Ancient Monuments Laboratory
Report 11/99

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Summary

Marriot's Warehouse is a two-storey barn-like building of brick and stone on the waterfront of King's Lynn. It is currently undergoing structural and archaeological assessment prior to an application for listed building consent and a programme of repair. This report covers the dendrochronological analysis of a series of oak timbers supporting the first floor as well as the tiebeams and arch-braces from the roof trusses. This analysis was undertaken to clarify the dating of the surviving timbers so as to inform repair decisions. The results indicate at least three phases of oak timbers are present in the building, with at least one of these phases principally re-used in their present locations. The felling dates indicated for these three phases are AD 1498/9, 1569/70, and AD 1583/4. The AD 1498/9 material may be re-used from nearby monastic buildings after their dissolution. The AD 1569/70 phase may be the remains of an original single-storey building, whilst the AD 1583/4 material may be associated with modification, including the raising of the walls.

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Introduction

This document is a technical archive report on the tree-ring analysis of oak timbers from the bridging joists, joists, and roof of Marriot's Warehouse, King's Lynn, Norfolk (NGR TF616196). It is beyond the dendrochronological brief to describe the building in detail or to undertake the production of detailed drawings. As part of a multifaceted and multidisciplinary study of the building, 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. The conclusions may therefore have to be modified in the light of subsequent work.

Marriot's Warehouse is a two-storey barn-like building located on, and aligned with, the historic waterfront of King's Lynn (Fig 1). The building is grade II* listed and has recently been the subject of a structural analysis (Heywood and Barker 1998). The building is in need of substantial remedial works. The ground-floor ceiling/first-floor floor consists of a series of huge transverse bridging joists, some replaced with softwood, with a series of smaller joists. These smaller joists include some obviously re-used oaks and a large number of softwood beams running between the bridging joists. The roof above consists of a series of tiebeams with a complex arrangement of arch-bracing and wall posts with corbels, possibly dating from around AD 1600 (Heywood and Barker 1998, 3). Above this is a series of raking, strutted, king-post trusses in softwood thought to be of eighteenth- or nineteenth-century origin (Heywood and Barker 1998, 3).

A tree-ring dating programme of the bridging beams and the tiebeams of Marriot's Warehouse was requested by Paul Edwards from English Heritage to inform the listed building consent for proposed repairs and alterations to this important and complex building.

Methodology

The general methodology and working practises used at the Sheffield Dendrochronology Laboratory are described in English Heritage (1998). The methodology used for this building was as follows.

A brief survey identified those oak timbers with the most suitable ring sequences for analysis. Those with more than 50 annual rings and some survival of the original sapwood and bark-edge were sought. The dendrochronological sampling programme attempted to obtain cores from as broad a range of timbers, in terms of structural element types, scantling sizes, and carpentry features, as was possible within the terms of the request. The softwood timbers were specifically excluded from the sampling brief (Bayliss pers comm).

The most promising timbers 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 core holes were left open. The ring sequences in the cores were revealed by sanding.

The complete sequences of growth rings in the samples that were selected for dating purposes were measured to an accuracy of 0.01mm using a micro-computer based travelling stage (Tyers 1997a). The ring sequences were plotted onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition cross-correlation algorithms (Baillie and Pilcher 1973) were employed to search for positions where the ring sequences were highly correlated. These positions were checked visually using the graphs and, where these were satisfactory, new mean sequences were constructed from the synchronised sequences. The *t*-values reported below are 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 must be obtained from a range of independent sequences, and that these positions are supported by satisfactory visual matching.

All the measured sequences from this assemblage were compared with each other and any found to cross-match were combined to form a site master curve. These, and any remaining unmatched ring sequences were tested against a range of reference chronologies, using the same matching criteria: high *t*-values, replicated values against a range of chronologies at the same position, and satisfactory visual matching. Where such positions are found these provide calendar dates for the ring-sequence.

The tree-ring dates produced by this process initially only date the rings present in the timber. The interpretation of these dates relies upon the nature of the final rings in the sequence. If the sample ends in the heartwood of the original tree, a *terminus post quem (tpq)* for the felling of the tree is indicated by the date of the last ring plus the addition of the minimum expected number of sapwood rings which are missing. This *tpq* may be many decades prior to the real felling date. Where some of the outer sapwood or the heartwood/sapwood boundary survives on the sample, a felling date range can be calculated using the maximum and minimum number of sapwood rings likely to have been present. The sapwood estimates applied throughout this report are a minimum of 10 and maximum of 46 annual rings, where these figures indicate the 95% confidence limits of the range. These figures are applicable to oaks from England and Wales. Alternatively, if bark-edge survives, then a felling date can be directly utilised from the date of the last surviving ring. The dates obtained by the technique do not by themselves necessarily indicate the date of the structure from which they are derived. It is necessary to incorporate other specialist evidence concerning the re-use of timbers and the repairs of structures before the dendrochronological dates given here can be reliably interpreted as reflecting the construction date of phases within the structure.

A further important element of the tree-ring analysis of buildings and archaeological assemblages is the identification of 'same tree' groups within the sampled material. Inspection of timbers, both in buildings and archaeological sites, often suggests that the patterns of knots or branching in timbers are so similar that they appear to be derived from a single tree. Tree-ring analysis is often used to support these suggestions. The identification of 'same tree' groups is based on a combination of high levels of matching

between samples, extremely similar longer term growth trends, and individual anatomical anomalies within the timbers. High *t*-values are not by themselves necessarily indicative of two series being derived from a single tree. Conversely low *t*-values do not necessarily exclude the possibility. It is the balance of a range of information that provides the evidence.

Results

Timbers with surviving bark or at least partial sapwood survival were preferentially selected for sampling where possible. Disintegration of the cores and especially of the sapwood during the coring process proved a problem with a number of samples, this may have been due to the cold and damp conditions in the building.

A total of 16 timbers were selected as most suitable for sampling (Table 1; Figs 2 – 3). The samples were numbered **1-16** inclusive.

Two of the 16 samples when examined in the laboratory were rejected, one of these (sample **12**) because of it having an insufficient number of rings for reliable analysis, the other (sample **3**) due to its excessive fragmentation (Table 1). The 14 series which were measured were initially compared with each other. The data was generally found to have poor inter-correlation. However, ten sequences were found that either matched together to form an internally consistent group (Table 2), or were dated directly by matching to reference data (Table 3). A 274-year site mean chronology was calculated, named MARRIOTS (Fig 4). The site mean was then compared with dated reference chronologies from throughout British Isles and northern Europe. Table 4 shows the correlation of the mean sequences at the dating position identified for the sequence, AD 1310 - 1583 inclusive. Table 5 lists the site mean chronology.

The remaining four measured samples did not match either the rest of the material from Marriot's nor dated reference chronologies.

Interpretation

The 274-year chronology MARRIOTS is dated AD 1310 to 1583 inclusive. It was created from ten timbers. Inspection of the bar diagram (Fig 4), and the internal and external correlation matrices (Tables 2 and 3) suggests they are derived from three different groups. In total four of the dated samples were complete to bark-edge, with five others retaining either some sapwood or complete to the heartwood/sapwood boundary (Fig 4). Four timbers form an early group of which one, sample **7**, was felled in winter AD 1498/99. The three others from this group (samples **4**, **13**, and **15**) despite none retaining bark-edge appear likely to have been felled at the same time. A late group is formed by three other timbers. Two samples, **14** and **16**, were felled in spring or summer AD 1583 and winter AD 1583/4 respectively whilst sample **10** is clearly identified as being derived from the same tree as sample **16** (Table 2, note that this sample thus must have the same felling date).

Between the early and late groups are three timbers which may form a third group or may be derived from several other groups. A possibly re-used joist (sample **6**) was felled in winter AD 1569/70, whilst a definitely re-used joist (sample **9**) consists entirely of heartwood and could be felled any time after AD 1516. The reasonable degree of similarity between the tree-ring sequences from **6** and **9** (Table 2), their similar scantling (Table 1), and their similar patina suggests both are re-used and both are of the same date. The interpretation of sample **5** is less certain. This sample is probably complete to the heartwood/sapwood boundary and the felling date range calculated for it of AD 1553-89 inclusive covers both the felling date of sample **6** in AD 1569/70 and the felling dates of samples **10**, **14** and **16** in AD 1583/4. The sampling record suggests at least 10mm of sapwood was lost during coring but at its projected 1mm/year growth rate this would only bring the date of the outermost ring of the sample to around AD 1553, which is still some way from either felling date. On the basis of its cross-correlation with reference chronologies (Table 3) it appears most likely to belong to the AD 1569/70 group, although this interpretation must remain conjectural.

Discussion

Considering the relatively limited sampling programme undertaken the dendrochronological results outlined above clearly indicate that the building has had a complex history of construction, re-use, and modification. It is not possible to state categorically the correct interpretation of the results presented here. None of the dated oaks need necessarily be primarily associated with the building, indeed the entire structure could be a collection of salvaged building materials. The presence of re-used masonry presumed to come from one of the three nearby dissolved friaries (Heywood and Barker, 1) suggests the possibility that the massive transverse bridging joists and tiebeams dating to AD 1498/9 have been derived from a similar source. The very late fifteenth-century date for these certainly tallies with current evidence for a building boom on monastic sites in the 50 years prior to the Dissolution (see eg Tyers 1998a). The exceptional size, particularly of samples **4** and **7** (Table 1), and their eight-metre length would certainly make such material attractive for salvaging, although it is not clear if there is any physical evidence for their re-use. Alternatively they may be an original part of the initial form of the present structure.

The second group of material is more difficult to interpret. At least one, or possibly two, of the timbers are re-used joists, the possibly re-used one was felled in AD 1569/70. Since many of the visible oak joists have angled joint housings they may originally have been derived from a roof. The third timber of this group is another of the transverse bridging joists which, although not complete to bark-edge, is likely, from the recorded depth of the sapwood that fragmented during sampling, to have been felled at around the same time. These timbers could be dating the original construction of the building, with it using some older timbers from the monastic complex. Elements of the original roof could then have been re-used when shortly afterwards the building was extensively remodelled.

The final dated oak construction phase is indicated by the three roof tiebeams, two with felling dates in AD 1583 or 1584. These timbers appear to suggest the walls were raised and the roof reconstructed,

presumably to allow for more and improved storage. Clearly the undated oaks and the replacement softwood transverse timbers and joists could be from these or other phases of repair and remodelling.

Conclusion

The dendrochronological analysis of timbers from Marriot's Warehouse indicates timbers from a variety of dates are present within the structure. My preferred interpretation is for the construction of a perhaps single-storied structure around AD 1569/70 using significant quantities of re-used timbers dating from the very late-fifteenth century. These could possibly be derived from nearby dissolved monastic properties. In AD 1583/4 this structure was perhaps remodelled possibly to provide better storage facilities. This may had involved raising the roofline, reflected in the standing masonry, and the incorporation of some of the original roof timbers in the floor and re-use of some other major elements, already re-used once before, as tiebeams for the new roof. Such complexity was not necessarily expected and it is not possible to entirely resolve the history of this building from a relatively limited sampling brief. This leaves many other possible interpretations of the results. The discovery of additional waterlogged structural timbers under the floor during the period between assessment and sampling of the building clearly raises the possibility of additional timbers being available to assist in the interpretation of the building. Similarly since the proposed works in the building dictate the removal of some structural timbers it would be helpful if the brief required that these are tagged and kept aside for future dendrochronological assessment. It should be appreciated that even if these are already sampled timbers, any additional slices from them may help refine the felling dates, or allow currently undated sequences to be dated.

Acknowledgements

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Figure 1 Location of Marriot's Warehouse, King's Lynn

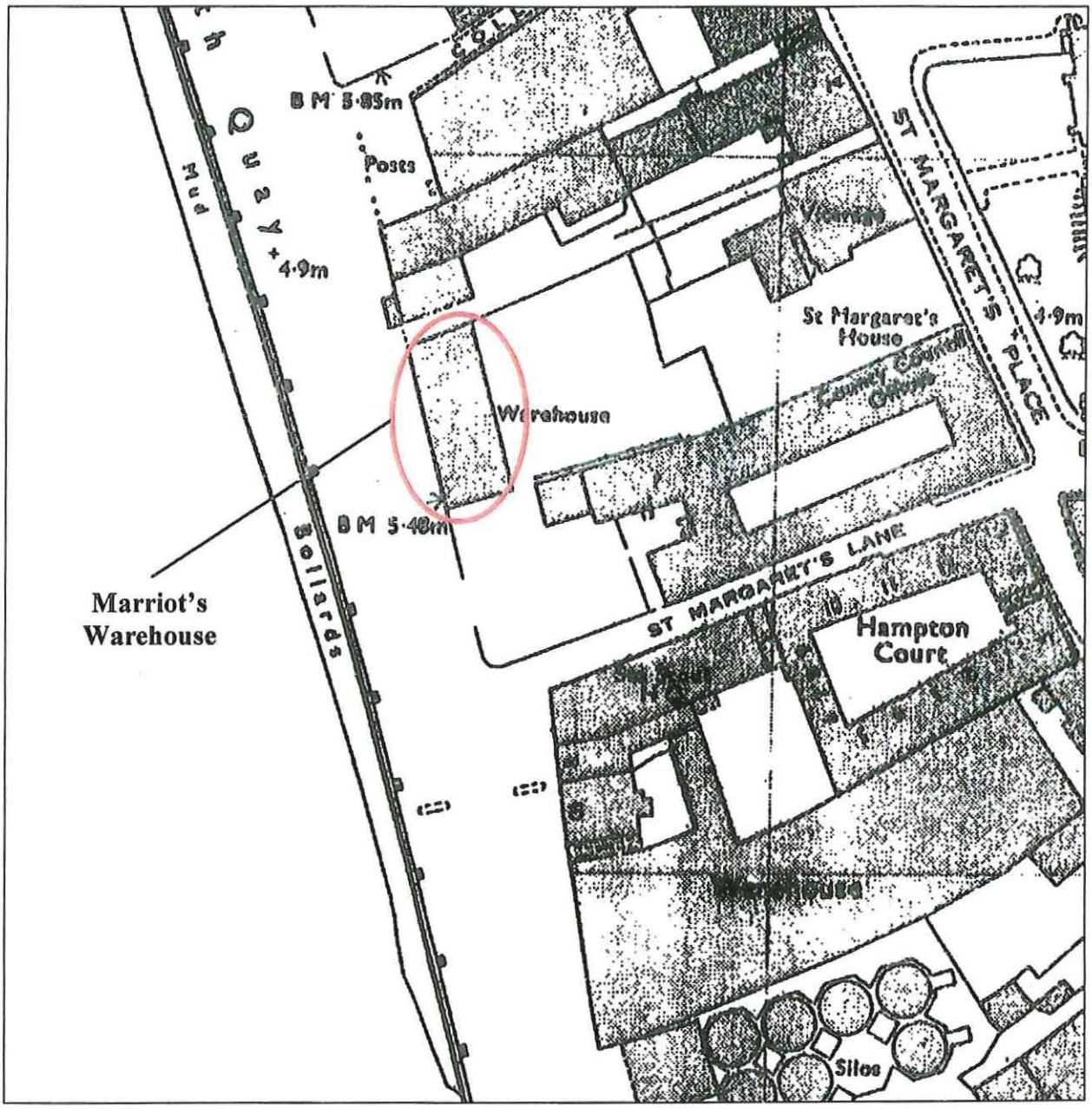


Figure 2 Ground floor plan showing approximate sample locations (after Heywood and Barker 1998, fig 7). The softwood traverse beams are labelled with an 'S', note that only the sampled joists are shown on this diagram.

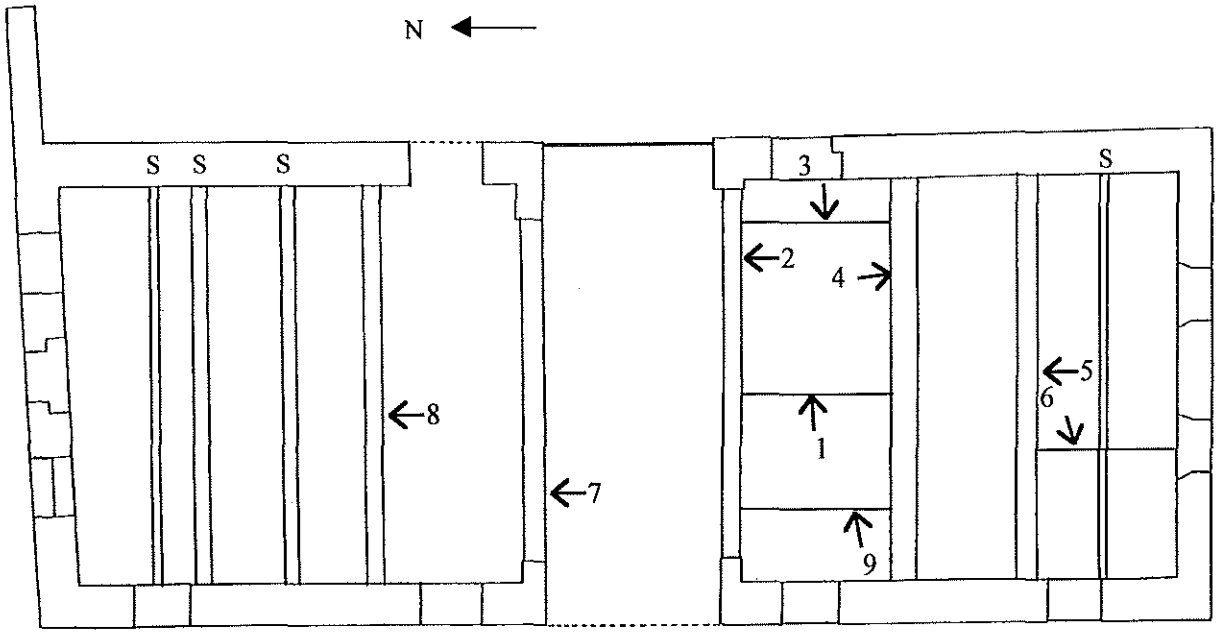


Figure 3 First floor plan showing approximate sample locations (after Heywood and Barker 1998, fig 8). The softwood tiebeams are labelled with an 'S', note that the northernmost beam is the wrong way round and too close to the wall to be accessible for coring.

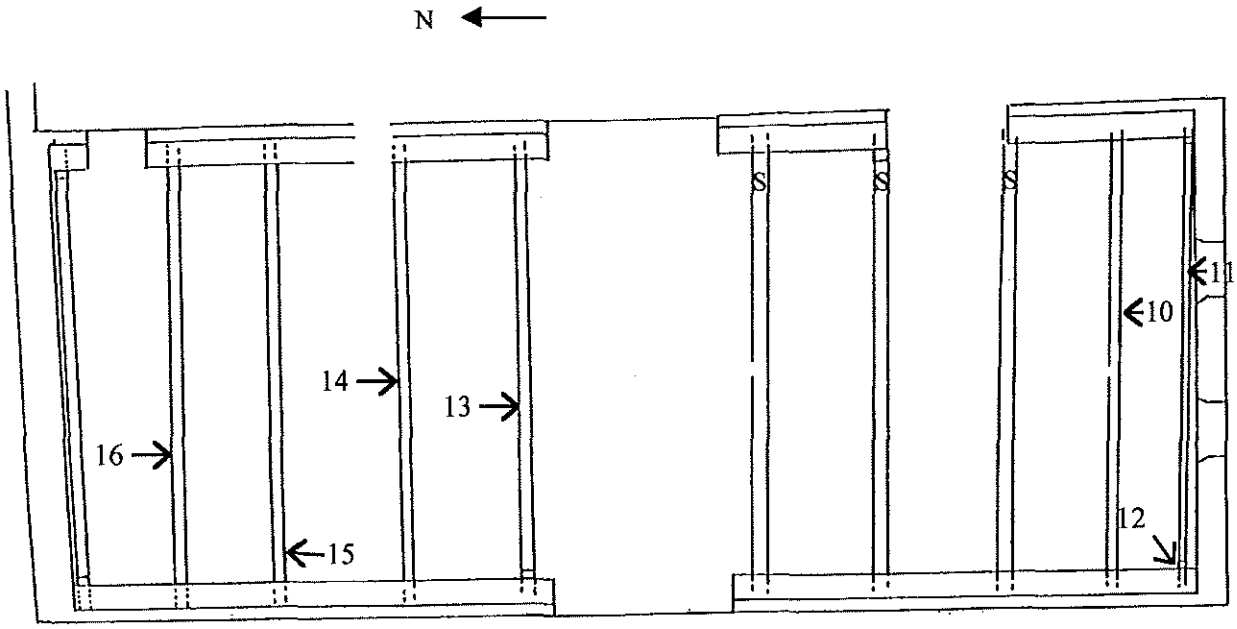
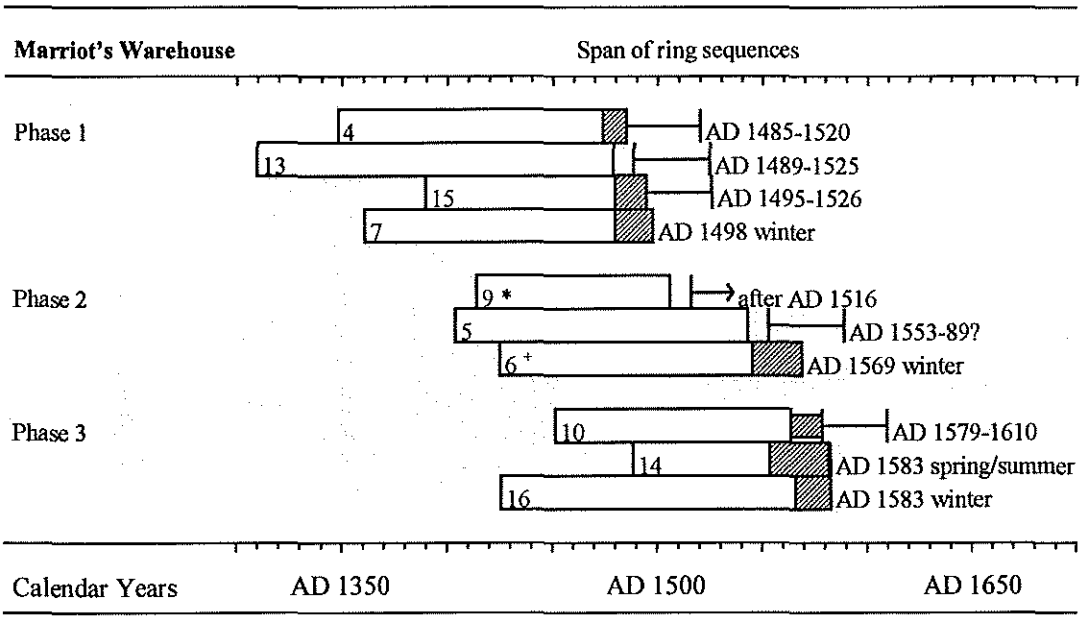


Figure 4 Bar diagram showing the chronological positions of the 10 dated timbers. The felling period for each sequence is also shown



* definitely re-used timber
+ possibly re-used timber

KEY

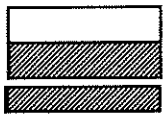


Table 1

List of samples

Core No	Origin of core	Cross-section size (mm)	Cross-section of tree	Total rings	Sapwood rings	ARW mm/year	Date of sequence	Felling period
1	Ground-floor joist – re-used	150 x 145	Quarter	73	h/s	0.97	undated	
2	Ground-floor bridging joist	420 x 405	Whole	60	16+bw	3.93	undated	
3	Ground-floor joist – re-used	150 x 115	Half	*c* 50	-		unmeasured	
4	Ground-floor bridging joist	500 x 500	Whole	138	11	2.14	AD 1348-1485	AD 1485-1520
5	Ground-floor bridging joist	390 x 370	Whole	140	h/s?	1.78	AD 1404-1543	AD 1553-89?
6	Ground-floor joist – possibly re-used	145 x 115	Quarter	145	24+bw	1.14	AD 1425-1569	AD 1569 winter
7	Ground-floor bridging joist	480 x 450	Whole	138	18+bw	1.72	AD 1361-1498	AD 1498 winter
8	Ground-floor bridging joist	380 x 350	Whole	57	12	3.11	undated	
9	Ground-floor joist – re-used	155 x 120	Quarter	93	-	1.76	AD 1414-1506	after AD 1516
10	First-floor tiebeam	370 x 220	Half	113	h/s+15s	1.66	AD 1452-1564	AD 1579-1610
11	First-floor tiebeam	380 x 230	Half	144	h/s?	1.48	undated	
12	First-floor wall post	220 x 110	Half	*c* 25	-		unmeasured	
13	First-floor tiebeam	380 x 250	Quarter	170	h/s	1.89	AD 1310-1479	AD1489-1525
14	First-floor tiebeam	380 x 260	Half	95	29+bs	2.01	AD 1489-1583	AD 1583 spring/summer
15	First-floor tiebeam	380 x 300	Whole	106	15	2.13	AD 1390-1495	AD 1495-1526
16	First-floor tiebeam	360 x 250	Half	158	17+bw	1.81	AD 1426-1583	AD 1583 winter

Total rings = all measured rings.
sapwood rings: h/s heartwood/sapwood boundary, h/s? possible heartwood/sapwood boundary, +bw = winter bark-edge, +bs = spring/summer bark-edge, +(value)s = additional sapwood rings were only counted, the felling period column is calculated using these additional rings..
ARW = average ring width of the measured rings

Table 2

t-value matrix for the timbers forming the chronology MARRIOTS, divided into the three suggested phase groups. KEY: - = *t*-values under 3.0, \ = no overlap

	7	13	15	5	6	9	10	14	16
4	-	-	-	-	-	-	-	\	-
7		3.42	3.05	-	-	-	3.84	\	-
13			3.80	-	-	-	-	\	-
15				-	-	-	-	\	-
5					-	-	3.50	-	3.26
6						5.79	-	-	-
9							-	-	-
10								4.19	11.76
14									4.75

Table 3

t-value matrix for the timbers forming the chronology MARRIOTS against independent reference chronologies, divided into the three suggested phase groups.
KEY: - = *t*-values under 3.0, \ = no overlap

Area	Reference chronology	4	7	13	15	5	6	9	10	14	16
Bedfordshire	Chicksands Priory (Howard *et al* 1998a)	4.48	4.38	5.61	-	-	-	-	3.76	-	3.37
Berkshire	Windsor Kitchen (Hillam forthcoming)	4.41	-	3.56	-	4.35	5.90	6.11	-	3.97	-
Buckinghamshire	Northall (Sheffield Dendrochronology Laboratory unpubl)	4.20	4.04	7.61	3.15	-	-	-	-	\	-
East Midlands	East Midlands (Laxton and Litton 1988)	4.32	5.77	4.13	3.01	4.64	5.60	4.32	5.30	5.33	4.15
Essex	Clacton, Cann Hall (Tyers 1998b)	3.25	3.49	4.44	3.51	-	-	3.33	-	-	-
Essex	Netteswellbury Barn (Tyers 1997b)	4.77	-	4.09	-	-	-	-	\	\	\
Essex/London	Queen Elizabeth's Hunting Lodge (Tyers and Hibberd 1993)	-	-	3.01	-	4.38	3.90	3.86	-	-	-
Gloucestershire	Gloucester, Westgate Street (Howard *et al* 1998b)	4.09	4.30	-	-	4.25	6.86	4.56	3.16	3.50	-
Gloucestershire	Twyning Bellframe (Tyers 1996a)	3.45	-	6.78	-	-	-	-	\	\	-
Hampshire	Alton (Hillam 1978)	3.20	3.36	4.88	-	-	3.77	3.53	-	-	-
Herefordshire	Hereford City Project (Tyers 1996b)	3.03	3.43	4.53	-	4.19	4.62	4.83	3.05	-	-
Kent	Kent (Laxton and Litton 1989)	3.04	3.04	3.74	-	5.33	3.37	4.98	-	-	-
London	Southwark, Hays Wharf (Tyers 1996c and 1996d)	5.10	3.86	6.17	-	6.47	6.06	5.59	3.46	4.62	3.71
London	Sutton House (Tyers 1991)	4.66	-	5.03	-	-	3.95	-	-	-	-
Norfolk	Norwich, Dragon Hall (Boswijk and Tyers 1998)	3.81	-	5.42	-	-	\	\	\	\	\
Staffordshire	Burton-on-Trent, Sinai Park (Tyers 1997c)	3.21	4.49	-	-	3.09	3.85	5.73	4.14	4.66	-
Warwickshire	Astley Castle (Howard *et al* 1997)	\	\	\	\	4.42	4.29	\	3.86	4.67	5.74
Worcestershire	Droitwich, Upwich 3 (Groves and Hillam 1997)	-	3.06	-	-	5.76	4.35	-	4.68	4.56	3.29
Yorkshire	Nostell Priory (Tyers 1998a)	6.36	3.27	3.09	3.22	4.73	3.99	3.70	4.97	4.38	3.76

Table 4

Dating the mean sequence MARRIOTS, AD 1310-1583 inclusive. *t*-values with independent reference chronologies

Area	Reference chronology	*t*-values
Bedfordshire	Chicksands Priory (Howard *et al* 1998a)	8.19
Berkshire	Windsor Kitchen (Hillam forthcoming)	7.29
Buckinghamshire	Northall (Sheffield Dendrochronology Laboratory unpubl)	7.39
East Midlands	East Midlands (Laxton and Litton 1988)	9.40
Essex	Clacton, Cann Hall (Tyers 1998b)	6.31
Essex	Netteswellbury Barn (Tyers 1997b)	5.32
Essex/London	Queen Elizabeth's Hunting Lodge (Tyers and Hibberd 1993)	5.94
Gloucestershire	Gloucester, Westgate Street (Howard *et al* 1998b)	6.78
Gloucestershire	Twyning Bellframe (Tyers 1996a)	6.44
Hampshire	Alton (Hillam 1978)	4.85
Herefordshire	Hereford City Project (Tyers 1996b)	6.51
Kent	Kent (Laxton and Litton 1989)	6.66
London	Southwark, Hays Wharf (Tyers 1996c and 1996d)	10.41
London	Sutton House (Tyers 1991)	5.56
Norfolk	Norwich, Dragon Hall (Boswijk and Tyers 1998)	6.70
Staffordshire	Burton-on-Trent, Sinai Park (Tyers 1997c)	5.45
Warwickshire	Astley Castle (Howard *et al* 1997)	6.90
Worcestershire	Droitwich, Upwich 3 (Groves and Hillam 1997)	7.14
Yorkshire	Nostell Priory (Tyers 1998a)	6.81

Table 5

Ring-width data from site master MARRIOTS, dated AD 1310-1583 inclusive

Date	Ring widths (0.01mm)										No of samples									
AD 1310										203										1
	167	261	355	518	661	702	347	212	317	264	1	1	1	1	1	1	1	1	1	1
	279	182	127	150	179	145	160	296	203	145	1	1	1	1	1	1	1	1	1	1
	150	139	168	282	314	251	217	168	207	224	1	1	1	1	1	1	1	1	1	1
	165	120	111	129	188	164	163	135	172	162	1	1	1	1	1	1	1	2	2	2
AD 1351	376	326	322	297	229	205	167	128	165	198	2	2	2	2	2	2	2	2	2	2
	150	226	205	232	175	160	167	181	228	195	3	3	3	3	3	3	3	3	3	3
	163	178	159	230	224	272	224	188	201	233	3	3	3	3	3	3	3	3	3	3
	263	321	261	197	261	254	328	300	261	240	3	3	3	3	3	3	3	3	3	4
	230	179	235	251	242	257	192	218	203	237	4	4	4	4	4	4	4	4	4	4
AD 1401	215	242	250	264	241	234	232	249	248	251	4	4	4	5	5	5	5	5	5	5
	268	242	203	151	150	153	154	236	194	256	5	5	5	6	6	6	6	6	6	6
	219	182	238	231	193	175	172	222	261	193	6	6	6	6	7	8	8	8	8	8
	235	252	182	190	198	197	188	186	160	179	8	8	8	8	8	8	8	8	8	8
	164	153	212	176	149	179	183	166	181	175	8	8	8	8	8	8	8	8	8	8
AD 1451	164	206	198	158	150	167	151	141	131	142	8	9	9	9	9	9	9	9	9	9
	155	135	144	142	146	133	145	155	153	179	9	9	9	9	9	9	9	9	9	9
	139	128	126	132	134	129	114	129	148	158	9	9	9	9	9	9	9	9	9	8
	171	153	151	158	128	142	172	163	151	150	8	8	8	8	8	7	7	7	8	8
	127	122	143	156	170	192	148	131	166	183	8	8	8	8	8	7	7	7	6	6
AD 1501	156	196	190	208	179	214	182	141	169	146	6	6	6	6	6	6	5	5	5	5
	168	203	175	173	141	163	134	233	208	148	5	5	5	5	5	5	5	5	5	5
	149	205	184	180	155	169	204	184	141	135	5	5	5	5	5	5	5	5	5	5
	208	192	168	177	179	173	151	153	178	173	5	5	5	5	5	5	5	5	5	5
	149	101	108	121	136	138	122	134	180	166	5	5	5	4	4	4	4	4	4	4
AD 1551	185	149	175	151	193	175	157	124	162	152	4	4	4	4	4	4	4	4	4	4
	147	170	165	179	179	192	180	175	196	222	4	4	4	4	3	3	3	3	3	2
	225	176	149	148	148	125	134	147	126	173	2	2	2	2	2	2	2	2	2	2
	97	118	182								2	2	1							