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SOUTHVIEW COTTAGE, MAIN STREET, NORWELL, NOTTINGHAMSHIRE
TREE-RING ANALYSIS OF TIMBERS

SCIENTIFIC DATING REPORT

Matt Hurford, Robert Howard and Cathy Tyers

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SUMMARY

Analysis by dendrochronology was undertaken on 15 samples obtained from Southview Cottage, Main Street, Norwell, Nottinghamshire. This resulted in the production of two site chronologies. The first, NRWDSQ01, comprises 11 samples with an overall length of 175 rings, these rings dated as spanning the years AD 1132–1306. The second site chronology, NRWDSQ02, comprises 2 samples with an overall length of 124 rings. These rings are dated as spanning the years AD 1650–1773. Interpretation of the sapwood and the heartwood/sapwood boundaries on the dated samples indicate the presence of at least two, and probably three, phases of felling. A range of structural elements were probably felled in AD 1306, implying medieval origins for this cottage. Whilst it is possible that two other timbers could also have been felled in AD 1306, it appears perhaps more likely that these represent a slightly earlier felling phase, which took place in the late-thirteenth century. Eighteenth-century repairs or modifications are represented by two wall plates felled in AD 1773. Two measured samples remain ungrouped and undated.

CONTRIBUTORS

Matt Hurford, Robert Howard, and Cathy Tyers

ACKNOWLEDGEMENTS

The laboratories would like to thank Mr and Mrs Corbett for their enthusiastic support for this programme of analysis and for kindly allowing access for sampling. We would also like to thank Michael Jones for his considerable assistance in arranging this project and for providing background information about the building. Various members of the Norwell Parish Heritage Group were involved in the production of the drawings, most notably Sue Sinclair. Thanks are also given to the English Heritage Scientific Dating Section for advice and assistance throughout the production of this report

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INTRODUCTION

Southview Cottage, also recently known as South View Cottage, lies to the north-west of Main Street in Norwell (SK 7723461727, Figs 1–2). It is orientated north-west to south-east, but for ease of reference within this report the building has been described so that the north-east long elevation is referred to as the north elevation. The cottage originally comprised the two easternmost timber-framed bays adjacent to Main Street (Fig 3). A one-storey Victorian extension projects south from the original two-bay structure parallel with Main Street. The original cottage was further extended to the west during the 1930s and a modern conservatory also added to the west of this extension at a later date. A longitudinal pentice running along the northern wall, now roofed with the main building, may have been associated with an earlier re-roofing, perhaps when pantiles replaced the original thatched roof.

Modern restoration has obscured much of the timber-framing but parts of three cross-frames, including wall-posts and a tiebeam, and some longitudinal framing, including wall-plates and braces, are visible at ground-floor and first-floor levels (Figs 4 and 5) . The roof was probably originally of principal-rafter type but now comprises a series of common rafter frames that support the modern roof, with collars present on frames 4, 7, 13, 16, and 19. The purlins are carried on the collars. Differential smoke blackening on the common rafter frames, and empty mortice holes and lap joints on a number of them, suggest that they are all reused (Fig 6). Modern plasterwork hides the point at which the rafters link with the wall plates so it is not possible to ascertain whether the extant rafters are also reset. There was no evidence for any of the other sampled timbers being reused, though examination was severely restricted due much of the timberwork being encased in brick or plaster.

The tree-ring dating, funded by English Heritage as part of a dendrochronological training programme for the first author, forms part of a wider project being undertaken by Norwell Parish Heritage Group. This wider project is funded with a Heritage Lottery Fund grant awarded to Norwell Parish Heritage Group in 2006 to facilitate the production of a Village Trail, a Children's Trail and a number of booklets, one of which is devoted to the timber-framed buildings of the village (Jones 2009). The dendrochronological analysis of the timbers is intended to provide independent dating evidence which aids the understanding of the timber framed buildings in Norwell and their historic development. Historical analysis on the crafts and trades within the village is providing a social dimension for the usage of a number of buildings, at least from the nineteenth century onwards. Tracing their earlier history is problematic as they were almost entirely in the hands of Southwell Minster from the eleventh century to the 1950s and the surviving records relating to ownership and occupancy are often unhelpful for the location and identification of current buildings. It is hoped that evidence deriving from the tree-ring dating project will assist in the identification of occupation, usage and ownership, which at present is limited to the late nineteenth century onwards.

SAMPLING

A total of 15 samples was obtained by coring, each sample being given the code NRW–D (for Norwell, site 'D') and numbered 01–15. The positions of these samples are marked on the plans (Figs 7–13). Details of the samples are given in Table 1. In this table the timbers have been located and numbered following the scheme on the drawings provided with cross-frames and common rafter frames being labelled from west to east in the original two-bay timber-framed building.

ANALYSIS AND RESULTS

Each of the 15 samples obtained was prepared by sanding and polishing and its annual growth rings widths were measured. These measured data (given at the end of this report) were then compared with each other by the Litton/Zainodin grouping procedure (see Appendix), allowing two groups to be formed, the samples of each group cross-matching with each other as shown in Figures 14 and 15.

The 11 samples of the first group were combined at the offset positions shown to form NRWDSQ01, a site sequence of 175 rings. This site sequence was then compared to a full range of reference chronologies for oak, this indicating a consistent and repeated cross-match with a number of these when the date of its first ring is AD 1132 and the date of its last ring is AD 1306. The evidence for this dating is given in Table 2.

The two samples of the second group were also combined at their indicated offset positions to form NRWDSQ02, a site sequence of 124 rings. This site sequence was also compared to a full range of reference chronologies for oak, producing a consistent and repeated cross-match with a number of them when the date of its first ring is AD 1650 and the date of its last ring is AD 1773. The evidence for this dating is given in Table 3.

The two site chronologies were then compared with the two remaining ungrouped samples, but there was no further satisfactory cross-matching. The two ungrouped samples were then compared individually with the reference chronologies, but again, there was no satisfactory cross-matching and so these samples, therefore, must remain undated.

This analysis can be summarised as follows:

Site chronology/samples	Number of samples	Number of rings	Date span (where dated)
NRWDSQ01	11	175	AD 1132–1306
NRWDSQ02	2	124	AD 1650–1773
NRW-D01	1	----	undated
NRW-D15	1	----	undated

INTERPRETATION

Site sequence NRWDSQ01 incorporates 11 dated samples (Table 1; Fig 14). One of the dated samples, NRW-D10, retains complete sapwood. This last, complete, sapwood ring, and thus the felling of the tree, is dated to AD 1306.

A further five samples with heartwood/sapwood boundaries, NRW-D05–08 and NRW-D11, in site chronology NRWDSQ01, were probably also felled at this time. The date of the heartwood/sapwood boundary of these five samples ranges from AD 1274 (NRW-D08) to AD 1287 (NRW-D11). The average date of this boundary on these five samples is AD 1281. Using the 95% confidence limit of 15–40 sapwood rings appropriate for mature oaks in this part of England would give the timbers represented an estimated felling date in the range AD 1296–1321. This estimated range encompasses the precise felling date obtained from sample NRW-D10 and hence, given that there is no structural evidence to the contrary, it is probable that these timbers were also felled in AD 1306.

Two further samples, NRW-D02 and D09, in site chronology NRWDSQ01, also retained their heartwood/sapwood boundary. The boundary date on these two samples, however, is somewhat earlier than on those discussed above (Table 1; Fig 14), the average date being AD 1253. Using the same 95% confidence limit for the sapwood rings as above, 15–40 rings, would give the two timbers represented an estimated felling date in the range AD 1268–93. Such an estimated felling date would suggest that these two timbers were felled earlier than those discussed above. It is of course possible that these two timbers could have been felled in AD 1306, but for this to be the case sample NRW-D02, with a heartwood/sapwood boundary date of AD 1256, would have had 50 sapwood rings, whilst sample NRW-D09, with a heartwood/sapwood boundary date AD 1250, would have had 56 sapwood rings. While such high numbers of sapwood rings are not unknown, they are relatively uncommon.

The remaining three dated samples in site chronology NRWDSQ01 have no trace of sapwood and it is thus not possible to calculate their likely felling date ranges. The last measured ring dates range from AD 1268 (NRW-D13) to AD 1276 (NRW-D04). It is therefore feasible that these three samples were felled in either AD 1306 or towards the end of the AD 1268–93 felling date estimate range. However, as the end dates for these heartwood only samples are later than the heartwood/sapwood boundary rings on the AD 1268–93 samples, it seems more likely that they belong to the later group.

Site sequence NRWDSQ02 incorporates the two remaining dated samples, NRW-D12 and NRW-D14, both from wall plates in bay 2 (Fig 15). Both samples retain complete sapwood. The last, complete, sapwood ring on both, and thus the felling, is dated to AD 1773.

DISCUSSION

Tree-ring analysis has demonstrated that the dated timbers from Southview Cottage are likely to represent at least two, and possibly more, separate felling periods. The majority of the dated timbers within the original two-bay structure, including several reused common rafters, the bay 1 wall plates, a wall post and a brace, were mostly probably felled in AD 1306. It does however appear distinctly possible that a brace and a reused common rafter were felled slightly earlier in the latter decades of the thirteenth century. However the wall plates in bay 2 were felled significantly later in AD 1773.

The dendrochronological analysis therefore appears to suggest a potential medieval origin for Southview Cottage but the clear reuse of common rafters suggests that the extant roof structure is not primary. The apparent widespread presence of medieval timbers does however allow for the possibility that the extant structure, notably the common rafter roof structure, could have incorporated timbers from the initial construction phase of Southview Cottage. It is possible, but clearly not proven, that these alterations may have been made when the wall plates in bay 2 were replaced in the late-eighteenth-century.

Although dendrochronology cannot be used to identify the precise source of timber, it would appear that the timbers represented in site sequence NRWDSQ01 are likely to be derived from woodlands local to Norwell. As will be seen from Table 2, the highest *t*-values, and thus the greatest degree of similarity, are obtained with reference chronologies from sites generally relatively close to Norwell.

The timbers represented in site sequence NRWDSQ02 match each other at t=16.1, suggesting that they were probably derived from the same-tree. NRWDSQ02 does not match the local reference chronologies as well as site sequence NRWDSQ01 (Table 3), but it is clearly less well-replicated and there are fewer local reference chronologies for the eighteenth century. The overall conclusion is, however, that the two wall plates are likely to have come from woodland in the region (Table 3).

Of the 15 samples measured, only two remain ungrouped and undated, probably because the number of rings in these samples is close to the lower limit of statistical reliability.

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TABLES

Table 1: Details of tree-ring samples from Southview Cottage, Norwell, Nottinghamshire

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
NRW-D01	North common rafter frame 6 (reused)	42	14	----	----	----
NRW-D02	South common rafter frame 5 (reused)	65	13	AD 1205	AD 1256	AD 1269
NRW-D03	South common rafter frame 7 (reused)	44	no h/s	AD 1228	----	AD 1271
NRW-D04	South common rafter frame 13 (reused)	145	no h/s	AD 1132	----	AD 1276
NRW-D05	North common rafter frame 16 (reused)	99	h/s	AD 1186	AD 1284	AD 1284
NRW-D06	North common rafter frame 17 (reused)	122	12	AD 1170	AD 1279	AD 1291
NRW-D07	North common rafter frame 11(reused)	108	18	AD 1191	AD 1280	AD 1298
NRW-D08	North wall post, cross-frame 1	104	h/s	AD 1171	AD 1274	AD 1274
NRW-D09	East brace from cross-frame 1 north wall post to wall plate	88	11	AD 1174	AD 1250	AD 1261
NRW-D10	North wall plate, bay 1	110	17C	AD 1197	AD 1289	AD 1306
NRW-D11	South wall plate, bay 1	126	14	AD 1176	AD 1287	AD 1301
NRW-D12	North wall plate, bay 2	117	22C	AD 1657	AD 1751	AD 1773
NRW-D13	West brace from cross-frame 3 north post to wall plate bay 2	75	no h/s	AD 1194	----	AD 1268
NRW-D14	South wall plate, bay 2	124	22C	AD 1650	AD 1751	AD 1773
NRW-D15	Tiebeam, cross-frame 3	48	no h/s	----	----	----

h/s = the heartwood/sapwood ring is the last ring on the sample
C = complete sapwood is retained on the sample

Table 2: Results of the cross-matching of site sequence NRWDSQ01 and relevant reference chronologies when the first-ring date is AD 1132 and the last-ring date is AD 1306

Reference chronology	*t*-value	Span of chronology	Reference
3-3A Vicars' Court, Lincoln	13.7	AD 1090–1286	(Hillam and Groves 1996)
40–4 Castlegate, Newark, Nottinghamshire	12.8	AD 1169–1330	(Arnold *et al* 2002)
22/4 Kirkgate, Newark, Nottinghamshire	12.3	AD 1177–1337	(Arnold *et al* 2002)
East Midlands	12.3	AD 882–1981	(Laxton and Litton 1988)
5 Church Street, Newark, Nottinghamshire	10.7	AD 1185–1267	(Arnold *et al* 2002)
Manor House, Home Farm, Cropwell Bishop, Nottinghamshire	8.7	AD 1138–1293	(Howard *et al* 1985)
'Severns', Castle Road, Nottingham	8.5	AD 1030–1334	(Howard *et al* 1996)
Old White Hart, Newark, Nottinghamshire	8.3	AD 1163–1312	(Laxton *et al* 1984)

Table 3: Results of the cross-matching of site sequence NRWDSQ02 and relevant reference chronologies when the first-ring date is AD 1650 and the last-ring date is AD 1773

Reference chronology	*t*-value	Span of chronology	Reference
Pitchforks and 1 and 2 Greasleys Cottages, Norwell, Nottinghamshire	7.7	AD 1624–1747	(Hurford *et al* 2010)
Wheelwright's Shop, Chatham Docks, Kent	7.2	AD 1615–1780	(Bridge 1998)
St. John the Baptist Church, Grimston, Leicestershire	6.6	AD 1674–1754	(Arnold *et al* 2005)
East Midlands	6.2	AD 882–1981	(Laxton and Litton 1988)
Ragnall House (barn), Ragnall, Nottinghamshire	6.1	AD 1607–1717	(Howard *et al* 1997)
Chicksands Priory, Bedfordshire	5.8	AD 1670–1814	(Howard *et al* 1998)
Combermere Abbey, Whitchurch, Cheshire	5.7	AD 1595–1727	(Howard *et al* 2003)
Kibworth Harcourt Post Mill, Leicestershire	5.6	AD 1582–1773	(Arnold *et al* 2004)

FIGURES

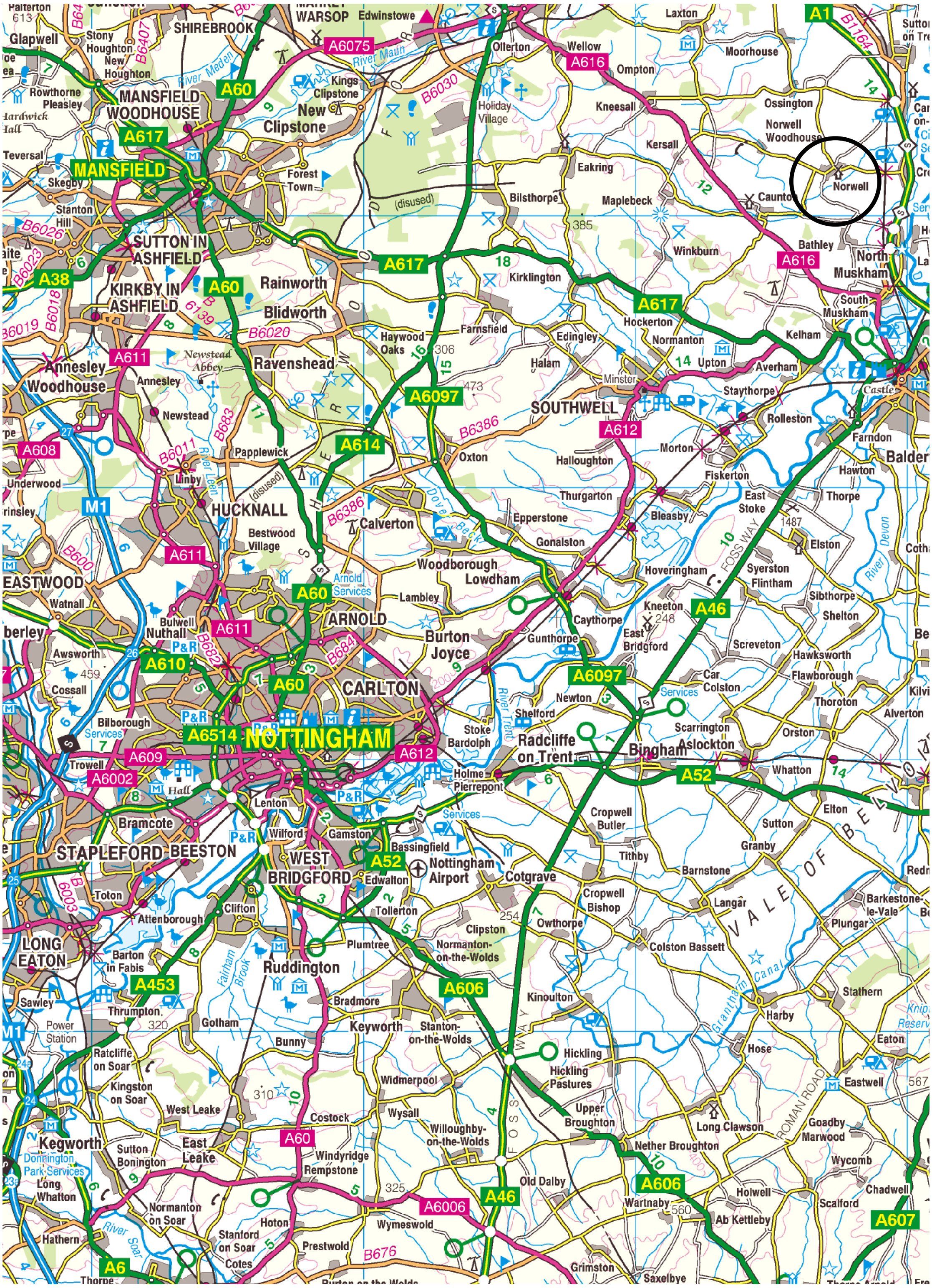


Figure 1: Map to show general location of Southview Cottage, Norwell,

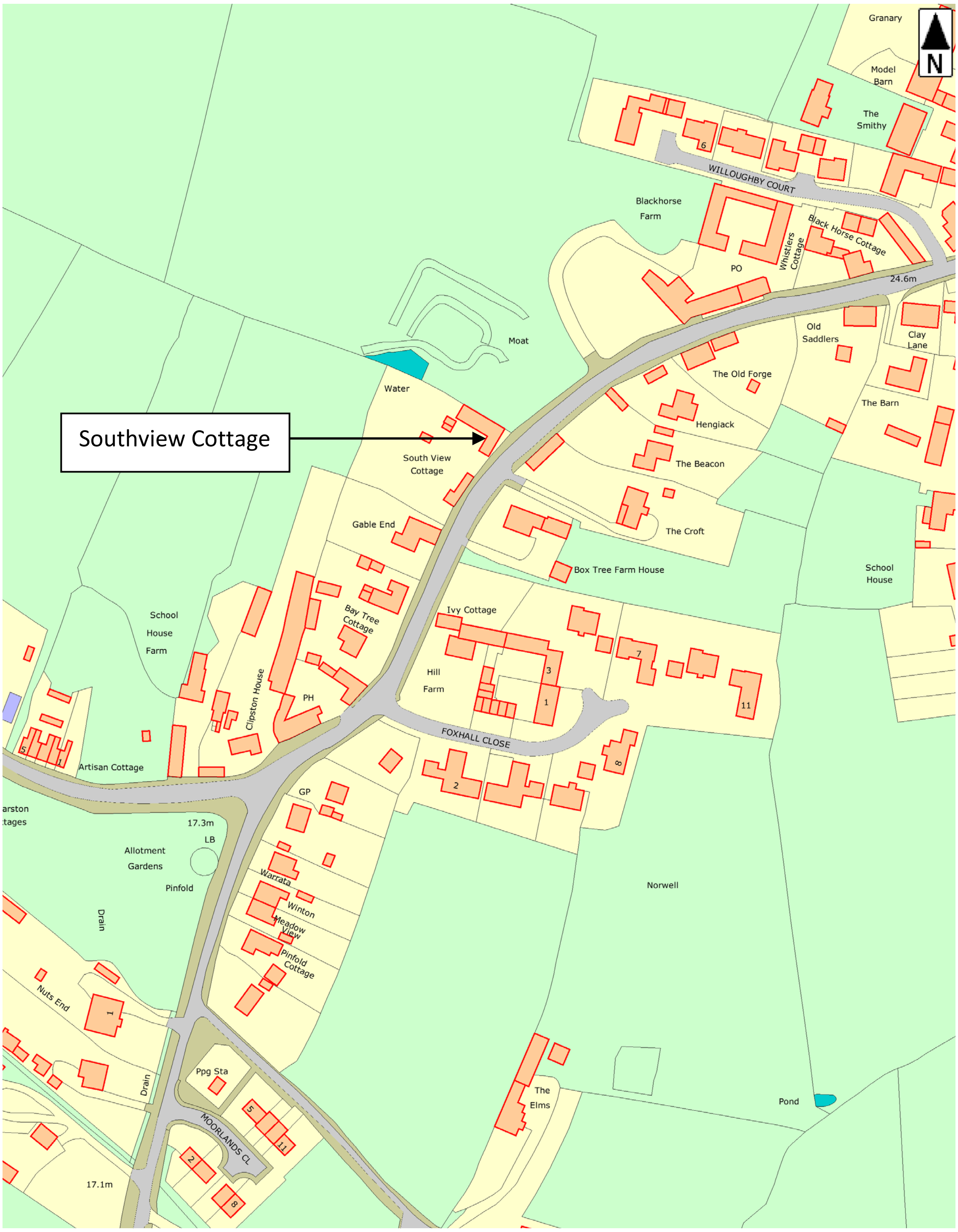


Figure 2: Map to show the location of Southview Cottage within the village of Norwell (ba

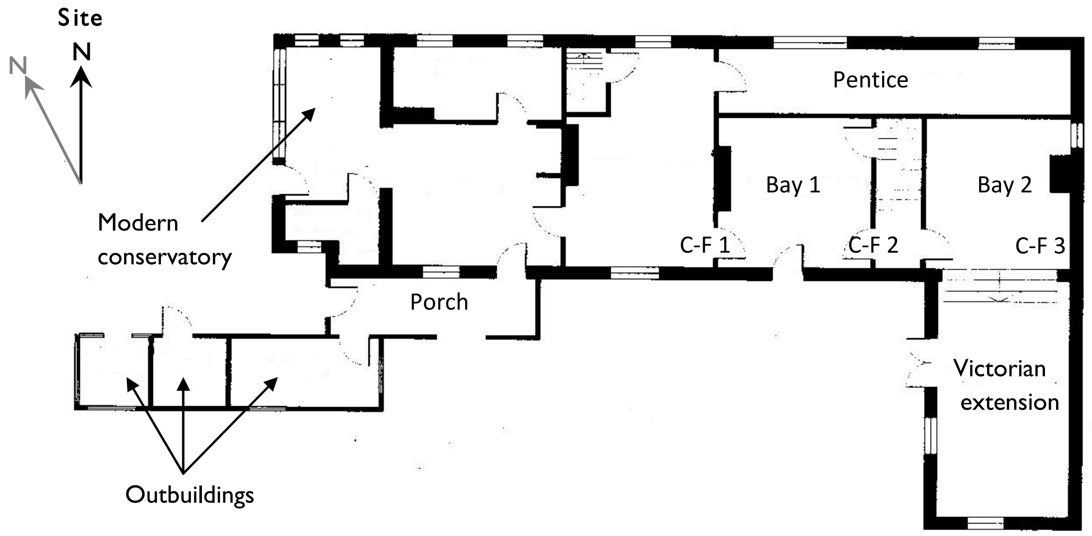


Figure 3: Ground-floor plan of Southview Cottage (based on a drawing produced by Alasdair Morrison and Partners) showing the cross-frame and bay numbering scheme

Figure 4: Bay 2 first-floor north wall plate and brace and cross-frame 3 tiebeam, viewed looking north-east

Figure 5: Bay 2 first-floor south wall plate and cross-frame 3 tiebeam, viewed looking south-east

Figure 6: General view of Bay 2, viewed looking towards the east gable wall

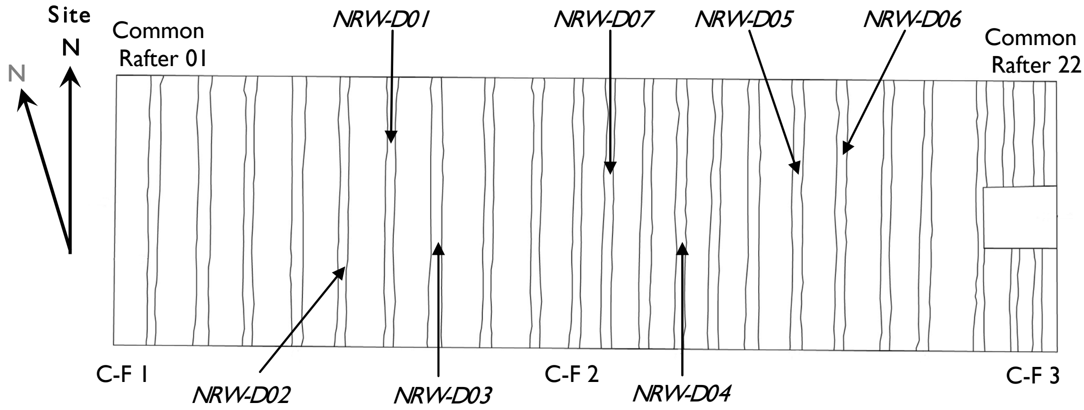


Figure 7: Location of the samples taken from the common rafters

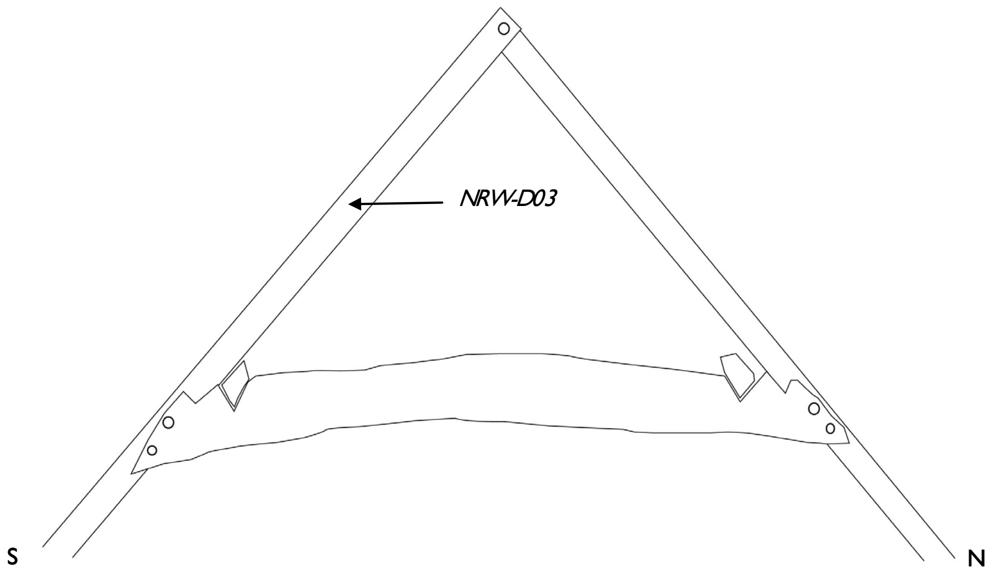


Figure 8: Location of sample on common rafter frame 7, viewed looking west

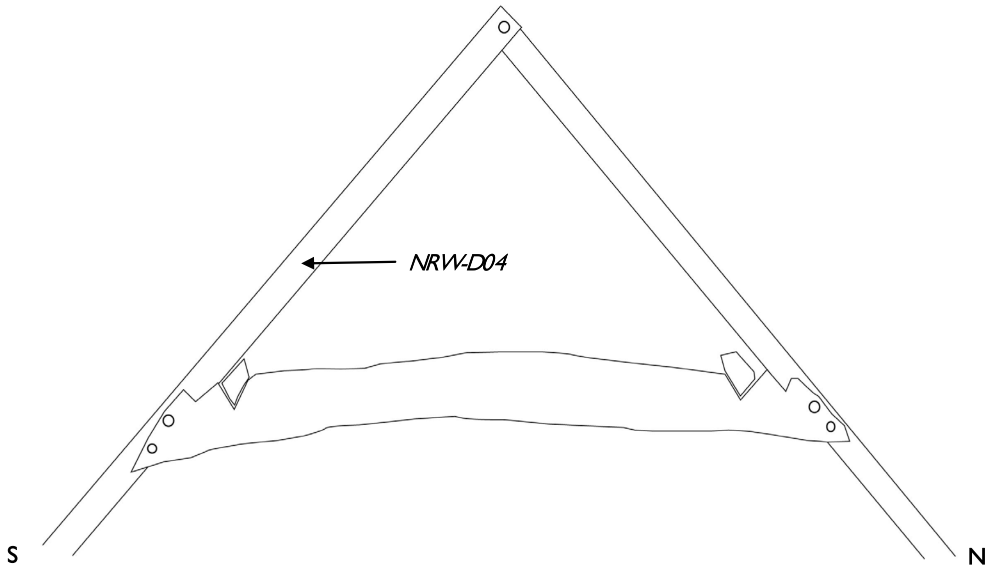


Figure 9: Location of sample on common rafter frame 13, viewed looking west

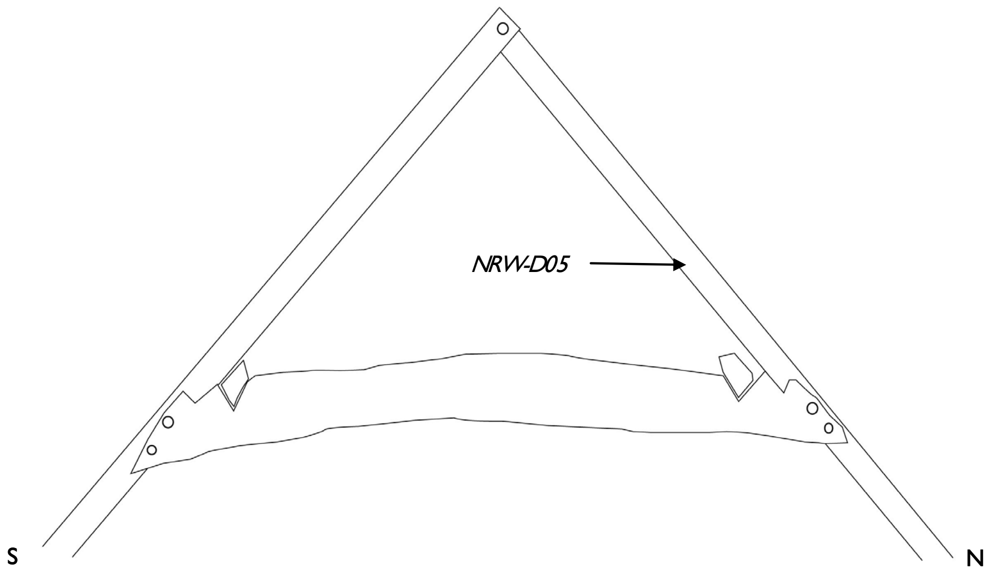


Figure 10: Location of sample on common rafter frame 16, viewed looking west

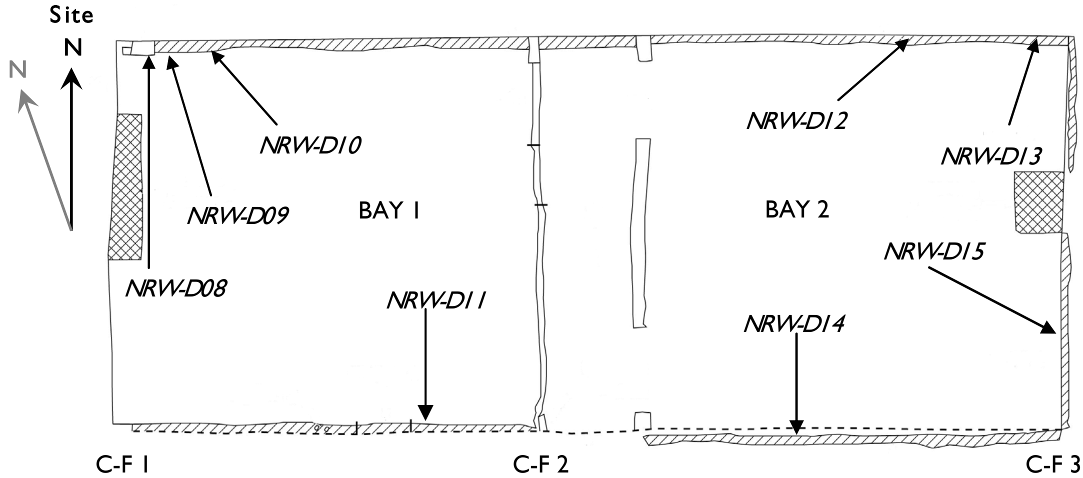


Figure 11: Location of samples taken at first-floor level

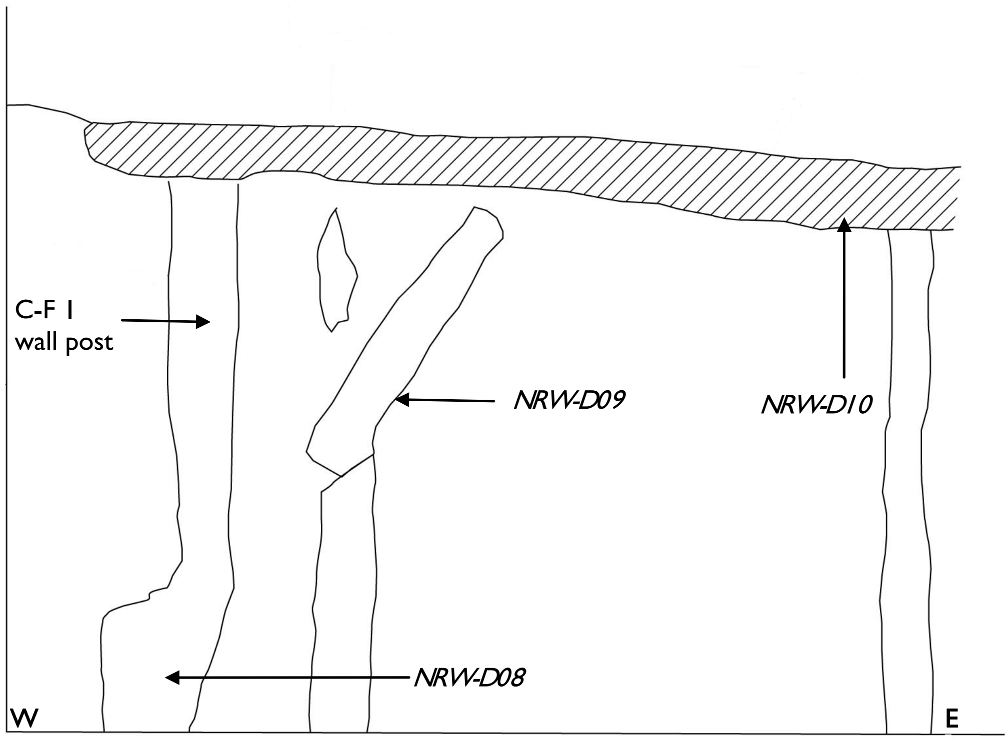


Figure 12: Internal elevation of part of the north wall in bay 1, showing the location of the samples taken at first-floor level

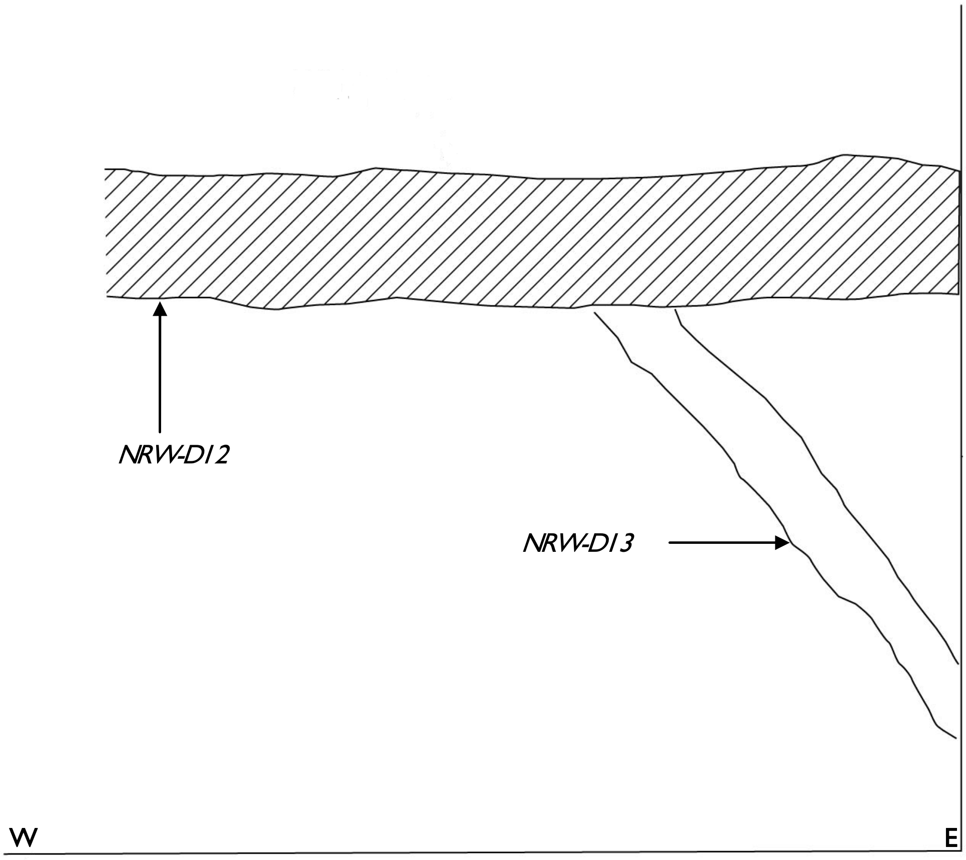
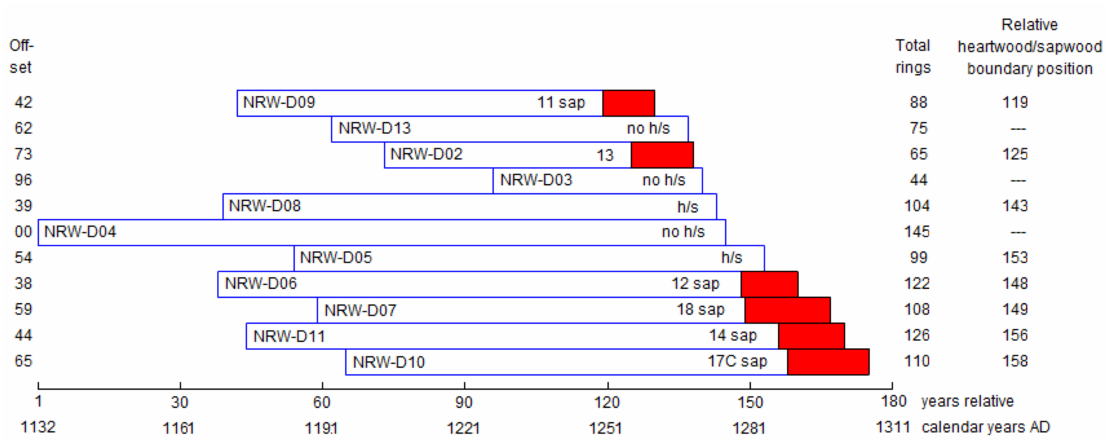
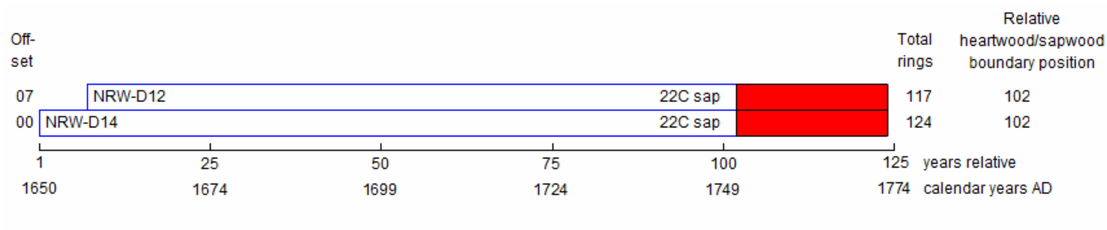


Figure 13: Internal elevation of part of north wall in bay 2, showing the location of the samples taken at first-floor level



White bars ☐ = heartwood rings;
filled bars ■ = sapwood rings
h/s = the last ring of the sample is at the heartwood/sapwood boundary
C=complete sapwood is retained on the sample

Figure 14: Bar diagram of the samples in site chronology NRWDSQ01



White bars = heartwood rings;
filled bars = sapwood rings
h/s = the last ring of the sample is at the heartwood/sapwood boundary
C=complete sapwood is retained on the sample

Figure 15: Bar diagram of the samples in site chronology NRWDSQ02

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

NRW-D01A 42
189 406 362 496 330 230 196 280 256 273 226 259 241 244 229 263 245 291 188 282
297 200 181 193 164 289 180 166 102 156 173 177 203 175 132 135 125 124 252 233
164 161
NRW-D01B 42
264 399 363 505 337 240 198 279 264 259 238 253 229 262 220 271 237 304 183 282
294 208 178 198 156 296 187 176 105 164 177 170 216 176 130 127 127 127 255 237
159 218
NRW-D02A 65
136 129 119 173 227 148 139 82 87 101 93 115 107 110 145 111 125 57 140 121
127 108 119 107 104 92 112 76 34 48 119 76 177 125 95 75 34 31 38 47
75 66 59 43 54 80 85 52 60 62 82 72 90 90 103 98 99 190 81 80
70 93 74 175 110
NRW-D02B 65
131 125 117 172 224 135 126 84 84 97 89 114 100 103 141 125 126 58 135 120
132 108 111 118 99 89 111 77 41 42 122 79 170 129 92 71 44 31 33 54
79 68 63 38 53 84 82 53 39 74 78 67 79 89 108 98 104 210 76 74
84 86 75 156 134
NRW-D03A 44
68 68 90 87 96 52 58 104 86 107 97 105 81 68 46 80 76 85 82 73
35 41 70 59 46 27 47 43 53 51 69 77 55 57 66 56 40 46 36 37
48 39 47 76
NRW-D03B 44
74 72 94 79 101 49 63 106 87 107 89 107 78 70 48 74 83 84 84 72
35 46 59 63 47 32 41 31 50 59 75 82 54 61 66 56 44 48 36 32
47 38 46 71
NRW-D04A 145
76 137 161 175 79 87 101 100 128 121 104 77 75 94 122 83 85 80 82 60
74 94 101 87 96 83 74 73 80 77 91 88 101 85 101 71 104 88 89 56
37 54 61 70 99 53 59 77 66 76 45 77 48 58 61 92 70 82 62 53
50 59 53 59 75 63 63 83 64 71 53 70 59 54 42 37 55 49 64 59
56 46 59 46 66 47 34 45 32 55 48 47 57 63 39 45 45 56 77 64
55 41 45 78 59 89 63 82 50 32 41 43 57 49 36 44 29 44 46 57
43 59 59 46 47 38 37 31 40 41 51 47 32 30 43 27 33 32 31 39
40 36 43 42 41
NRW-D04B 145
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54 35 50 77 61 89 63 84 45 34 28 45 53 61 37 32 33 54 42 54
50 57 45 56 41 38 34 34 50 47 43 51 41 40 30 34 30 36 29 37
41 41 50 42 41
NRW-D05A 99
86 139 99 99 151 125 102 135 121 158 152 113 161 231 125 133 95 74 106 112
103 82 125 111 167 162 107 154 137 75 71 75 67 99 76 97 61 80 115 113
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73 72 54 48 75 71 61 71 86 73 65 83 70 75 53 56 56 60 40 54
62 51 85 68 65 73 68 68 47 66 57 40 48 41 69 63 58 74 59

NRW-D05B 99
126 160 100 102 145 128 115 133 127 148 166 102 159 242 122 126 95 79 112 109
101 85 121 116 162 166 105 147 105 88 66 79 72 101 74 95 59 82 110 121
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64 54 84 72 55 77 66 70 50 60 63 46 47 53 59 66 61 77 66
NRW-D06A 122
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62 65 56 61 62 58 61 60 69 66 60 67 56 100 80 116 89 46 62 65
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106 89 129 69 120 116 99 93 145 136 107 105 164 119 141 101 109 117 117 134
136 108 101 91 79 73 72 73 113 107 85 47 78 100 139 109 72 55 58 88
59 76 34 56 91 66 139 89 82 83 43 41 30 60 96 38 101 37 72 112
108 61 69 95 102 96 142 76 43 46 43 75 59 42 46 53 49 85 75 55
85 76 70 64 54 47 44 38 30 90 100 111 78 64 57 49 46 53 105 169
152 101 83 62 90 55 44
NRW-D07B 108
101 83 115 80 109 112 107 107 147 124 108 107 167 132 135 96 101 120 114 122
131 92 103 94 70 85 72 71 115 106 88 45 78 99 135 115 71 52 57 83
67 74 42 49 93 62 139 92 71 83 43 38 36 66 92 42 97 36 70 113
105 63 69 91 112 99 133 79 44 44 46 68 61 42 45 53 52 86 74 63
80 81 69 61 51 46 45 41 40 80 97 113 78 60 61 45 48 48 111 168
145 94 80 69 89 48 57 64
NRW-D08A 103
88 67 82 133 189 148 133 162 178 142 208 223 191 130 137 168 212 142 152 208
166 230 287 179 190 192 217 190 282 209 210 137 141 107 146 112 137 154 223 261
204 123 88 103 111 120 121 78 99 72 93 66 129 140 153 204 170 170 164 194
145 124 82 64 116 120 144 138 196 130 67 64 54 62 88 59 53 50 35 60
86 66 62 73 74 68 65 67 45 65 79 131 112 66 79 75 80 114 81 79
128 114 130
NRW-D08B 104
81 69 77 126 197 137 137 158 177 152 223 221 191 132 144 164 219 144 152 204
170 223 281 197 180 221 223 211 266 195 213 135 136 112 142 123 129 150 216 314
199 124 99 107 107 123 117 81 91 83 71 79 126 141 175 211 177 167 156 180
157 113 85 60 128 104 157 142 196 131 65 60 51 73 87 56 37 58 43 57
82 70 72 69 73 59 58 63 51 55 76 136 109 74 93 61 85 108 90 84
122 121 124 147
NRW-D09A 87
273 250 132 82 112 143 118 177 161 98 80 96 193 234 165 115 140 181 128 172
156 211 201 126 97 112 103 118 63 84 92 83 54 61 48 71 73 89 85 61
73 78 53 81 53 83 109 85 67 68 79 90 67 67 74 77 83 73 79 52
81 97 73 81 78 74 76 72 47 53 64 66 70 82 76 102 73 102 67 68
83 103 79 78 66 86 125

NRW-D09B 88
260 249 135 81 135 174 142 176 156 103 73 90 183 227 169 107 129 184 132 176
153 209 202 141 89 110 106 104 71 70 95 81 43 68 49 63 75 81 84 72
61 80 52 80 46 85 107 84 65 76 74 92 71 75 75 77 84 67 82 66
76 94 75 83 74 78 75 69 49 57 57 69 70 79 75 103 74 102 64 68
87 108 80 74 65 80 114 119
NRW-D10A 110
90 104 97 79 75 60 81 72 70 63 62 80 109 115 149 130 103 110 81 125
92 86 102 73 56 39 70 69 104 78 63 63 58 100 77 84 35 37 66 60
117 94 135 74 45 48 57 81 85 71 81 38 41 83 100 70 89 90 94 83
106 67 32 38 61 81 102 134 147 129 104 172 175 139 230 185 245 228 162 106
100 67 62 147 151 163 140 138 139 161 97 108 182 280 209 142 145 115 101 59
40 53 91 124 133 130 111 75 72 131
NRW-D10B 110
125 118 91 81 67 62 81 65 75 55 73 80 124 120 144 136 98 104 86 125
91 86 108 65 58 40 64 68 105 81 62 60 64 103 78 74 36 42 71 57
112 94 127 82 45 46 57 66 89 75 75 44 45 86 104 76 88 99 96 81
100 70 45 37 62 87 99 147 167 128 104 186 200 169 248 212 286 259 176 113
98 74 61 155 147 164 136 141 142 163 105 103 180 277 206 144 152 115 102 56
42 51 92 121 133 127 116 73 76 132
NRW-D11A 125
121 105 112 109 89 165 157 135 87 86 100 97 82 80 123 100 105 159 113 175
179 157 128 124 93 95 64 71 43 57 50 60 87 105 112 104 101 100 97 116
146 121 101 136 128 93 66 107 105 97 99 69 64 70 79 61 87 64 36 85
69 128 85 101 102 54 76 114 146 163 104 91 49 67 96 92 93 116 115 111
136 130 102 67 55 67 102 164 187 186 171 114 150 152 126 160 115 119 130 113
108 114 67 65 180 197 181 168 165 154 178 180 138 172 208 158 126 131 112 76
44 35 47 61 63
NRW-D11B 126
149 92 101 106 104 164 135 121 95 94 102 97 73 80 110 115 100 149 119 150
192 175 129 139 86 101 63 70 42 47 45 56 78 88 99 95 111 129 110 133
150 126 91 148 130 93 63 117 112 96 94 74 64 72 74 65 92 57 44 89
63 117 90 110 101 63 71 107 134 162 100 97 59 70 92 92 91 134 107 115
134 127 102 55 52 75 104 157 191 182 163 113 153 153 149 146 113 112 126 136
113 101 76 74 153 204 171 177 171 148 177 187 132 174 218 149 130 132 104 83
45 30 53 58 64 79
NRW-D12A 117
118 186 178 209 182 181 218 139 171 205 177 185 169 124 127 164 162 127 133 236
315 287 241 249 279 331 215 106 87 172 155 108 74 56 55 53 87 147 133 84
151 160 142 114 114 73 65 100 70 96 136 103 88 58 72 103 76 66 56 63
51 76 47 60 94 111 50 48 59 76 87 63 72 67 75 51 44 60 85 62
35 60 59 57 41 49 40 53 48 82 63 58 76 92 181 124 88 90 89 129
132 110 175 106 113 96 96 147 86 63 81 153 175 121 93 64 99
NRW-D12B 117
154 190 172 210 178 193 204 106 138 195 185 179 173 129 130 144 150 103 134 211
321 279 248 270 273 353 207 114 80 168 159 115 66 64 50 44 93 153 116 88
145 158 139 112 107 70 61 103 72 107 134 94 76 57 75 97 74 63 62 55
45 71 45 66 86 103 51 53 56 84 92 60 65 64 79 50 35 63 85 70
38 62 59 58 40 45 40 51 55 78 66 55 78 92 191 115 96 86 87 126
142 109 174 117 112 102 94 149 87 61 77 145 174 122 92 70 96
NRW-D13A 75
140 269 303 238 233 231 158 172 143 162 128 140 173 148 186 185 185 198 171 158
166 167 176 172 161 194 198 177 163 166 185 217 177 216 226 211 203 172 130 108
113 188 116 221 185 184 188 109 96 160 142 121 141 147 94 127 175 226 114 160
148 129 107 96 120 121 173 158 194 139 113 143 140 118 155

NRW-D13B 75
204 250 300 244 262 243 143 161 139 161 137 132 173 148 191 179 192 196 177 165
161 156 193 171 163 197 202 162 165 171 191 218 190 205 218 208 198 175 127 110
112 191 109 217 180 180 195 114 95 167 127 132 137 140 93 121 184 225 118 165
144 132 104 93 117 125 165 160 191 135 131 136 138 121 164
NRW-D14A 124
121 194 135 249 209 251 257 254 308 280 300 240 287 286 152 149 215 191 178 146
120 129 141 117 113 116 225 324 263 217 194 207 227 159 110 81 189 171 124 91
72 97 76 98 121 109 94 131 89 73 63 76 48 57 74 60 55 94 60 61
41 46 55 43 41 36 39 54 54 47 43 55 67 43 59 50 78 69 56 65
70 89 61 40 64 120 107 56 83 115 86 56 58 44 61 47 77 65 55 81
74 136 98 77 104 81 103 128 125 150 102 102 93 107 136 80 66 96 113 119
103 85 74 98
NRW-D14B 124
155 192 140 248 212 247 254 243 309 292 289 240 286 285 160 149 218 181 178 153
116 140 132 121 106 125 227 332 265 207 196 201 231 161 113 77 188 170 124 95
73 100 73 98 119 101 100 130 90 81 63 73 49 55 68 57 58 84 65 57
44 51 45 51 40 35 41 50 59 38 43 61 68 47 58 61 75 72 49 66
70 86 59 43 69 121 97 58 81 113 85 45 63 50 57 55 62 66 53 86
74 137 88 77 103 86 132 124 126 146 110 98 86 118 134 80 63 102 110 117
101 87 81 104
NRW-D15A 47
169 197 239 143 222 188 194 166 160 194 177 132 129 159 143 150 117 158 108 138
108 109 132 111 116 83 86 86 110 128 111 109 119 127 107 73 62 104 90 121
118 101 78 105 102 105 116
NRW-D15B 48
199 185 248 150 211 196 187 161 151 217 175 114 132 134 142 143 116 165 118 128
103 118 131 123 111 91 83 91 105 129 115 118 110 110 119 61 65 104 83 114
129 105 92 111 110 88 114 138

APPENDIX: TREE-RING DATING

The Principles of Tree-Ring Dating

Tree-ring dating, or dendrochronology as it is known, is discussed in some detail in the Laboratory's Monograph, *An East Midlands Master Tree-Ring Chronology and its uses for dating Vernacular Building* (Laxton and Litton 1988) and *Dendrochronology: Guidelines on Producing and Interpreting Dendrochronological Dates* (English Heritage 1988). 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

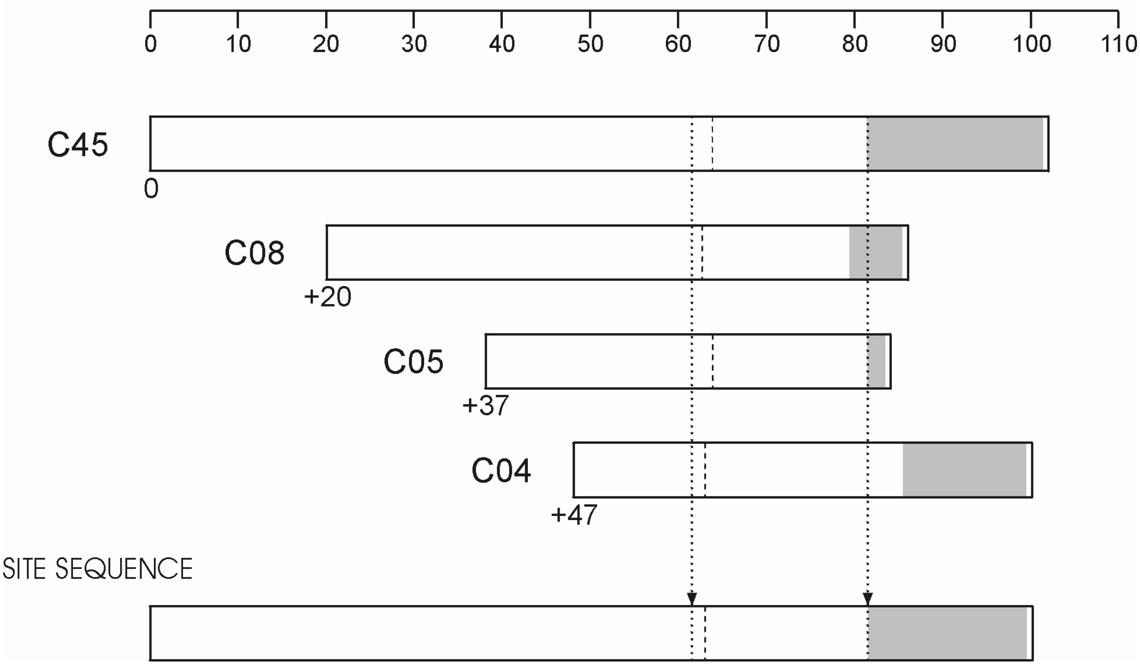


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

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

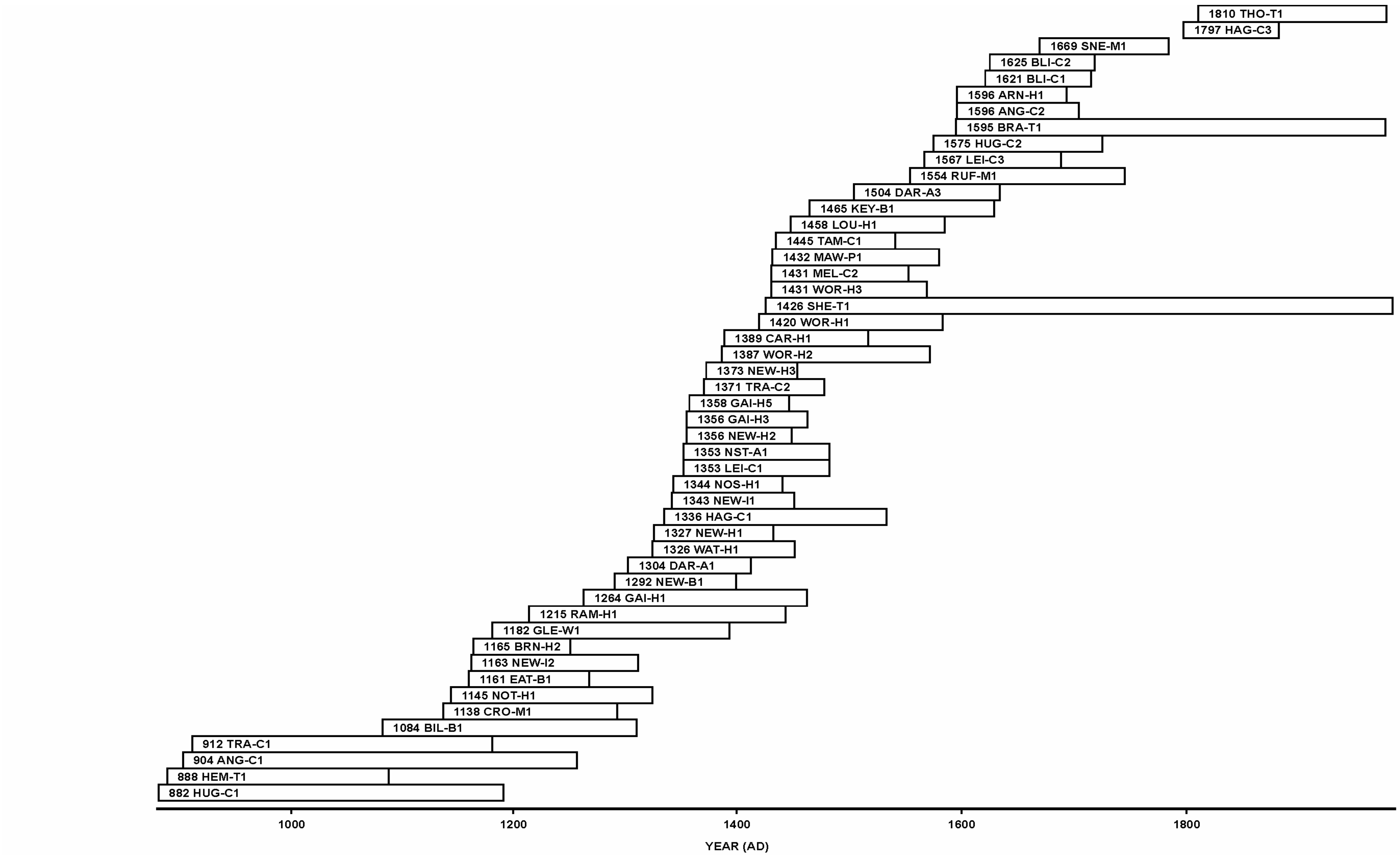
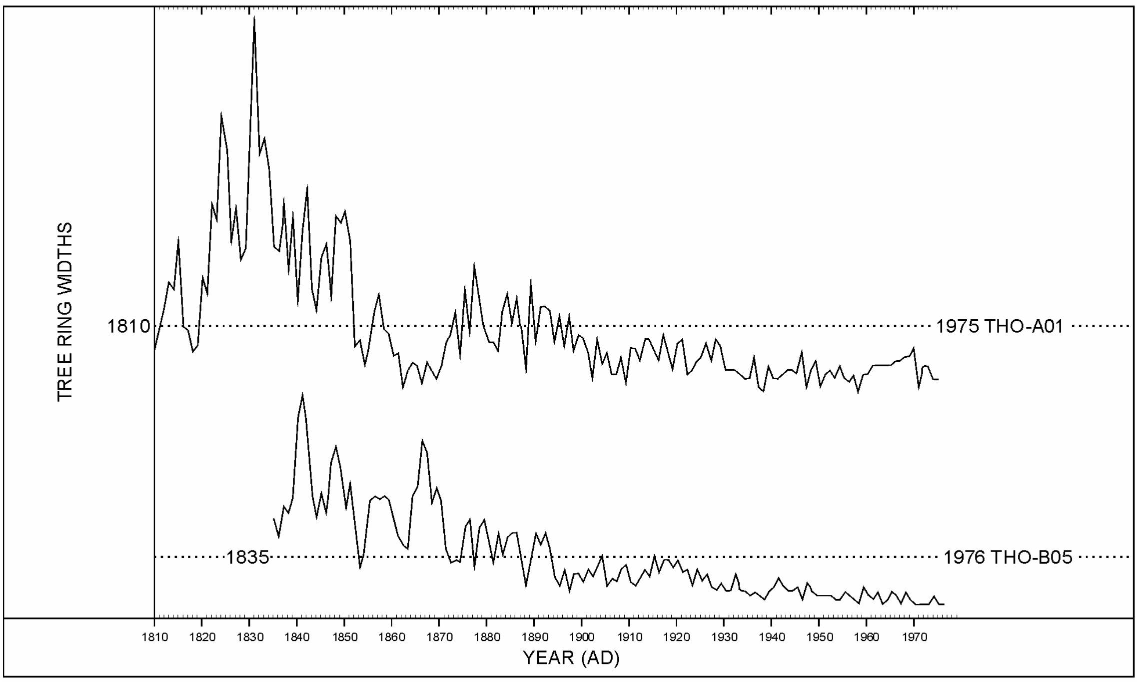


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

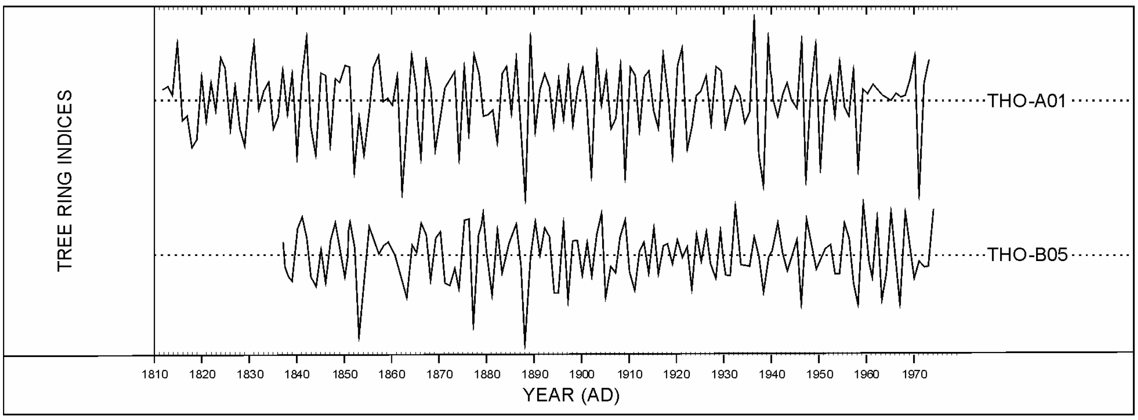


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

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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