Centre for Archaeology Report 79/2004

Tree-Ring Analysis of Timbers from the Hall Roof, West Gateway, and Gates at Fulham Palace, London Borough of Hammersmith and Fulham

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ISSN 1473-9224

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Tree-Ring Analysis of Timbers from the Hall Roof, West Gateway, and Gates at Fulham Palace, London Borough of Hammersmith and Fulham

Dr Martin Bridge[1] and Daniel Miles[2]

Summary

Many of the major structural timbers of the hall roof, including principal rafters and ties, were found to be of elm (*Ulmus* spp.). Amongst the oak timbers, two collars dated, one retaining complete sapwood, being felled in spring AD 1493, making the likely construction date about a decade earlier than was previously thought. The major timbers in the gateway were also sampled and five of these dated, one retaining complete sapwood being felled in spring AD 1495, showing that this range is probably part of the same campaign of building as the hall. The gates within this gateway have been considered as possibly incorporating twelfth-century work. This study however found no evidence for any alterations to the gates, and dated five of the seven boards sampled against Baltic chronologies, finding them to be contemporaneous with the gateway, and thus primary Tudor work.

Keywords

Dendrochronology
Standing Building

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Introduction

Fulham Palace (NGR TQ 241 762; Fig 1) is a former palace of the bishops of London. The building (Fig 2) is aligned north-west to south-east, but these have been nominally referred to as west to east throughout this report, with the main gateway being the west gate. The Great Hall and service rooms are thought to have been built between AD 1506-22 for Bishop Fitzjames. The hall roof is of four bays, and was originally extended by at least one further bay. The purlins have tenons with soffit spurs and there is a double row of windbraces. The elbowed canting struts were secured by free tenons.

The Tudor gateway on the west side of the west courtyard contains heavy oak gates thought possibly to incorporate twelfth- or thirteenth-century work. One of the reasons given for this early date appears to be the use of lap-jointed canted ledges. The gate leaves consist of a top, bottom, and moulded mid-rail into which muntins are jointed which have a deep hollow chamfer on the outside face (Fig 8). Each leaf has ten panels of fine-grained oak, five above and five below the mid-rail. The panels are flat on the back, but have a raised, slightly concave, bevel on the outer face, typical of the later Tudor period. The meeting stiles have a large half-round projecting tongue on the north meeting stile which fits into a corresponding hollow on the south leaf when closed together, creating an effective weatherseal. The design and execution of the gates are extremely sophisticated, and clearly reflected the high status of the bishopric of London.

Several other phases of later work are also found within the complex. English Heritage commissioned the present study of the hall roof, gateway, and gates as part of a multi-disciplinary interpretation project being carried out along with a Heritage Lottery funded restoration project.

Methodology

The site was visited in June 2004. Oak timbers with more than 50 rings, traces of sapwood, and accessibility were the main considerations in the initial assessment. Those building timbers judged to be potentially useful were cored using a 15mm auger attached to an electric drill. The cores were glued to wooden laths, labelled, and stored for subsequent analysis. The panels of the gates were sampled using a technique specially developed for such situations. A jig guide was mounted on the door allowing the long borer to be kept in a straight line through the middle of the board. The borer was operated by an electric drill, and was kept cool and clear of dust by the injection of compressed air along the shaft during coring. The resulting core was approximately 5mm in diameter, leaving a hole of slightly larger diameter, which was plugged and stained to match the surrounding wood characteristics.

The cores were prepared for measuring by sanding using an electric belt-sander with progressively finer grit papers down to 1000 grit. Any further preparation necessary, eg where bands of narrow rings occurred, was done manually. Suitable samples had their tree-ring sequences measured to an accuracy of 0.01 mm 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. Ring sequences were plotted to allow visual comparisons to be made between sequences on a light table. This activity also acts as a measure of quality control in identifying any errors in the measurements when the samples crossmatch.

In comparing one sequence or site sequence against another, *t*-values over 3.5 are considered significant, although in reality it is common to find *t*-values of 4 and 5 which are demonstrably spurious because more than one matching position is indicated. For this reason, it is necessary to obtain some *t*-values of 5, 6, and higher, and for these to be well replicated from different, independent chronologies and with local and regional chronologies well represented. Where two individual sequences match with a *t*-value of 10 or above, and visually exhibit exceptionally similar ring patterns, they most likely came from the same parent tree. Same-tree matches can also sometimes be identified through the external characteristics of the timber itself, such as knots and shake patterns.

For this report cross-matching and dating was accomplished by using a combination of both visual matching and a process of qualified statistical comparison by computer. The ring-width series were compared on an IBM compatible computer for statistical cross-matching using a variant of the Belfast CROS program (Baillie and Pilcher 1973). Two programs were used in the analysis – one by Ian Tyers (1999), as well as a version of the Belfast CROS program written in BASIC by D Haddon-Reece, and latterly re-written in Microsoft Visual Basic by M R Allwright and P A Parker.

When cross-matching between samples is found, their ring-width sequences are averaged to form an internal 'working' site mean sequence. Other samples may then be incorporated after comparison with this 'working' master until a final site sequence is established. This is then compared with a number of reference chronologies (multi-site chronologies from a region) and dated individual site masters in an attempt to date it. Individual long series which are not included in the site mean(s) are also compared with the database to see if they can be dated.

The dates thus obtained represent the time of formation of the rings available on each sample. Interpretation of these dates then has to be undertaken to relate these findings to the construction date of the phase under investigation. An important aspect of this interpretation is the estimate of the number of sapwood rings missing. The building timbers used in the hall roof and the gateway used the sapwood estimates based on those proposed for this area by Miles (1997), where 95% of oaks contain 9 – 41 rings, whilst the sapwood estimate applied to Baltic timbers is 8-24 (Tyers 1998). Where complete sapwood or bark is present on the sample the exact date of felling of the tree used may be determined.

The dates derived for the felling of the trees used in construction do not necessarily relate directly to the date of construction of the building. However, evidence suggests that, except in the re-use of timbers, construction in most historical periods took place within a very few years after felling (Salzman 1952; Hollstein 1965).

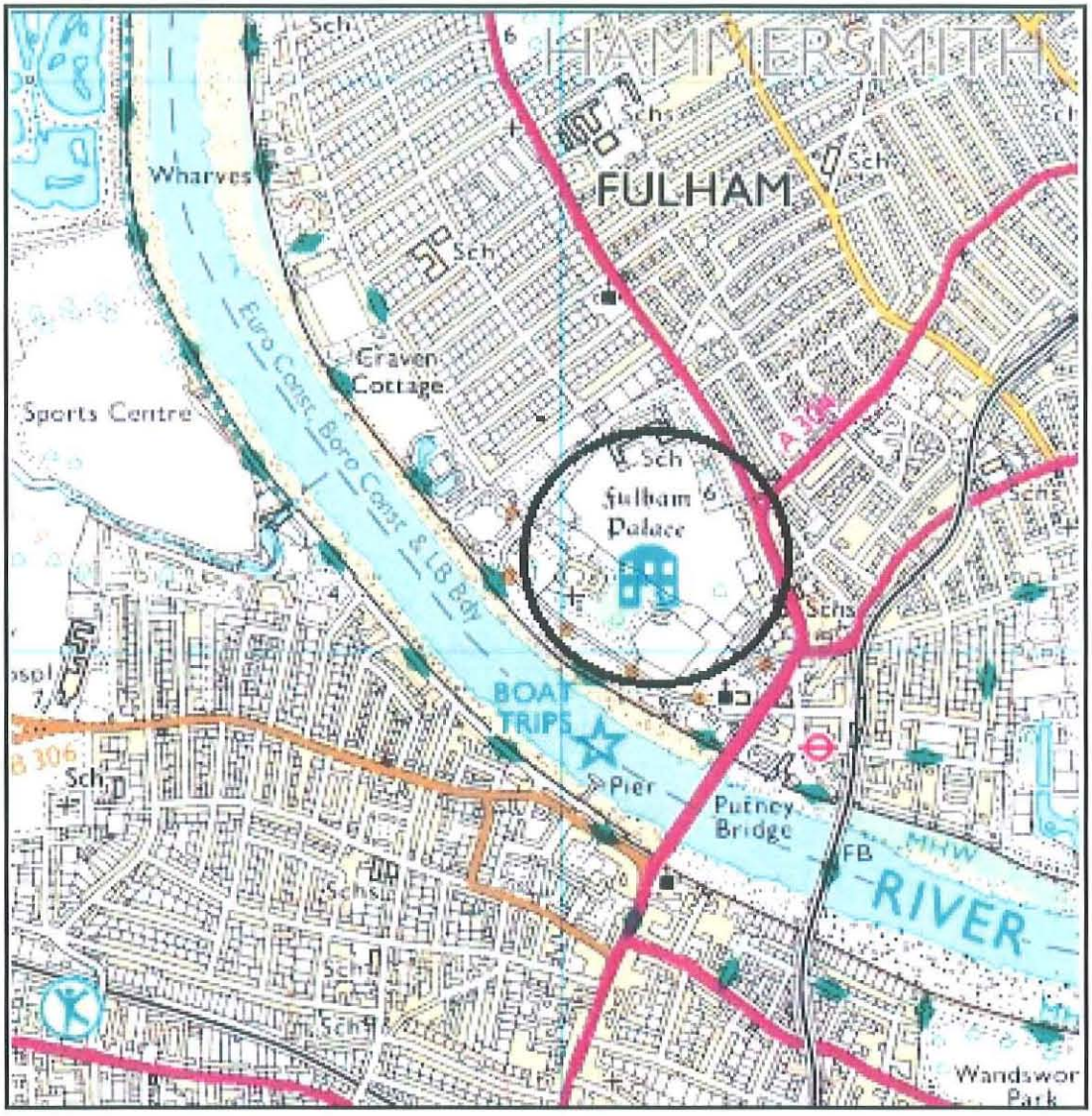

Figure 1:

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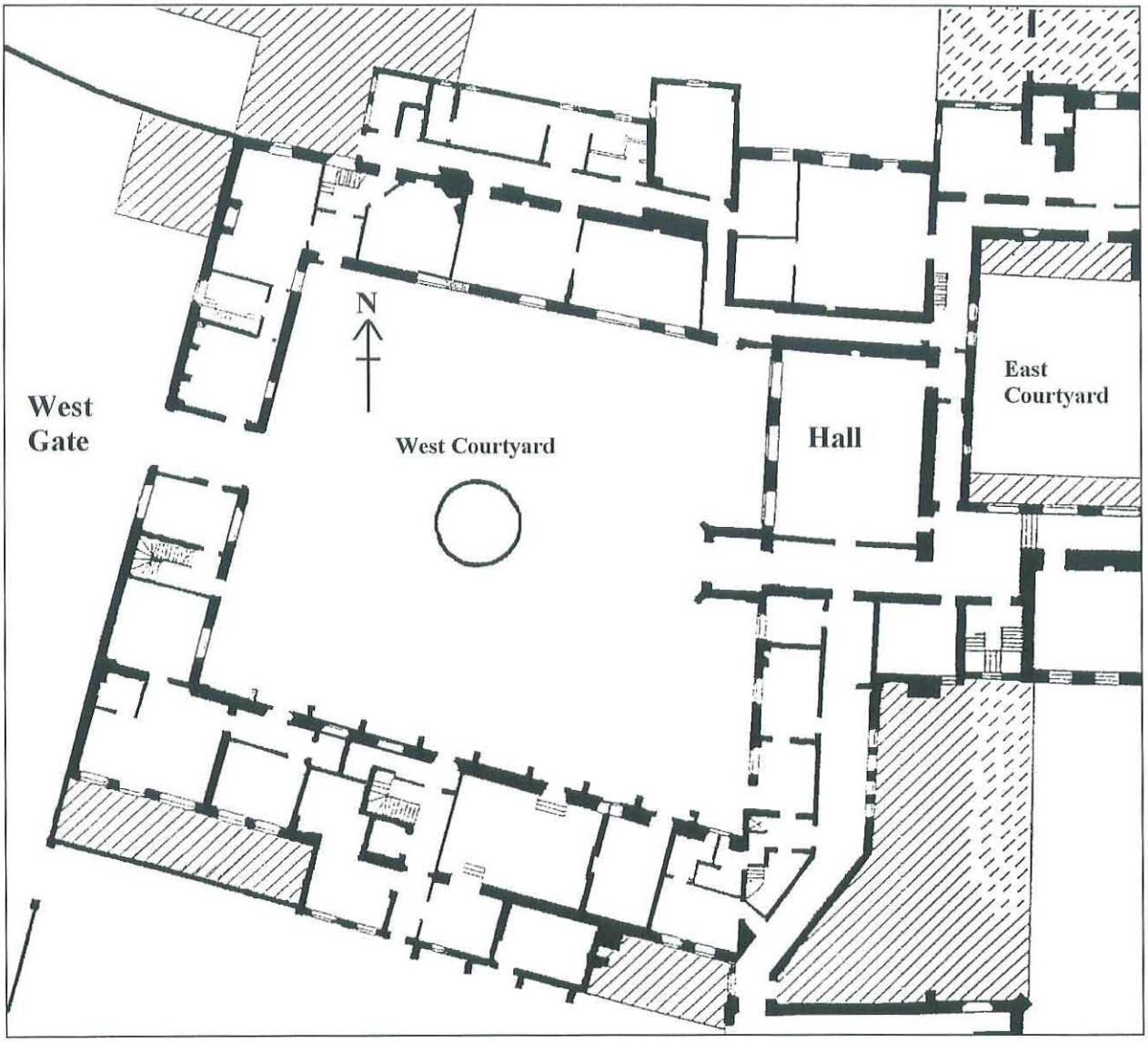

Figure 2: Plan of the north-west section of Fulham Palace showing the location of the Hall and the West Gate discussed in this report

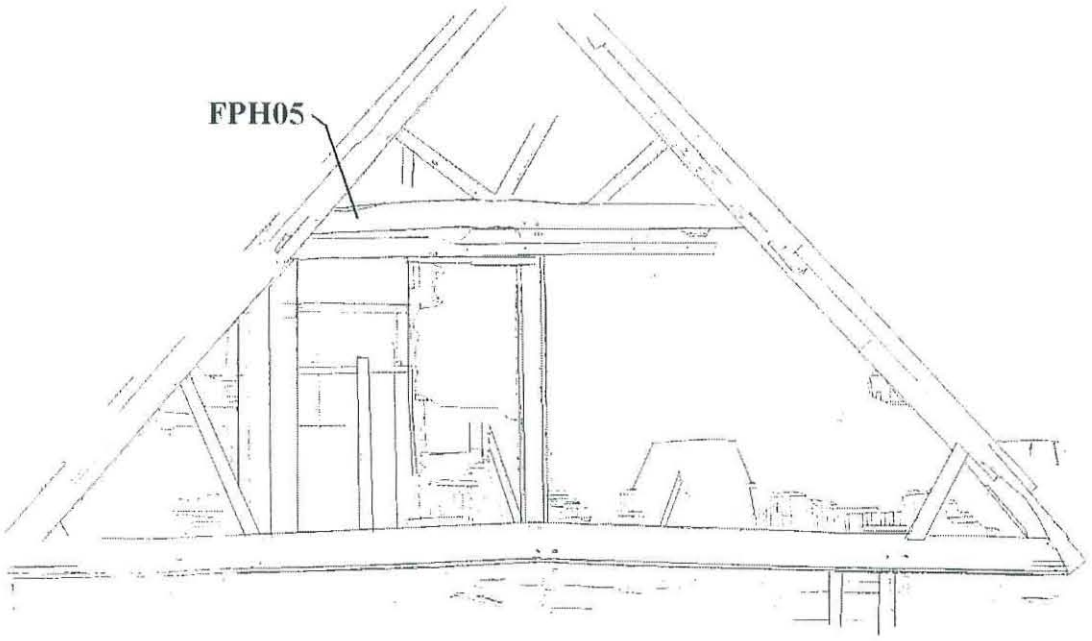

Figure 3: The north gable end (truss 4) showing the location of sample **FPH05** (adapted from an original drawing by Engineering Surveys Ltd)

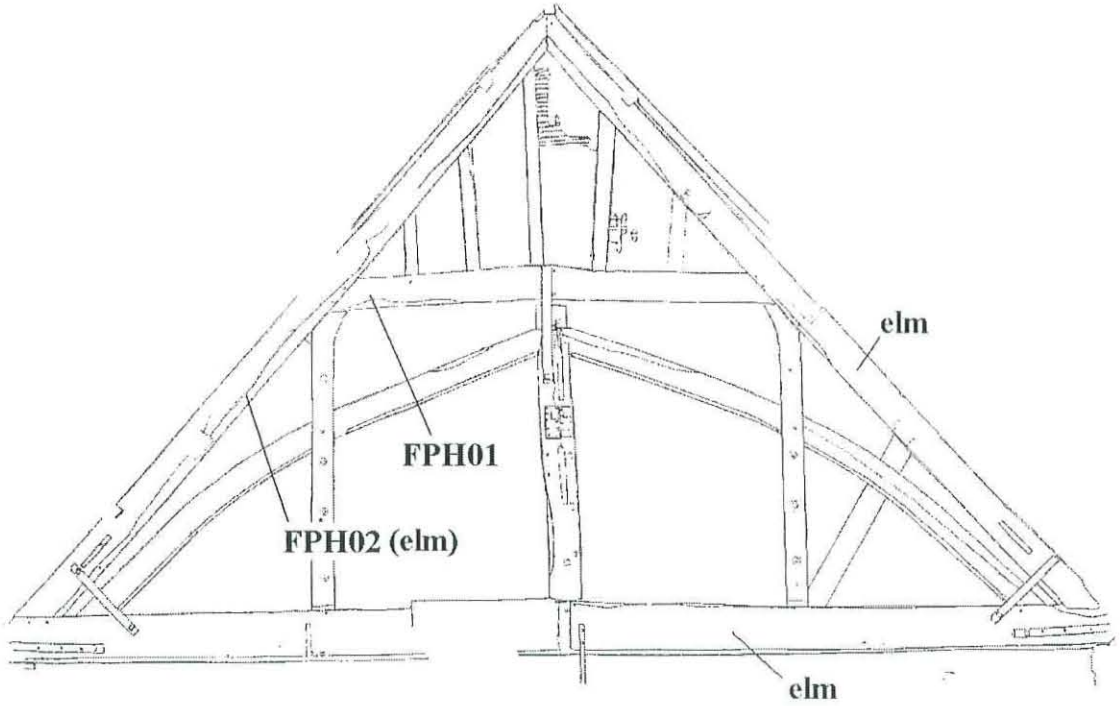

Figure 4: Truss 2 (central truss) showing the location of samples **FPH01** and **FPH02** (adapted from an original drawing by Engineering Surveys Ltd)

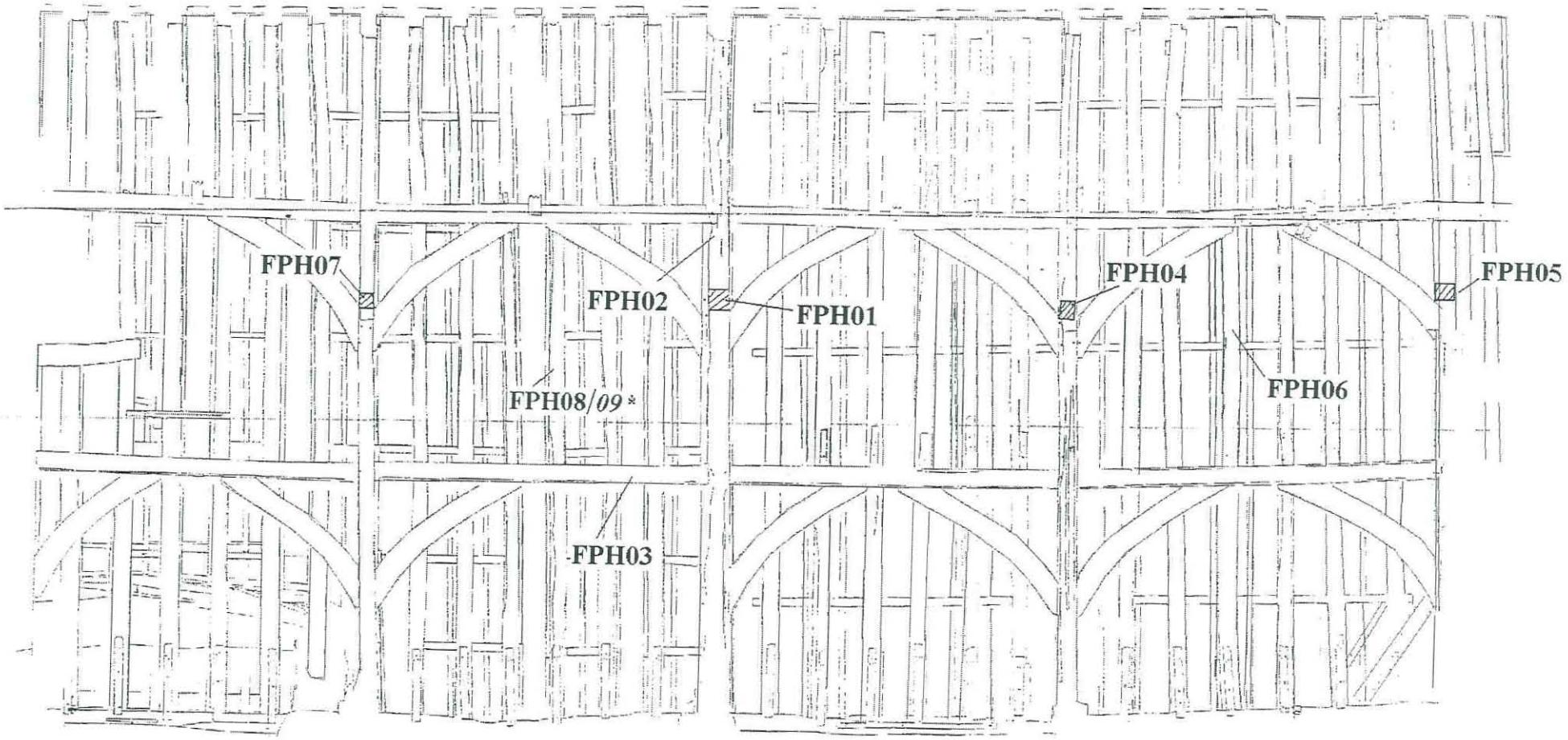

Figure 5: Drawing of the west side of the hall roof, Fulham Palace, showing the locations of the dendrochronological samples, the starred sample in italics being from the equivalent rafter on the east side of the roof (adapted from an original drawing by Engineering Surveys Ltd)

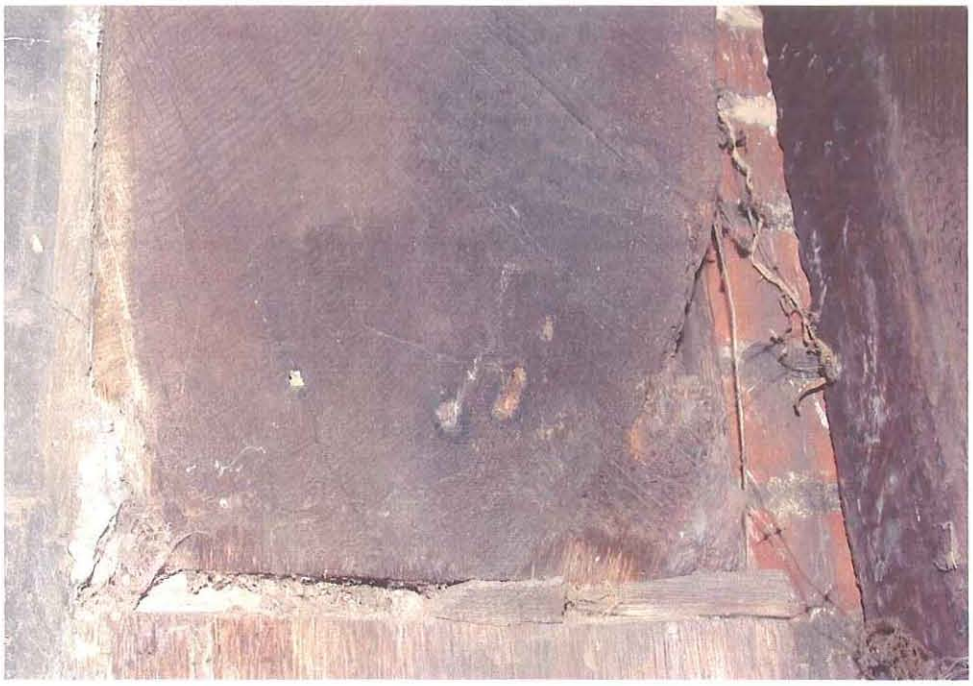

Figure 6: Photograph of the doorhead (**FPG06**) with complete sapwood

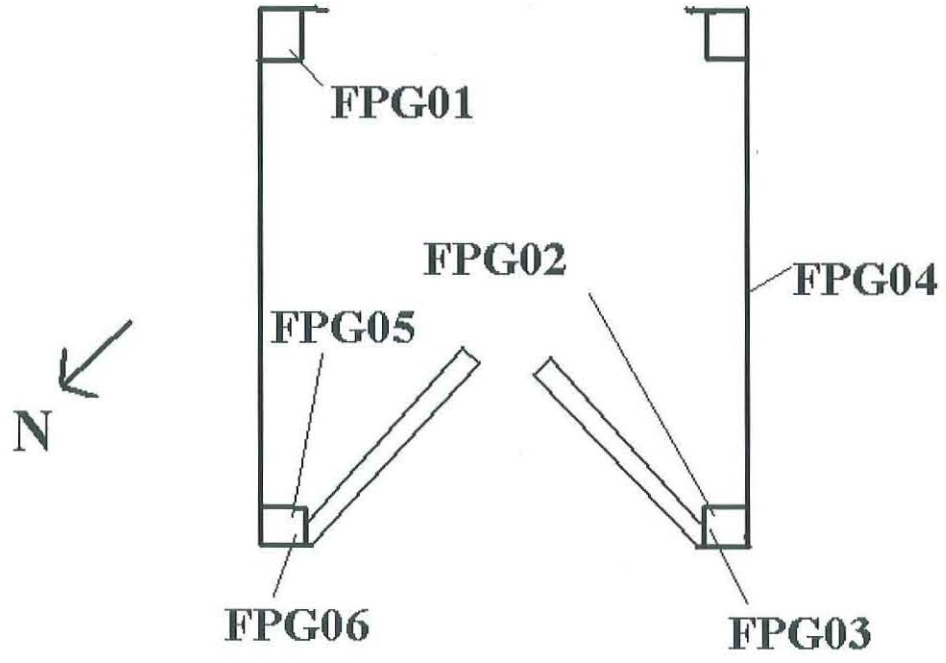

Figure 7: Sketch plan of the gateway (not to scale) showing the approximate locations of the timbers sampled for dendrochronology

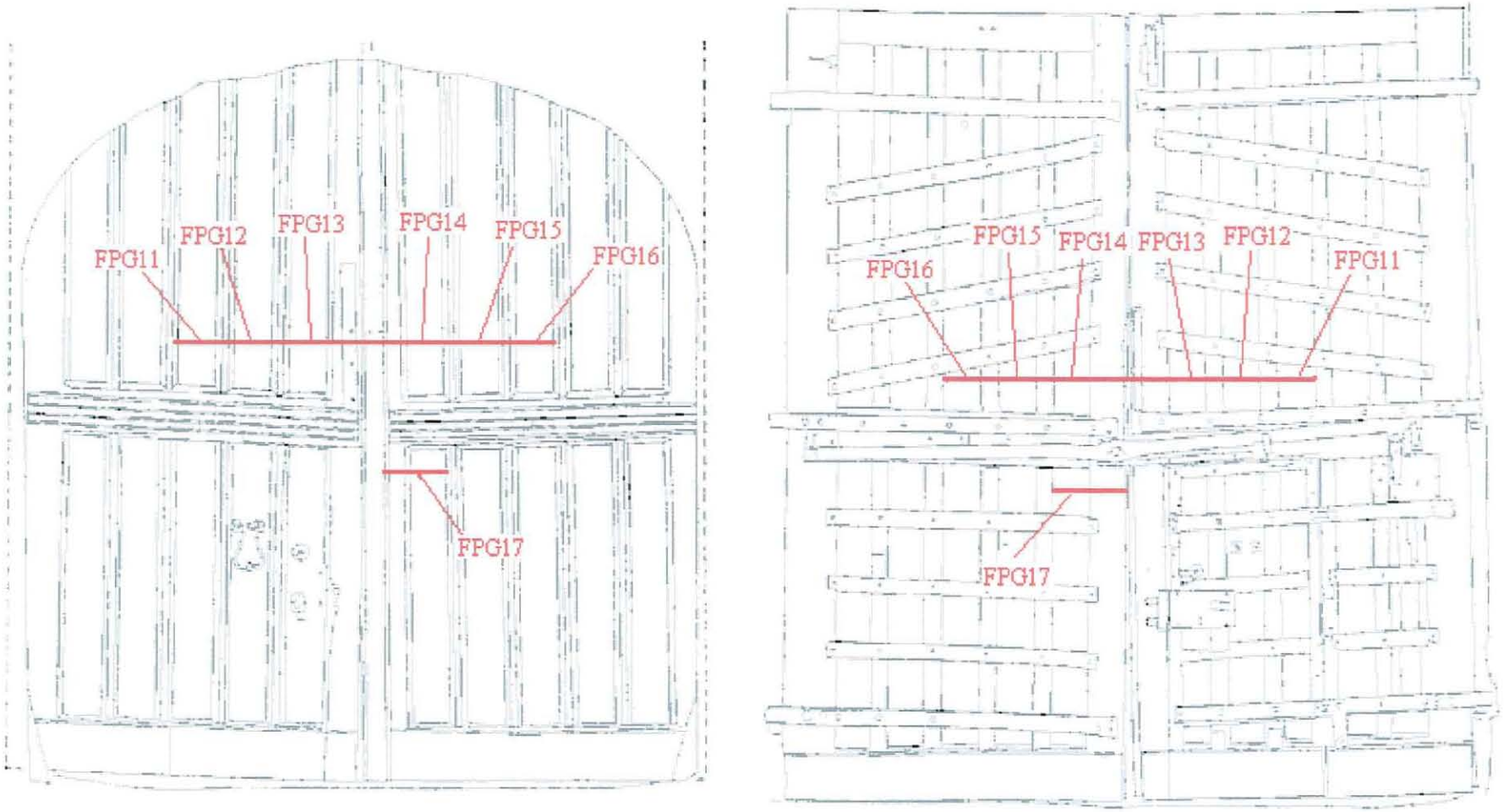

Figure 8: Photogrammetrically-generated elevations of the front or west face (left) and rear or east face (right) of the gates, showing line of sampling in

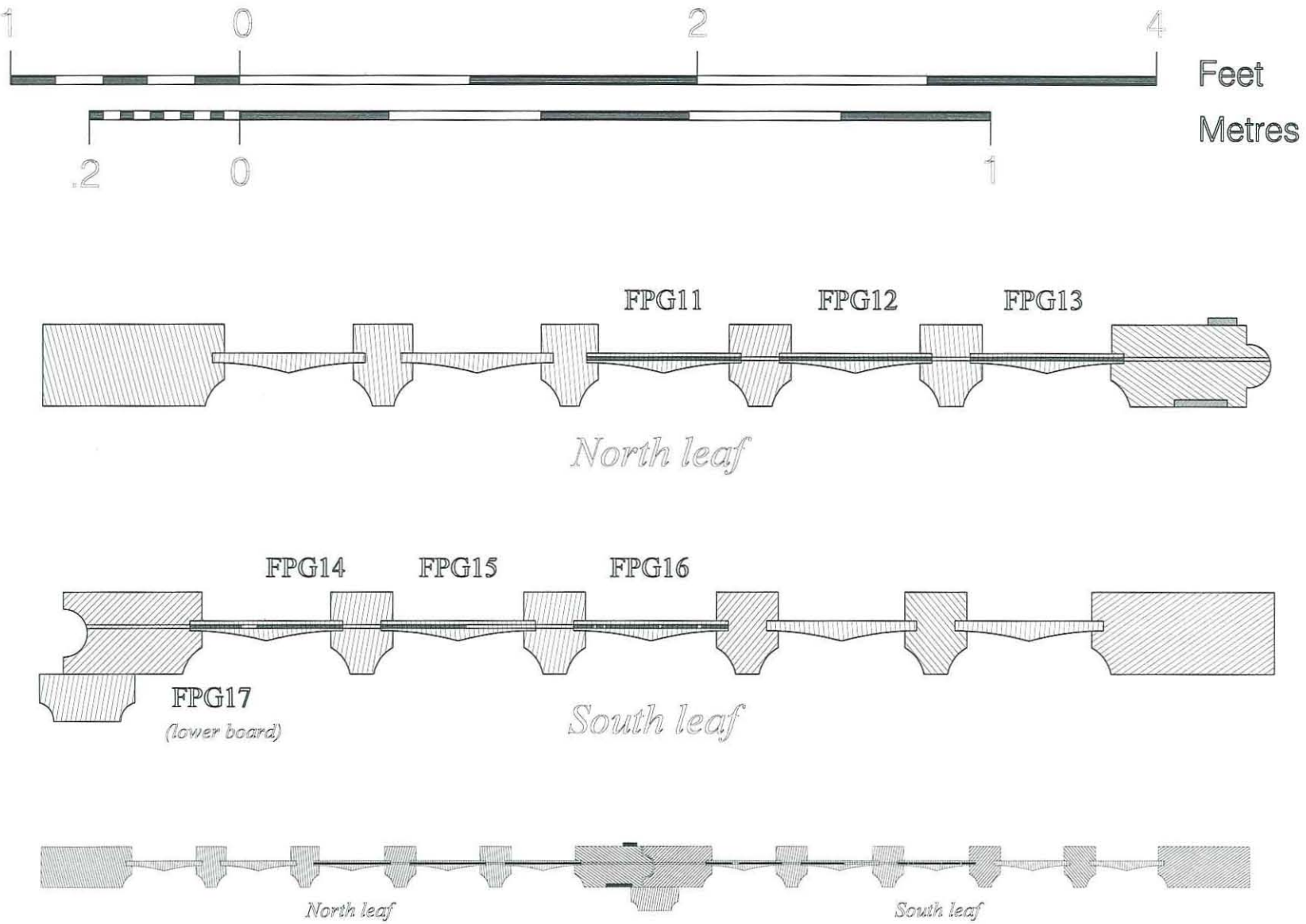

Figure 9: Drawing of the gates, showing the locations of the cores extracted

Sampling

All of the samples, with one exception, were of oak (*Quercus* spp.). Sample **FPH02**, from the principal rafter of the central truss in the hall roof, however, was found to be of elm (*Ulmus* spp.). Close inspection of the timbers revealed that the other principal rafters and the tie beams were also of elm. Most of the common rafters were judged to have too few rings to make them worthy of coring, and the number of oak timbers suitable for dating in the hall roof was therefore limited.

In the gateway, the sampling brief requested that the wall framing of the gate passage was also sampled in addition to the gate posts and of course the gates themselves. Only a few timber members were exposed on the south side of the gate passage. Whilst they might have sufficient numbers of rings for dating, they were of halved timbers orientated so that the sapwood was on the south side of the timber. This side had been incorporated in contemporary Tudor brickwork which thickened beyond the point of the gate swing, forming a recess for the gate to open flush with the rest of the passage wall. The room to the south of the gateway was inspected, but apart from an axial ceiling beam, no other primary phase timbers were exposed.

Nevertheless, the gate posts appeared to have reasonable ring counts and some evidence of sapwood. The spandrel to the north-west gate post (**FPG06**; Fig 6) had both complete sapwood and bark, but as it was close to the shoulder where tenoned into the side of the post, there was little material to core, necessitating several core samples.

Locations of the samples are shown in Figures 3 – 7, and described, along with other basic information, in Table 1.

The gates were also assessed for dating potential. The framework of the gates, consisting of stiles, rails, and moulded muntins (Fig 8), were all of medium to fast grown oak without any evidence for sapwood, making them unsuitable for dating purposes. However, the bevelled boards themselves were eminently suitable, consisting of very clean, slow-grown oak which immediately suggested a likely Baltic origin. The obvious difficulty would be in obtaining samples as the edges and ends of the boards are contained in grooves of the moulded muntins and mid-rail. However, by using the micro-borer, it was possible to drill through the meeting stile into then through the first board. By continuing the same bore hole, it was possible to sample a further two boards by drilling through the intervening stiles as shown in Figure 9. Thus three boards were sampled from the north gate leaf above the mid-rail, and three more boards were similarly sampled on the south gate leaf. An attempt was made to sample the lower tier of boards just within the lower rebate of the mid-rail, but this was abandoned when it was found that the boards had virtually slipped out of the rebate over the course of time. Details of the samples from the gate are detailed in Table 2 and in Figures 8 and 9.

Results

The first stage of the analysis was to compare all ring sequences from the site and through the similarity of the growth rings, identify and combine any timbers which had originated from the same parent tree. Following this matching trees were combined to form site chronologies.

From the gateway, the spandrel to the north-west gate post (**FPG06**) was cored three times. These series from the same timber were compared visually (Figure 10), the *t*-test not being applicable for short sequences. A section of complete sapwood had become detached during coring (**FPG06c3**), however the break with the adjacent segment (**FPG06c2**) was a clean one. As there was no actual overlap to confirm that there were no rings missing between the two segments, comparisons with similar reference chronologies confirmed that the outermost section was correctly positioned. Therefore this, along with the other five dated segments, were combined to form the mean **FPG06**.

Table 3 shows the cross-matching between dated sequences from the hall roof and the gateway. Whilst the internal cross-matching is not very strong, the series were dated individually with the reference chronologies as a check, the best results for each timber being shown in Table 4. These series were combined to form the site master **FULHAM1**.

Many of the shorter sections from the boards in the gates were cross-matched visually. The strong matches between **FPG12a1**, **FPG12a2**, and **FPG14** (Table 5) suggests that they are from the same tree, and these sequences were combined to form a single sequence **FPG1214**. This mean was then compared with the other sequences and were found to match as shown in Table 6. These were then combined to form the mean **FULHAM2** ,comprising **FPG11**, **FPG13a2**, **FPG1516**, and **FPG1214**. Some segments did not date, primarily due to them having insufficient rings or overlaps.

The two site chronologies **FULHAM1**, containing the dated series from the hall roof and gateway, and **FULHAM2**, the boards from the gates, were then dated by comparison with the available reference datasets, the best matches being shown in Tables 7 and 8 respectively. **FULHAM1** was found to cover the period AD 1356 – 1494, and **FULHAM2** AD 1319 – 1484.

Figures 11 and 12 are bar diagrams showing the relative positions of overlap of the dated timbers in the two site chronologies, along with the interpreted likely felling dates for the individual timbers. The data for the site chronologies are given in Table 9.

Table 1: Details of Oak (*Quercus* spp.) and Elm (*Ulmus* spp.) timbers sampled from Fulham Palace

Sample Number	Timber and position	No of rings	Mean width (mm)	Mean sens (mm)	Dates AD Spanning	H/S bdry AD	Sapwood complement	Felling seasons and dates/date ranges (AD)
Hall Roof								
FPH01	Collar, truss 2	120	1.32	0.22	1367 – 1486	1473	13	1486 - 1514
FPH02 *ELM*	W principal rafter, truss 2	nm	nm	nm	undated	-	-	unknown
FPH03	West lower purlin, bay 1-2	39	nm	nm	undated	-	-	unknown
FPH04	Collar, truss 3	107	1.13	0.21	undated	-	11	unknown
FPH05	Collar, truss 4	119	1.27	0.19	1374 - 1492	1480	12¼C	spring 1493
FPH06	Rafter 3 west, bay 3-4	<40	nm	nm	undated	-	-	unknown
FPH07	Collar, truss 1	101	1.70	0.26	undated	-	2	unknown
FPH08	Rafter 4 west, bay 1-2	50	1.94	0.24	undated	-	h/s	unknown
FPH09	Rafter 4 east, bay 1-2	51	1.45	0.22	undated	-	h/s	unknown
FPG01	North (inner) door post	71	1.83	0.21	1393 - 1463	1463	h/s	1472 - 1504
FPG02	South (outer) door post	99	1.99	0.21	1375 - 1473	1473	h/s	1482 - 1514
FPG03	South spandrel to inner door-head	69	1.42	0.18	1402 - 70	1470	h/s	1479 - 1501
FPG04	Brace on south wall	<40	nm	nm	undated	-	-	unknown
FPG05	North (outer) door post	67	2.29	0.20	1402 - 68	1468	h/s (+11 nm)	1479 - 1509
FPG06	North spandrel to outer door-head	139	1.29	0.13	1356 - 1494	1473	21¼C	spring 1495

Key: ¼C = complete sap with spring vessels of the next year present; h/s bdry = heartwood/sapwood boundary - last heartwood ring date; mean sens = mean sensitivity; nm = not measured. Sapwood estimate of 9-41 used (Miles 1997)

Table 2: Details of Baltic oak boards from the west gates, Fulham Palace

Sample Number	Timber and position	No of rings	Mean Width (mm)	Mean sens (mm)	Dates AD spanning	H/S bdry AD	Sapwood complement	Felling seasons and dates/date ranges (AD)
Gate leaves								
FPG11	Board 1 north leaf	131	1.39	0.15	1342 - 1472	1459	13 (+1nm)	1474 - 83
FPG12a1	Board 2 north leaf	77	1.42	0.16	1353 - 1429	-	-	
FPG12a2	ditto	53	1.47	0.17	1432 - 1484	1480	4 (+1nm)	1489 - 1504
FPG13a1	Board 3 north leaf	15	1.56	0.22	-	-	-	-
FPG13a2	ditto	151	1.11	0.17	1319 - 1469	-	-	after 1477
FPG14	Board 4 south leaf	80 (+1nm)	1.41	0.15	1401 - 1480	-	-	(1489 - 1504)
FPG15a1	Board 5 south leaf	23	1.27	0.23		-	-	
FPG15a2	ditto	60 (+1nm)	1.26	0.22	1381 - 1440	-	-	after 1449
FPG16a1	Board 6 south leaf	26	0.96	0.19	-	-	-	
FPG16a2	ditto	32	1.18	0.22	-	-	-	
FPG16a3	ditto	39	1.33	0.22	-	-	-	
FPG16a4	ditto	9	1.42	0.13	-	-	-	
FPG16a5	ditto	33 (+1nm)	1.00	0.21	-	-	-	
FPG17	Board 7 south leaf	47 (+1nm)	1.18	0.23	-	-	-	
FPG1214	**12a1 + 12a2 + 14**	*132*	*1.44*	*0.16*	*1353 - 1484*			*1489 - 1504*

Key: h/s bdry = heartwood/sapwood boundary - last heartwood ring date; mean sens = mean sensitivity; nm = not measured. Sapwood estimate of 8-24 used (Tyers 1998)

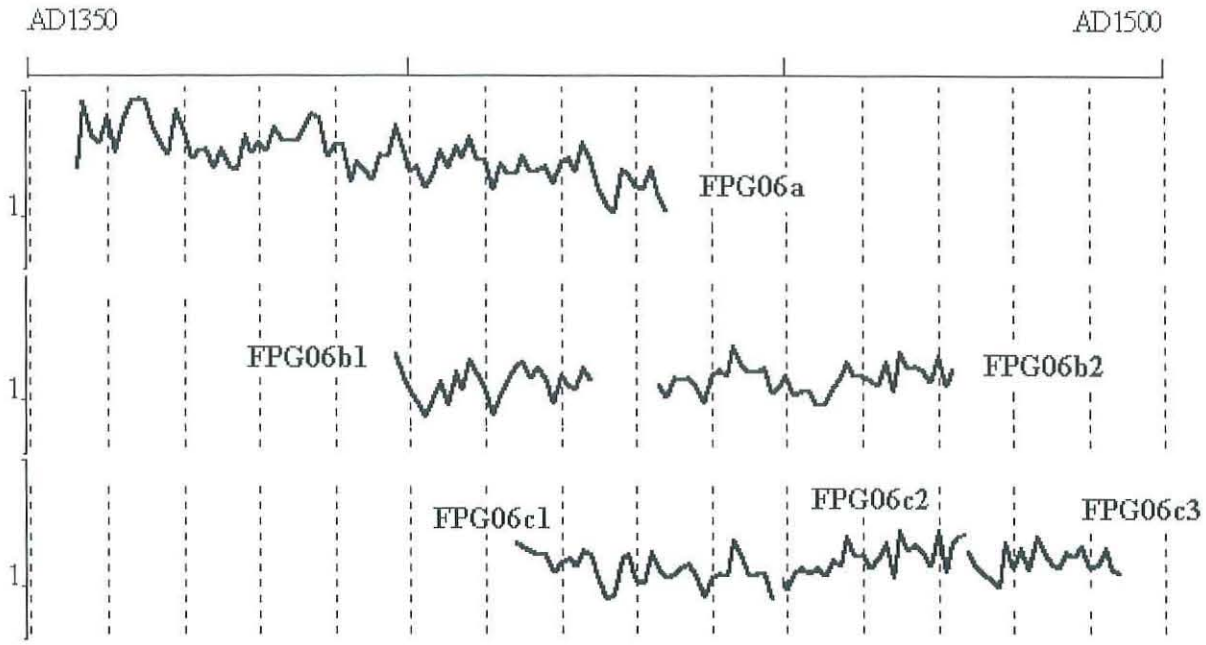

Figure 10: Plots of the individual components of FPG06, showing how these pieces from the same tree were matched together into a single series. The *y*-axis is a logarithmic scale of ring width in millimetres

Table 3: Matrix of *t* -values and overlaps for components of **FULHAM1** from the hall roof and west gateway

Sample:	**FPH05**	**FPG01**	**FPG02**	**FPG03**	**FPG05**	**FPG06**
Last ring date AD:	1492	1463	1473	1470	1468	1494
FPH01	3.1 / 113	3.8 / 71	3.4 / 99	4.3 / 69	2.0 / 67	3.6 / 120
	FPH05	2.5 / 71	2.0 / 99	3.4 / 69	3.4 / 67	4.0 / 119
		FPG01	8.2 / 71	3.0 / 62	3.1 / 62	3.2 / 71
			FPG02	2.8 / 69	5.5 / 67	3.4 / 99
				FPG03	2.4 / 67	8.0 / 69
					FPG05	1.8 / 67

Sample and end date (AD)	Reference chronology	Yrs overlap	*t*-values
FPH01 1486	Anglia03 *(Bridge unpubl)*	120	6.5
	WC_Kitchen *(Hillam and Groves 1996)*	120	6.5
	White Tower 3 *(Miles and Worthington 1997)*	120	6.2
FPH05 1492	Rye Cottage *(Miles and Worthington 1997)*	113	6.9
	Hants02 *(Miles 2003)*	119	6.1
	Barton Stacey *(Miles and Worthington 2002)*	112	6.0
FPG01 1463	Southern England 98 *(Bridge 1998a)*	71	8.0
	WC_Kitchen *(Hillam and Groves 1996)*	71	7.9
	Mary Rose 'original' *(Bridge and Dobbs 1996)*	71	7.6
FPG02 1473	London *(Tyers pers comm.)*	99	9.2
	Southern England 98 *(Bridge 1998a)*	99	8.3
	Mary Rose 'original' *(Bridge and Dobbs 1996)*	99	7.9
FPG03 1470	Otley_EN *(Tyers 2000)*	69	6.2
	Oracle3 *(Miles unpubl)*	69	5.4
	Barton Stacey *(Miles and Worthington 2002)*	69	5.2
FPG05 1468	Abbots Barton *(Miles and Worthington 1998)*	67	7.4
	Southern England 98 *(Bridge 1998a)*	67	6.3
	WC_Kitchen *(Hillam and Groves 1996)*	67	5.9
FPG06 1494	White Tower 3 *(Miles and Worthington 1997)*	134	7.9
	Southern England 98 *(Bridge 1998a)*	139	7.0
	Cathedral Barn, Hereford *(Tyers 1996)*	133	6.6

Table 4: Best matches for the individual timbers in site chronology FULHAM1

Table 5: Matrix of *t* -values and overlaps for components of **FPG1214**

Sample:	**FPG12a2**	**FPG14**
Last ring date AD:	1484	1480
FPG12a1	0.0 / 0	12.3 / 29
FPG12a2		17.2 / 49

Table 6: Matrix of *t* -values and overlaps for components of **FULHAM2**

Sample:	**FPG13a2**	**FPG15a2**	**FPG1214**
Last ring date AD:	1469	1440	1484
FPG11	7.56 / 128	7.80 / 60	5.47 / 120
FPG13a2		4.25 / 60	2.61 / 117
FPG15a2			2.12 / 60

Table 7: Dating evidence for the site chronology **FULHAM1,** AD 1356 - 1494 (regional multi-site chronologies have the file name in **bold**)

	County or region:	*Chronology name:*	*Short publication reference:*	*File name:*	*Spanning:*	*Overlap:*	*t-value:*
	Southern England	Southern England Master	*(Bridge 1998a)*	**SENG98**	944-1790	139	12.9
	London	White Tower, Tower of London	*(Miles and Worthington 1997)*	WHTOWER3	1301-1489	134	11.9
	Berkshire	Windsor Castle Kitchen	*(Hillam and Groves 1996)*	WC_KITCH	1331-1573	139	10.6
	London	London Master Chronology	*(Tyers pers comm.)*	**LONDON**	413-1728	139	10.5
	Hampshire	Hampshire Master Chronology	*(Miles 2003)*	**HANTS02**	443-1972	139	9.6
‡	Hampshire	Church Farm, Barton Stacey	*(Miles and Worthington 2002)*	BRTNSTCY	1381-1539	114	8.9
	Unknown	*Mary Rose* 'original' timbers	*(Bridge and Dobbs 1996)*	ORIGINAL	1334-1503	139	8.9
	Hertfordshire	The Gables, Braughing	*(Bridge 2002)*	BRAUGH2	1379-1450	72	8.8
	Surrey	The Street, Charlwood	*(Miles and Worthington 2001)*	chd89	1375-1432	58	8.5
	Oxfordshire	Oxford Master Chronology	*(Haddon-Reece et al 1993)*	**OXON93**	632-1987	139	8.5
‡	Hampshire	Abbots Barton	*(Miles and Worthington 1998)*	ABTSBRTN	1387-1559	108	8.4
	Herefordshire	Prowse Barn	*(Tyers et al 1997)*	PROWSEBN	1380-1473	94	8.4
	Somerset	Shapwick House	*(Miles and Haddon-Reece 1996)*	SHAPWCK1	1268-1488	133	8.2
	East Midlands	East Midlands Master	*(Laxton and Litton 1988)*	**EASTMID**	882-1981	139	8.1
	Surrey	East Barn, Newdigate	*(Bridge 1998b)*	EASTBARN	1312-1483	128	8.1
	Herefordshire	Cathedral Barn, Hereford	*(Tyers 1996)*	HERECB2	1359-1491	133	7.8
	Southern England	Southern England Master	*(Hillam and Groves 1994)*	**SOUTH**	406-1594	139	7.8
	Kent	Stonepitts Manor, Seal	*(Arnold et al 2003)*	KSMASQ01	1389-1497	106	7.8
	Kent	Kent Master Chronology	*(Laxton and Litton 1989)*	**KENT88**	1158-1540	139	7.6
	Hampshire	Great Hall, Winchester	*(Bridge 2000)*	WINCHGH	1379-1451	73	7.6

‡ Component of HANTS02

Table 8: Dating evidence for the site chronology **FULHAM2 ,** AD 1319 - 1484 (regional multi-site chronologies have the file name in **bold**)

	County or region:	*Chronology name:*	*Short publication reference:*	*File name:*	*Spanning:*	*Overlap:*	*t-value:*
	Baltic countries	Baltic Master Chronology	*(Hillam and Tyers 1995)*	BALTIC1	1156-1597	166	11.6
	Eastern Baltic	Winchester College	*(Miles 1995)*	WNCHSTR1	1207-1495	166	8.5
	Eastern Baltic	Magdalen College, Oxford	*(Miles and Worthington 2000)*	MAGDALN3	1222-1494	166	7.4
	Eastern Baltic	White Tower, Tower of London	*(Oxford Dendro Lab unpubl)*	WHTOWER8	1245-1440	122	6.5
	Eastern Baltic	Hull Blaydes Staithe	*(Hillam 1991)*	HULL_BAS	1148-1464	146	4.8
	Eastern Baltic	Magdalen College, Oxford	*(Miles and Worthington 2000)*	MAGDALN2	1080-1416	98	3.9

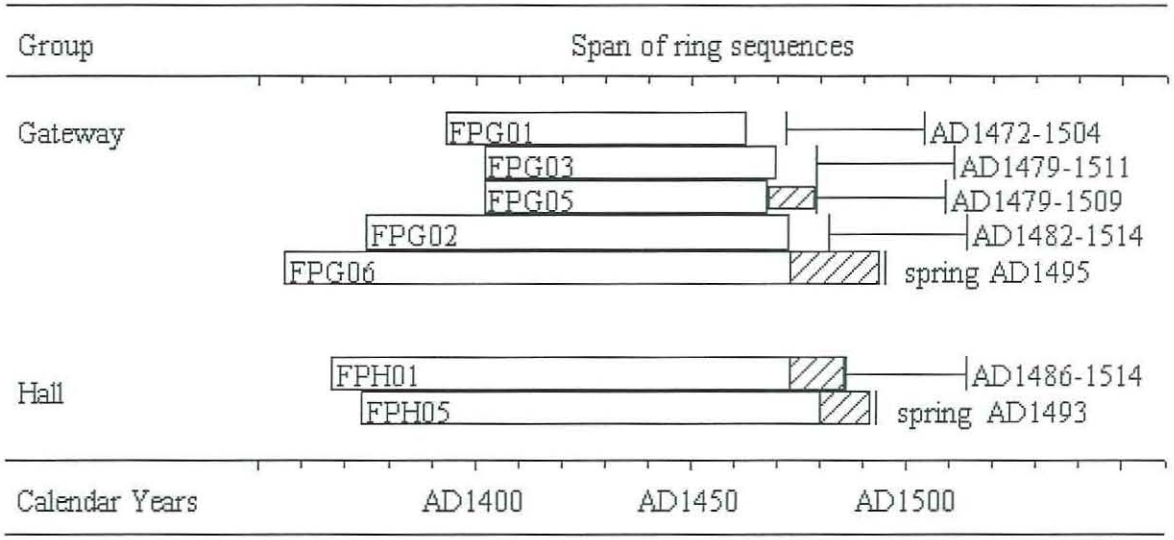

Figure 11: Bar diagram showing the relative positions of overlap of the dated timbers in chronology **FULHAM1**, along with their interpreted felling dates. Hatched bars represent sapwood rings and narrow bars additional unmeasured rings

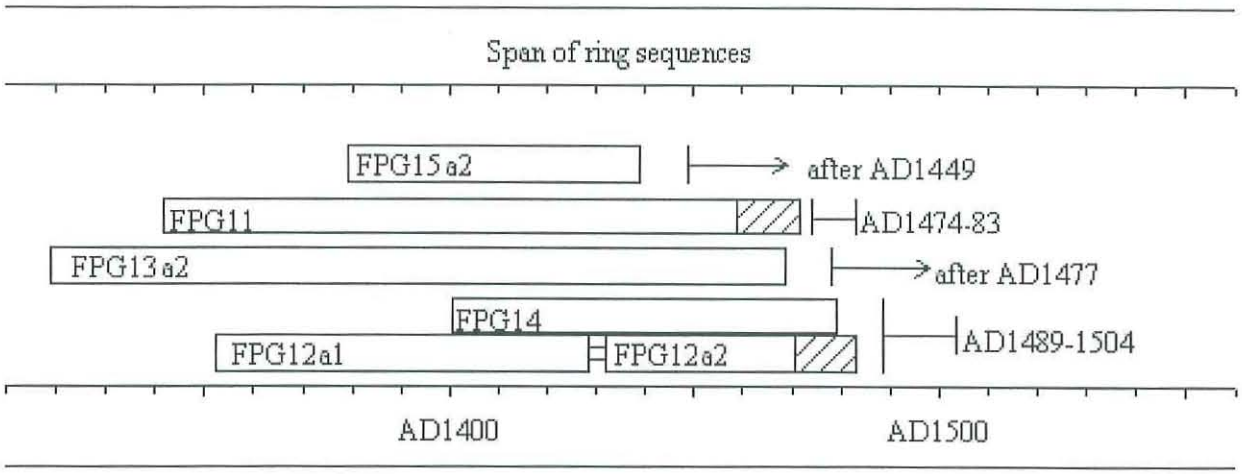

Figure 12: Bar diagram showing the relative positions of overlap of the dated sections of boards from the gates at Fulham Palace, along with their interpreted felling dates. Hatched sections represent sapwood, narrow bars indicate missing unmeasured rings

Interpretation and Discussion

The cross-matching between the timbers from the hall roof and the gateway is not strong, and may suggest different sources for the timbers in each area. Only one timber in each area retained complete sapwood, and these produced felling dates two years apart. With so few available timbers it is difficult to draw firm conclusions, but both were clearly part of the same extended building campaign. Taken at face value, the spring AD 1493 date for the hall roof might suggest that the hall range was constructed immediately before the west gatehouse range with its spring AD 1495 date, but variations in felling dates over two or more years are not uncommon, particularly in large projects, and without further felling dates from both ranges, no further refinement can be made in the interpretation of a construction date. Certainly the hall roof would not have been constructed any *earlier* than AD 1493, and similarly the west range gatehouse could not have been constructed *before* AD 1495.

The gates themselves appear to have been constructed for their present site, and we could find no evidence of them having been adapted from earlier gates, despite suggestions that this may have been so. The outer mouldings to the muntins were not applied as suggested, but were found to be fashioned out of the solid (Fig 8). Similarly, the mid-rails were moulded out of the solid, although one of the gate leafs had the moulding replaced onto the mid-rail. The moulded parting stop is clearly a later introduction, possibly nineteenth-century or later.

The canted ledges are very closely paralleled to those in the gates of Founder's Tower of Magdalen College, Oxford (west cloister range) which have been dated to AD 1476/7 by dendrochronology and appear in the building accounts for AD 1479 (Miles and Worthington 2000). Here the gates are divided vertically with the upper half having similarly canted ledges, whilst in the lower half the ledges are horizontal. Each leaf has four panels similarly let into the muntins and backed by the thinner canted and horizontal ledges. Each panel has a bevelled mould to the face, which is a slightly concave, again like the Fulham example. The Magdalen gates are finished to a slightly

higher degree of decoration which includes tracery to the upper parts of the panels and a double hollow chamfer moulding to muntins.

Another parallel can be seen at The Old Schools, Cambridge (formerly the old court of King's College, opening onto Trinity Lane), dated to *c* AD 1440 (Hewett and Gibson 1993). Here the doors are the same overall shape and have similarly canted ledges, but are instead morticed and tenoned rather than lap-jointed at as Fulham.

A similarity was noted to the canted ledges of the west doors of Peterborough Cathedral, probably dating to the last quarter of the twelfth century (Hewett 1985, 160-1). Whilst the use of canted ledges has been found through a wide date range, as have notch-lap and half-dovetail joints, the principal difference between the Peterborough and other early examples is that boards were generally fixed to the outside of the framing to give a flat uniform surface. During the thirteenth and fourteenth centuries mouldings were sometimes planted onto the surface of uniformly-boarded doors to give some degree of decoration. However, by about AD 1400 doors and gates were found to have the vertical muntins moulded and made the full thickness of the doors, as at Winchester College. This style of construction continued to be developed during the early Tudor period when the boards themselves were bevelled as in the Fulham example.

The boards are of Baltic origin, as indicated by their strong matches with chronologies from this region and sites within Britain that have used Baltic timbers. A few rings of sapwood remained on some boards, allowing likely felling dates to be derived, suggesting that the gates are contemporaneous with the gateway, from the last decade of the fifteenth century.

To conclude, the limited dendrochronological survey at Fulham Palace has shown that the hall roof, west gateway in the west range, and the gates themselves, are all part of a single, possibly extended, building programme during the episcopate of Richard Hill (AD 1489-96) or just possibly during the episcopate of Thomas Savage (AD 1496-1501). Clearly it was not constructed during the episcopates of Thomas Kempe (AD 1448-89) or Fitzjames (1506-22) as generally thought. This would also suggest that the majority of the west courtyard dates from the 1490s rather than the first quarter of the sixteenth century.

To further assist in the architectural development of Fulham Palace, it is suggested that the upper floors and roof of the gatehouse range should be investigated when repairs are underway, as should the north and south ranges. Also, the porch at the east side of the courtyard is thought to be an early addition, and this too would benefit from a detailed study of the timberwork. If any of the timberwork in these areas has any dating potential, then efforts should be made to obtain further samples with complete sapwood.

Acknowledgements

This work was commissioned by Dr Peter Marshall of English Heritage, and we would like to thank Amanda Grieve and Derek Hamilton of the Scientific Dating Service for their help on site. Scott Cooper, project director for Fulham Palace for the Borough of Hammersmith and Fulham, arranged access and also assisted with additional problems of access on site. Cathy Groves, Sheffield University made valuable comments on an earlier draft of this report.

References

Arnold, A J, Howard, R E, and Litton, C D, 2003 *Tree-ring analysis of timbers from Stonepitts Manor, Seal, Kent*, Centre for Archaeol Rep, **39/2003**

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

Bridge, M C, 1998a Compilation of master chronologies from the South, unpubl computer file *SENG98*, University of London Dendrochronology Laboratory

Bridge, M C, 1998b *Tree-ring analysis of timbers from the Home Farm complex, Newdigate, Surrey*, Anc Mon Lab Rep, **37/98**

Bridge, M C, 2000 List 105 - Tree-ring dates, *Vernacular Architect*, **31,** 85-8

Bridge M C, 2002 Tree Ring Dates, List 124, *Vernacular Architect,* **33**, 74-8

Bridge, M C, and Dobbs, C, 1996 Tree-ring studies on the Tudor warship Mary Rose, in *Tree Rings, Environment, and Humanity* (eds J S Dean, D M Meko, and T W Swetnam), 515-523, Arizona

Haddon-Reece, D, Miles, D H, Munby, J T, and the late Fletcher, J M, 1993 Oxfordshire Mean Curve - a compilation of master chronologies from Oxfordshire, unpubl computer file *OXON93*, Oxford Dendrochronology Laboratory

Hewett, C A, and Gibson, A, 1993 The Carpentry of Seven Cambridge College Doors, *Trans Anc Mon Soc,* **37,** 95-115

Hillam, J, 1991 *Tree-ring analysis of Native and Baltic timbers from Blaydes Staithe, Hull, Humberside*, Anc Mon Lab Rep, **108/91**

Hillam, J, and Groves, C, 1994 Compilation of master chronologies from the South, unpubl computer file *SOUTH*, Sheffield Dendrochronology Laboratory

Hillam, J, and Groves, C, 1996 Tree-Ring Research at Windsor Castle: Aims and Initial Results, in *Tree Rings, Environment, and Humanity* (eds J S Dean, D M Meko, and J W Swetnam), 515-23, Arizona

Hillam, J, and Tyers, I, 1995 Reliability and repeatability in dendrochronological analysis: tests using the Fletcher archive of panel-painting data, *Archaeometry* **37**, 395-405

Hollstein, E, 1965 Jahrringchronologische von Eichenholzern ohne Walkande, *Bonner Jahrb,* **165,** 12-27

Laxton, R R, and Litton, C D, 1988 *An East Midlands Master Tree-Ring Chronology and its use for dating Vernacular Buildings*, Univ Nottingham, Dept of Classical and Archaeol Studies, Monograph Ser, **3**

Laxton, R R, and Litton, C D, 1989 Construction of a Kent Master Chronological Sequence for Oak, 1158-1540 AD, *Medieval Archaeol*, **33**, 90-8

Miles, D H, 1995 List 64 - Tree-ring dates, *Vernacular Architect*, **26,** 60-2

Miles, D, 1997 The interpretation, presentation, and use of tree-ring dates, *Vernacular Architect,* **28,** 40-56

Miles, D, 2003 Dating Buildings and Dendrochronology in Hampshire, in *Hampshire Houses 1250 - 1700: Their Dating and Development* (ed E Roberts), 220-6, Southampton (Hampshire County Council)

Miles, D H, and Haddon-Reece, D 1996 List 72 - Tree-ring dates, *Vernacular Architect*, **27**, 97-102

Miles, D H, and Worthington, M J, 1997 Tree-ring dates, *Vernacular Architect*, **28**, 159-81

Miles, D H, and Worthington, M J, 1998 Tree-ring dates, *Vernacular Architect*, **29**, 111-29

Miles, D H, and Worthington, M J, 2000 Tree-ring dates, *Vernacular Architect*, **31,** 90-113

Miles, D H, and Worthington, M J, 2001 Tree-ring dates, *Vernacular Architect*, **32**, 74-86

Miles, D H, and Worthington, M J, 2002 Tree-ring dates, *Vernacular Architect*, **33**, 81-102

Munro, M A R, 1984 An improved algorithm for crossdating tree-ring series, *Tree Ring Bulletin,* **44**, 17-27

Salzman, L F, 1952 *Building in England down to 1540,* Oxford

Tyers, I, 1996 *The tree-ring analysis of six secular buildings from the city of Hereford*, Anc Mon Lab Rep, **17/96**

Tyers, I, 1998 *Tree-ring analysis and wood identification on timbers excavated on the Magistrates Court Site, Kingston upon Hull, East Yorkshire*, ARCUS Rep, **410**

Tyers, I, 1999 *Dendro for Windows Program Guide 2nd edn*, ARCUS Rep, **500**

Tyers, I, 2000 *Tree-ring analysis of panelling from Otley Hall, Otley, Suffolk,* ARCUS Rep, **550**

Tyers, I, Groves, C, Hillam, J, and Boswijk, G, 1997 List 80 - Tree-ring dates, *Vernacular Architect*, **28**, 138-58

Table 9: Ring width data for the two site chronologies, FULHAM1 AD 1356-1494 and FULHAM2 AD 1319-1484

Ring widths (0.01mm)										no of trees									
FULHAM1																			
183	411	275	249	353	220	329	425	438	420	1	1	1	1	1	1	1	1	1	1
312	286	230	316	272	210	230	274	288	265	1	2	2	2	2	2	2	2	3	4
296	227	284	240	252	231	240	187	187	190	4	4	4	4	4	4	4	4	4	4
278	270	259	190	174	170	121	132	155	186	4	4	4	4	4	4	4	5	5	5
220	160	235	245	182	164	142	162	193	173	5	5	5	5	5	5	7	7	7	7
227	173	213	176	151	178	204	176	170	139	7	7	7	7	7	7	7	7	7	7
141	151	179	125	205	213	155	219	195	179	7	7	7	7	7	7	7	7	7	7
146	165	205	179	158	155	220	141	151	167	7	7	7	7	7	7	7	7	7	7
128	132	134	115	123	138	143	151	142	122	7	7	7	7	7	7	7	7	7	7
124	130	127	136	140	141	118	132	157	137	7	7	7	7	7	7	7	7	7	7
151	148	145	136	136	122	113	131	94	136	7	7	7	7	7	7	7	7	6	6
116	117	136	119	140	108	128	131	123	130	6	6	6	5	5	4	4	4	3	3
110	96	99	155	135	162	145	181	173	147	3	3	3	3	3	3	3	3	3	3
150	183	154	156	137	133	143	125	114		3	2	2	2	2	2	2	1	1	
FULHAM2																			
134	128	147	101	126	119	125	151	198	157	1	1	1	1	1	1	1	1	1	1
122	122	122	118	141	126	140	177	117	137	1	1	1	1	1	1	1	1	1	1
189	149	131	176	140	188	196	162	162	176	1	1	1	2	2	2	2	2	2	2
186	219	192	176	159	137	102	122	85	87	2	2	2	2	3	3	3	3	3	3
122	131	114	132	140	138	145	133	150	122	3	3	3	3	3	3	3	3	3	3
119	119	120	107	134	130	148	144	191	176	3	3	3	3	3	3	3	3	3	3
167	175	187	162	162	181	134	134	162	151	3	3	4	4	4	4	4	4	4	4
172	161	157	165	157	169	117	131	89	127	4	4	4	4	4	4	4	4	4	4
123	157	127	160	116	138	132	144	135	142	4	4	4	4	4	4	4	4	4	4
138	121	160	154	129	122	143	139	126	100	4	4	4	4	4	4	4	4	4	4
91	102	104	104	76	111	111	102	83	90	4	4	4	4	4	4	4	4	4	4
124	107	115	120	103	116	114	140	150	109	4	4	4	4	4	4	4	4	4	4
120	103	125	136	156	123	125	115	132	129	4	4	3	3	3	3	3	3	3	3
108	125	122	111	102	137	114	118	125	102	3	3	3	3	3	3	3	3	3	3
95	115	82	71	71	98	101	84	94	111	3	3	3	3	3	3	3	3	3	3
91	89	100	118	127	153	149	149	137	119	3	2	2	2	1	1	1	1	1	1
103	119	142	179	120	131					1	1	1	1	1	1				