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160 King Street Great Yarmouth Norfolk

Tree-Ring Analysis of Oak Timbers and Conifer Boards

Martin Bridge and Cathy Tyers

Discovery, Innovation and Science in the Historic Environment

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Front Cover: 160 King Street, from the back, Great Yarmouth. Photograph Martin Bridge

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160 KING STREET
GREAT YARMOUTH
NORFOLK

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SUMMARY
Fifteen oak timbers from floor-framing, wall-framing, and the roof of the building were sampled. Three series contained too few rings for further analysis. All 12 measured samples cross-matched each other and appear to form a single group of timbers felled at the same time. Precise felling dates of winter AD 1654/55 and spring AD 1655 have been obtained, indicating that construction was most likely in AD 1655, or within a year or two after this date.

Photographs were taken of the end-grain of four conifer boards, two from each of two doors in the attic. The ring width series were derived from these photographs. No cross-matching was found between the individual board series, and no acceptable consistent cross-dating was found.

CONTRIBUTORS
Martin Bridge and Cathy Tyers

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CONTENTS

INTRODUCTION

The building lies within the historic heart of Great Yarmouth (Fig 1) and is listed Grade II (Listing Entry Number 1246577). It is thought to be a late-sixteenth century timber-framed house, with an early nineteenth-century brick façade, and a twentieth-century shop front. A recent measured survey by the Great Yarmouth Preservation Society (Grigorov 2018) raised the possibility that some of the timber-frame could be earlier than the presumed late sixteenth-century date. Thus, dendrochronological analysis was requested by Trudi Hughes, Historic England Heritage at Risk Architect/Surveyor, to provide independent dating evidence for the primary construction, and later phases of development. This would inform a listing review and a management strategy for the future care and preservation of the building.

METHODOLOGY

An assessment of the structural timbers for dendrochronological study sought accessible oak (*Quercus* sp) timbers with more than 50 rings and where possible traces of sapwood, although slightly shorter sequences are sometimes sampled if little other material is available. Those timbers judged to be potentially useful were cored using a 16mm auger attached to an electric drill. The cores were labelled and stored for subsequent analysis. Three conifer doors in the attic were also assessed and following this two doors had the bottom of their boards cleaned by sanding with digital photographs being taken for subsequent measurement using CooRecorder 9.1 (Cybis Dendrochronology 2017), converted to data in the same format as the other measured series via CDendro 9.1 (Cybis Dendrochronology 2017) and TRiCYCLE (Brewer *et al* 2011).

The cores were polished on a belt sander using 80 to 400 grit abrasive paper to allow the ring boundaries to be clearly distinguished. The samples had their tree-ring sequences measured to an accuracy of 0.01mm, using a specially constructed system utilising a binocular microscope with the sample mounted on a travelling stage with a linear transducer linked to a PC, which recorded the ring widths into a dataset. The software used in measuring and subsequent analysis was written by Ian Tyers (2004a). Cross-matching was attempted by a combination of visual matching and a process of qualified statistical comparison by computer. The ring-width series were compared for statistical cross-matching, using a variant of the Belfast CROS program (Baillie and Pilcher 1973). Ring sequences were plotted on the computer monitor to allow visual comparisons to be made between sequences. This method provides a measure of quality control in identifying any potential errors in the measurements when the samples cross-match.

In comparing one sample or site master against other samples or chronologies, *t*-values over 3.5 are considered significant, although in reality it is common to find demonstrably spurious *t*-values of 4 and 5 because more than one matching position is indicated. For this reason, dendrochronologists prefer to see some *t*-value ranges of 5, 6, and higher, and for these to be well replicated from different, independent chronologies with both local and regional chronologies well represented, except where imported timbers are identified. Where two individual

samples match together with a *t*-value of 10 or above, and visually exhibit exceptionally similar ring patterns, they may have originated from the same parent tree. Same-tree matches can also be identified through the external characteristics of the timber itself, such as knots and shake patterns. Lower *t*-values, however, do not preclude same-tree derivation.

Ascribing felling dates and date ranges

Once a tree-ring sequence has been firmly dated in time, a felling date, or date range, is ascribed where possible. With samples which have sapwood complete to the underside of, or including bark, this process is relatively straightforward. Depending on the completeness of the final ring (ie if it has only the spring vessels/early wood formed, or the summer growth/late wood) a precise felling date and season can be given. If the sapwood is partially missing, or if only a heartwood/sapwood transition boundary survives, then an estimated felling date range can be given for each sample. The number of sapwood rings can be estimated by using an empirically derived sapwood estimate with a given confidence limit. If no sapwood or heartwood/sapwood boundary survives then the minimum number of sapwood rings from the appropriate sapwood estimate is added to the last measured ring to give a *terminus post quem* (*tpq*) for felling, a felled-after date.

A review of the geographical distribution of dated sapwood data from historic timbers has shown that a sapwood estimate relevant to the region of origin should be used in interpretation, which in this area is 9–41 rings (Miles 1997). It must be emphasised that dendrochronology can only date when a tree has been felled, not when the timber was incorporated into the structure or object under study.

RESULTS

The property's long axis lies SW-NE but has been taken as E-W for the purposes of this report. The assessment showed that none of the timbers in the east end of the building that were thought to be of nineteenth- and twentieth-century origin had enough rings to make them suitable for reliable dendrochronological investigation. These timbers were, therefore, not sampled. However, core samples were taken from a series of timbers in floor-frames, wall-frames, and the roof, thought to represent the primary construction phase of the building. The oak samples taken, as well as the ring series derived from photographs of the cross-sectional surface of two conifer boards from each of the two three-boarded attic doors are detailed in Table 1. The locations of the sampled oak timbers are illustrated in Figures 2 and 3, whilst one of the conifer doors investigated is shown in Figure 4, the other door being its mirror image.

Three oak samples, including the only one from a wall-frame timber, were found to have ring sequences of less than 30 years and were excluded from further analysis as unsuitable for reliable dating purposes. The measured series from the remaining 12 oak samples cross-match each other (Table 2). Although sample ksgy04 was relatively short, it gave a significant match against one other sample, which was visually good and subsequently supported when it was compared individually against oak reference chronologies. The relative positions of overlap of the 12 cross-

matched series are shown in Figure 5. The 12 cross-matched oak series were combined into a 104-year long site chronology, KSGYt12. This was compared with an extensive database of oak reference chronologies where it was found to cross-date consistently to the period AD 1551–1654, some of the strongest matches being shown in Table 3.

Although one of the three conifer doors assessed was rejected as unsuitable for analysis, two boards from two of the doors were included in this analysis. The photographs taken of the boards yielded relatively short sequences for each board and they did not show any similarities with each other. Formal identification of the wood type was not undertaken as this would have required the removal of a small section from each board for microscopic analysis. They were, therefore, compared individually to a series of both pine and other conifer species reference chronologies available in the database but none of the board sequences could be reliably dated.

The raw ring-width measurements are given for all of the measured oak and conifer series in the Appendix.

INTERPRETATION AND DISCUSSION

All 12 dated samples are clearly broadly coeval and the analysis suggests that they form a coherent group most likely all felled at the same, or similar, time (Fig 5). Three samples from floor-frame timbers and two samples from roof timbers retained complete sapwood. One of these was derived from a tree felled in the winter of AD 1654/55, whilst the other four were derived from trees felled in spring AD 1655. Complete sapwood was present on another timber but the outermost 1-3 rings were lost from the core during sampling, thus producing a narrow felling date range of AD 1654–6 for this timber. Four of the remaining dated samples have some sapwood and produce felling date ranges compatible with the precise felling dates obtained. The remaining two samples have no sapwood but the analysis suggests that these are likely to be coeval and hence felled as part of the same felling event, with the joist, ksgy04, appearing to represent the trimmed down inner part of a longer-lived tree.

The dating evidence obtained for structural timbers from floor-framing and the roof suggests that construction was shortly after felling in AD 1655, or within a year or two after this date. Based on the assumption that the dated timbers are associated with the primary phase of construction, the building appears to be more recent than suggested previously, as it had been thought that the main part of the building was sixteenth century.

The oak trees from which the dated timber were derived appear likely to have grown relatively locally with the strongest cross-dating generally being with reference chronologies from the surrounding counties.

The four conifer boards analysed from the two doors could not be dated. No relative dating was established between their ring series and, thus, whether the boards are coeval can neither be confirmed nor refuted by this analysis. Although formal wood

type identification was not undertaken it is thought that the boards were most likely pine (*Pinus sylvestris* L.)

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TABLES

Table 1: Details of samples taken from 160 King Street, Great Yarmouth. Roof trusses are numbered from the west end

Sample No	Location	Total number of rings	Date of sequence (AD)	Sapwood	Mean ring width (mm)	Mean sensitivity	Felling date range (AD)
Floor framing (oak)							
ksgy01	First floor ceiling beam over stair landing	72	1582–1654	24¼C	2.07	0.21	spring 1655
ksgy02	First floor east room, 4th joist from west wall	63	1592–1654	16¼C	2.27	0.20	spring 1655
ksgy03	First floor east room, 1st joist from west wall	<30	-	-	NM	-	-
ksgy04	First floor east room, 5th joist from west wall	44	1553–1596	-	2.49	0.19	after 1605
ksgy05	First floor east room, 3rd joist from west wall	77	1551–1627	-	2.16	0.22	after 1636
ksgy06	First floor east room, 2nd joist from west wall	70	1585–1654	20¼C	1.89	0.17	spring 1655
Wall framing (oak)							
ksgy07	Stud in south wall of first floor east room	<30	-	-	NM	-	-
Roof (oak)							
ksgy08	South principal rafter, truss 4	60	1594–1653	16 (+1-3C)	2.40	0.25	1654–56
ksgy09	Collar, truss 3	<30	-	-	NM	-	-
ksgy10	South principal rafter, truss 3	44	1611–1654	19C	1.76	0.18	winter 1654/55
ksgy11	North principal rafter, truss 3	63	1580–1642	2	2.84	0.17	1649–81
ksgy12	North principal rafter, truss 2	69	1586–1654	20¼C	2.17	0.15	spring 1655
ksgy13	North principal rafter, truss 1	39	1590–1628	3	2.12	0.18	1634–66
ksgy14	South principal rafter, truss 1	57	1587–1643	5	3.00	0.18	1647–79
ksgy15	North principal rafter, truss 4	54	1595–1648	9	2.93	0.22	1648–80
Door boards (conifer)							
GYDr1M	Door 1 middle board	52	-	-	0.73	0.15	-
GYDr1O	Door 1 outer board	65	-	-	0.86	0.22	-
GYDr2I	Door 2 inner board	74	-	-	1.02	0.17	-
GYDr2M	Door 2 middle board	73	-	-	1.51	0.18	-

Key: NM = not measured; ¼C = complete sapwood, felled the following spring; C = complete sapwood, winter felled

Table 2: Cross-matching between the dated samples from 160 King Street, Great Yarmouth (t-values in excess of 3.5 are considered significant)

	t-value (years overlap)										
Sample No	ksgy02	ksgy04	ksgy05	ksgy06	ksgy08	ksgy10	ksgy11	ksgy12	ksgy13	ksgy14	ksgy15
ksgy01	5.92 (63)	\	3.20 (45)	2.30 (70)	4.09 (60)	3.79 (44)	3.91 (60)	3.64 (69)	4.14 (39)	3.04 (57)	6.20 (54)
ksgy02		\	4.18 (36)	4.38 (63)	3.49 (60)	4.17 (44)	3.51 (51)	3.42 (63)	5.18 (37)	3.71 (52)	5.45 (54)
ksgy04			5.88 (44)	\	\	\	\	\	\	\	\
ksgy05				2.58 (43)	4.75 (34)	\	4.15 (48)	4.09 (42)	3.58 (38)	2.84 (41)	4.78 (33)
ksgy06					3.36 (60)	8.43 (44)	3.18 (58)	6.76 (69)	2.34 (39)	5.29 (57)	4.23 (54)
ksgy08						2.65 (43)	3.93 (49)	4.46 (60)	4.04 (35)	3.99 (50)	8.35 (54)
ksgy10							3.79 (32)	3.61 (44)	\	6.30 (33)	3.61 (38)
ksgy11								6.73 (57)	3.05 (39)	6.29 (56)	4.77 (48)
ksgy12									3.40 (39)	6.31 (57)	5.87 (54)
ksgy13										1.48 (39)	4.86 (34)
ksgy14											3.84 (49)

\ = overlap less than 30 years, no *t*-value calculated

Table 3: Dating evidence for the site chronology KSGYt12, AD 1551–1654

Source region	Chronology:	Publication reference:	Filename:	Span of chronology (AD)	Overlap (years)	*t*-value
Northamptonshire	Kirby Hall, Deene, Corby	(Arnold *et al* forthcoming)	KRBHSQ01	1378–1795	104	9.0
Suffolk	Norton Hall Barn, Stanton Street	(Arnold *et al* 2017)	NRTNSQ02	1519–1626	76	7.9
Oxfordshire	84 St Aldates, Oxford	(Miles and Bridge 2013)	ALDATES2	1529–1636	86	7.4
London	Kew Palace roof	(Bridge and Miles 2017)	KEWx1	1547–1630	80	6.8
Oxfordshire	Manor Farm, Stanton St John	(Miles and Worthington 1998)	STNSTJN3	1533–1637	87	6.6
Norfolk	Burrage House/Old Post Office, New Buckenham	(Tyers 2004b)	NBBP_T3	1543–1683	104	6.5
Essex	New House, Cressing Temple	(Tyers 1997)	NEWHOUSE	1560–1633	74	6.5
Cambridgeshire	Sutton-in-the-Isle	(Tyers 1995)	SUTTON	1508–1615	65	6.4
Norfolk	Abbey Farm, Thetford	(Howard *et al* 2000)	THTASQ03	1556–1628	73	6.3
Norfolk	Pinchpot, New Buckenham	(Tyers 2004b)	NBPP_T5	1530–1687	104	6.3
Leicestershire	St Nicholas' Church, Bringhurst	(Arnold *et al* 2005)	LBFFSQ01	1502–1687	104	6.3
London	Queen's House, Greenwich	(Bridge and Miles 2016)	GRNWICH	1516–1633	83	6.3

FIGURES

Figure 1: Maps to show the location of 160 Kings Street in Great Yarmouth, circled. Scale: top right 1:5000; bottom 1:1250. © Crown Copyright and database right 2020. All rights reserved. Ordnance Survey Licence number 100024900. © British Crown and SeaZone Solutions Ltd 2020. All rights reserved. Licence number 102006.006. © Historic England.

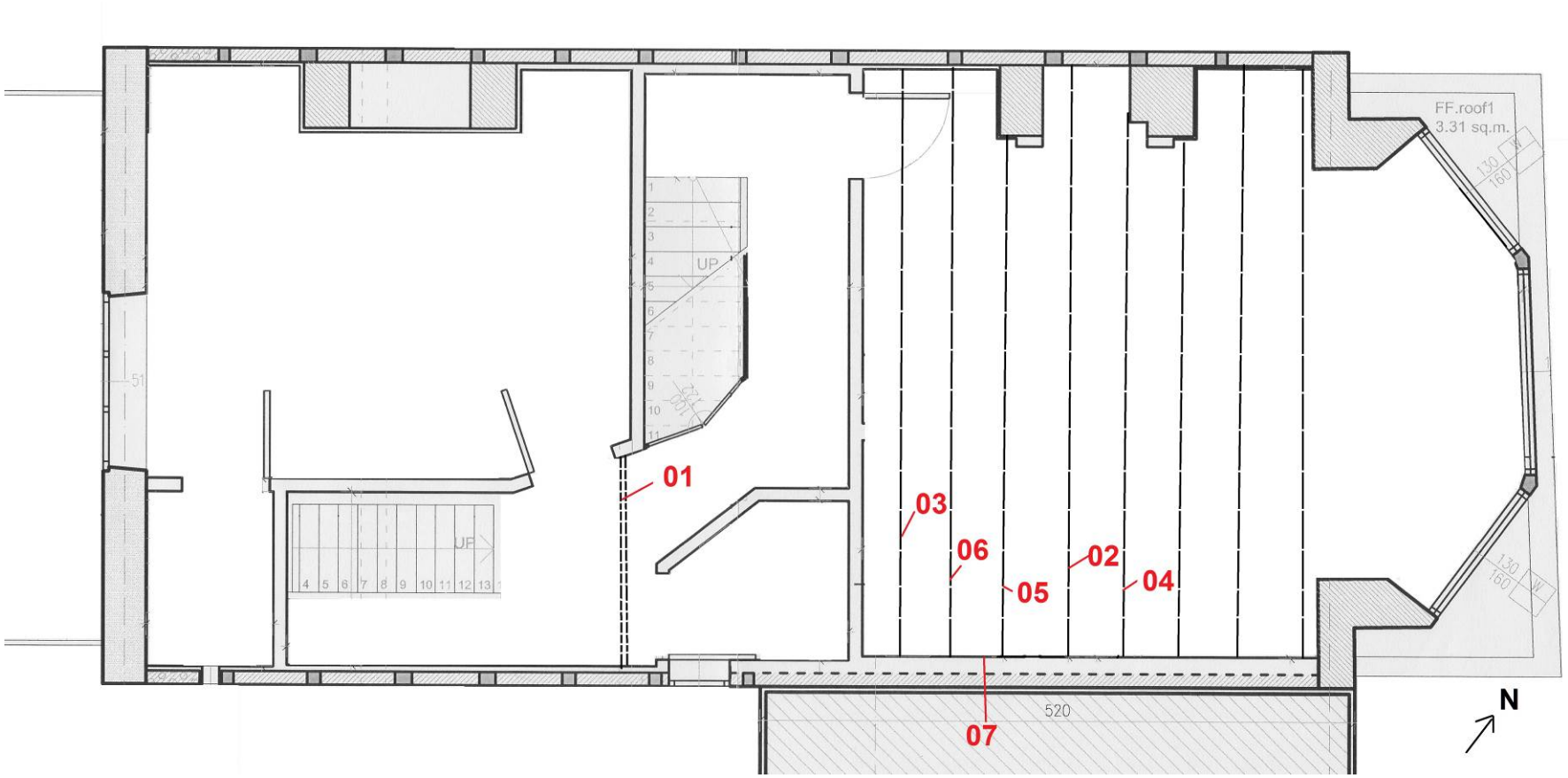

Figure 2: First-floor plan showing the approximate positions of timbers sampled for dendrochronology (after Grigorov 2018)

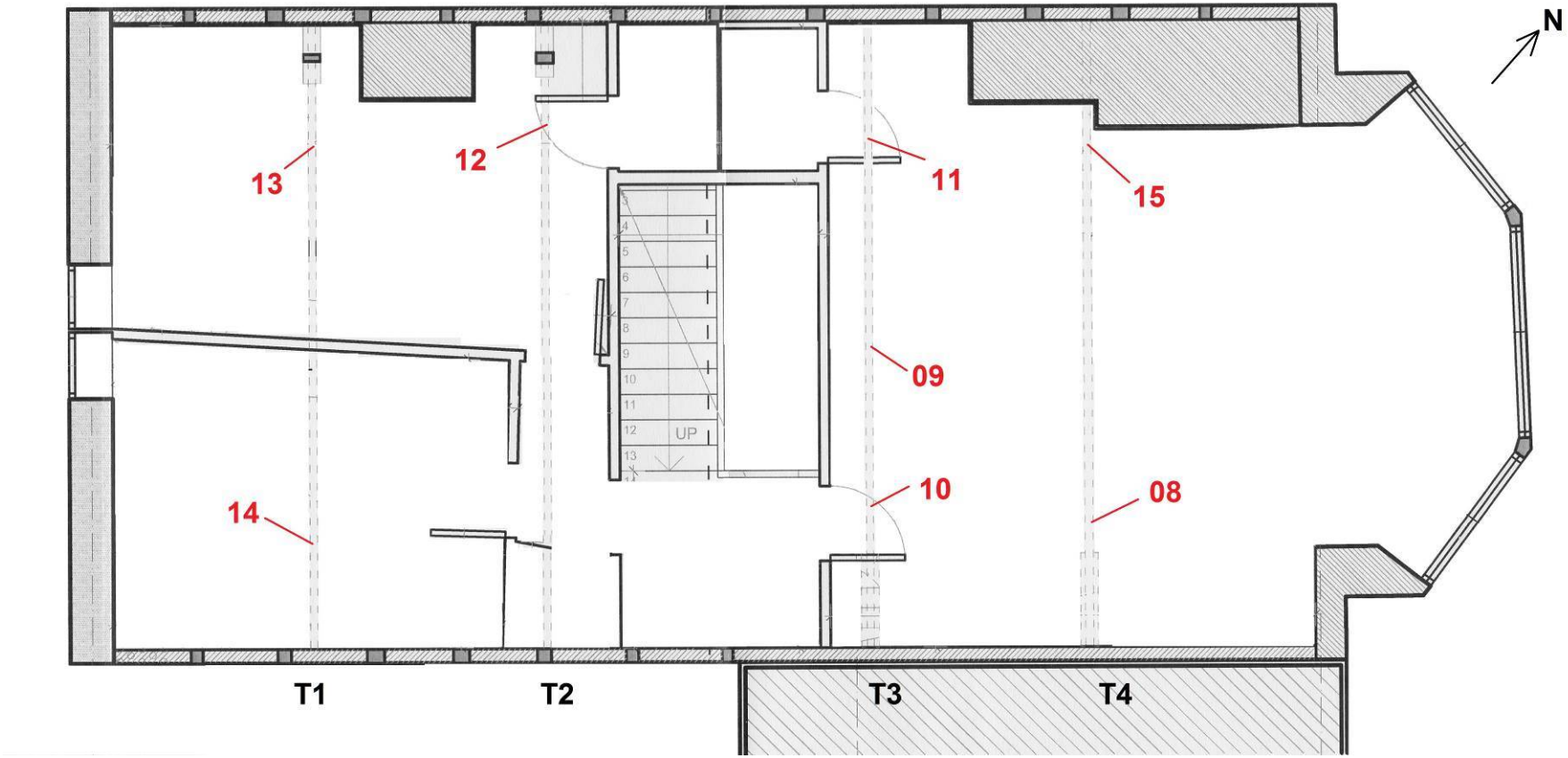

Figure 3: Attic floor plan showing the positions of the roof trusses and approximate positions of timbers sampled for dendrochronology (after Grigorov 2018)

Figure 4: Ex situ *door 1, the inner (hinge side) and middle boards were measured (photo Martin Bridge)*

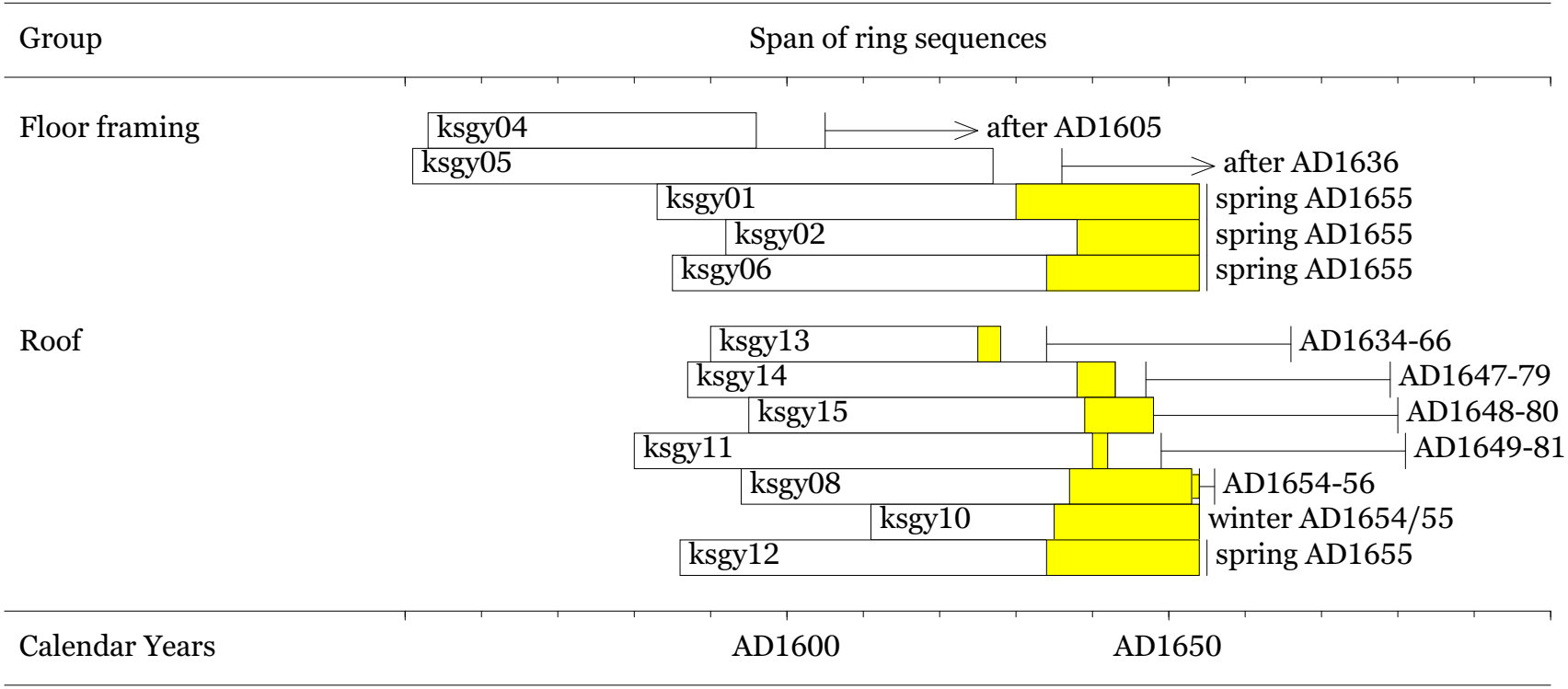

Figure 5: Bar diagram showing the relative positions of overlap of the dated samples, along with their actual or likely felling date ranges. White bars represent heartwood, yellow bars represent sapwood, narrow yellow bars represent additional unmeasured rings

APPENDIX

Ring width values (0.01mm) for the sequences measured

ksgy01

368	382	358	321	305	236	316	123	235	247
219	285	325	378	360	410	442	443	398	317
385	371	221	343	234	160	126	113	216	240
286	149	127	122	147	166	178	161	207	247
186	140	204	153	155	127	122	105	112	150
168	128	149	150	167	194	149	145	125	91
98	156	196	174	120	140	116	82	69	56
53	79								

ksgy02

159	236	349	248	366	363	370	286	335	327
365	375	317	205	251	255	227	191	209	260
367	321	255	182	157	174	195	156	243	234
272	250	195	257	232	268	189	128	94	78
82	121	90	116	126	174	314	308	256	214
145	141	204	320	274	263	269	212	147	158
127	124	162							

ksgy04

155	120	144	136	140	222	266	274	257	262
240	195	168	172	218	315	366	374	310	217
167	201	185	179	176	165	155	265	198	110
126	187	218	373	321	240	266	302	411	355
512	510	484	305						

ksgy05

169	123	235	120	157	130	122	299	310	187
189	209	158	134	113	174	205	249	355	365
274	165	185	197	254	243	214	173	185	238
201	132	145	201	234	302	315	283	250	182
216	216	281	326	275	249	182	169	137	166
131	161	214	203	176	250	312	258	211	140
204	357	349	309	253	154	107	154	162	258
269	294	202	200	242	235	271			

ksgy06

362	366	330	298	269	187	153	174	239	242
190	217	221	350	243	295	293	325	275	200
160	207	259	255	214	220	175	258	217	200
147	147	185	171	177	207	231	238	230	163
169	145	169	178	165	123	96	140	114	126
119	151	121	168	123	141	112	106	149	116
152	157	142	171	134	103	111	84	81	108

ksgy08

467	436	364	332	391	366	314	202	232	248
264	179	300	319	262	160	154	192	222	270
211	163	176	164	244	252	322	275	353	226

174 219 302 238 225 252 181 107 208 296
147 203 276 234 226 292 267 166 119 216
168 307 190 217 193 181 259 241 153 105

ksgy10
233 386 339 273 191 159 213 175 169 223
234 250 244 180 177 185 221 221 195 156
135 186 151 123 174 169 143 196 169 161
132 117 130 123 151 162 123 171 125 102
101 65 82 116

ksgy11
543 427 288 297 342 398 419 478 423 381
253 234 233 224 258 382 415 340 366 329
293 201 199 225 261 183 264 297 276 195
222 192 285 317 310 261 213 245 160 163
311 317 471 266 210 267 214 264 251 236
194 186 237 251 240 240 249 231 312 329
314 261 221

ksgy12
483 510 456 421 230 261 293 325 368 378
396 334 391 324 300 271 286 263 236 227
310 347 306 232 238 176 223 227 201 179
149 185 202 179 261 265 293 208 169 182
160 158 146 158 119 87 138 113 124 127
136 100 152 141 149 110 104 121 121 129
162 143 133 125 107 101 121 90 93

ksgy13
139 213 214 205 222 227 329 326 322 304
247 238 300 267 270 230 314 352 259 192
142 202 238 176 150 125 109 122 136 136
189 147 206 176 139 202 152 179 156

ksgy14
327 372 354 237 207 262 354 416 458 554
497 503 386 384 299 334 380 472 310 384
390 338 260 320 241 412 651 489 296 225
293 262 238 338 312 329 254 195 190 211
299 251 246 192 156 202 189 184 184 219
184 198 188 199 167 141 187

ksgy15
509 499 446 501 356 343 202 220 228 233
170 316 376 322 202 189 232 293 348 215
207 193 193 346 231 300 288 441 301 252
332 312 326 319 343 284 267 430 374 241
290 211 238 298 354 288 207 136 268 251
352 249 296 230

GYDr1M
45 54 60 66 72 82 68 75 52 62

68 72 77 99 91 85 95 97 99 128
118 82 82 67 45 52 43 37 57 42
53 56 63 70 68 34 47 59 59 64
84 89 74 81 76 78 78 85 84 101
97 130

GYDr1O
134 114 108 111 89 99 72 79 98 119
83 98 85 66 89 84 109 131 116 88
107 63 85 94 106 97 85 108 93 100
135 133 111 90 65 62 57 63 57 73
77 69 98 100 71 83 63 90 65 58
93 80 69 58 54 41 29 82 52 35
61 55 104 104 141

GYDr2I
58 59 69 55 53 50 49 65 89 133
144 174 168 139 124 118 116 114 135 112
104 122 127 117 140 148 158 180 107 89
91 84 86 89 99 107 155 146 173 147
183 140 110 86 56 33 46 46 56 64
84 79 92 127 135 153 107 104 84 85
107 140 87 104 64 80 61 71 64 91
92 91 89 72

GYDr2M
79 104 83 99 125 88 99 92 70 67
124 134 125 136 196 221 196 186 234 206
266 200 209 219 228 209 291 193 193 228
146 108 111 114 108 111 124 212 206 231
215 215 197 177 124 98 111 51 70 75
114 98 101 184 231 228 174 123 184 166
155 161 155 141 118 105 120 98 121 124
146 117 174

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