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Tree-Ring Analysis of Elm and Oak Timbers

Martin Bridge and Cathy Tyers

Discovery, Innovation and Science in the Historic Environment

Research Report Series no. 105-2019

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SUMMARY
The elm samples taken mostly had too few rings for further analysis, although two longer sequences matched each other and were combined into a single 71-year elm chronology. This showed abrupt growth changes, and could not be dated against the available oak reference material. Six oak roof timbers and an oak floor-beam appear to form a single group of timbers most likely all felled at the same time. One retained complete sapwood and was from a tree felled in winter AD 1633/34. A beam in the basement was from an oak felled in spring AD 1618, and this may either represent a substantial break in the construction of the building, or the use of a stockpiled timber.

CONTRIBUTORS
Martin Bridge and Cathy Tyers

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INTRODUCTION

The investigation of the elm timbers at The Packhorse contributes to an on-going research programme, *Developing the dendrochronology of elm in historic buildings*, funded by Historic England through its Heritage Protection Commissions programme, and led by Martin Bridge from the UCL Institute of Archaeology.

Developing the dendrochronology of elm in historic buildings

Ring-width dendrochronology of oak timbers from historic buildings in England is well established, with dating having been obtained on more than 3000 buildings (or parts thereof), with nearly one third of these having been funded by Historic England (and its predecessors). Dendrochronological evidence is a valuable component underpinning the discovery and identification of assets in the historic environment, aiding decisions relating to protection, management, and conservation, and enhancing appreciation and enjoyment of these buildings.

During this work on oak timbers, a significant amount of historic fabric constructed from timbers other than oak, most notably elm, has been identified, but this has previously been rejected as unsuitable for dendrochronological investigation. Elm in buildings has been identified in counties from Cornwall to Kent and up into the Midlands and beyond, but formal records of the presence of elm are scant as such buildings have been generally dismissed for dating purposes and thus the presence of elm in the published record is rare. The inability to date historic buildings (or sections of buildings) constructed of elm by ring-width dendrochronology is seen as problematic in some areas of the country which have a comparatively high proportion of such buildings; buildings which nevertheless form a significant part of the historic environment but could not be afforded the same level of understanding in comparison to their oak counterparts.

Prior to the start of this project, only four instances of dating elm by ring-width dendrochronology have been successful (Groves and Hillam 1997; Haddon-Reece *et al* 1989, 1990; Bridge and Miles 2015). Each of these studies involved matching elm with oak from the same site, although the Ashdon, Essex example matched oak chronologies over a wide area (Bridge and Miles 2015). This project aimed to establish whether the use of standard ring-width dendrochronology could be extended to the dating of historic buildings in England where elm (*Ulmus* sp.) is the sole, or predominant species used rather than oak (*Quercus* sp.). A systematic approach was adopted concentrating on elm in the geographical areas where it is most commonly found. Buildings were thus sought that contained a significant number of elm timbers with sufficient numbers of rings that might be matched against either oak timbers in the same building or oak chronologies from the surrounding area (Fig 1).

An article will summarise the overall outcomes of the project (Bridge and Tyers forthcoming). However, each building sampled for dendrochronology has an associated building survey report or similar publication, whilst the primary archive of the dendrochronological analysis is reported in the Historic England Research Report Series.

The Packhorse

This Grade II listed property (LEN 1232550; Fig 2) sits parallel to Old School Hill, which is a steep hill running north-south in the heart of the village of South Stoke. It has a basement at the south end of the building, two floors and an attic area, and has, since at least the middle of the nineteenth-century, been used as an inn (Parfitt and Parfitt 2017). The roof is of simple principal rafter and collar form, with four trusses and one tier of butt purlins. A carved date over a doorway suggests a construction date of AD 1674.

METHODOLOGY

Fieldwork for the present study was carried out in February 2017, following an initial assessment of the potential for elm dendrochronology some weeks beforehand. In the initial assessment, based on the general criteria used for oak timbers, accessible elm timbers with more than 50 rings and where possible traces of sapwood were sought, although slightly shorter sequences may be 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. Additional oak timbers with complete sapwood were also sampled to provide same-site comparative material to increase the chances of producing dating evidence and to confirm the dating suggested by the carved date over the doorway.

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 (2004). 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 oak 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 oak 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. Threshold values for elm samples are as yet unknown, but are likely to be of similar value.

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 or early wood formed, or the latewood or summer growth, 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. In oak, 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*) or felled-after date.

A review of the geographical distribution of dated sapwood data from historic oak 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). The equivalent values for elm are as yet unknown, but the results of this project suggest that the range of the number of sapwood rings in elm timbers is likely to be much lower. One problem that has been encountered in considering elm is that it has often proved very difficult to determine the position of the heartwood/sapwood boundary, even when it is known that the complete sapwood is present on a timber. It must be emphasised that dendrochronology can only date when a tree has been felled, not when the timber was used to construct the structure or object under study.

RESULTS AND DISCUSSION

Basic information about the samples taken is given in Table 1, with the locations of samples from the roof being illustrated in Figure 3. A photograph of the roof, facing south, is provided in Figure 4. The location of the sample from the axial floor beam on the first floor, pkhrO11, is illustrated on Figure 5. No plan is available to locate the ceiling beam in the basement, pkhrO13. The ring-width measurements for the 14 measured samples are given in the Appendix.

Most of the elm samples yielded far fewer rings than were desirable. The only two samples with more than 30 rings did however cross-match each other (t = 4.6 with 57 years overlap) and the two series were combined into a 71-year elm site master. This showed abrupt growth changes, and gave no acceptable consistent matches with the oak reference material.

Six of the oak series from roof timbers, as well as an axial floor beam from the first floor cross-matched (Table 2) and were combined to form a 104-year long site chronology, PACKHRSE, which was subsequently dated to the period AD 1530–1633, a selection of the strongest matches being shown in Table 3a. The oak series pkhrO13, from a beam in the basement does not cross-match with the seven dated oak series but it can be dated individually (Table 3b). The relative positions of overlap of all the dated oak samples are shown in Figure 6. Although the cross-dating for both the site chronology and the individually dated series are geographically well spread, the trees are more likely to have grown in the local area with those represented in the site chronology showing a stronger south-west signal than the individually dated series.

The seven dated timbers (six from the roof and one from a ceiling beam) in the site chronology PACKHRSE appear to form a coherent group, most likely felled at the same time. One timber retained complete sapwood, and was from a tree felled in winter AD 1633/34. Evidence suggests that, with the exception of reused timbers, in most historical periods construction took place within a very few years of felling (Miles 2006). This makes AD 1634 the likely date of the construction of the roof, although it may possibly have been a year or two later. The axial floor beam at first-floor level has a likely felling date range of AD 1622–54 and has similar levels of matching with the roof timbers (Table 2). It is therefore thought likely to be of part of the same group.

The single timber in the basement has an earlier felling date of spring AD 1618. This may represent an earlier period of work in the construction of the building, or the use of a stockpiled timber in this part of the building. It does not give significant matches against the other dated timbers, and is likely to be from a different source.

These results are interesting because there is a date carved into a door-head at ground floor level of AD 1674 which many may assume is the date of the building, but the dendrochronology shows that the building is earlier. This agrees with the list description, which suggests that the building of AD 1674 probably incorporated elements of an earlier structure. The history of the building is discussed in more detail by Parfitt and Parfitt (2017).

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TABLES

Table 1: Details of the samples taken from The Packhorse Inn, South Stoke, Somerset

Sample number	Timber and position	No of rings	Mean ring width (mm)	Dates spanning (AD)	h/s boundary (AD)	Sapwood rings	Mean sens	Felling date ranges (AD)
Elm timbers from the roof								
pkhrE01	East principal rafter, T1	60+6NM	1.84	-	-	C	0.34	-
pkhrE02	West principal rafter, T1	68	1.97			-	0.35	-
pkhrE03	West principal rafter, T2	<30	NM	-	-	-	-	-
pkhrE04	East principal rafter, T2	<30	NM	-	-	-	-	-
pkhrE05	East principal rafter, T3	<30	NM	-	-	-	-	-
pkhrE06	West principal rafter, T3	<30	NM	-	-	-	-	-
pkhrE07	Stud in T3, fifth from east side	<30	NM	-	-	-	-	-
Oak roof timbers								
pkhrO01	West upper purlin, bay T1-T2	68	1.62	1530–97	-	-	0.18	after 1606
pkhrO02	West upper purlin, north end bay	82	1.02	1543–1624	1617	7	0.18	1626–58
pkhrO03	East upper purlin, north end bay	57	1.24	1556–1612	-	-	0.16	after 1621
pkhrO04	East upper purlin, bay T2-T3	57	1.70	-	-	2	0.19	-
pkhrO05	West lower purlin, bay T2-T3	70	1.42	1555–1624	1620	4	0.16	1629–61
pkhrO06	Stud in T3	<40	NM	-	-	-	-	-
pkhrO07	East principal rafter, T4	68	1.59	-	-	h/s (+6NM)	0.21	-
pkhrO08	East purlin, south end bay	83	1.12	1543–1625	1618	7	0.20	1627–59
pkhrO09	Tiebeam, T4	83	1.46	-	-	2	0.19	-
pkhrO10	Tiebeam, T3	54	2.00	-	-	h/s (+17NM)	0.23	-
pkhrO12	Tiebeam, T1	102	1.54	1532–1633	1617	16C	0.20	winter 1633/34
Other oak timbers								
pkhrO11	Axial floor beam, first floor south room	56	2.35	1558–1613	1613	h/s	0.30	1622–54
pkhrO13	Ceiling beam, basement south end room	94	1.55	-	-	12¼C	0.19	spring 1618

Key: Mean sens = mean sensitivity; NM = not measured; h/s = heartwood-sapwood boundary; C = complete sapwood, winter felled; ¼C = complete sapwood, felled during the following spring

Table 2: Cross-matching between oak samples from The Packhorse ('t' values in excess of 3.5 are significant)

	t-values					
Sample No	pkhrO02	pkhrO03	pkhrO05	pkhrO08	pkhrO11	pkhrO12
pkhrO01	2.5 (55)	2.4 (42)	4.0 (43)	3.5 (55)	2.4 (40)	3.7 (66)
pkhrO02		3.8 (57)	6.1 (70)	4.3 (82)	1.6 (56)	5.5 (82)
pkhrO03			5.9 (57)	5.6 (57)	4.4 (55)	5.0 (57)
pkhrO05				6.3 (70)	3.5 (56)	5.2 (70)
pkhrO08					5.3 (56)	5.3 (83)
pkhrO11						3.7 (56)

Table 3a: Dating evidence for the oak site master, PACKHRSE, AD 1530–1633

Source region	Chronology:	Publication reference:	Filename:	Span of chronology (AD)	Overlap (years)	*t*-value
Devon	Pound Farm,Luppit	(Tyers *et al* forthcoming)	lppbT12a	1557–1664	77	8.4
Devon	Poltimore House, Poltimore	(Arnold *et al* 2005)	POLBSQ04	1534–1725	100	7.0
Cambridgeshire	Sutton-in-the-Isle	(Tyers 1995)	SUTTON	1508–1615	86	6.9
Devon	Lower Coombe Farmhouse	(Miles *et al* 2003)	BRDNINCH	1548–1624	77	6.7
Denbighshire	Craig y Castell, Dyserth	(Bridge *et al* 2017)	CRAIGYC	1510–1614	85	6.7
Devon	Sydenham House, Marystow	(Arnold *et al* 2015)	SYDHSQ01	1394–1654	104	6.6
Oxfordshire	Greys Court, Rotherfield Greys	(Miles *et al* 2009)	GREYSCTA	1319–1618	89	6.6
Buckinghamshire	34-35 Crown Court, West Wycombe	(Miles and Bridge 2013)	WWB	1550–1647	84	6.6
Somerset	8 Market Place, Shepton Mallet	(Miles 2002)	SHPTNMLT	1518–1677	104	6.6
Dorset	Sherborne House	(Bridge 2014)	SHERHO1	1540–1670	94	6.3

Table 3b: Dating evidence for the oak sequence, pkhrO13, AD 1524–1617

Source region	Chronology:	Publication reference:	Filename:	Span of chronology (AD)	Overlap (years)	*t*-value
Norfolk	Marriots Warehouse	(Tyers 1999)	MARRIOTS	1310–1583	60	6.0
Oxfordshire	Cottesmore Farm, Ewelme	(Miles and Worthington 1997)	COTTESMR	1433–1601	78	6.0
Shropshire	High Grosvenor	(Miles and Haddon-Reece 1994)	HGROVNR9	1442–1590	67	5.5
Oxfordshire	Chazey Court	(Miles *et al* 2004)	CHAZEY1	1507–1614	91	5.5
Surrey	Reigate Floor Boards	(Tyers 1990)	REIGATE	1401–1590	67	5.2
Berkshire	Shalford	(Miles and Worthington 2001)	SHALFRD2	1403–1574	58	5.1
London	Anchor Brewhouse, Shad Thames	(I Tyers pers comm)	ABMB_T4	1488–1593	70	5.1
Oxfordshire	Bodleian Library	(Miles and Worthington 1999)	BDLEIAN3	1395–1610	87	5.0
Warwickshire	Middleton Hall	(Arnold *et al* 2006)	MIDHSQ02	1390–1646	94	4.9
Northamptonshire	Dower House, Fawsley	(Howard *et al* 1999)	FAWASQ01	1427–1575		4.9
Derbyshire	West Lodge, Hardwick Old Hall	(Howard *et al* 2002)	HDWBSQ01	1397–1625		4.9

FIGURES

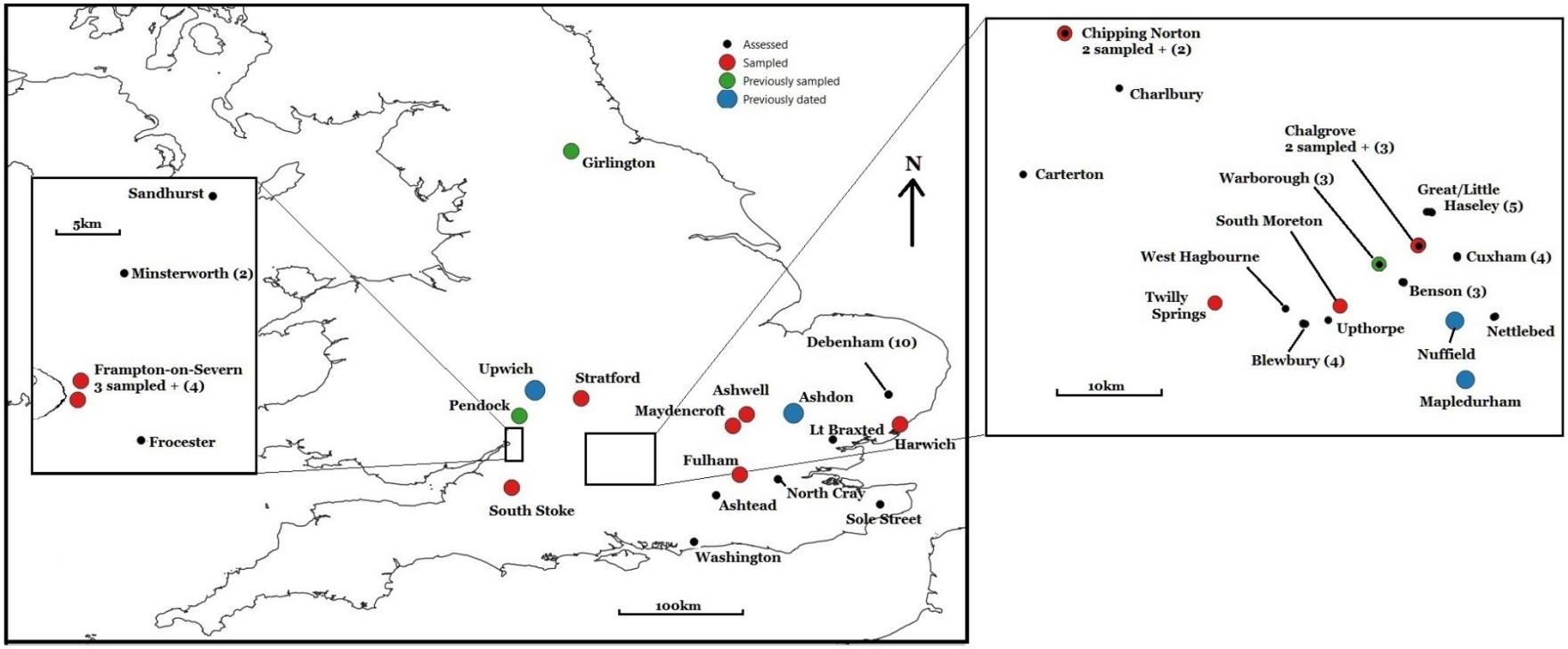

Figure 1: Map showing the distribution of sites sampled, some of which were dated, prior to the start of this project, and sites assessed and sampled properties for this project. Numbers in brackets after a place name represent the number of properties assessed in that location

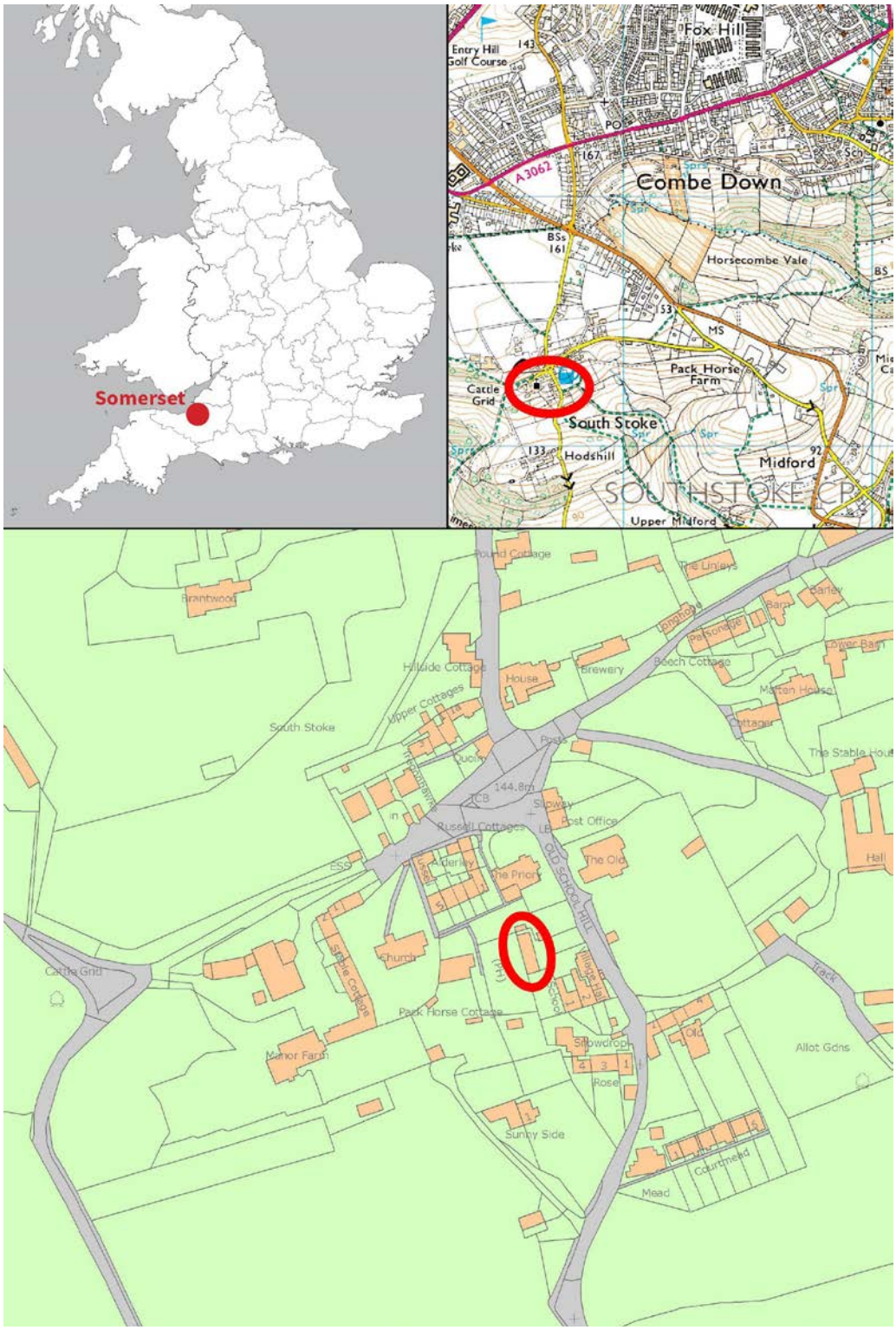

Figure 2: Maps to show the location of Packhorse, South Stoke, Somerset, circled. Scale: top right 1:20000; bottom 1:2000. © Crown Copyright and database right 2020. All rights reserved. Ordnance Survey Licence number 100024900. © British Crown and SeaZone Solutions Ltd 2020. All rights reserved. Licence number 102006.006. © Historic England

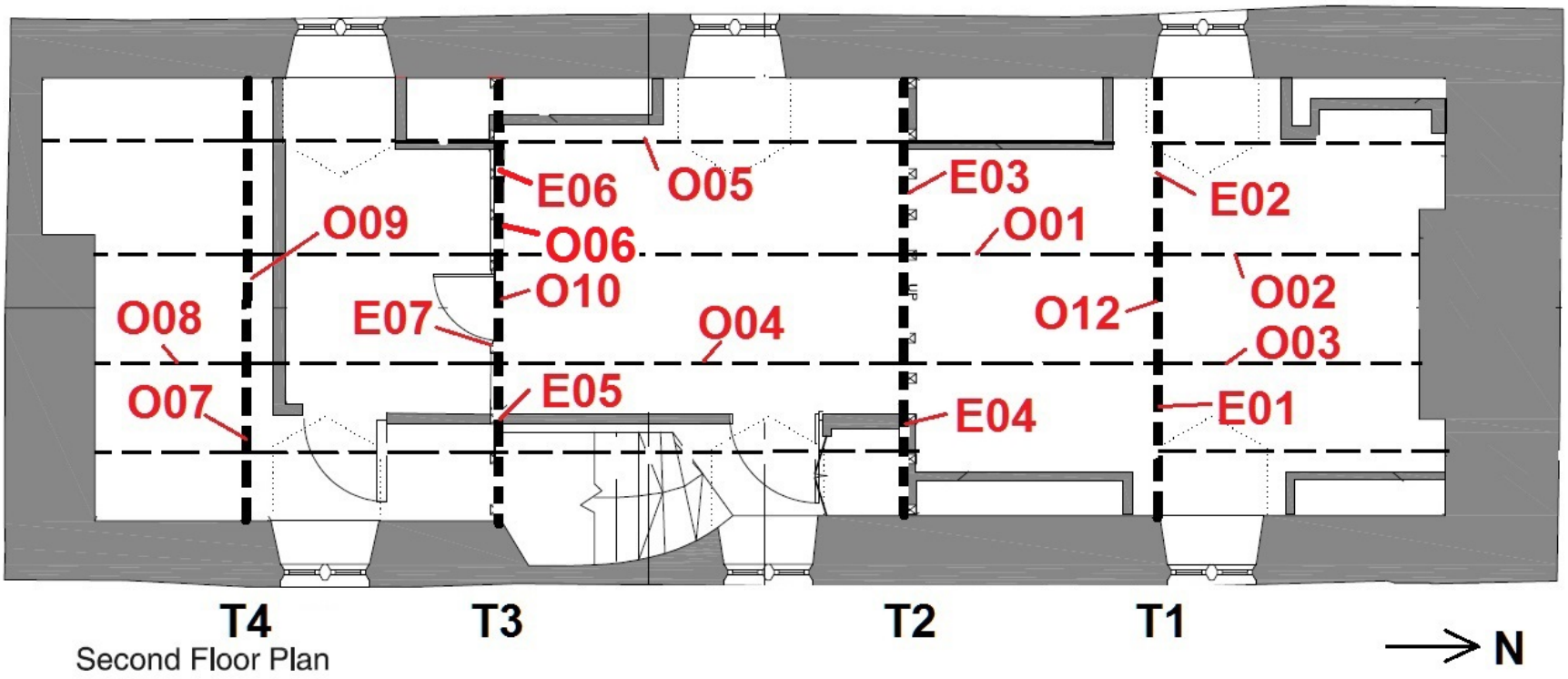

Figure 3: Plan of the attic of The Packhorse, showing the locations of some of the samples taken for dendrochronology, adapted from drawings supplied by the South Stoke Local History Committee with permission from the Packhorse Community Pub Limited

Figure 4: View of the attic facing south (photograph Martin Bridge)

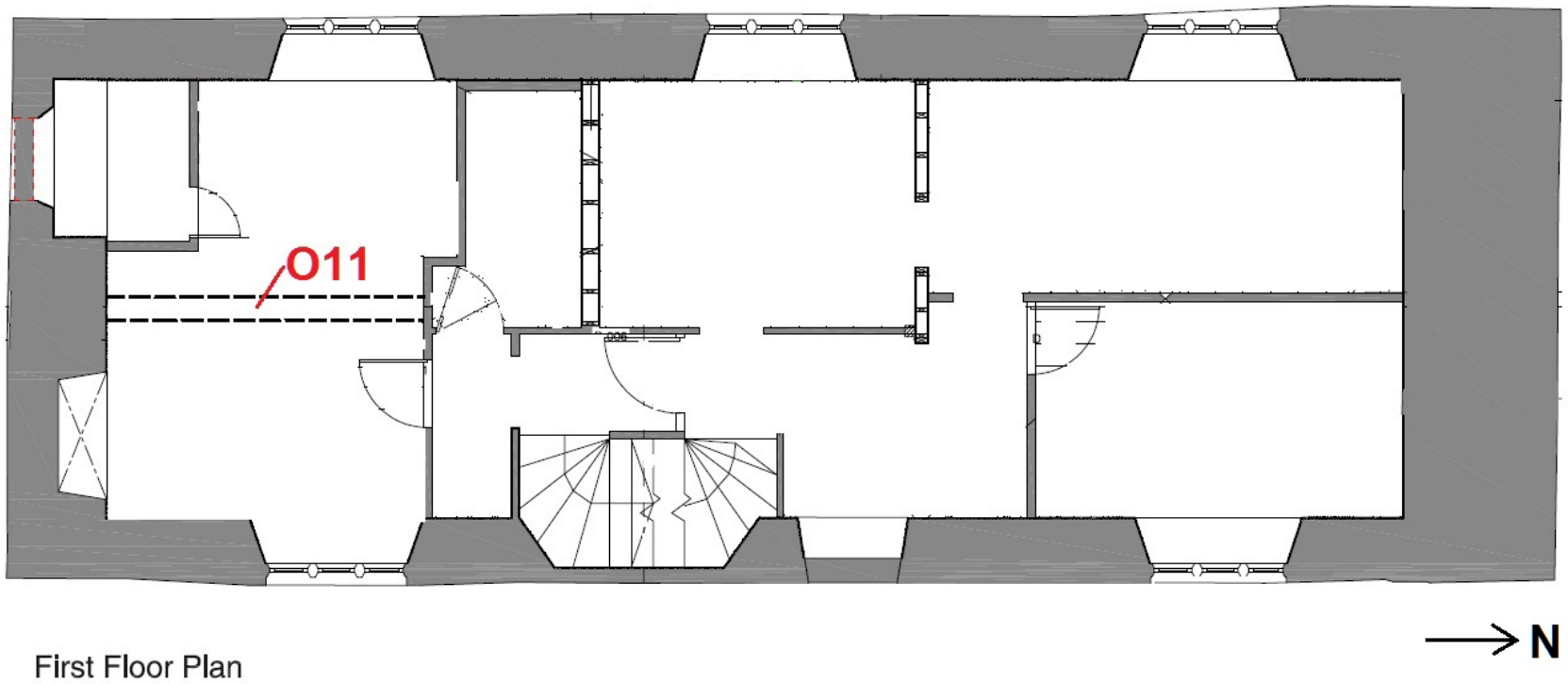

Figure 5: Drawing of the first floor of The Packhorse, showing the location of dendrochronological sample pkhrO11, adapted from drawings supplied by the South Stoke Local History Committee with permission from the Packhorse Community Pub Limited

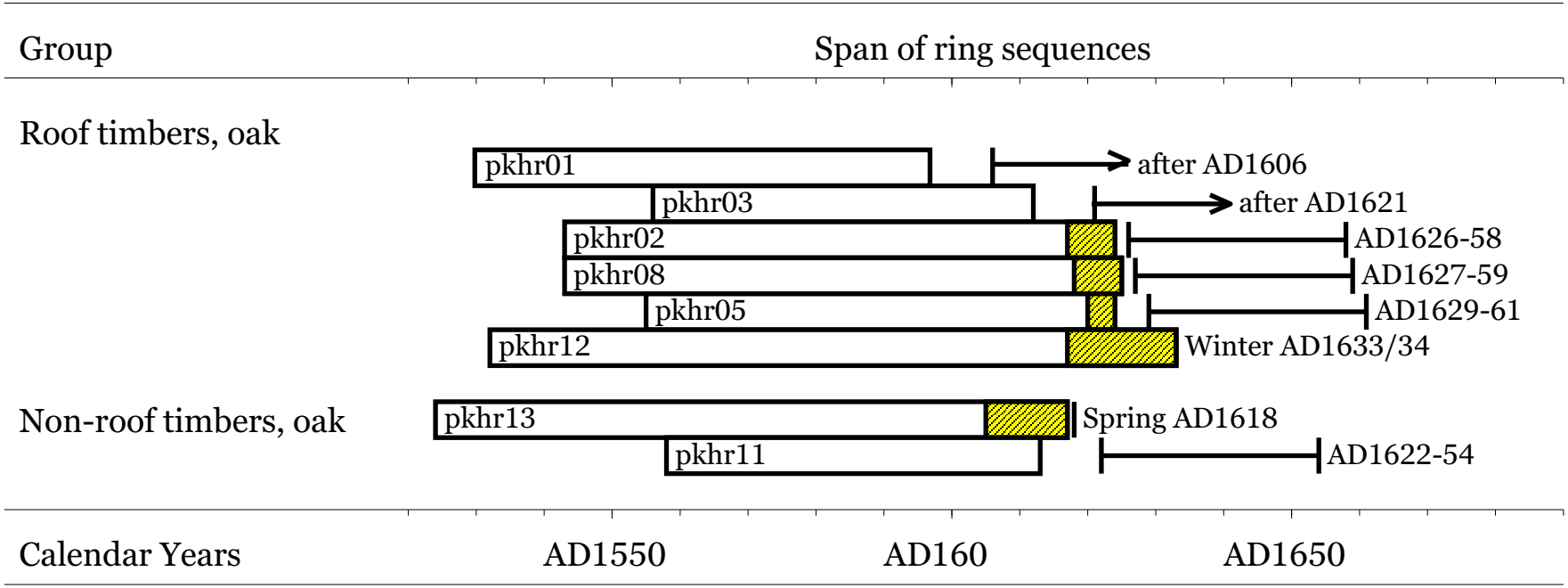

Figure 6: Bar diagram showing the relative positions of overlap of the dated samples, along with their actual felling dates or likely felling date ranges. White bars represent heartwood rings, yellow hatched bars represent sapwood rings

APPENDIX

Ring width values (0.01mm) for the sequences measured

Elm

pkhrE01

510	336	269	208	123	123	48	71	68	70
73	226	164	147	243	75	121	145	188	113
71	70	94	38	38	67	196	190	167	150
76	112	112	163	365	270	387	447	340	339
211	40	43	65	56	44	77	140	230	190
152	209	210	342	339	252	291	339	400	379

pkhrE02

77	130	85	71	41	47	50	58	95	196
272	207	74	77	41	43	39	32	30	76
33	125	231	180	140	263	140	196	176	169
130	90	112	126	89	92	207	214	251	100
150	122	380	379	303	552	501	399	364	392
348	243	128	58	155	105	153	290	240	296
255	388	492	331	342	299	352	573		

Oak

pkhrO01

241	288	226	270	253	273	303	268	261	308
275	170	164	151	108	143	170	140	186	241
219	187	188	183	204	254	155	145	201	239
183	145	130	112	112	78	56	63	78	112
123	152	102	118	114	86	105	81	87	100
123	110	100	81	124	126	167	127	135	216
138	144	162	159	161	144	150	124		

pkhrO02

188	123	130	115	141	158	163	136	212	174
153	130	147	109	103	125	149	114	101	107
82	97	50	65	87	125	86	98	95	87
89	77	84	93	63	63	92	74	57	59
72	80	94	99	72	85	87	66	105	89
89	76	100	108	91	90	89	86	65	72
97	98	92	102	132	98	106	108	98	95
91	97	117	82	128	115	100	119	111	62
93	77								

pkhrO03

147	151	181	186	171	143	171	102	102	79
94	112	110	121	118	110	90	109	142	110
109	80	105	135	110	92	122	97	110	117
104	105	146	166	88	111	135	128	137	158
150	116	136	127	119	97	95	94	105	94
183	164	149	133	142	137	133			

pkhrO04

184	165	224	256	205	248	229	153	164	225
311	229	166	217	272	291	182	175	195	316
317	247	174	298	124	148	129	130	127	104
140	149	106	117	123	138	103	102	117	96
133	136	140	115	141	120	107	124	123	154
127	157	154	156	163	137	111			

pkhrO05

184	120	125	174	181	156	167	164	136	147
105	119	146	140	137	162	164	110	112	121
129	128	78	73	116	103	89	105	109	161
208	156	125	158	196	118	168	149	172	180
176	193	183	154	114	128	97	113	108	120
108	167	170	137	176	168	124	109	153	161
163	162	181	157	156	148	158	122	109	153

pkhrO07

220	357	267	227	169	173	179	296	360	280
199	225	187	212	259	195	326	352	198	225
262	309	218	193	196	181	170	173	185	149
133	119	149	141	130	66	43	40	61	54
65	84	97	146	171	163	150	67	38	44
34	34	50	65	105	107	117	137	128	153
119	115	106	119	120	122	161	115		

pkhrO08

171	96	60	84	134	184	258	196	246	179
155	266	201	126	155	183	211	195	161	182
132	145	114	111	107	123	104	97	121	87
77	100	90	69	58	58	81	88	74	61
70	84	107	80	58	88	126	85	104	107
97	124	108	96	79	83	81	75	78	77
74	99	75	123	120	99	83	99	108	81
103	87	90	64	95	91	105	104	88	80
104	98	113							

pkhrO09

147	196	144	155	152	289	220	148	143	187
192	156	151	122	178	211	112	118	114	134
106	100	127	97	134	165	123	115	127	179
150	168	166	134	91	105	78	88	78	82
111	110	107	128	180	145	142	165	130	168
173	151	161	182	213	98	78	60	70	94
90	127	126	151	137	206	166	127	163	176
173	155	220	198	211	134	176	173	206	178
169	154	129							

pkhrO10

216	214	240	235	257	271	401	320	234	232
291	301	229	250	495	287	467	428	246	240

352 361 298 342 277 268 240 266 187 200
167 231 134 129 136 70 41 37 50 63
88 96 117 138 143 132 69 43 25 24
29 34 91 78

pkhrO11
124 201 293 251 380 235 400 317 266 378
276 444 403 346 163 186 294 252 223 189
203 206 350 204 180 198 170 307 219 241
260 268 151 266 248 239 400 301 188 103
86 95 115 139 200 232 230 140 303 222
215 142 236 174 105 190

pkhrO12
166 193 240 227 180 147 158 203 178 174
172 172 137 208 170 264 188 178 151 214
210 175 211 286 123 130 151 172 137 118
147 115 139 99 103 100 111 104 85 136
88 77 100 98 97 67 67 61 75 64
106 106 134 190 163 128 151 159 89 139
134 172 164 171 236 186 127 123 112 93
102 142 124 115 214 231 170 140 164 192
183 211 211 228 141 257 229 204 181 130
160 192 114 158 182 160 142 212 186 155
155 107

pkhrO13
190 140 194 199 255 231 189 310 294 291
266 316 294 249 218 250 291 251 145 176
180 277 271 256 227 239 182 161 140 134
183 206 155 105 119 174 120 147 143 113
131 140 136 156 130 141 148 100 102 87
75 82 79 103 119 120 159 83 57 95
98 95 87 72 96 102 104 225 126 144
150 108 121 113 71 77 107 126 116 135
114 100 104 103 179 179 136 105 100 106
123 105 99 207

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