111 183 186 194 180 312 177 132 152 307 286 253 183
126 112 131 114 220 213 189 230 201 121 192 212 198 192 172 160 150 173 125 128
100 111 58 54 32 27 28 44 36 42 47 67 60 60 63 63 70 54 67 71
86 40 39 70 61 131 87 100 139 137 129 66 149 178 136 136 93 86 67 74
59 71 69 39 62 58 60 31 26 43 39 22 37 43 30 31 32 55 44 40
39 42 42 43 40 32 31 55 63

BEV-H17A 84
229 136 134 153 150 166 148 123 65 36 33 46 25 25 56 67 67 61 56 87
88 99 172 172 72 84 90 96 126 144 168 162 156 123 122 54 65 47 66 74
62 43 52 53 65 76 70 74 79 83 55 60 80 62 69 64 56 57 57 36
32 34 35 38 41 41 39 42 52 33 30 35 33 31 32 32 46 35 32 28
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BEV-H17B 84
225 140 142 159 156 177 157 127 61 48 31 52 33 37 59 63 61 74 51 100
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63 54 44 57 71 70 74 72 80 93 52 63 79 67 73 61 59 61 51 46
27 46 34 43 38 42 42 29 58 32 34 35 38 26 39 31 43 31 34 39
54 41 56 32

BEV-H18A 75
266 289 284 235 104 61 39 77 110 133 184 250 221 202 165 180 198 192 185 250
298 208 144 185 229 210 71 57 78 69 67 49 73 97 106 125 108 93 70 159
167 97 79 86 109 135 153 107 77 107 98 84 84 58 80 79 60 100 61 42
71 65 74 78 59 58 44 40 46 49 44 75 61 75 71

BEV-H18B 75
273 275 292 232 105 61 49 63 110 126 185 251 221 209 173 196 209 195 180 234
291 214 150 179 211 218 73 52 64 76 81 65 66 115 114 124 113 89 71 155
170 97 80 89 111 130 162 114 70 110 99 84 82 63 81 70 68 95 66 45

73 64 75 78 46 62 46 43 43 48 53 64 74 68 75

BEV-H19A 89
164 60 57 54 48 86 84 132 176 142 101 61 73 80 115 141 164 178 102 45
121 142 174 44 63 56 57 44 29 34 49 59 83 76 78 43 73 144 121 70
158 85 171 249 236 84 116 99 112 57 48 109 190 91 112 50 42 119 137 116
90 56 93 97 82 86 120 107 234 239 195 101 82 83 96 108 82 118 50 51
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BEV-H19B 89
151 59 57 55 39 68 82 137 183 131 99 64 73 69 120 136 173 181 79 58
101 156 163 43 78 49 61 44 37 29 38 69 79 77 82 45 65 143 115 83
168 86 169 240 248 76 122 98 110 58 53 102 198 86 115 42 38 102 132 114
101 56 78 82 69 93 123 111 234 242 190 118 85 74 100 120 90 118 79 66
88 83 101 77 80 36 35 26 36

BEV-H20A 111
183 246 239 187 261 283 228 177 219 180 162 171 190 260 185 170 170 245 129 83
76 128 94 131 110 125 86 89 62 103 131 134 114 105 88 127 117 120 108 102
127 147 144 154 171 161 184 170 187 131 86 94 47 52 44 43 48 57 48 55
47 59 63 65 78 79 88 71 67 67 67 74 63 65 70 73 75 65 96 73
68 75 74 38 38 25 29 31 29 27 26 39 33 31 38 32 27 43 23 36
46 38 43 66 35 61 50 48 69 54 76

BEV-H20B 111
181 253 241 195 264 270 232 178 222 183 161 168 193 257 190 167 170 244 128 83
79 126 102 127 103 128 88 88 61 102 135 127 115 104 90 125 117 130 109 99
130 145 149 157 163 160 187 171 187 131 83 96 51 53 38 46 52 54 51 57
40 56 65 59 72 84 82 73 67 69 66 73 62 60 75 74 78 63 95 68
71 75 63 38 25 22 30 33 32 24 38 33 35 33 34 32 30 39 28 38
36 26 54 60 35 51 58 49 77 54 65

BEV-H21A 79
224 215 238 274 371 305 201 112 106 114 71 58 53 100 113 136 146 111 197 221
287 384 345 144 118 157 160 199 269 476 376 279 194 198 76 63 57 50 62 59
37 47 49 59 53 92 110 96 209 85 59 79 66 82 102 85 94 51 50 32
39 52 26 51 53 40 42 43 26 32 44 34 33 43 33 28 31 25 35

BEV-H21B 79
243 218 229 279 367 303 201 110 107 116 90 64 60 94 121 136 145 109 195 218
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BEV-H22A 95
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66 78 75 84 55 80 84 63 63 82 61 53 46 52 32 23 29 35 37 37
36 34 62 38 37 39 40 30 41 32 38 31 30 24 33

BEV-H22B 95
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159 128 72 61 42 34 33 34 55 70 55 77 65 72 95 111 161 175 61 94
106 108 128 151 171 150 140 113 130 70 38 37 43 47 62 47 49 53 73 42
71 79 68 90 53 79 94 59 68 75 60 55 48 45 30 36 27 34 34 42
42 29 53 40 32 42 39 25 46 33 30 35 31 34 38

BEV-H23A 113
136 165 236 171 186 175 272 127 94 86 136 121 143 129 126 98 102 88 102 120
147 86 100 84 116 115 132 114 98 129 171 176 168 176 185 179 165 209 124 85
103 67 68 58 54 55 70 69 57 61 66 81 72 71 97 88 70 78 82 77
61 68 68 79 82 73 60 95 107 115 121 88 41 36 40 40 27 37 36 64
65 57 44 59 64 52 45 46 63 69 41 59 58 46 61 70 87 80 62 89
58 68 98 77 66 95 110 113 64 82 124 192 137

BEV-H23B 113
141 168 237 173 183 174 276 136 94 92 147 132 138 132 141 91 107 79 96 124
117 105 93 85 118 112 129 113 96 133 180 171 169 173 187 180 165 203 131 83
100 71 64 54 60 57 67 70 57 58 70 75 79 74 94 76 67 81 78 70
67 61 62 80 88 75 62 88 101 109 118 90 50 37 37 27 35 41 40 59
74 55 51 69 63 50 49 53 50 71 44 53 69 45 56 67 90 93 48 80
59 65 78 62 65 87 109 118 58 87 133 192 137

BEV-H24A 62
346 310 332 334 282 164 197 184 175 209 184 178 62 69 50 48 62 55 68 75
53 75 76 91 102 129 138 110 59 49 77 98 145 144 145 129 98 63 121 69
58 50 53 51 65 48 59 60 69 76 89 96 84 101 85 92 151 114 113 110
91 97

BEV-H24B 62
380 313 322 336 279 172 194 187 177 212 183 182 61 69 49 53 51 59 73 74
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64 45 63 60 55 53 63 61 76 69 99 97 87 102 104 97 158 136 96 105
82 86

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 Figure 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	

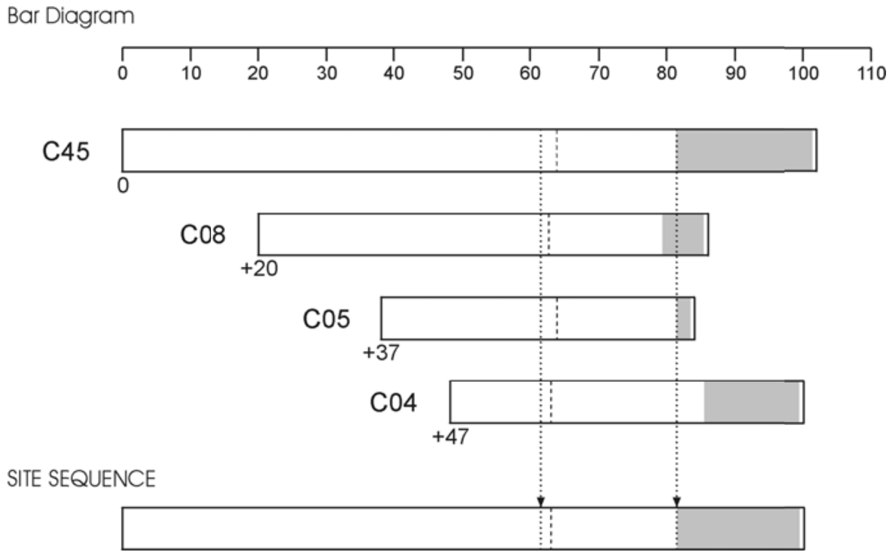


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

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.

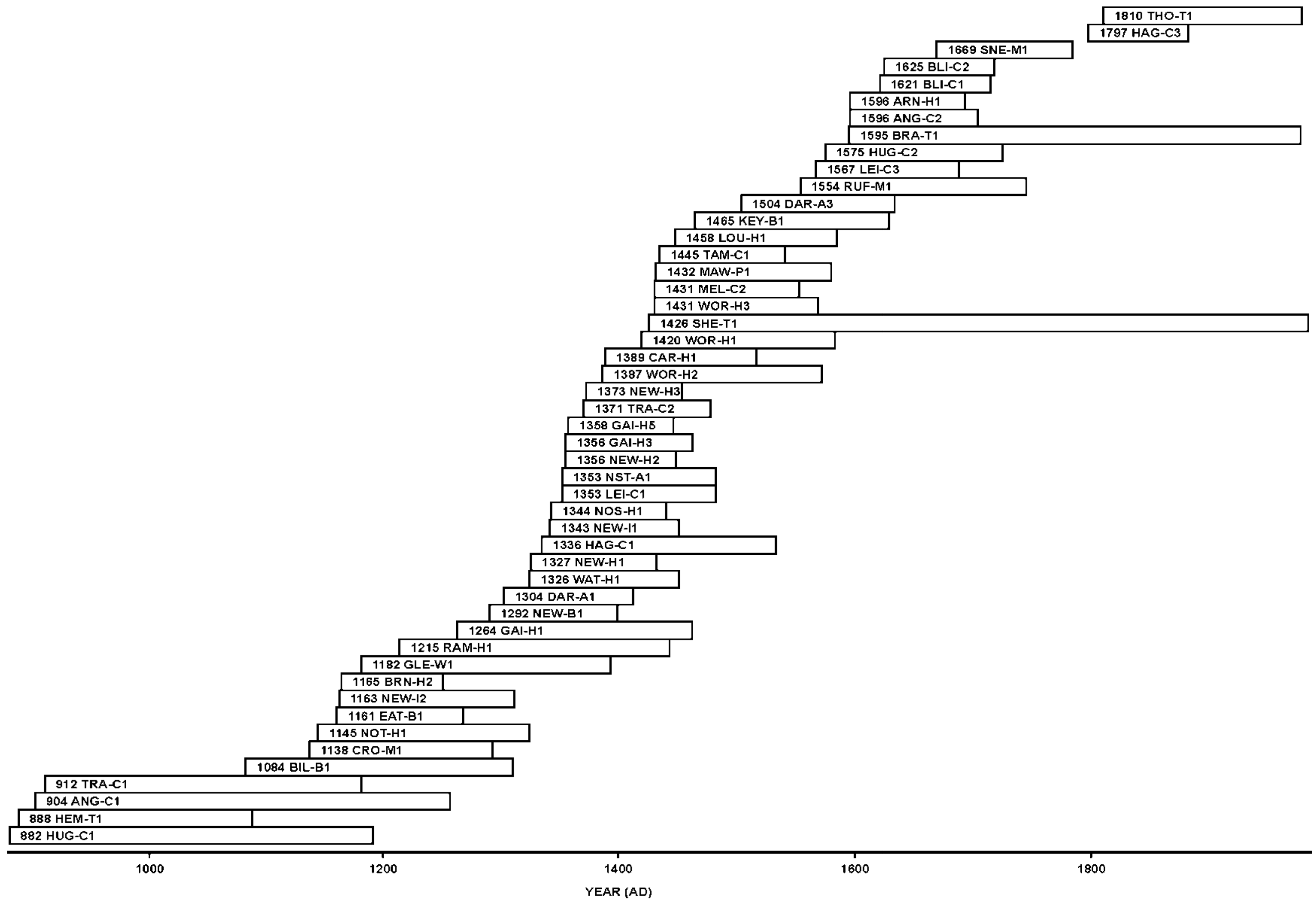
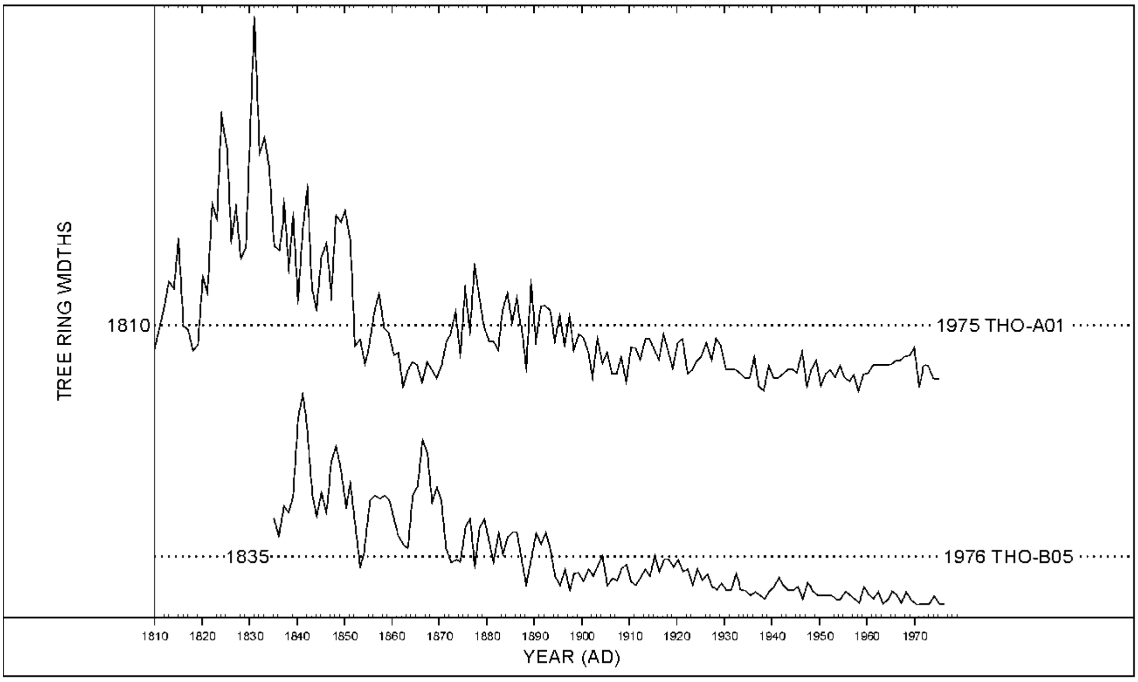


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

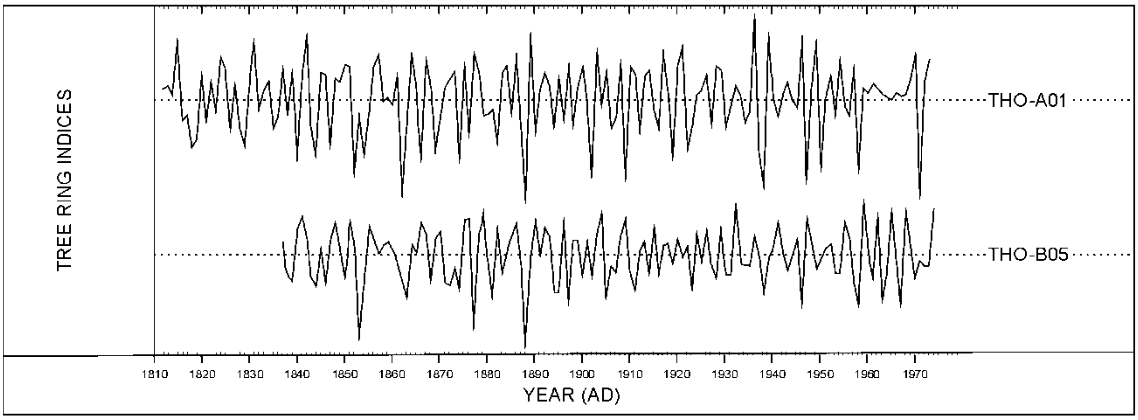


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

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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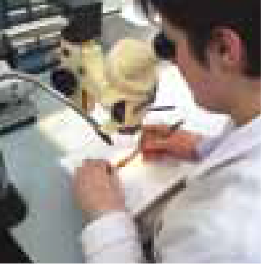
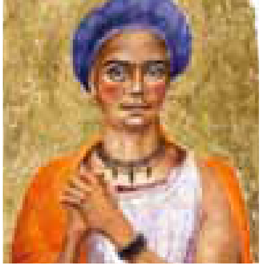


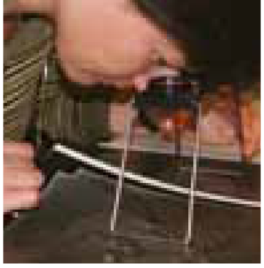


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Historic England works to improve care, understanding and public enjoyment of the historic environment. We undertake and sponsor authoritative research. We develop new approaches to interpreting and protecting heritage and provide high quality expert advice and training.

We make the results of our work available through the Historic England Research Report Series, and through journal publications and monographs. Our online magazine Historic England Research which appears twice a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities.

A full list of Research Reports, with abstracts and information on how to obtain copies, may be found on www.HistoricEngland.org.uk/researchreports

Some of these reports are interim reports, making the results of specialist investigations available in advance of full publication. They are not usually subject to external refereeing, and their conclusions may sometimes have to be modified in the light of information not available at the time of the investigation.

Where no final project report is available, you should consult the author before citing these reports in any publication. Opinions expressed in these reports are those of the author(s) and are not necessarily those of Historic England.

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Ancient Monuments Laboratory (AML) Reports Series
The Centre for Archaeology (CfA) Reports Series
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