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Ancient Monuments Laboratory
Report 31/98

TREE-RING ANALYSIS OF OAK TIMBERS FROM PENRHOS COURT, NEAR KINGTON, HEREFORDSHIRE

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Summary

Tree-ring analysis was undertaken on 16 samples from the cruck hall and cross-wing at Penrhos Court, Herefordshire. Seven timbers were dated and these indicated four separate felling phases: two timbers from the cruck hall were felled in the mid-AD 1430s; one from the cross-wing was felled in the mid/late-fifteenth century; two timbers from a floor in the north bay of the cross-wing were felled in the mid-sixteenth century; whilst two timbers from an inserted floor in the hall were felled in the late-sixteenth or early-seventeenth century. In view of the complexity of these results a detailed structural survey and a documentary research would perhaps help elucidate the historic development of Penrhos Court. The small number of dated timbers from each identified construction phase suggests that the results of the tree-ring analysis should be treated with some caution until then.

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TREE-RING ANALYSIS OF OAK TIMBERS FROM PENRHOS COURT, NEAR KINGTON, HEREFORDSHIRE

Introduction

This document is a technical archive report on the tree-ring analysis of timbers from Penrhos Court, near Kington, Herefordshire. 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 buildings, 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 buildings. The conclusions presented here may therefore have to be modified in the light of subsequent work.

Penrhos Court, a Grade II* listed building, lies in the parish of Lyonshall, about 2 km east of Kington, Herefordshire (NGR SO318562). The following brief description is based on the listing entry, plans associated with the restoration work made available by architects Michael Reardon and Associates, and observations made on site during sampling. It should be noted that these are architectural plans and hence do not provide a detailed record of the historical aspects of the extant building. It is a multiperiod farmhouse with major construction phases thought to date to the late-thirteenth/early-fourteenth, the sixteenth, and the mid-seventeenth centuries. Less substantial modifications were undertaken during the mid-nineteenth century and finally extensive restoration work was carried out during the 1970s, 1980s, and 1990s. The property is currently used as a family home, restaurant, and hotel. The three-bay cruck hall, aligned north-east/south-west, is thought to be of late-thirteenth or early-fourteenth century date (Figs 1 and 2). At the north-east end of the cruck hall there is an inserted floor and a large inserted stack. A two-storey cross-wing, thought to have been added during the sixteenth century, adjoins this north-east end of the cruck hall (Figs 1, 3, and 4). A further wing (two-storeys and an attic) and projecting porch, thought to date from the mid-seventeenth century, further extend the structure to the north-east (Fig 1), though according to the listing entry this is thought to have been largely reconstructed.

The dendrochronological analysis was requested by John Yates, the English Heritage Inspector of Historic Buildings for the West Midlands team. The principal aims of the analysis indicated in the brief provided by English Heritage were to provide evidence for the date of construction of the cruck hall and the two-storey cross-wing and hence, by dating this important and largely

complete cruck structure, aid the typological dating of other similarly constructed buildings in the region.

Methodology

The timbers in the accessible areas of the cruck hall and cross-wing were carefully examined in order to identify those timbers with the most suitable ring sequences for analysis and allow a sampling strategy to be formulated. Those timbers of oak (*Quercus* spp.) with at least 50 annual rings and some survival of the original sapwood and bark-edge were sought. Oak is currently the only species used for routine dating purposes in the British Isles. Samples with over 50 rings are generally required in order to ensure that the growth pattern is unique (Hillam *et al* 1987).

The most promising timbers were sampled using a 15mm diameter corer attached to an electric drill. The cores were taken from the timbers in the direction most suitable for maximising the numbers of rings in the sample. The core holes were left open. The ring sequence of each core was 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; Munro 1984) were employed to search for positions where the ring sequences were highly correlated. These positions were checked 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.

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 date only 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 missing sapwood rings. 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 55 annual rings, where these figures indicate the 95% confidence limits of the range. These figures are applicable to oaks from the British Isles (Hillam *et al* 1987). If bark-edge survives, then a felling date can be directly utilised from the date of the last surviving ring. In this instance if the growth rate is sufficiently high, the completeness of the last surviving ring can be determined by the anatomical differences between the spring growth wood and the later summer growth wood (Baillie 1982, 47). It is possible to differentiate reliably timber felling periods into two categories: timbers felled in the spring/early summer; and those felled either later in the year or before the start of the growing season of the subsequent year.

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 reuse 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 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. Timbers originally derived from the same parent log

generally have *t*-values of greater than 10.0, though lower *t*-values do not necessarily exclude the possibility. It is the balance of a range of information that provides the link.

Results

Many of the timbers in the hall and cross-wing clearly contained insufficient numbers of rings for dendrochronological dating purposes. The sampling strategy applied to both areas therefore attempted to sample timbers that might otherwise have been considered borderline. This is an approach that has been applied in certain areas of the country, such as Essex and Devon, where extensive localised sampling has allowed samples with fewer rings than 50 to be successfully dated (Groves forthcoming). A total of 16 oak (*Quercus* spp.) timbers were selected for sampling. Details of the samples and their locations are provided in Table 1 and Figs 1-4. As is common with medieval oak timbers the sapwood was prone to disintegration and several cores lost some or all of the sapwood; several samples also broke or hit unexpected voids.

Hall: cruck structure

This area was dominated by timbers converted from halved trunks. The timbers thought to be associated with the primary construction phase were all oak but many were clearly unsuitable for analysis. Although sapwood and bark-edge were quite commonly present, the sapwood proved to be very fragile and most disintegrated during coring. Two of the timbers, **6** and **8**, were cored twice in an attempt to overcome the loss of bark-edge. This was successful for timber **6**, but failed with timber **8** as the bark-edge and outer few sapwood rings disintegrated again on the repeat core. The problems of sapwood disintegration resulted in four of the borderline timbers producing samples with too few rings for further analysis (Table 1). Samples from two other timbers were rejected as the cores had fragmented very badly. Only two, **6** and **8**, of the nine samples contained more than 50 rings (Table 1). Cruck blades are often thought to represent two halves of the same-tree so, although no obvious physical similarities had been noted when on site, sample **2**, with 44 rings, was also measured. The decision to proceed with the analysis of these three samples (**2**, **6**, **8**) was only made due to the similarity of the primary phase cruck hall material with some of the cross-wing timbers in terms of their overall physical appearance. The resultant ring sequences from samples **2**, **6**, and **8** could not be reliably cross-matched, though a weak match was identified both visually and statistically between **2** and **6** (Table 2).

Hall: inserted floor

Two samples (**15** and **16**) were removed from girding beams (Figs 1 and 3; Table 1). The girding beams were converted from halved trunks. These were considered potentially broadly contemporary with the cross-wing addition and were therefore capable of increasing the possibility of obtaining calendar dates for the cores from the cross-wing timbers. Both samples were measured, and a weak match was identified, both visually and statistically, between them (Table 3).

Cross-wing

The exposed floor joists aligned north-west/south-east in the northernmost room were numbered during assessment 1-15 from south-west to north-east (Figs 1 and 4). The joists were predominantly timbers converted from halved or quartered trunks, whereas the storey posts were generally either trimmed whole or halved trunks. The structural elements were all oak but many were rejected before sampling as they clearly had too few rings for dendrochronological dating purposes. Sapwood and bark-edge were again quite commonly present but as in the cruck hall, it usually disintegrated during sampling. Only five timbers were considered likely to contain sufficient numbers of rings. Sample **14** fragmented and was rejected. The four other samples were all measured, including **10** with only 49 rings (Table 1). No reliable cross-matches were identified between these four ring sequences, though again a weak match was identified both visually and statistically between **12** and **13** (Table 3).

Hall and cross-wing comparison

In the absence of any reliable cross-matching within each area sampled, all of the individual ring sequences were compared with each other. Consistent but weak cross-matches were identified indicating two groups of samples were contemporary: **2**, **6**, and **10** (Table 2); and **12**, **13**, **15**, and **16** (Table 3). To assist with the confirmation of these linkages all of the individual ring sequences were compared with a wide range of medieval and post-medieval reference chronologies from England, Wales, and elsewhere in Europe. Rather surprisingly for such short ring patterns, with the exception of **15** which has 139 rings, they all matched consistently well with a range of chronologies at the same relative positions indicated by the weak intra-site matches identified. The ring sequences from samples **2**, **6**, and **10** were combined to form a 61-year master curve, PENRHOS1, which dates to AD 1381-1441 inclusive (Fig 5; Table 4). The ring sequences from samples **12**, **13**, **15**, and **16** were combined to form a 139-year master curve, PENRHOS2, which dates to AD 1420-1558 inclusive (Fig 5; Table 5).

The average ring widths of the two groups of dated timbers are noticeably different. The earlier group of timbers, **2**, **6**, and **10**, appear to have been derived from relatively fast-grown, short-lived trees. The second group (**12**, **13**, **15**, and **16**) are derived from slower-grown, generally longer-lived trees. For this reason, although it would be possible to create a single 178-year site master chronology, the two site master chronologies are kept separate. The difference in average ring widths of the two chronologies would introduce a false trend into a combined sequence at the period of overlap. The chronologies PENRHOS1 and PENRHOS2 are listed in Tables 6 and 7.

No reliable crossdating could be obtained for samples **8** and **11**, so these samples remain undated by dendrochronological analysis.

Interpretation

Hall: cruck structure

The two dated timbers were the opposing blades of cruck B (Fig 2). The bark-edge was present on sample **6**. Its outermost measured ring dates to AD 1435 but the spring vessels of the following years growth were present. This indicates that the timber was felled in AD 1436 during the early part of the growing season. The bark-edge was also present on timber **2** but up to 3mm had been lost during sampling from the outermost edge of the core. The average ring width of this sample suggests that a maximum of one ring is likely to have been lost (Table 1). A felling date of AD 1435-36 is therefore indicated for timber **2**, which implies that it is contemporary with timber **6**. There is no apparent evidence for reuse, so if these timbers are associated with the primary construction phase a date of AD 1436 or shortly thereafter is implied for the cruck hall.

Hall: inserted floor

The outermost measured ring of sample **15** marked the heartwood-sapwood boundary, indicating that the timber was felled during the period AD 1568-1613. This can be refined slightly since during sampling it was noted that approximately 20mm of sapwood were lost, although this still did not include the bark-edge. The average ring width of this sample suggests that this represented about 22 sapwood rings. The combined evidence therefore suggests that this timber was felled in the period after *c* AD 1580 but before AD 1613. The outermost measured ring of sample **16** was thought to probably mark the heartwood-sapwood boundary. This timber was therefore felled after AD 1564 and probably before AD 1610. If these two

timbers are contemporary a combined felling date range of *c* AD 1580-1609 is indicated. There is no apparent evidence for reuse and, assuming that the two dated timbers are associated with the initial construction of the floor, a late-sixteenth or early-seventeenth century date is implied for the insertion of the floor.

Cross-wing

Sample **10**, the south-west storey post from cross-frame E, retained some sapwood indicating that this timber was felled during the period AD 1446-91. There is no apparent evidence for re-use and, if this timber is associated with the primary construction phase, a mid/late-fifteenth century date is implied for the cross-wing.

The outermost measured ring of sample **12**, a floor joist from the north-west bay, marked the heartwood-sapwood boundary, indicating that the timber was felled during the period AD 1524-69. Again it is possible to refine this slightly since during sampling it was noted that approximately 25mm of sapwood and bark-edge were lost. The average ring width of this sample suggests that this represented about 24 sapwood rings. Allowing for some variation in the average ring width and the actual amount of sapwood lost, it therefore seems likely that this timber was felled during the period *c* AD 1533-43. Sample **13**, also a floor joist from the north-west bay, had retained some sapwood. Bark-edge was present on this timber but it was not possible to estimate how much additional sapwood had been lost so a felling date range of AD 1540-85 was produced. If these two timbers are contemporary a combined felling date range of AD 1540 to *c* AD 1543 is suggested. There is no apparent evidence for reuse and, assuming that the two dated timbers are associated with the initial construction of the floor, a mid-sixteenth century date is implied.

Discussion

The identification of four phases of felling from only seven dated timbers requires that the construction dates implied for the various areas should be treated with caution, it would be greatly preferable to have more dated samples from each phase. It is commonplace to assume use of freshly felled 'green' timber for building projects (Rackham 1990, 67; Charles and Charles 1995) so the felling phases identified provide dates for the initial use of the timbers. However, the relationship of this 'initial use date' to the 'actual date' of the primary construction phase of the hall, cross-wing, and inserted floors is based on a number of assumptions. Firstly, these timbers are in each case assumed to be associated with the primary construction phase of the relevant area. Secondly, that none of the dated timbers are re-used.

During the sampling of the timbers, no obvious signs of re-use, such as redundant carpentry features, were noted, and none of the sampled timbers gave the appearance of being associated with later repairs or modifications. However as indicated earlier it is beyond the dendrochronological brief to undertake detailed examination of the building. The possibility remains that some of the dated timbers have been introduced from elsewhere during the extensive restoration work. Such issues need to be addressed in order to place the dendrochronological results in context.

Assuming that re-use has not occurred the tree-ring analysis suggests that the hall pre-dates the cross-wing by between 10 and 55 years. The cruck hall appears to be over a century later than expected and the cross-wing somewhat earlier than the sixteenth-century date anticipated. The floor in the north-west bay of the cross-wing appears to have been inserted in the mid-sixteenth century, whilst the floor in the north-east end of the hall was inserted in the late-sixteenth or early-seventeenth century. The dendrochronological analysis, far from clarifying the understanding of the development of this building, has actually raised more questions which need to be addressed. Detailed survey and documentary research is clearly vital to elucidate the historical development of the building. In such circumstances it would also be usual to undertake additional dendrochronological work. However at Penrhos Court, although it would be recommended that a dendrochronologist is at least consulted during any detailed survey work, it seems likely that the borderline nature of the timbers may preclude any further sampling, particularly from the two areas of major importance: the cruck trusses in the hall and the cross-frames in the cross-wing. Dendrochronological assessment of the later seventeenth-century wing may also be of use if further investigation is carried out since timbers from this wing may assist with the construction of an improved local sequence.

The differences in average ring widths and age of trees used between the fifteenth- and sixteenth/seventeenth-century timbers have implications for changing local woodland resources or are perhaps part of a more widespread change. This latter possibility is supported by the apparently widespread use of short-lived fast grown timber in the fifteenth century that has previously been noted in both other buildings in Herefordshire (Tyers 1996a), and from buildings further away such as in Essex (author unpubl) or Devon (Groves pers comm). The availability of longer-lived slower grown trees in the latter half of the sixteenth century has also been observed relatively regularly in buildings. This has been particularly noted at buildings associated with former abbey estates. There are suggestions that this is due to well-managed abbey woodlands becoming available to provide timber for construction after the dissolution

(Eastbury Manor, Barking, built *c* AD 1566 provides a good example of this trend (Tyers 1997b)). This perceived difference in the two main groups of timbers at Penrhos Court could be addressed more fully, but due to the difficult nature of the material, any further analysis may have to rely more on documentary evidence rather than additional dendrochronological analysis.

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Table 1 Details of samples from Penrhos Court.

Sample	Description of timber	Type	Size (mm)	No. of Rings	Sapwood rings	Bark	ARW	Date of sequence	Felling
Hall: cruck structure									
1	Cruck B north-west packing piece	oak	180 x 170	*c* 35	h/s	no	-	rejected; too few rings	-
2	Cruck B north-west blade	oak	390 x 150	44+	10+<*3mm*	+yes	4.93	AD 1392-1435	AD 1435-36
3	Cruck B north-west cruck stud	oak	440 x 220	*c* 35	h/s	no	-	rejected; too few rings	-
4	Cruck A north-west cruck stud	oak	280 x 160	*c* 30	h/s	no	-	rejected; too few rings	-
5	Cruck A north-west blade	oak	400 x 160	-	-	-	-	rejected; fragmented	-
6	Cruck B south-east blade	oak	380 x 145	55	15+spring	yes	2.66	AD 1381-1435	AD 1436
7	Cruck C collar	oak	410 x 110	-	-	-	-	rejected; fragmented	-
8	Cruck C south-east blade	oak	400 x 165	63	9	no	2.38	undated	-
9	Cruck D south-east blade	oak	395 x 220	*c* 35	c6	-	-	rejected; too few rings	-
Hall: inserted floor									
15	South-east girding beam	oak	290 x 210	139+	h/s+~*20mm*	no	0.90	AD 1420-1558	AD *c* 1580-1613
16	North-west girding beam	oak	240 x 200	92	?h/s	no	0.83	AD 1463-1554	AD 1564-?1609
Cross-wing									
10	Cross-frame E south-west storey post, ground floor	oak	embedded	49	5	no	2.82	AD 1393-1441	AD 1446-91
11	Cross-frame F north-east storey post, first floor	oak	embedded	71	h/s	no	3.03	undated	-
12	North-west bay first-floor joist 3	oak	290 x 100	83+	h/s+~*25mm*	yes	1.05	AD 1432-1514	AD *c* 1533-*c*43
13	North-west bay first-floor joist 2	oak	345 x 100	50	10	no	1.20	AD 1491-1540	AD 1540-85
14	North-west bay first-floor joist 9	oak	255 x 130	-	-	-	-	rejected; fragmented	-

KEY

No. of Rings	total number of measured rings including sapwood rings
Sapwood rings	total number of measured sapwood rings present
ARW	average ring width or growth rate (mm/year)
h/s	heartwood/sapwood boundary
+	unmeasured rings on the sample or the distance, if known, of disintegrated sapwood. These have been used in the calculation of the felling date
+spring	spring vessels of following years growth present immediately below the bark

Table 2 *t*-values between individual dated timbers from PENRHOS1.

Sample	6	10
2	3.57	3.30
6		4.15

Table 3 *t*-values between individual dated timbers from PENRHOS2. - indicates a *t*-value less than 3.00.

Sample	13	15	16
12	3.11	4.74	3.48
13		-	-
15			3.00

Table 4 example *t*-values between PENRHOS1 and independent reference sequences.

Reference sequence	PENRHOS1
Devon pilot project (Groves forthcoming)	5.27
Gloucestershire, Gloucester, Mercers Hall (Howard *et al* 1996)	4.09
Herefordshire, Hereford, Booth Hall/High Town (Boswijk and Tyers 1997)	3.72
Herefordshire, Hereford, Cathedral Barn *2* (Tyers 1996a)	4.09
Herefordshire, Hereford, Farmers Club (Tyers 1996a)	4.47
Herefordshire, Kings Pyon (Groves and Hillam 1993)	4.00
Shropshire, Plowden Hall *2* (Miles and Haddon-Reece 1993)	5.52
Worcestershire, Lower Sapey (Tyers 1995)	3.50
South Yorkshire, Sheffield, Bishops House (Sheffield Dendrochronology Laboratory unpubl data)	5.10
Welsh/English Borders (Siebenlist-Kerner 1978)	4.39
Powys, Llanigon, Lower Wenalt (Sheffield Dendrochronology Laboratory unpubl data)	4.98

Table 5 example *t*-values between PENRHOS2 and independent reference sequences.

Reference sequence	PENRHOS2
East Midlands Master (Laxton and Litton 1988)	8.49
Berkshire, Windsor Castle kitchen, (Hillam forthcoming)	6.56
Herefordshire, Hereford Farmers Club (Tyers 1996a)	9.62
Herefordshire, Tupsley (Tyers 1997c)	6.35
Kent Master (Laxton and Litton 1989)	5.64
Kent, Longport Farmhouse (Tyers unpubl)	7.57
Staffordshire, Sinai Park (Tyers 1997d)	7.18
Worcestershire, Droitwich, Upwich *3* (Groves and Hillam 1997)	9.34
Worcestershire, Mamble *B* (Tyers 1996b)	7.38
West Yorkshire, Landshead Farm (Boswijk and Hillam 1997)	6.31
Welsh/English Borders (Siebenlist-Kerner 1978)	8.63

Table 6 Ring-width data from site master PENRHOS1, dated AD 1381-1441 inclusive.

Date	Ring widths (0.01mm)										No of samples									
AD 1381	113	120	98	132	99	140	166	188	160	158	1	1	1	1	1	1	1	1	1	1
	236	399	341	365	326	387	364	399	371	441	1	2	3	3	3	3	3	3	3	3
AD 1401	369	375	461	444	405	405	439	362	439	334	3	3	3	3	3	3	3	3	3	3
	269	359	314	342	324	353	335	329	233	383	3	3	3	3	3	3	3	3	3	3
	317	274	383	331	379	387	372	450	428	335	3	3	3	3	3	3	3	3	3	3
	295	316	243	330	332	232	230	210	203	245	3	3	3	3	3	1	1	1	1	1
	237										1									

Table 7 Ring-width data from site master PENRHOS2, dated AD 1420-1558 inclusive.

Date	Ring widths (0.01mm)										No of samples									
AD 1420										167										1
	175	142	158	181	166	156	141	122	123	100	1	1	1	1	1	1	1	1	1	1
	105	148	136	139	149	130	125	108	103	91	1	2	2	2	2	2	2	2	2	2
	107	98	104	111	110	109	101	95	128	96	2	2	2	2	2	2	2	2	2	2
AD 1451	109	93	101	116	100	123	106	100	83	86	2	2	2	2	2	2	2	2	2	2
	88	82	111	75	77	84	83	85	76	74	2	2	3	3	3	3	3	3	3	3
	72	78	70	76	87	71	60	57	79	74	3	3	3	3	3	3	3	3	3	3
	86	77	90	98	94	97	101	80	81	108	3	3	3	3	3	3	3	3	3	3
	108	106	114	111	117	139	112	99	96	86	4	4	4	4	4	4	4	4	4	4
AD 1501	90	99	91	102	89	104	99	101	120	98	4	4	4	4	4	4	4	4	4	4
	104	100	95	96	81	82	81	98	105	85	4	4	4	4	3	3	3	3	3	3
	97	106	84	89	83	102	100	99	89	86	3	3	3	3	3	3	3	3	3	3
	90	82	76	81	102	105	96	88	89	103	3	3	3	3	3	3	3	3	3	3
	101	80	84	86	74	61	55	58	59	60	2	2	2	2	2	2	2	2	2	2
AD 1551	64	52	68	64	83	63	75	73			2	2	2	2	1	1	1	1		

Figure 1 Plan of Penrhos Court, based on drawings by Michael Reardon and Associates, showing the location of the samples. No scales are available for the original drawing.

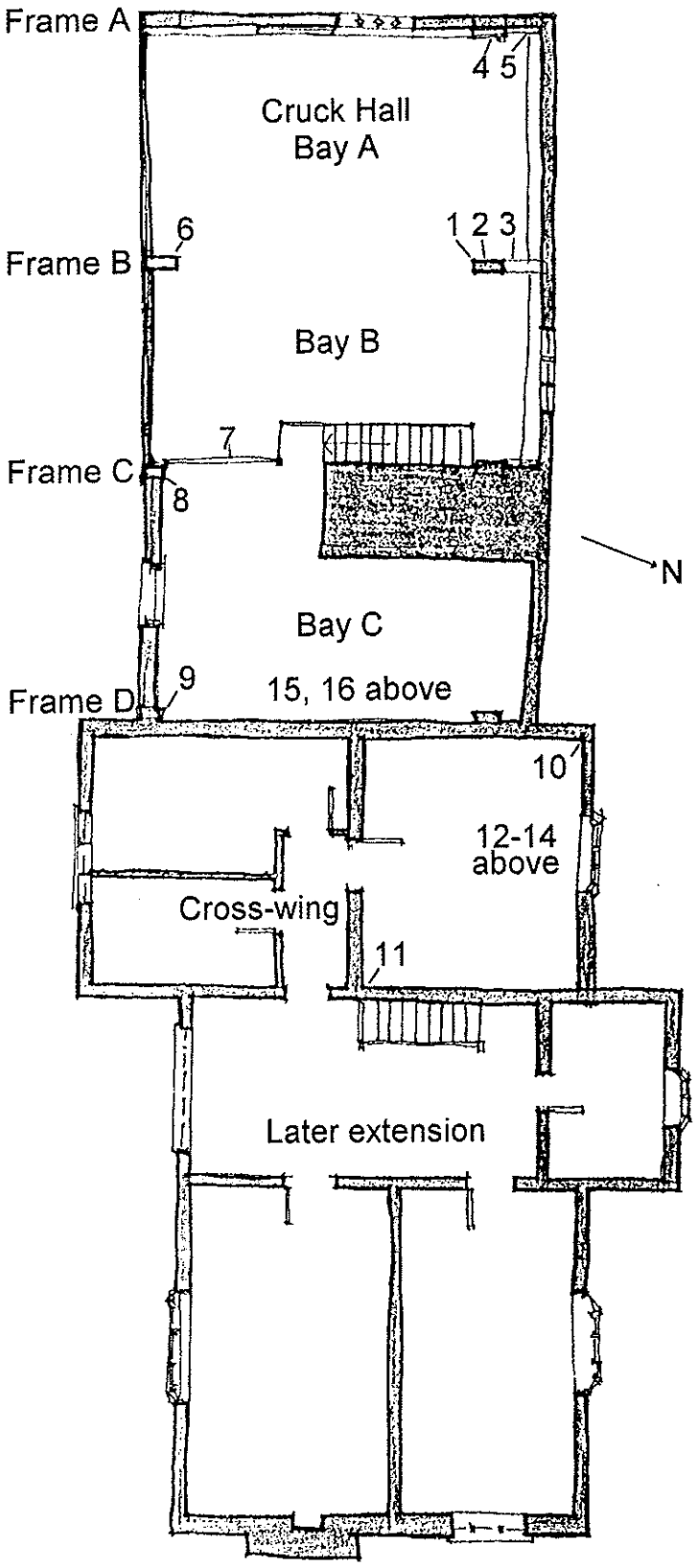


Figure 2 Typical truss from the hall, based on drawings by Michael Reardon and Associates, showing the approximate location of samples 1-3 and 6. No scales are available for the original drawing.

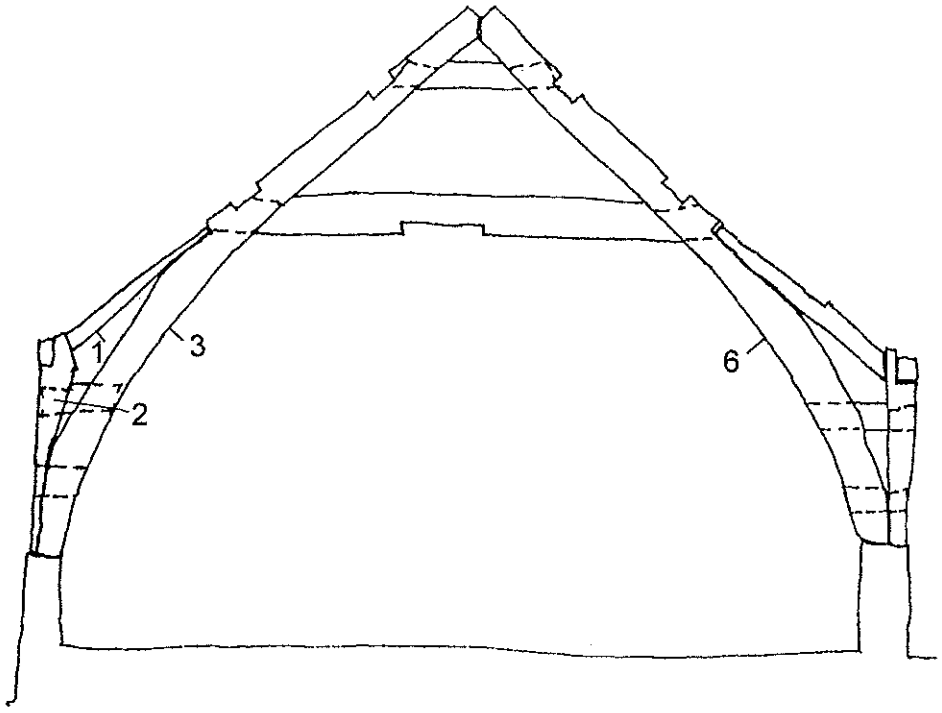


Figure 3 South-west elevation of cross-wing, based on drawings by Michael Reardon and Associates, showing the approximate location of samples 10, 15 and 16. No scales are available for the original drawing.

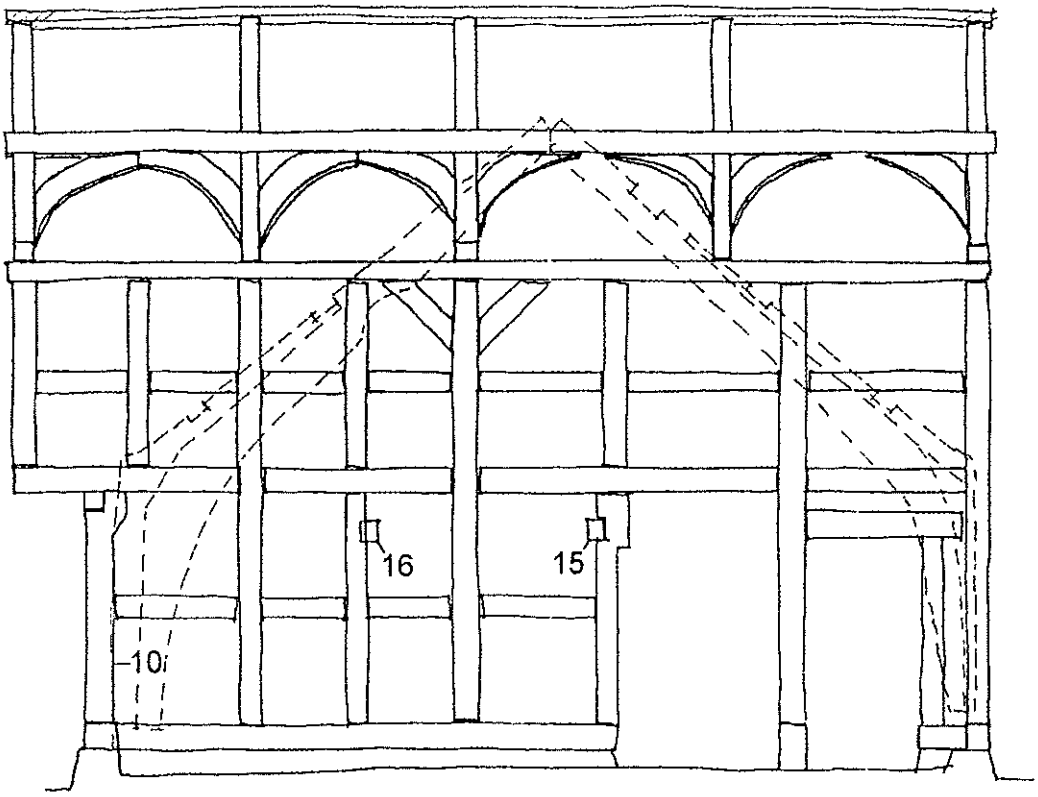


Figure 4 Cross-wing central cross-frame from the south-west, based on drawings by Michael Reardon and Associates, showing the approximate location of samples 11-14. No scales are available for the original drawing..

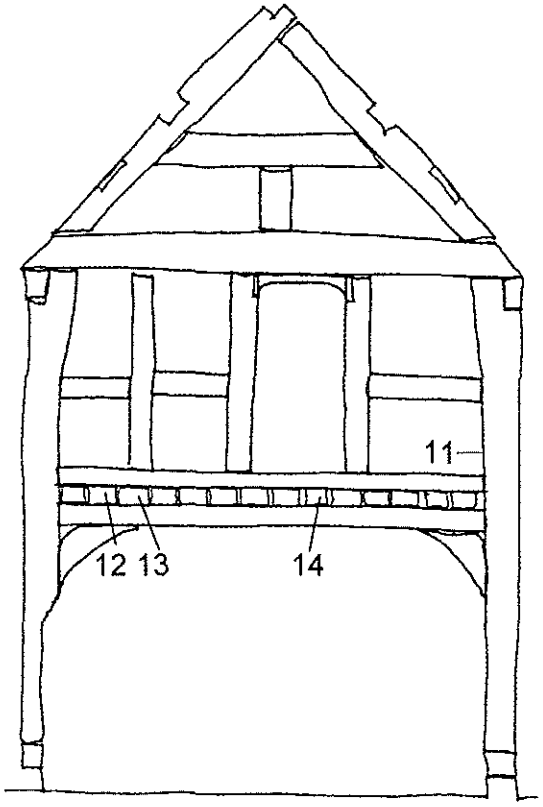
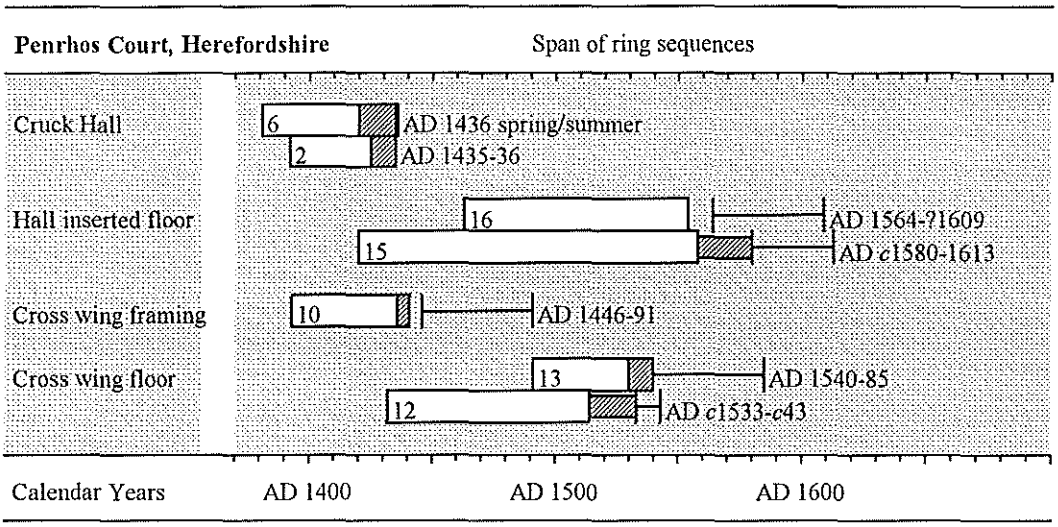
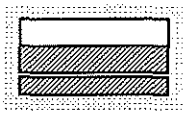


Figure 5 Bar diagram, showing the position of the dated sequences. Felling interpretations are based on a 10-55 sapwood estimate (Hillam *et al* 1987) where no bark-edge is present.



KEY



heartwood
sapwood
unmeasured sapwood