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Manor Farm Barn, Manor Court, High Street, Harmondsworth, London Borough of Hillingdon

Dendrochronological Analysis of Oak Structural Timbers and Boards

Ian Tyers

Discovery, Innovation and Science in the Historic Environment

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SUMMARY

A number of tree-ring dates had been obtained from Harmondsworth Barn during a major repair following a fire in the 1980s. In 2012 the barn came into English Heritage guardianship following a period of neglect. An extended tree-ring dating programme was commissioned on oak timbers from the barn to inform future management and interpretation. The results identified that oak timbers from the barn, its modified doorways, and its weatherboarding were datable by tree-ring dating techniques. The results showed that all dated timbers were derived from early fifteenth century timbers with at least some material felled in the period AD 1423–6. Fragmentation of the samples and the poor condition of the sapwood prevents detailed identification of the buildings' sequence and the timescale of its construction. This report archives all the dendrochronological results.

CONTRIBUTORS

Ian Tyers

ACKNOWLEDGEMENTS

Original samples from timbers at Harmondsworth Barn were supplied in 1985 by Richard Harris (Research Director, Weald and Downland Open Air Museum) and Peter McCurdy (McCurdy and Co). In 2012 the sampling and analysis of additional timbers at Harmondsworth Barn was funded by English Heritage (EH). In 2012 practical help and valuable discussions were provided by Peter Marshall, Scientific Dating Coordinator (EH), and Justine Bailey (Friends of the Great Barn at Harmondsworth). In 2013 Peter McCurdy very kindly discussed the weatherboarding and supplied offcuts from repairs undertaken in the 1980's. Cathy Tyers, Scientific Dating Team (EH) discussed the results.

ARCHIVE LOCATION

Greater London HER
1 Waterhouse Square
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DATES OF INVESTIGATION

1985, 1993, and 2012–3

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CONTENTS

INTRODUCTION

This document is a technical archive report on the tree-ring analysis of oak timbers from Harmondsworth Barn, West London. It is beyond the dendrochronological brief to describe the building in detail or to undertake the production of detailed drawings. Elements of this report may be combined with detailed descriptions, drawings, and other technical reports at some point in the future to form either a comprehensive publication or an archive deposition on the building.

Harmondsworth Barn stands less than 1 km north of Heathrow Airport surrounded by the A4 arterial road and the M4 and M25 motorways (Fig 1). This Grade I listed barn was dubbed by the late poet laureate and heritage campaigner Sir John Betjeman as the "Cathedral of Middlesex". Built by Winchester College as part of its manor farm at Harmondsworth, the oak-framed barn is an outstanding example of medieval carpentry and contains one of the most intact interiors of its era (Fig 2). The barn is aligned north-south, with its entrance doors to the east (Fig 3). It is nearly 60 metres long, 12 metres wide, and 11 metres tall and is of 12 bays with aisles. The building is now in English Heritage guardianship.

METHODOLOGY

Tree-ring dating employs the patterns of tree-growth to determine the calendar dates for the period during which the sampled trees were alive. The amount of wood laid down in any one year by most trees is determined by the climate and other environmental factors. Trees over relatively wide geographical areas can exhibit similar patterns of growth, and this enables dendrochronologists to assign dates to some samples by matching the growth pattern with other ring-sequences that have already been linked together to form reference chronologies.

The original visit to the barn was during repairs following a fire in the mid-1980s. Cores and offcuts obtained by Richard Harris and Peter McCurdy were analysed at this time, and summary results published in the *Vernacular Architecture* journal (Tyers and Hibberd 1993). The dates obtained from these samples had by that stage made their way into the Pevsner entry for Harmondsworth in the London North-West volume (Cherry and Pevsner 1991, 325). Prior to this some cores appear to have been taken from the building by one or more pioneers of the subject. John Fletcher noted a date from a 'sillbeam' from Harmondsworth (Fletcher *et al* 1984, 62) and one of the village residents has located correspondence relating to a visit by Walter Horn, from the US, in 1967 to the barn. During the 1980s John Fletcher was working through the 120-odd cores obtained by Walter Horn, Freddie Charles, and Veronika Siebenlist in the 1960s and 1970s from numerous totemic buildings sampled during the earliest stages of dendrochronological work in this country, so these apparently different records may actually be the result of one sampling visit.

Following its acquisition by English Heritage the building was visited in April 2012 by the author of this report in company with Peter Marshall (EH Scientific Dating) and Justine Bailey (Secretary, Friends of the Great Barn, Harmondsworth) as an assessment of the dendrochronological potential of the timbers in the structure had been requested by Mike Dunn (EH Principal Inspector of Historic Buildings and Areas). This assessment aimed to identify whether oak timbers with sufficient numbers of rings for analysis existed in any part of the complex. This assessment concluded that timbers in the building contained suitable oak material.

Sampling was subsequently commissioned in order to inform future management and interpretation of this important building, which took place during May 2012. The assignment was subsequently extended to ascertain, if possible, the date of the weatherboarding, and offcuts stored at McCurdy and Co's offices since the 1980s. A subset of these were analysed and returned to McCurdy and Co during 2013. The *in situ* timbers selected for coring were sampled using a 15mm diameter corer attached to an electric drill. The cores were taken as closely as possible along the radius of the timbers so that the maximum number of rings could be obtained for subsequent analysis. The ring sequences in the cores were revealed by sanding. The weatherboarding offcuts were measured directly on their cut edges.

These preparations revealed the width of each successive annual tree ring. Each prepared sample could then be accurately assessed for the number of rings it contained and, at this stage, it was also possible to determine whether the sequence of ring widths within it could be reliably resolved. Dendrochronological samples need to be free of aberrant anatomical features, such as those caused by physical damage to the tree, which may prevent or significantly reduce the chances of successful dating.

Standard dendrochronological analysis methods (see eg English Heritage 1998) were applied to each suitable sample. The complete sequence of the annual growth rings in the suitable samples was measured to an accuracy of 0.01mm using a micro-computer based travelling stage. The sequence of ring widths was then plotted onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition, cross-correlation algorithms (eg Baillie and Pilcher 1973) were employed to search for positions where the ring sequences were highly correlated. Highly correlated positions were checked using the graphs and, if any of these were satisfactory, new composite sequences were constructed from the synchronised sequences. Any *t*-values reported below were derived from the original CROS algorithm (Baillie and Pilcher 1973). A *t*-value of 3.5 or over is usually indicative of a good match, although this is with the proviso that high *t*-values at the same relative or absolute position need to have been obtained from a range of independent sequences, and that these positions were supported by satisfactory visual matching.

Not every tree can be correlated by the statistical tools or the visual examination of the graphs. There are thought to be a number of reasons for this: genetic variations; site-

specific issues (for example a tree growing in a stream bed will be less responsive to rainfall); or some traumatic experience in the tree's lifetime, such as injury by pollarding, defoliation events by caterpillars, or similar. These could each produce a sequence dominated by a non-climatic signal. Experimental work with modern trees shows that 5–20% of all oak trees cannot be reliably cross-matched, even when enough rings are obtained.

Converting the date obtained for a tree-ring sequence into a useful date requires a record of the nature of the outermost rings of the sample. If bark or bark-edge survives, a felling date precise to the year or season can be obtained. If no sapwood survives, the date obtained from the sample gives a *terminus post quem* for its use. If some sapwood survives, an estimate for the number of missing rings can be applied to the end-date of the heartwood. This estimate is quite broad and varies by region. This report uses a minimum of 10 rings and a maximum of 46 rings as a sapwood estimate (see eg English Heritage 1998, 10–11).

Where bark-edge or bark survives, the season of felling can be determined by examining the completeness, or otherwise, of the terminal ring lying directly under the bark. Complete material can be divided into three major categories:

- 'early spring', where only the initial cells of the new growth have begun - this is equivalent to a period in March/April, when the oaks begin leaf-bud formation;
- 'later spring/summer' where the early wood is evidently complete but the late wood is evidently incomplete, which is equivalent to May-through-September of a normal year, and
- 'winter' where the latewood is evidently complete and this is roughly equivalent to September-to-March (of the following year) since the tree is dormant throughout this period and there is no additional growth put on the trunk.

These categories can overlap as, for example, not all oaks simultaneously initiate leaf-bud formation. It should also be noted that slow growing or compressed material cannot always be safely categorised.

Timber technology studies demonstrate that many of the tool marks recorded on ancient timbers can only have been done on green timber. There is little evidence for long-term storage of timber or of widespread use of seasoned, rather than green timber in the medieval period (see eg English Heritage 1998, 11–12).

Reused timbers can only provide tree-ring dates for the original usage date, not their reuse. Identifying reused timbers requires careful timber recording which notes the presence of features which are not functional in the structure. It is always possible that some timbers exhibit no evidence of earlier usage, and are thus 'hidden' reused timbers. The dendrochronological impact of this problem is particularly acute where only single timbers have been dated from a structure.

The analysis may highlight potential same-tree identifications if two or more tree-ring sequences are obtained that are exceptionally highly correlated. Such pairs, or sometimes more, are then used as a same-tree group and each can be given the interpreted date of the most complete of the samples. They are most useful where several timbers date but only one has any sapwood or where same-tree identifications yield linkages between different areas.

RESULTS

Six samples were analysed in *c* 1985, and some of these were reanalysed in 1993. These were labelled samples 1–6 inclusive. In 2012, 14 timbers from across the building were cored. These cores were labelled 7–20 inclusive. In 2013 six weatherboard offcuts were examined for direct measurement of their tree-ring sequences, these were labelled 21–26. Figure 3 shows the distribution of the core samples through the barn.

Each core sample or offcut was assessed for the wood type, the number of rings it contained, and whether the sequence of ring widths could be reliably interpreted. This assessment confirmed that all of the sampled timbers were oak (*Quercus* spp) and that 24 of the 26 were suitable for dendrochronological analysis. The exceptions included one core, sample 20, that was unsuitable for analysis due to the presence of a band of very narrow rings which could not be reliably measured, and board 26 had too few rings for analysis.

Although there was good survival of sapwood in the barn it should be noted that successful coring of the sapwood proved difficult throughout due to the obviously severe attack by woodworm and its unusually fragile condition. In numerous instances the sapwood became detached from the rest of the core. The woodworm damage within the cores also resulted in problems in reliably differentiating and measuring the rings within the surviving sapwood. However, an estimate of unmeasured rings could usually be made, which are detailed in Table 1.

The 24 suitable samples from the building were prepared for analysis, measured, and the resultant ring series were initially compared with other material from the building. Various interim composite groupings were made of sequences during this process. Finally the interim composites and the individual sample series were individually compared with reference series of medieval and later oak tree-ring data from throughout Britain. These results were reviewed and a final single composite series was constructed from 23 samples from the barn. This group is formed by intra-site cross-matching (Table 2), supported by good external cross-matching. Sequence Harm_T23 is a 165-year composite that matches with reference data (Table 3) at AD 1262 to AD1426 inclusive. A summary of the results for the component and individual samples is provided in Table 1 and Figure 4.

The measurement data for all the measured samples are listed in Appendix 1

DISCUSSION

Structural Timbers

The six offcuts (Samples 1–6; Table 1) obtained during repairs from structural timbers that were analysed in 1985 and 1993 (Tyers and Hibberd 1993) had previously indicated that the primary construction for the barn was dated to the mid AD1420s.

Fourteen core samples, 11 from the primary construction phase of the barn (Samples 7–17; Table 1) and three associated with modifications to the doorways (Samples 18–20; Table 1) were obtained in 2012. All three of the sampled timbers associated with the door modifications appeared likely to be reused with the only potentially fresh timbers clearly having too few rings for analysis.

Two of the earlier slices, and one of the new cores, have intact sapwood with bark edge and six of the new cores have detached sapwood with bark edge. In combination these appear to indicate that felling of the major structural elements of the structure occurred over the period AD 1423–6. The remaining ten incomplete timbers appear to be consistent with these mid AD 1420s felling dates. The internal cross-matching produces three *t*-values in excess of 10.0 indicating possible same-tree derivation, the most notable being a *t*-value of 12.94 between sample 16, one of the arcade posts, and sample 19, one of the door modification timbers. This probably links these elements to a single phase of construction. It therefore seems likely that all of the dated timbers were originally associated with the primary construction phase of the barn, which presumably occurred shortly after felling, and therefore in the mid AD 1420s. The Winchester College accounts include a reference to carpenters viewing timber in 1423/4 in Kingston and then being at Harmondsworth in 1425/6 (Cherry and Pevsner 1991, 325). The tree-ring results suggest that the two dated timbers associated with the door modifications were probably reused from the original form of these entrances.

Three unusual and carefully plugged holes were observed in two of the sampled timbers; two, *c* 31mm diameter in the truss 9 east arcade post and another, *c* 21mm diameter, in the truss 8 west arcade post. In both cases these holes were on the corners where bark-edge was present. Such locations are nearly always chosen for dendrochronological sampling, and they were only noticed because new sampling was being undertaken on these timbers. It seems reasonable to conclude that these apparent core holes relate to the earlier work of either Horn or Fletcher discussed above. Further examination of other timbers in the barn (eg the sill beams) may link these observations.

Weatherboarding

The cladding boards around the outside of the barn consists of two layers; the outer layer is mostly relatively recent softwood, but some of the inner layer contained thin oak

planking with reasonable numbers of annual rings and some surviving sapwood. However, these are too thin for either coring, or micro-boring. Instead, sections of inner planking removed during the repairs following the fire in the early 1980s were located and assessed for their potential for analysis. These offcuts are oak boards, of radial or near radial sections (they are tangentially sawn, with good saw marks), from relatively fast-grown trees. They retain no sapwood and they are short sections derived from long boards. The supplied sections were between 125mm and 280mm in width, and *c* 20–25mm in thickness. Five of these offcuts contain enough rings to analyse, other offcuts with fewer rings were not examined.

The five suitable offcuts were analysed. Three of them cross-match each other, and some of the Harmondsworth structural material (Table 2) as well as other London and south-eastern English regional data sets. These providing end-dates of AD 1413, AD 1410, and AD 1405 respectively. A fourth board has an end date of AD 1340, again matching the barn structural timbers and other regional data sets, although this does not overlap the other dated board series. The remaining analysed board doesn't match either the boards, or the structural material, or the regional reference series at any date. The final, and smallest, off-cut had too few rings to analyse. The earliest-end date is presumably the inner part of a wider board, or a board made from the inner part of a longer lived tree, whilst the three offcuts with later-end dates are presumably either the outer parts of old trees or from young trees. The undated board does not appear to represent another phase of material.

Assuming that this group of offcuts is representative of the wider assemblage of weatherboards in the barn, it seems likely that much of the extant oak weatherboarding at Harmondsworth is contemporaneous with the structural timbers from the barn.

BIBLIOGRAPHY

Baillie, M G L, and Pilcher, J R, 1973 A simple crossdating program for tree-ring research, *Tree Ring Bulletin*, **33**, 7–14

Blatherwick, S, and Bluer, R, 2009 *Great houses, moats and mills on the south bank of the Thames: medieval and Tudor Southwark and Rotherhithe*, MoLA Monograph Series **47**, Museum of London Archaeology

Bridge, M C, 2000 *Tree-ring analysis of timbers from St Andrew's Church, Ford, West Sussex*, Anc Mon Lab Rep, **27/2000**

Cherry, B, and Pevsner, N, 1991 *The Buildings of England: London 3 North West*, Penguin

English Heritage, 1998 *Dendrochronology: guidelines on producing and interpreting dendrochronological dates*, English Heritage

Fletcher, J M, Tapper, M, and Morris, J J, 1984 Tree-ring dates for buildings: List 14, *Vernacular Architect*, **15**, 69

Groves, C, Hillam, J, and Pelling-Fulford, F, 1997 Dendrochronology in *Excavations on Reading Waterfront sites, 1979–1988* (J W Hawkes and P J Fasham), Wessex Archaeol Rep, **5**, 64–70

Miles, D, 2007 *HM Tower of London (TOL99 and TOL100), London Borough of Tower Hamlets: Scientific Dating Report –The Tree-Ring Dating of the White Tower*, English Heritage Res Dept Rep Ser, **35/2007**

Tyers, I, 1996 *Tree-ring analysis of the bellframe at the church of St Mary Magdalene, Twyning, Gloucestershire*, Anc Mon Lab Rep, **29/96**

Tyers, I, 1997a *Dendrochronological analysis of timbers from Wanborough Barn, near Guildford, Surrey*, ARCUS Rep, **319**

Tyers, I, 1997b *Tree-ring analysis of seven buildings in Essex*, ARCUS Rep, **292**

Tyers, I, and Hibberd, H, 1993 Tree-ring dates from Museum of London Archaeology Service: List 53, *Vernacular Architect*, **24**, 50–4

Worthington, M, and Miles, D, 2006 *New College, Oxford: Scientific Dating Report – Tree-Ring Dating of The Bell Tower and Cloister Door*, English Heritage Res Dept Rep Ser, **56/2006**

FIGURES

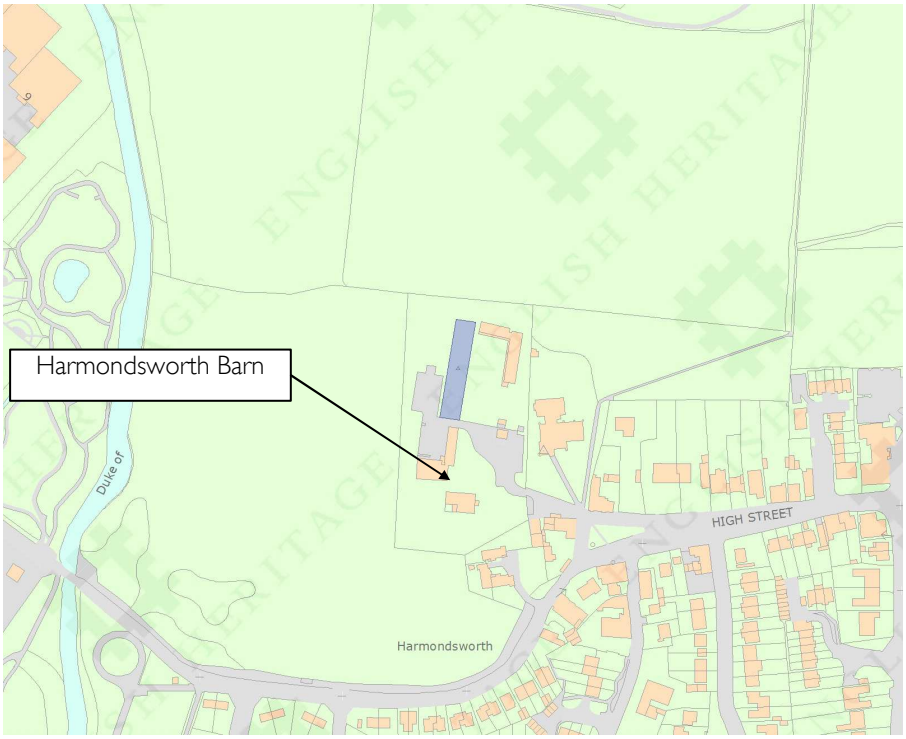


Figure 1: Location of Harmondsworth Barn. © Crown Copyright and database right 2015. All rights reserved. Ordnance Survey Licence number 100024900

Figure 2: Harmondsworth Barn internal view, photo Peter Marshall

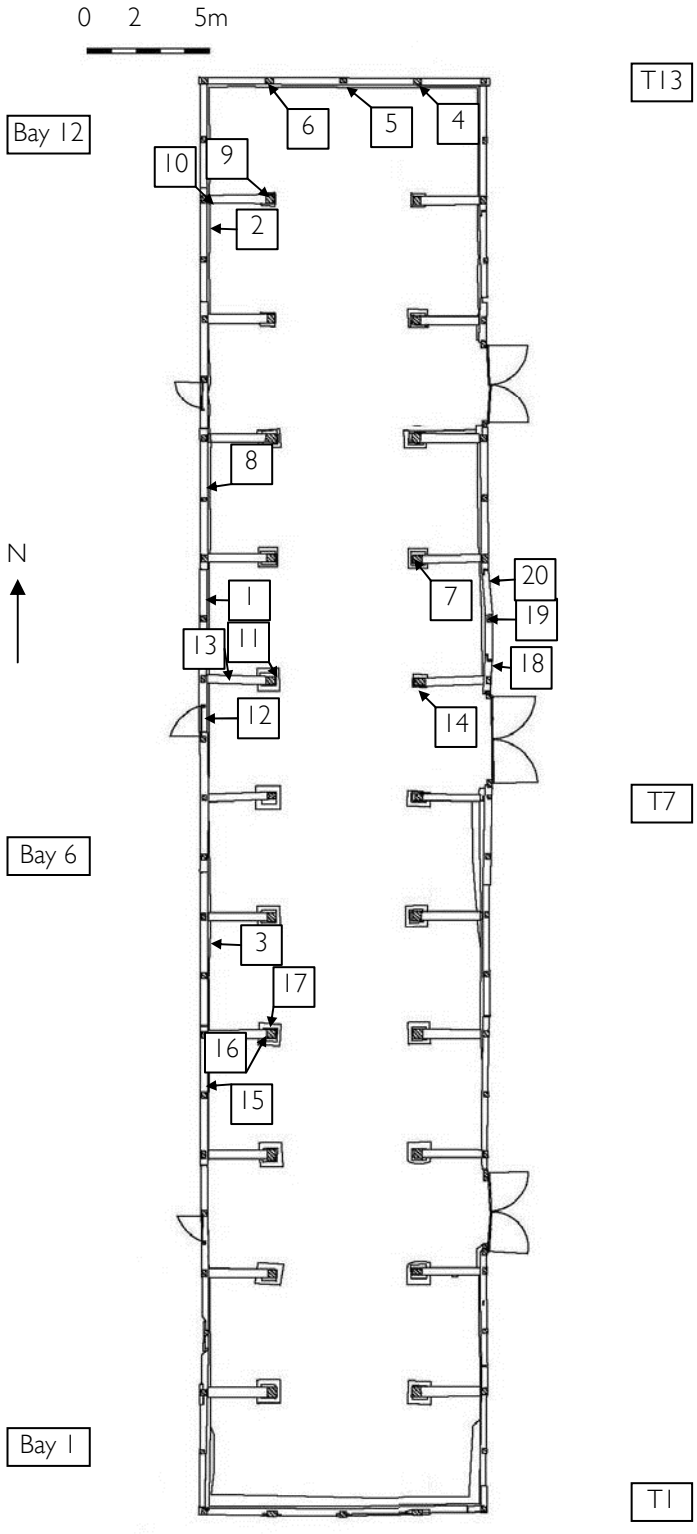


Figure 3: Harmondsworth Barn plan showing bay and truss numbering and the approximate location of the sampled timbers, survey drawing supplied by English Heritage

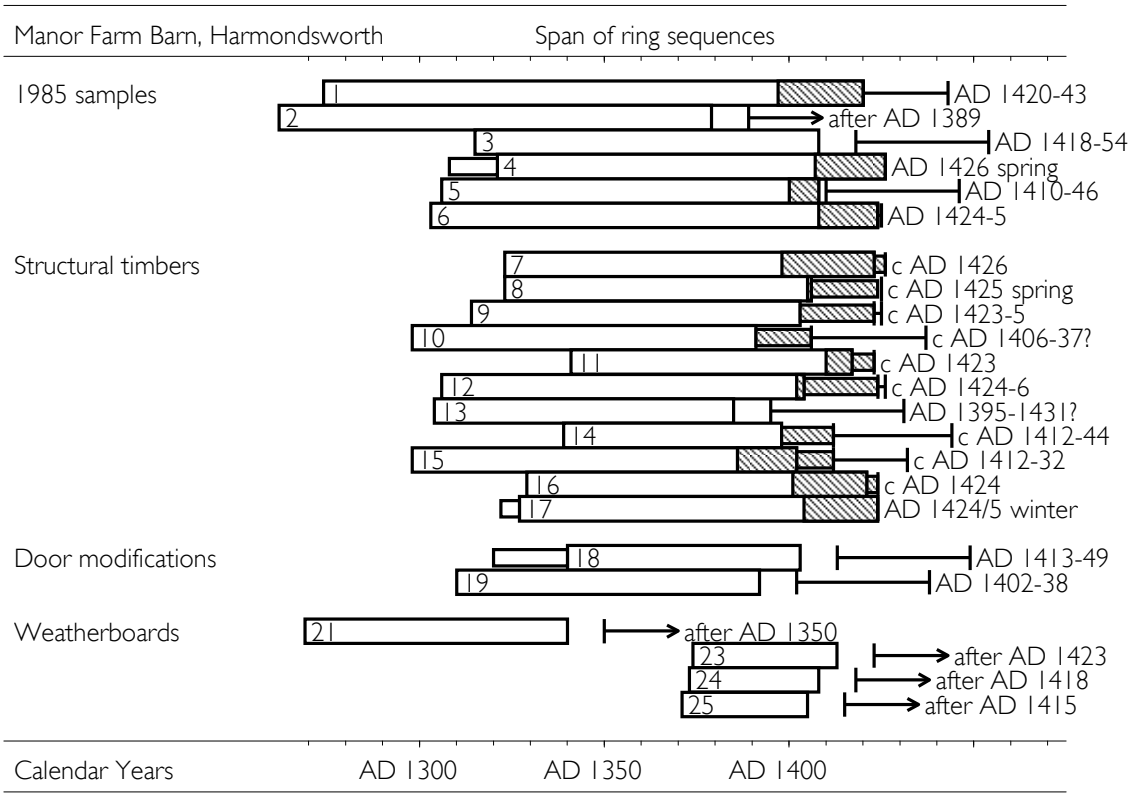
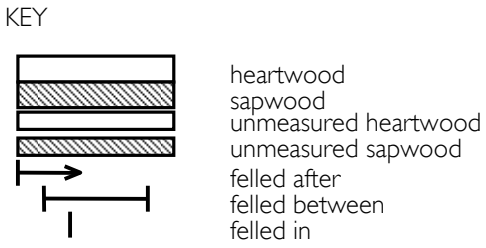


Figure 4: Bar diagram showing the absolute dating positions of the 23 dated tree-ring sequences for samples from Harmondsworth Barn. The interpreted felling dates are also shown for each sample



TABLES

Table 1: Details of the 26 oak samples from timbers from Harmondsworth Barn

Sample	Location and function	Rings	Sapwood	Date of measured sequence	Interpreted result
Main structural timbers					
1	Bay 8 west sill beam	147	23	AD 1274–1420	AD 1420–43
2	Bay 11 west sill beam	118	-	AD 1262–1379	after AD 1389
3	Bay 5 arcade plate	94	H/S	AD 1315–1408	AD 1418–54
4	Truss 13 east arcade post	106	19Bs	AD 1321–1426	AD 1426 spring
5	Truss 13 centre post	103	8	AD 1306–1408	AD 1410–46
6	Truss 13 west arcade post	122	16B	AD 1303–1424	AD 1424–25
7	Truss 9 east arcade post	101	25+*3*B	AD 1323–1423	*c* AD 1426
8	Bay 9 north west mid rail	84+	1+*18*Bs	AD 1323–1406	*c* AD 1425 spring
9	Truss 12 west arcade post	90	H/S+*n*+*20*Bs	AD 1314–1403	*c* AD 1423–5 spring
10	Truss 12 west aisle post	94+	?H/S+*nn*+*15*Bw	AD 1298–1391	*c* AD 1406–37 winter
11	Truss 8 west arcade post	77+	7+*6B*	AD 1341–1417	*c* AD 1423
12	Bay 7 west wall plate	99+	2+*n*+*20*Bw	AD 1306–1404	*c* AD 1424–6 winter
13	Truss 8 west aisle tie	82	?H/S	AD 1304–1385	?AD 1395–1431
14	Truss 8 east arcade post	60+	H/S+*14*	AD 1339–1398	*c* AD 1412–44
15	Bay 4 north-west mid rail	105+	16+*10*	AD 1298–1402	*c* AD 1412–32
16	Truss 5 west arcade post	93+	20+*3*B	AD 1329–1421	*c* AD 1424
17	Truss 5 west stylobate	98	20Bw	AD 1327–1424	AD 1424/5 winter
Bay 8 Door modifications					
18	Bay 8 south-east mid rail	64	H/S	AD 1340–1403	AD 1413–49
19	Bay 8 centre midrail	83	H/S	AD 1310–1392	AD 1402–38
20	Bay 8 north-east mid rail	30+*45*+35	H/S	unsuitable	-
Northern External Boards					
21	Board offcut 280 x 25mm	72	-	AD 1269–1340	after AD 1350
22	Board offcut 220 x 25mm	58	-	not dated	-
23	Board offcut 230 x 25mm	40	-	AD 1374–1413	after AD 1423
24	Board offcut 195 x 20mm	36	-	AD 1373–1408	after AD 1418
25	Board offcut 165 x 20mm	35	-	AD 1371–1405	after AD 1415
26	Board offcut 125 x 20mm	*28*	-	unsuitable	-

KEY For locations see Figure 3. Interpretations based on 10–46 sapwood rings. The trusses are numbered 1–13 from south to north, the bays are number 1–12 from south to north. H/S is heartwood/sapwood edge; B is bark but season indistinguishable; Bw is bark after complete ring (ie winter felled), Bs is bark after additional partial ring (ie spring felled); a number in italics gives the estimated number of unmeasured rings; *n* indicates possible loss of 1 or 2 rings between main core and detached sapwood fragment; *nn* indicates unknown loss of rings between main core and detached sapwood fragment

Table 2: The t-values between 23 sampled oak timbers from Harmondsworth Barn. - t-value less than 3.0; \ no or short overlap. These series were combined to form the composite sequence Harm_T23 used in Table 3

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	21	23	24	25
1	4.81	6.35	5.76	5.04	7.33	5.30	8.43	3.79	4.83	-	7.40	6.50	6.33	5.70	8.24	-	3.77	7.50	4.24	4.86	-	-
2		4.17	4.19	-	4.05	-	6.13	-	5.46	-	4.58	5.31	4.31	7.48	3.00	3.19	3.06	3.82	5.86	\	\	\
3			6.63	6.48	9.89	5.30	9.52	3.45	6.16	3.23	7.59	5.62	6.70	4.71	7.56	3.63	4.67	5.97	4.76	3.87	5.30	3.42
4				5.28	5.50	4.87	6.10	4.76	5.20	5.07	5.11	4.90	4.66	4.38	7.74	5.12	4.72	6.24	4.90	4.86	-	3.48
5					6.30	4.47	7.19	-	5.39	-	-	5.59	5.54	-	6.37	-	3.52	5.49	-	-	-	-
6						5.39	8.71	3.70	7.20	-	5.08	7.04	8.58	5.20	8.23	-	4.42	6.72	-	4.54	-	-
7							4.86	4.80	4.06	-	5.70	3.60	4.34	4.33	6.79	-	3.83	5.64	-	3.16	-	3.16
8								5.18	6.38	3.99	6.55	7.99	5.53	6.42	6.05	3.99	6.36	7.63	6.00	-	3.46	-
9									3.52	3.86	3.20	-	-	3.12	3.59	-	-	3.07	-	-	-	-
10										-	6.19	10.87	7.27	5.88	7.81	-	3.67	7.48	6.32	-	-	-
11											-	-	-	-	-	3.69	-	-	\	-	-	-
12												6.29	7.58	6.15	7.21	4.29	4.56	7.77	5.38	3.01	4.37	3.32
13													5.76	5.97	6.67	-	-	7.46	7.46	\	\	-
14														4.68	10.27	-	5.38	8.61	\	4.34	-	3.12
15															5.47	-	-	8.68	3.11	-	-	-
16																4.08	3.95	12.94	\	6.04	-	3.90
17																	3.93	3.71	\	-	-	-
18																		4.72	\	-	-	-
19																			3.99	-	-	-
21																				\	\	\
23																					5.72	5.44
24																						7.47

Table 3: Showing example t-values *between the composite sequence Harm_T23 constructed from oak timbers in Harmondsworth Barn and oak reference data.*

Reference chronology	Harm_T23 AD1262–1426
Surrey, Wanborough Barn (Tyers 1997a)	12.00
Essex, Netteswellbury Barn Harlow (Tyers 1997b)	10.42
London, Hays Wharf excavations (Blatherwick and Bluer 2009)	9.78
West Sussex, St Andrews Church Ford (Bridge 2000)	8.98
Gloucestershire, Twyning Bellframe (Tyers 1996)	8.78
Oxfordshire, Bell Tower New College Oxford (Worthington and Miles 2006)	8.71
London, Tower Hamlets White Tower Tower of London (Miles 2007)	8.54
Berkshire, Reading Waterfront sites (Groves *et al* 1997)	8.41

APPENDIX 1

harm01

375	359	258	286	245	371	433	328	332	259
253	217	242	171	223	338	372	422	392	436
324	230	157	196	141	104	130	203	205	151
238	171	256	295	335	274	223	274	289	220
314	397	283	292	267	281	245	271	185	112
159	96	72	227	187	139	142	58	127	176
174	156	162	83	79	163	121	130	122	116
178	97	206	154	120	94	121	141	89	78
95	104	92	122	73	86	95	55	49	160
117	135	102	107	120	137	138	101	104	107
90	86	81	87	121	119	101	123	130	97
81	99	131	136	151	130	143	117	94	151
118	119	140	116	113	153	103	147	105	111
105	89	106	78	131	109	63	117	144	163
141	105	138	122	127	81	106			

harm02

354	229	244	267	337	275	354	298	294	295
208	272	388	391	170	191	118	162	236	191
133	146	157	191	141	139	132	153	308	267
191	147	157	148	211	202	136	176	174	148
139	115	150	124	146	166	151	150	101	105
118	104	156	200	230	157	214	123	141	204
146	182	164	109	92	177	156	92	86	70
89	101	122	104	86	88	79	121	99	80
98	75	101	112	131	94	92	120	91	123
94	100	106	73	81	98	63	118	83	84
65	85	95	77	62	84	61	88	77	98
71	81	69	75	61	62	71	78		

harm03

417	437	406	305	364	271	216	316	186	141
94	83	179	204	187	134	113	151	162	189
211	153	98	126	202	129	93	110	133	171
170	227	177	172	180	158	174	119	169	124
111	91	148	91	142	82	65	84	180	180
117	105	112	88	174	169	140	190	123	147
144	151	100	179	232	237	181	293	146	107
160	264	249	219	135	106	156	100	164	128
157	161	132	139	170	128	160	122	159	182
115	172	116	129						

harm04

122	118	196	191	211	172	278	272	234	226
221	219	233	271	221	173	117	142	133	157
120	125	124	173	206	210	165	127	120	119
142	150	161	119	90	133	152	90	121	150
95	77	169	151	126	110	138	176	237	216
107	134	113	117	98	86	98	127	145	121
145	148	144	128	147	246	224	178	191	119
187	136	239	207	230	226	246	176	222	169
177	114	193	175	123	133	96	107	163	89
158	147	149	171	150	130	154	169	162	155
148	152	147	143	130	59				

harm05

232	224	190	103	208	148	161	218	227	252
147	143	121	331	252	288	297	287	178	147
98	202	167	169	198	146	162	111	122	158
164	59	159	201	159	168	102	100	179	148
142	144	120	117	145	135	118	123	128	185
161	143	130	166	134	107	84	213	225	159
167	287	309	262	250	166	179	149	235	231
154	160	285	281	277	262	272	146	143	150
256	210	209	207	162	172	110	182	88	197
133	132	163	153	147	236	136	151	211	141
210	160	136							

harm06

103	128	131	90	155	219	262	195	191	394
392	383	516	396	363	280	427	311	196	243
249	258	143	88	200	246	185	142	89	166
147	135	173	125	107	143	201	174	155	82
139	134	144	225	161	112	180	164	264	159
233	243	239	202	198	143	288	189	122	161
265	283	166	158	240	200	222	204	140	180
134	194	149	171	143	224	242	239	236	225
167	100	155	214	223	247	158	167	166	128
187	125	185	147	157	160	191	140	168	166
154	247	129	161	145	194	146	102	214	165
202	214	183	220	198	244	159	221	270	167
263	158								

harm07

210	189	188	109	121	261	249	165	153	162
140	109	114	107	84	85	153	131	140	121
110	157	162	220	242	183	157	137	237	242
212	210	147	121	169	87	115	101	104	78
164	205	147	110	123	170	213	205	198	236
206	266	317	177	128	271	193	157	155	174
126	86	81	127	140	185	146	130	93	79
83	76	54	72	89	88	86	76	125	116
126	145	108	155	154	146	137	104	137	145
168	180	112	128	101	76	85	130	144	126
196									

harm08

118	112	77	57	147	123	94	69	68	91
84	91	74	69	45	44	96	70	70	59
53	93	91	115	75	61	54	73	93	60
87	56	66	46	61	40	64	42	43	33
97	66	55	31	63	55	75	52	39	49
59	46	52	57	45	79	85	73	61	80
57	40	58	77	63	69	45	49	44	48
55	46	52	52	30	61	50	45	51	37
52	56	49	65						

harm09

318	451	463	354	312	282	258	267	158	214
170	274	133	329	278	352	128	121	77	128
129	120	52	58	64	170	160	135	84	75
87	133	74	108	79	62	45	128	131	164
107	144	118	81	56	55	49	56	50	119
122	89	74	75	137	158	157	106	135	163
142	113	75	100	104	197	198	214	183	144
84	135	95	124	119	92	82	73	64	108
107	80	91	93	165	117	117	112	143	143

harm10

283	326	376	272	166	237	308	214	177	241
283	194	197	222	256	251	335	418	378	288
245	234	184	218	181	230	158	120	82	135
170	107	93	93	82	65	137	116	86	63
78	108	87	84	76	76	58	91	129	92
92	72	71	75	56	59	74	63	57	74
51	86	55	36	39	107	68	49	54	66
67	56	47	47	52	52	63	60	49	55
79	66	71	78	69	53	47	60	79	81
91	68	61	54						

harm11

165	179	137	266	324	222	218	184	220	240
285	264	289	241	185	234	196	152	167	180
147	140	213	263	206	136	123	146	250	219
166	219	212	217	184	221	157	184	251	212
197	129	170	158	168	223	239	217	175	147
198	161	155	146	148	147	141	142	144	110
137	133	137	215	183	120	106	131	150	186
173	149	138	131	122	126	153			

harm12

211	267	217	168	146	116	93	88	159	146
256	224	189	161	159	178	183	140	168	131
81	147	156	126	80	82	79	79	119	103
95	73	59	94	95	73	69	84	84	70
117	108	84	82	84	129	74	69	92	65
56	116	76	83	76	62	62	124	101	91
65	84	85	125	125	102	126	106	103	131
107	90	110	128	128	126	140	120	106	103
129	123	148	115	136	164	107	130	102	118
121	111	89	123	110	108	101	115	141	

harm13

188	134	140	186	175	185	134	184	214	130
203	195	315	217	163	178	137	237	178	308
199	112	61	135	153	84	100	104	85	89
136	111	93	57	72	149	93	93	78	102
82	78	125	92	56	54	92	78	38	60
77	101	52	71	40	75	60	43	36	171
131	71	62	133	91	89	80	50	47	61
107	77	59	60	108	96	91	69	77	51
47	50								

harm14

229	178	168	159	172	207	208	357	255	222
311	227	322	177	178	201	171	180	203	154
175	164	124	116	277	224	184	172	270	245
271	291	239	228	144	156	197	166	146	224
209	262	293	227	204	117	158	195	195	183
154	153	188	129	180	123	164	168	140	154

harm15

254	137	222	256	225	164	182	169	158	142
200	156	125	119	151	146	261	229	235	195
250	135	199	177	136	154	151	129	110	171
163	111	86	68	105	86	117	115	63	56
56	95	87	58	77	59	63	73	118	92
62	72	63	79	48	60	70	52	50	59
56	59	50	41	43	74	79	64	32	54
55	64	72	56	55	47	46	49	43	47
59	43	39	51	72	61	51	60	64	57
52	54	42	52	51	34	52	44	41	45
50	46	36	44	35					

harm16

295	269	213	271	151	304	292	207	71	104
231	227	192	149	142	95	81	202	152	135
172	191	301	177	239	173	181	218	236	148
178	220	110	88	243	170	108	108	166	208
327	293	181	233	141	195	234	146	132	245
175	234	277	269	195	88	184	244	218	206
154	152	139	76	165	123	120	159	162	121
162	127	151	134	141	173	126	148	130	144
158	64	153	130	141	135	153	152	157	141
125	144	180							

harm17

244	340	257	259	238	265	253	395	260	303
143	163	257	242	123	135	115	187	218	247
171	138	134	164	228	205	142	124	93	136
185	124	142	149	151	98	70	52	49	52
76	79	114	96	79	88	93	61	99	96
111	118	138	146	120	127	177	112	132	189
162	135	89	92	167	133	161	132	123	139
145	125	140	107	113	95	140	156	163	150
132	149	121	106	137	107	131	115	122	90
110	155	95	159	177	216	154	217		

harm18

80	54	69	67	132	121	111	93	73	101
97	136	133	115	108	111	102	187	97	115
94	96	96	192	139	103	97	196	169	180
127	106	110	100	75	110	115	94	138	113
100	111	119	100	77	107	94	101	96	66
67	78	87	114	91	107	90	104	85	105
87	74	92	98						

harm19

190	248	300	346	413	410	403	380	387	314
258	221	179	164	192	157	119	166	145	141
123	103	99	80	114	123	88	60	64	95
88	78	84	95	98	88	175	115	90	101
130	145	92	83	76	84	99	120	88	97
91	64	52	97	98	75	70	109	138	153
153	108	120	108	96	122	83	74	101	87
83	110	119	93	72	81	118	100	142	99
98	111	74							

harm21

820	680	767	481	572	346	824	590	739	534
651	1040	1057	727	783	787	588	622	312	226
266	482	592	285	366	398	362	688	485	267
355	328	397	170	114	166	133	165	407	305
189	228	242	272	169	252	278	392	300	196
278	194	323	312	295	333	129	115	219	251
145	115	104	154	117	260	188	161	85	119
235	200								

harm22

445	502	364	509	545	466	356	359	299	290
394	363	354	468	305	391	348	338	317	277
263	342	281	450	441	394	583	316	244	223
276	277	320	290	297	294	315	271	354	270
289	346	336	359	339	318	212	258	293	282
265	294	318	238	196	347	247	228		

harm23

307	275	292	256	389	522	599	656	755	737
361	446	682	707	739	750	810	667	441	693
493	578	588	696	771	717	995	647	664	601
562	306	534	349	516	675	268	554	570	408

harm24

539	706	641	692	455	588	709	667	587	677
592	363	379	477	619	571	524	512	520	322
366	349	304	440	398	547	621	574	449	364
447	388	340	446	413	429				

harm25

368	397	318	490	419	441	385	491	569	602
614	576	493	324	305	444	596	647	561	496
495	290	405	316	237	345	330	383	453	558
502	406	557	417	434					

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