Centre for Archaeology Report 32/2004

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ISSN 1473-9224

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Summary

A tree-ring dating programme was commissioned on timbers in the clock tower and the Governor's Room of Holy Cross church, Crediton, Devon, by English Heritage in AD 2003. The tree-ring results indicate that timbers felled in the AD 1530s are present in the clock tower, and timbers from the mid-fifteenth century and late-eighteenth century are present in the Governor's Room.

Keywords

Dendrochronology
Standing Building

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Introduction

This document is a technical archive report on the tree-ring analysis of oak timbers from the clock tower and Governor's room in Holy Cross church, Crediton, Devon (NGR SS 8365 0020). It is beyond the dendrochronological brief to describe these parts of the church in detail or to undertake the production of detailed drawings. Elements of this report may be combined with detailed descriptions, drawings, and other technical reports at some point in the future to form either a comprehensive publication or an archive deposition on the building.

On the site of a former Saxon cathedral, Holy Cross church was a collegiate foundation from the twelfth century until the Reformation. It was bought by the townspeople of Crediton after the Dissolution, and from at least AD 1547 it has been a 'church peculiar' run by twelve Governors. It lies within the town of Crediton (Figs 1 and 2). Most of the fabric of the church is probably of early fifteenth-century date (Cherry and Pevsner 1989, 295-6).

The clock and bell tower stands over the central crossing. Access is from the churchyard via a stair up the west face of the north transept and then a stair turret within the north-west pier of the central crossing. Accessed from this turret is firstly the ringing chamber, and then above this is the clock chamber. This provides separate ladder access to the bell chamber above (Fig 3). The ringing-chamber ceiling, which is also the support for the clock-chamber floor, is composed of six unevenly spaced north-south beams (Fig 4). Propping the clock-chamber ceiling beams are fifteen posts with diagonal bracing. Ten of these utilise a single forked timber with a side branch forming the brace (Figs 3 and 5). The other five are vertical posts with an angled bracing timber. Due to the alignment of the branching of these posts it seems possible these braces are secondary, following the loss or removal of an original forking branch. Above these is the clock-chamber ceiling, also the bell-chamber floor. This ceiling consists of two north-south beams overlain by six unevenly spaced east-west beams (Fig 6). The wide central square of this arrangement forms the hatchway for lowering and raising the bells. Above this is a large timber nine-pit bellframe, housing eight bells (Fig 7). This is thought to date from sometime between AD 1774 and AD 1838 (Chris Pickford pers comm). It is entirely of oak. Most of the timbers are fast grown and circular sawn. However there are some hand-sawn oak timbers, which are presumed to be re-used.

The three-storey vestry is on the south side of the chancel. The top floor of this is known as the Governor's Room, formerly the collegiate chapter house (Cherry and Pevsner 1989, 296). The roof is of three low king post trusses (Fig 8). The floor of this room consists of wide and rebated oak floorboards supported by a grid of spine beams and joists visible from the rooms below (Fig 9).

Tree-ring analysis of timbers throughout the clock tower and the Governor's Room was commissioned by Francis Kelly, the local English Heritage Historic Buildings Inspector, to inform the interpretation of the structure and future grant aided repairs.

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.

The church was visited and an assessment of the dendrochronological potential of the various parts of the structure was undertaken. This assessment aimed to identify whether oak timbers with sufficient numbers of rings for analysis existed in each part of the structure. This assessment identified that several parts of the building contained suitable material.

A subsequent visit was made for the dendrochronological sampling of the suitable material in the church. The sampling programme aimed to obtain samples from as broad a range of timbers, in terms of structural element types, scantling sizes, carpentry features, and surface condition as was possible with respect to their suitability for analysis, their safe access, and within the terms of the request documentation.

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 filled with oak plugs. The ring sequences in the cores were revealed by sanding.

The complete sequences of growth rings in the cores were measured to an accuracy of 0.01mm using a micro-computer based travelling stage (Tyers 1999a). The ring sequences were plotted onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition a cross-correlation algorithm (Baillie and Pilcher 1973) was 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 (Tyers 1998). 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, seasoning, 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.

Results

Sixteen timbers were selected for sampling from the various elements of the tower: five from the clock-chamber floor or ringing-chamber ceiling, seven from the two layers of the clock-chamber ceiling, two from the forked bracing of the clock chamber, and two of the re-used timbers from the bellframe. These samples were numbered **1-16** (Table 1a; Figs 3-7). Eleven timbers were selected for sampling from the Governor's Room roof and floor structure, one from each of the three tiebeams, and eight from the joists and spine beams of the floor below. These samples were numbered **17-27** (Table 1b; Figs 8-9).

All the sampled timbers are oak (*Quercus* spp.). Four of the samples were found to be unsuitable for analysis since they contained either series of irresolvable bands of narrow rings or too few rings for reliable analysis. Three of these were from the tower,

and one was from the floor of the Governor's Room. The tree-ring series from the remaining 23 sampled timbers were measured and the resultant series were then compared with each other. All thirteen suitable samples from the tower structures were found to match together to form an internally consistent group (Table 2). A site mean chronology was calculated from these, named CREDITONT. The three samples from the tiebeams of the Governor's room roof trusses were found to match together to form an internally consistent group (Table 3). A site mean chronology was calculated from these, named CREDITONR. Four samples from Governor's room floor joists formed another internally consistent group (Table 4). A site mean chronology was calculated from these, named CREDITONJ. This leaves just two spine beams and a joist from the Governor's room floor that do not match with other samples.

The three site means and the three unmatched series were then compared with dated reference chronologies from throughout the British Isles and northern Europe. A single well correlated position was identified for both the CREDITONT and CREDITONR series, and for all three of the unmatched timbers, but not for the CREDITONJ sequence. Tables 5-7 shows example correlations at the identified dating positions of these sequences against independent reference chronologies. Tables 1a and 1b provides the chronological dates identified for each component sample by this process and their interpretation. Figures 10 and 11 show the chronological position identified for each component sample. Appendix 1 lists the individual sample series. The component samples of the CREDITONJ series are undated by the analysis reported here.

Interpretation and discussion

The 151-year chronology CREDITONT is dated AD 1386 to AD 1536 inclusive. It was created from 13 of the sampled timbers from the clock chamber and surrounding structures. Three of these datable samples are complete to the original bark surface, a further three samples retain some sapwood, and the other seven are all complete to the heartwood/sapwood boundary.

Starting at the bottom of the tower the first five dated samples are from the ceiling beams of the ringing chamber or clock-chamber floor. One of these retains a significant amount of detached sapwood but none of the others have any sapwood. Adding the minimum and maximum expected number of sapwood rings to the date of the heartwood/sapwood boundary on these samples, making allowance for the number of rings in the detached part of the sample **1** and assuming that all five samples are contemporaneous, suggests they were felled between AD 1524 and AD 1537.

The next datable sample comes from one of the forked timbers. Most of these timbers were much too knotty and twisted to be considered suitable for sampling. The only

suitable sample was from one of the posts with a replaced brace. This sample has no sapwood and adding the minimum and maximum expected number of sapwood rings to the date of the heartwood/sapwood boundary on this sample suggests it was felled between AD 1519 and AD 1555.

The next datable samples come from the two north-south beams of the lower clock-chamber ceiling. One is complete to the original bark surface and this was felled in the winter of AD 1535/6. The sample from the other beam has some sapwood and was felled between AD 1529 and AD 1565.

Five of the six east-west beams that form the upper layer of the clock-chamber ceiling were sampled, but only three of these were datable. Again one of these is complete to the original bark surface and this was felled in the spring of AD 1537. The other two datable samples from these beams have no sapwood. Adding the minimum and maximum expected number of sapwood rings to the date of the heartwood/sapwood boundary on these samples, and assuming that they are contemporaneous, suggests they were felled between AD 1525 and AD 1554.

Two samples taken from the re-used timbers in the bellframe were both datable. One is complete to the original bark surface and this was felled in AD 1532/3. It is not possible to determine the period within this due to the tree's slow growth rate over its last few rings. The other sample retains sapwood and ends in AD1530. The sampling notes indicate 1-2mm of the outer surface disintegrated during the coring. It thus seems likely that this sample is contemporaneous with the other one. The other timbers in the bellframe are both unsuitable for analysis and not part of the dating request (Francis Kelly pers comm).

The 80-year chronology CREDITONR is dated AD 1714 to AD 1793 inclusive. It was created from three tiebeams of the Governor's Room roof. Two of these samples are complete to the original bark surface, and both were felled in the winter of AD 1793/4. The other is complete to the heartwood/sapwood boundary and was felled between AD 1785 and AD 1821. There seems no reason to suppose this is not contemporary with the other two tiebeams.

The three individual samples derived from the ceiling beneath the Governor's Room do not match each other particularly well (samples **26** and **27** match with a *t*-value of 3.18). However each matches contemporary series from Devon and Cornwall (Table 7). All three are complete to the heartwood/sapwood boundary but retain no sapwood. Adding the minimum and maximum expected number of sapwood rings to the date of the heartwood/sapwood boundary on these samples, and assuming that all three are

contemporaneous, suggests they were felled between AD 1447 and AD 1470. The four joists from this ceiling that match together to form the 120 year CREDITONJ series appear to be contemporaneous on visual and structural details, but this sequence is undatable by current reference data.

Conclusion

Interpreting tree-ring dates for buildings is normally based on the assumption that the timbers were felled for immediate usage, which was normal practice in this period (Charles and Charles 1995). This assumption seems valid for rural and relatively simple structures, but becomes less so in towns or for complicated structures with unusual requirements for timber. The Crediton tower timbers are a possible candidate for stockpiling, since the structural requirements of the floors and ceilings are for reasonably long straight timbers (*c* 9-10m, the depths of the sockets into the walls is unknown) that may have been difficult to obtain locally.

There are three samples from the clock tower on which bark-edge survives; these were felled in AD 1532, the winter of AD 1535/6, and the spring of AD 1537. Crediton was dissolved in AD 1536 during the first stages of the Dissolution (Chris Pickford pers comm). If the material was stockpiled all of the tower timberwork could be a post-Dissolution structure, but utilising pre-Dissolution stockpiled timbers (which might or might not have been intended for this project). Alternatively, since the dates follow the sequence of construction, this might suggest that a replacement or remodelling programme of structural timberwork within the tower was being undertaken upwards during the AD 1530s. The results would then indicate it had reached the lower level of the clock-chamber ceiling by AD 1535/6. The upper level of beams in the clock-chamber ceiling includes at least one beam felled post-Dissolution in AD 1537. Whichever version is the correct interpretation both probably imply a pre-Dissolution project that was only completed in the post-Dissolution period.

The present bellframe uses at least one timber that predates the floor the bellframe rests on. This timber is definitely felled before the Dissolution. The differences in surface tooling to the rest of the bellframe timbers indicate this is a re-used timber. Of course it, and the other similar examples in the bellframe, are not necessarily originally from elsewhere in the tower or even the church. If it is a relict of an earlier bellframe then the tree-ring results indicate a bellframe was installed before the rest of the present tower timberwork was complete. This might imply that the rest of the tower timberwork was a response to unforeseen structural effects of ringing heavy bells. If these timbers are not derived from an earlier bellframe, it suggests that a bellframe built in the later eighteenth or early nineteenth century re-used timbers of slightly earlier date than those used elsewhere in the tower, which seems an unlikely co-incidence.

The tree-ring results indicate the floor of the Governor's Room includes mid fifteenth-century structural timbers (AD 1447-70). The church was referred to as being in a ruinous state in AD 1413, whilst its windows were praised in AD 1478 (Cherry and Pevsner 1989, 296). This would suggest that this floor is part of a major repair or building phase between these two descriptions. The dating of the joists and spine beams to this period may imply this is the date of the floorboards above. The roof tiebeams in the Governor's Room date to AD 1793/4. This is in an area where the windows are thought to date from a restoration of AD 1864 (Cherry and Pevsner 1989, 296). The tree-ring result implies that there may be several post-medieval repair or remodelling phases, at least in this area of the church.

Acknowledgements

The sampling and analysis programme was funded by English Heritage. Chris Pickford kindly discussed his observations on the clock chamber and bellframe, and gave permission to use the drawings used in Figures 3, 5, 6, and 7. Francis Kelly and Peter Marshall both from English Heritage put together the request documentation, and discussed its details whilst at the site. Cathy Groves provided useful discussion of the results and the report. Mr Holloway, Clerk to the Governors, kindly provided access to the building.

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Figure 1 Location of Crediton, Devon, within England and Wales.

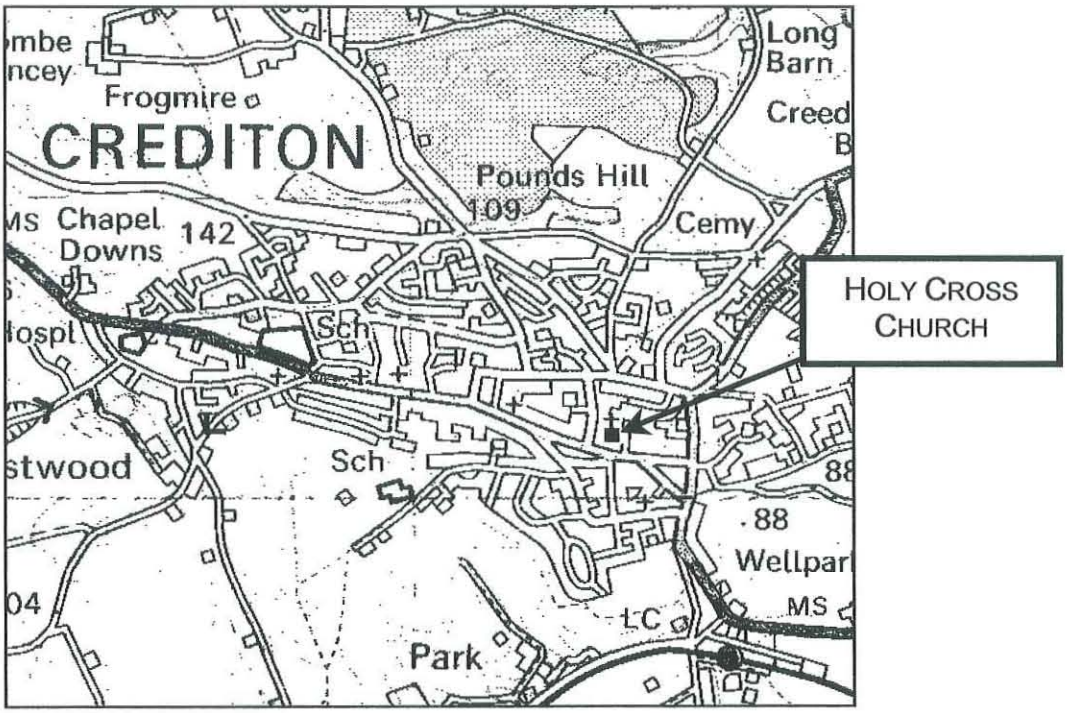

Figure 3 Sketch section of the clock chamber at Holy Cross church, Crediton, Devon (looking west), showing the relationship between the various horizontal beam groups and the forked timbers. The labelling scheme applied to the beams is also shown (figure based on a diagram supplied by Chris Pickford). See Figs 4-7 for the sample locations in these groups

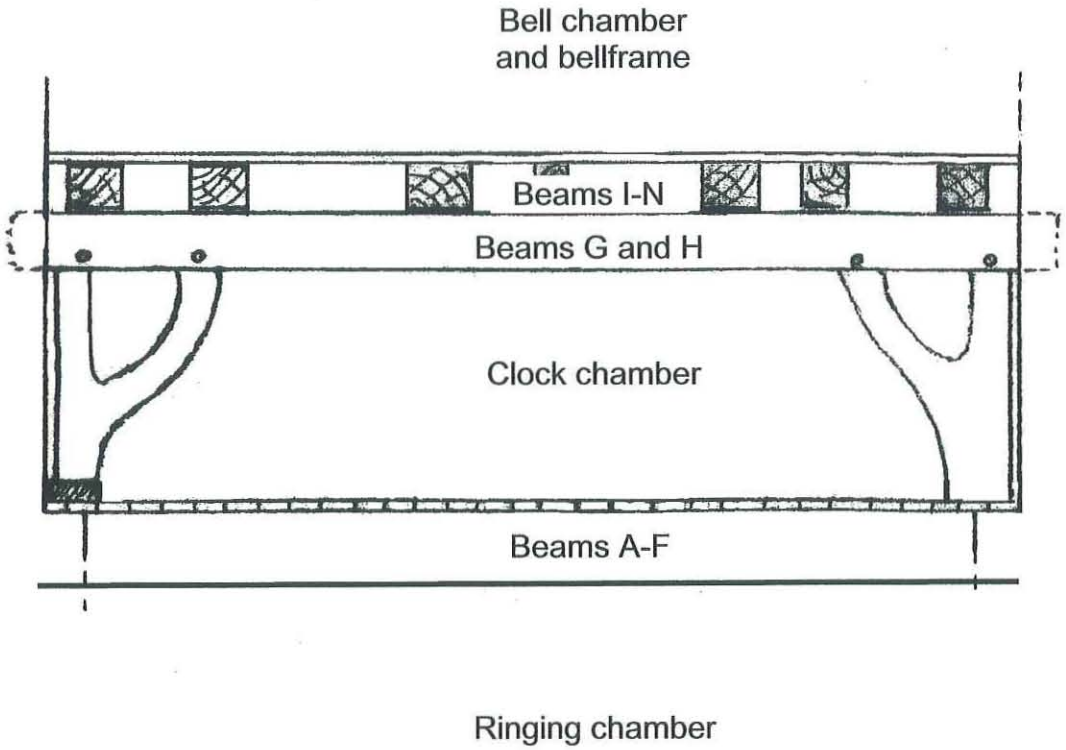

Figure 4 Sketch plan of the floor beams of the clock chamber at Holy Cross church, Crediton, Devon, showing labelling scheme applied. The labelled arrows indicate the sampled timbers visible on this plan

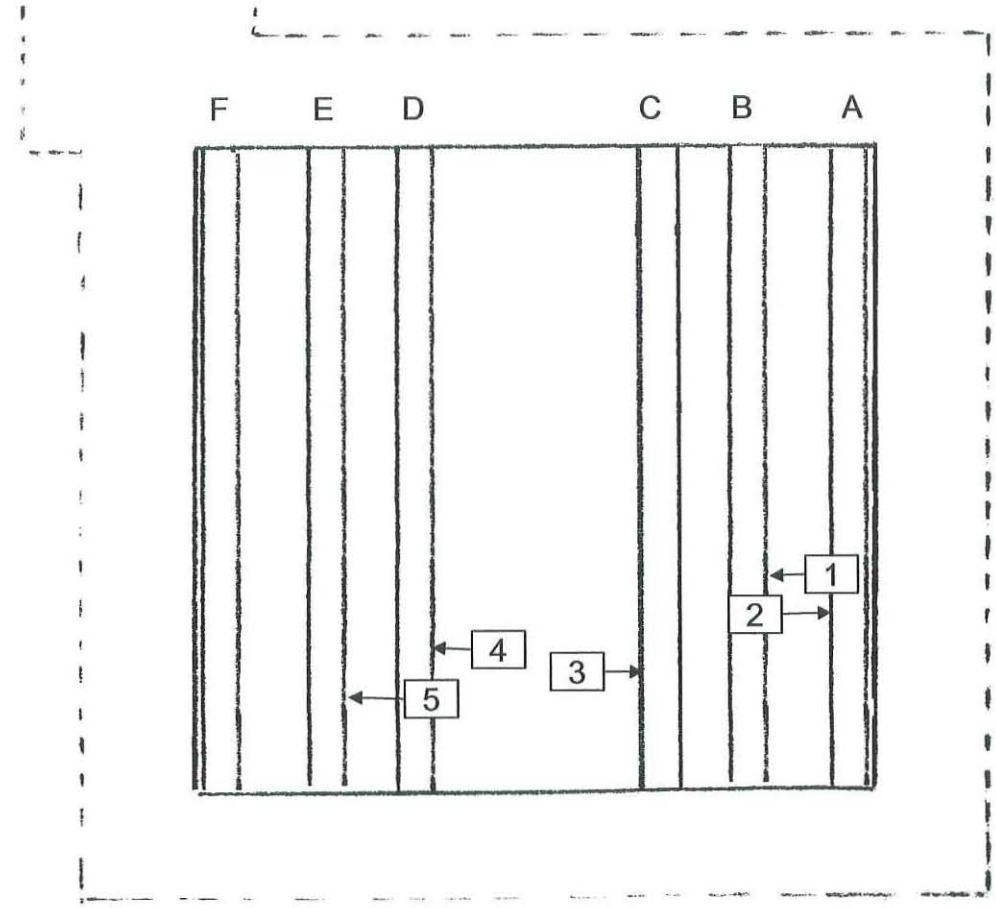

Figure 5 Sketch plan of the forked timbers in the clock chamber at Holy Cross church, Crediton, Devon, showing labelling scheme applied (figure and numbering based on a diagram supplied by Chris Pickford). The labelled arrows indicate the sampled timbers visible on this plan

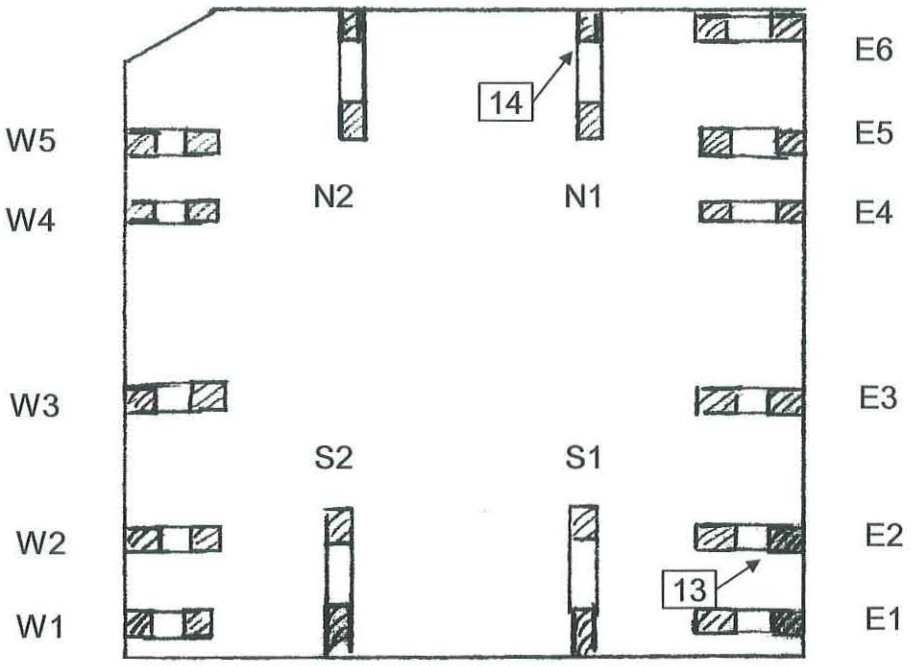

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Figure 6 Sketch plan of the ceiling beams of the clock chamber at Holy Cross church, Crediton, Devon, showing labelling scheme applied (figure based on a diagram supplied by Chris Pickford). The labelled arrows indicate the sampled timbers visible on this plan

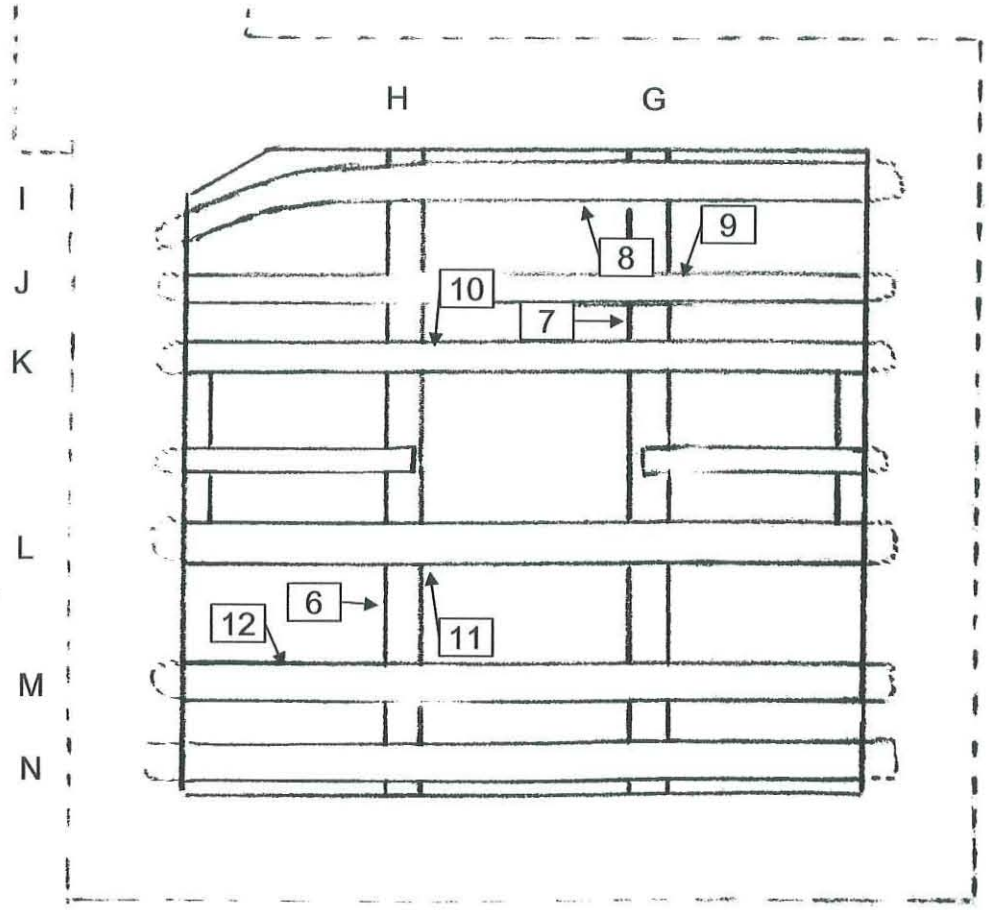

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Figure 7 Sketch plan of the bellframe at Holy Cross church, Crediton, Devon (figure based on a diagram supplied by Chris Pickford). The labelled arrows indicate the approximate location of the sampled timbers

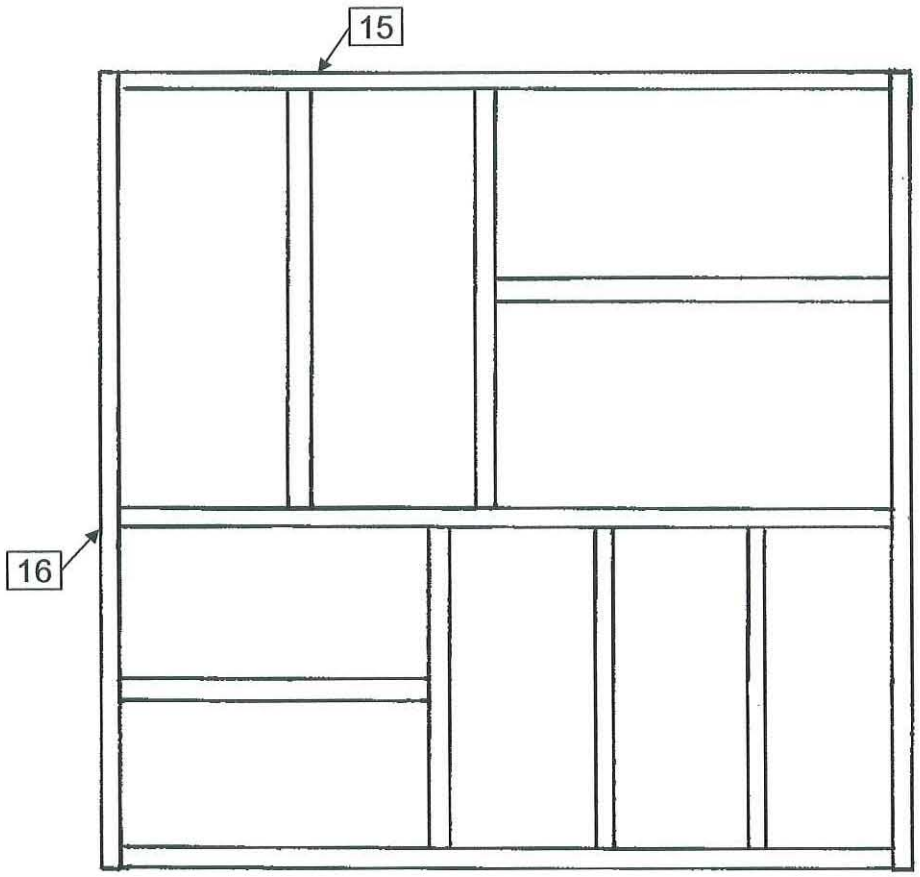


Figure 8 Simplified sketch plan of the Governor's Room roof at Holy Cross church, Crediton, Devon. The labelled arrows indicate the sampled timbers visible on this plan

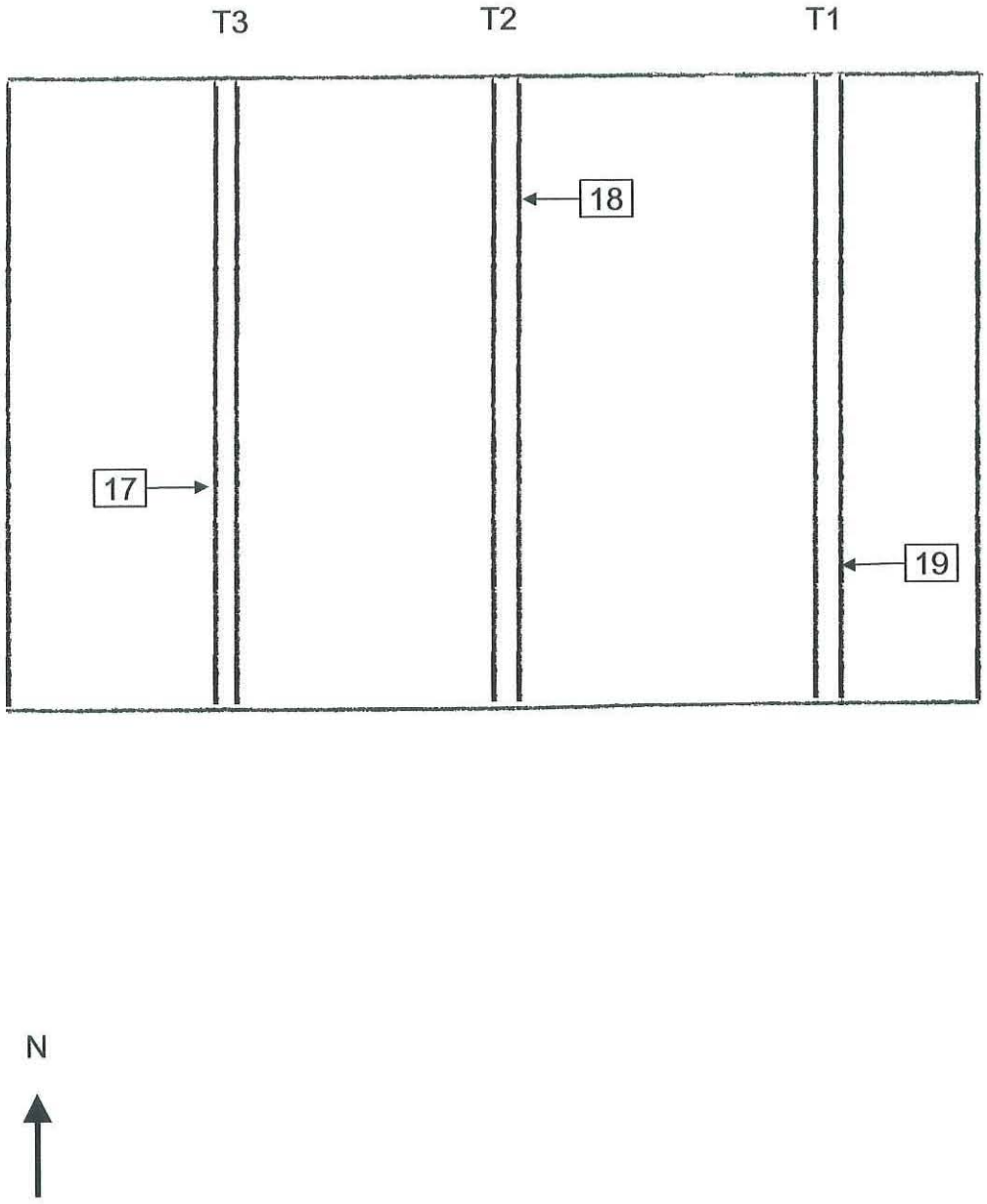


Figure 9 Simplified sketch plan of the Governor's Room floor at Holy Cross church, Crediton, Devon. Showing the spine beams (double line) and joists (single line), the hatched area is a dividing wall. The labelled arrows indicate the sampled timbers visible on this plan

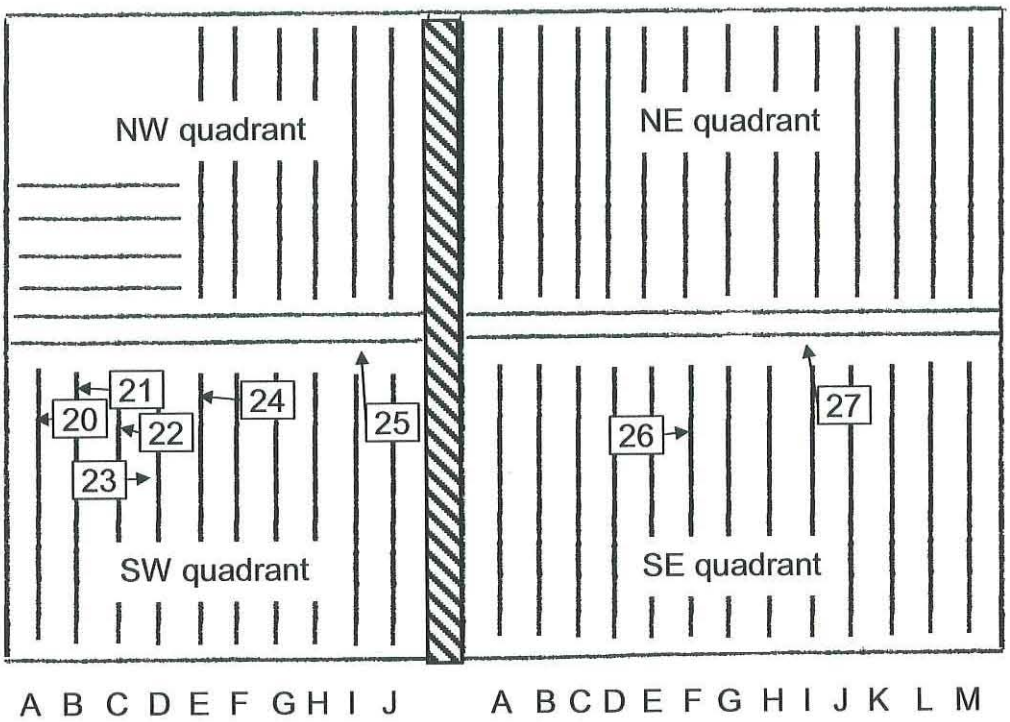
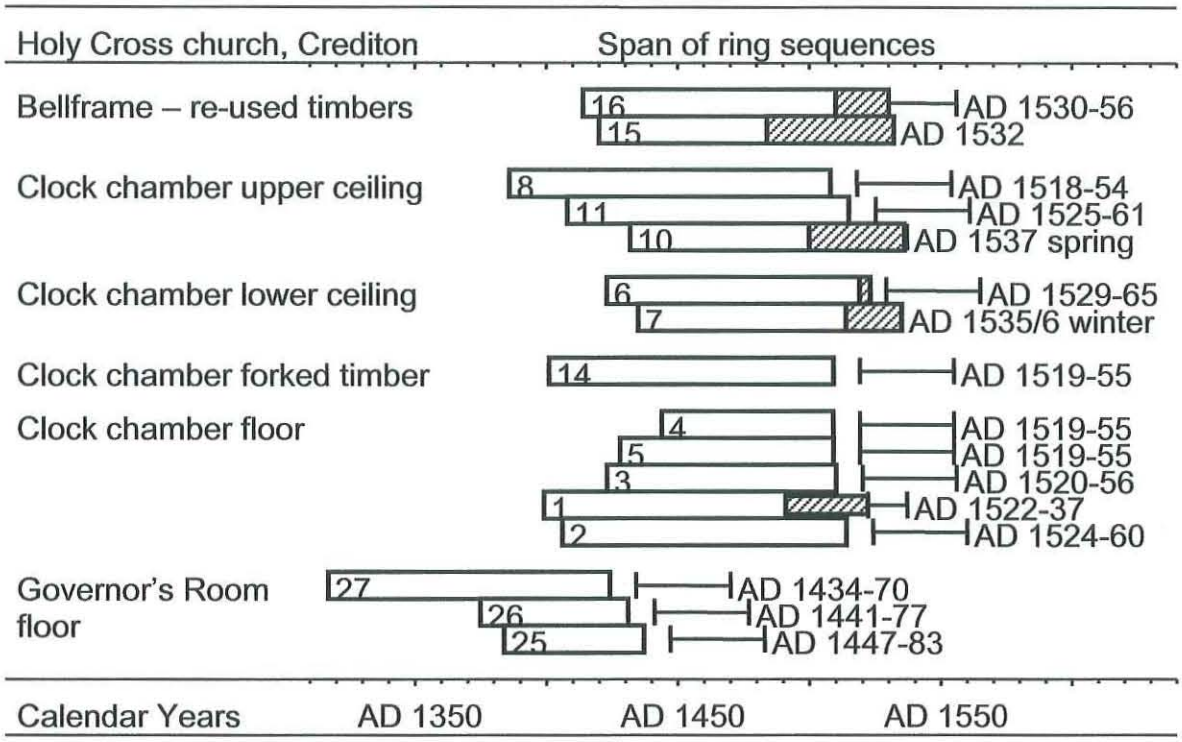


Figure 10 Bar diagram showing the chronological positions of the dated medieval timbers from Holy Cross church, Crediton, Devon. The first five groups are arranged as they are located up the tower. The estimated felling period for each sequence is also shown



KEY for figures 10 and 11

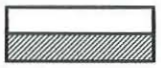


Figure 11 Bar diagram showing the chronological positions of the dated post-medieval timbers from Holy Cross church, Crediton, Devon. The estimated felling period for each sequence is also shown

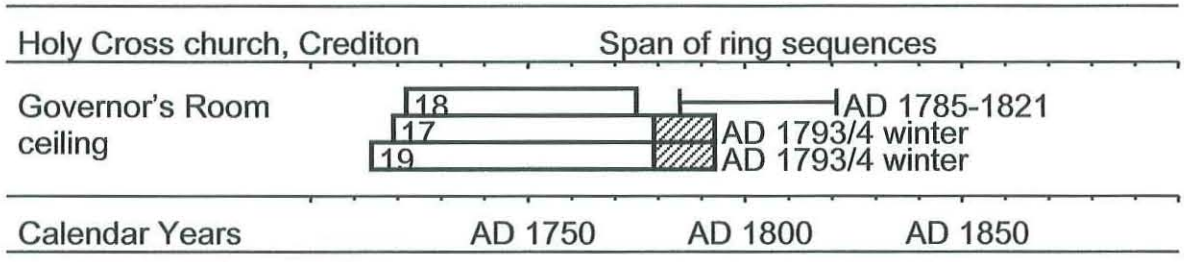


Table 1a List of samples from the tower at Holy Cross church, Crediton, Devon

Core No	Origin of core	Cross-section size (mm)	Total rings	Sapwood rings	ARW (mm/year)	Date of sequence	Felling period
1	Clock-chamber floor B	410 x 330	93	*+31sap*	1.43	AD1399-AD1491	AD1522-37
2	Clock-chamber floor A	350 x 300	109	H/S	1.00	AD1406-AD1514	AD1524-60
3	Clock-chamber floor C	380 x ?	88	H/S	2.11	AD1423-AD1510	AD1520-56
4	Clock-chamber floor D	410 x 330	66	H/S	1.72	AD1444-AD1509	AD1519-55
5	Clock-chamber floor E	370 x ?	82	H/S	1.93	AD1428-AD1509	AD1519-55
6	Clock-chamber ceiling H	420 x 400	101	4	2.13	AD1423-AD1523	AD1529-65
7	Clock-chamber ceiling G	400 x 400	101	21+Bw	3.10	AD1435-AD1535	AD1535/6 winter
8	Clock-chamber ceiling I	320 x 320	123	H/S	1.38	AD1386-AD1508	AD1518-54
9	Clock-chamber ceiling J	330 x 300	-	-	-	unmeasured	-
10	Clock-chamber ceiling K	340 x 330	105	36+½Bs	1.53	AD1432-AD1536	AD1537 spring
11	Clock-chamber ceiling L	400 x 340	108	H/S	1.50	AD1408-AD1515	AD1525-61
12	Clock-chamber ceiling M	340 x 340	-	-	-	unmeasured	-
13	Forked timber E5	300 x 150	-	-	-	unmeasured	-
14	Forked timber N2	270 x 240	109	H/S	1.84	AD1401-AD1509	AD1519-55
15	Bellframe endpost XXIII	220 x 130	113	48+B	1.07	AD1420-AD1532	AD1532
16	Bellframe endpost XX	220 x 130	117	20	1.53	AD1414-AD1530	AD1530-56

KEY for Table 1a See Figs 3-7 for sampling locations. Timbers dimensions could not always be measured due to access. Total rings = all measured rings, values in italics indicate unmeasurable or disconnected sections of the samples. Sapwood rings: H/S heartwood/sapwood boundary, +B bark-edge season indeterminate, +Bw bark winter felled, +½Bs bark spring felled in following year, ARW = average ring width of the measured rings

Table 1b List of samples from the Governor's Room at Holy Cross church, Crediton, Devon

Core No	Origin of core	Cross-section size (mm)	Total rings	Sapwood rings	ARW (mm/year)	Date of sequence	Felling period
17	T3 Tiebeam	400 x 210	75	14+Bw	3.79	AD1719-AD1793	AD1793/4 winter
18	T2 Tiebeam	350 x 260	54	H/S	3.93	AD1722-AD1775	AD1785-1821
19	T1 Tiebeam	370 x 230	80	14+Bw	3.49	AD1714-AD1793	AD1793/4 winter
20	South-west Joist A	135 x 110	52	H/S	1.83	undated	-
21	South-west Joist B	140 x 120	56	-	2.19	undated	-
22	South-west Joist C	135 x 125	86	H/S	1.40	undated	-
23	South-west Joist D	145 x 130	-	-	-	unmeasured	-
24	South-west Joist E	140 x 125	95	-	1.75	undated	-
25	West Spine beam	340 x 280	54	H/S	3.30	AD1384-AD1437	AD1447-83
26	South-east Joist F	145 x 130	57	H/S	2.74	AD1375-AD1431	AD1441-77
27	East Spine beam	350 x 260	108	H/S	2.05	AD1317-AD1424	AD1434-70

KEY for Table 1 See Figs 8 and 9 for truss numbering scheme, and Fig 6 for joists and beam arrangement. Total rings = all measured rings. Sapwood rings: H/S heartwood/sapwood boundary, +Bw bark-edge winter felled, ARW = average ring width of the measured rings

Table 2

t-value matrix for the timbers forming the chronology CREDITONT

	2	3	4	5	6	7	8	10	11	14	15	16
1	7.89	-	7.09	4.14	4.69	-	6.68	5.04	4.07	7.86	4.38	4.09
2		-	4.07	-	4.08	-	3.82	4.95	4.55	5.24	4.64	3.95
3			-	6.92	3.88	4.11	3.54	4.57	-	-	-	-
4				-	5.36	-	3.43	4.93	-	3.11	5.60	3.75
5					3.95	-	4.00	4.17	-	3.46	4.50	4.22
6						-	3.90	6.79	6.19	-	5.41	4.50
7							-	5.32	-	-	3.87	-
8								3.36	-	4.76	4.83	3.61
10									4.34	3.30	5.82	3.71
11										-	-	3.09
14											4.78	4.59
15												6.36

Table 3

t-value matrix for the timbers forming the chronology CREDITONR

	18	19
17	4.09	6.82
18		3.53

Table 4

t-value matrix for the timbers forming the chronology CREDITONJ

	21	22	24
20	4.45	5.17	9.51
21		5.68	6.34
22			7.55

Table 5

Dating the mean sequence CREDITONT, AD 1386-1536 inclusive. Example *t*-values with independent reference chronologies

Reference chronology	*t*-value
Avon, Tickenham Court Hall (Miles *et al* 1994)	8.03
Cornwall, Pendennis Castle nr Falmouth (author in prep)	8.74
Cornwall, Roscarrock nr St Endellion (author in prep)	8.56
Devon, Eastleigh Manor (Miles 1994)	8.14
Devon, Prowse Farm Barn (Tyers *et al* 1997)	6.81
Gloucestershire, 26 Westgate Street Gloucester (Howard *et al* 1998)	7.59
Herefordshire, White House Vowchurch (Nayling 1999)	8.53
Herefordshire, Widemarsh St Hereford Farmers Club (Tyers 1996)	9.36
Somerset, Lancin Farmhouse Wambrook (Tyers 1994)	8.11
Staffordshire, Black Ladies nr Brewood (Tyers 1999b)	7.55

Table 6

Dating the mean sequence CREDITONR, AD 1714-1793 inclusive. Example *t*-values with independent reference chronologies

Reference chronology	*t*-value
Berkshire, Skeleton Barn Hampstead Norreys (Miles 2001)	3.86
Cornwall, Boconnoc (Briffa *et al* 1986)	3.88
Cornwall, Cotehele House nr Calstock (author in prep)	3.52
Cornwall, South Coombeshead (Tyers and Groves 1999)	5.72
Devon, Buckland Yelverton (Morgan pers comm)	5.09
Devon, Exeter Cathedral (Mills 1988)	6.44
Kent, Chatham Dockyard Wheelwrights Shop (Bridge 1998)	3.57
London, H.M.S. Victory (Barefoot 1975)	4.12
Wiltshire, Clarendon House Granary (Tyers 2001)	4.29
Wiltshire, Savernake Forest (Briffa *et al* 1986)	4.19

Table 7

Dating samples **25-27**. Example *t*-values with independent reference chronologies

Reference chronology	25	26	27
Cornwall, Cotehele House nr Calstock (author in prep)	3.68	4.71	-
Cornwall, Pendennis Castle nr Falmouth (author in prep)	3.34	4.90	4.09
Cornwall, Roscarrock nr St Endellion (author in prep)	3.48	4.29	3.13
Devon, Churchstow Leigh Barton (Tyers and Groves 1999)	3.09	3.72	5.01
Devon, Crediton Holy Cross church tower (this report)	6.38	4.55	-
Devon, Kings Nympton Broomham (Tyers *et al* 1997)	5.37	3.84	3.42
Devon, Kings Nympton West Hele (Tyers *et al* 1997)	6.58	3.67	-
Devon, Prowse Farm Barn (Tyers *et al* 1997)	3.49	6.22	-
Devon, South Yarde Rose Ash (Groves and Hillam 1993)	-	5.90	5.26
Devon, West Challacombe (Tyers and Groves 1999)	-	3.72	6.35

Appendix 1 Ring width data for measured samples from Holy Cross church, Crediton, Devon, 100 = 1mm

chc01

304	306	253	138	184	336	308	388	270	287
350	270	176	186	175	188	180	146	190	257
118	123	118	107	246	213	177	185	174	226
130	145	146	315	141	139	183	234	224	164
85	149	141	111	130	151	150	178	122	110
127	94	148	95	84	139	112	136	121	126
63	62	56	77	74	85	83	109	85	76
51	70	76	64	72	72	117	75	54	49
38	50	82	79	89	88	66	83	85	64
44	54	69							

chc02

174	143	158	153	167	125	144	160	147	137
132	135	140	85	87	126	94	195	155	141
205	137	127	75	83	91	133	85	86	123
98	107	77	70	87	81	86	85	88	91
112	67	69	70	54	78	69	77	95	66
103	120	102	60	53	58	62	83	62	77
71	58	66	50	80	78	72	88	113	139
110	107	89	68	113	109	77	113	155	158
159	184	149	136	112	107	76	97	102	93
101	109	67	72	53	60	60	52	56	58
66	49	64	64	58	79	122	120	127	

chc03

485	192	154	227	202	281	202	342	305	359
216	345	286	277	222	278	344	270	369	248
198	159	128	122	183	310	233	224	259	164
223	440	279	408	251	272	180	246	190	165
218	152	198	269	267	224	172	208	211	189
168	162	265	185	107	114	168	140	168	235
231	162	230	194	214	183	135	149	119	84
111	103	147	196	182	101	129	116	123	153
156	257	245	145	162	158	154	129		

chc04

306	388	584	400	239	241	196	263	286	227
304	257	337	297	305	211	162	157	215	215
180	190	217	196	120	83	122	130	106	95
119	184	208	162	117	95	95	145	121	127
142	118	141	130	126	70	68	116	96	101
126	107	149	136	113	115	108	75	78	106
146	122	136	96	95	131				

chc05

439	292	346	319	484	313	384	334	339	370
342	300	290	272	261	289	241	261	267	315
303	222	280	266	182	206	191	186	221	187
199	130	179	143	122	147	126	150	161	167
125	109	122	157	122	148	137	210	190	136
131	162	122	146	158	176	150	164	194	203
157	94	151	119	94	105	79	135	181	154
94	142	105	100	98	101	114	95	103	84
96	111								

chc06

284	320	262	296	197	240	237	241	274	233
183	248	248	229	227	201	152	232	214	217
210	204	200	267	262	210	214	165	208	228
181	253	185	239	234	251	166	146	178	179
270	190	169	213	226	155	134	210	236	203
203	186	302	284	170	147	146	157	234	228
250	231	250	218	253	188	225	241	158	139
150	224	219	295	202	169	150	150	152	190
251	278	217	217	173	218	188	248	252	274
260	250	190	126	123	144	196	173	220	274
197									

chc07

155	82	80	66	219	262	467	320	534	500
425	430	382	423	481	351	444	314	277	537
381	527	496	553	558	525	377	362	497	254
352	453	381	353	331	336	254	247	294	323
397	328	344	290	362	326	292	295	303	383
429	397	442	423	334	363	318	281	344	232
230	473	309	250	504	523	210	410	247	332
299	212	137	150	237	96	149	269	264	259
261	136	116	93	169	109	316	240	161	121
143	282	289	241	165	171	190	215	245	284
323									

chc08

318	200	143	153	172	244	198	277	193	178
146	126	153	255	235	250	160	199	207	198
283	205	221	249	396	352	338	276	352	251
198	205	245	169	177	148	148	263	195	178
199	132	123	136	150	135	225	147	171	153
213	266	224	135	135	117	96	80	118	92
109	102	89	80	76	75	30	53	77	70
81	71	88	64	55	50	59	64	73	62
61	62	68	51	85	78	68	81	64	123
105	90	71	74	95	125	156	135	166	176
164	160	133	99	81	73	50	61	59	59
68	59	57	63	49	50	52	64	76	68
60	45	53							

chc10

231	168	275	399	376	322	194	227	213	293
188	222	213	210	303	253	283	273	230	222
158	165	193	129	194	176	173	117	101	149
173	228	132	174	174	130	93	95	116	119
109	125	127	181	118	112	86	89	92	112
150	168	176	197	171	196	133	115	125	121
92	97	123	143	209	140	126	132	136	109
105	133	163	152	118	88	93	114	111	114
141	133	150	112	105	92	97	156	109	125
121	104	100	99	88	107	110	105	67	108
102	104	111	112	139					

chc11

355	292	234	249	280	299	225	206	196	246
228	130	156	136	134	283	196	189	207	104
146	106	127	132	121	120	150	233	129	121
73	70	95	113	112	117	104	93	149	111
90	150	78	88	76	80	82	82	49	73
86	63	56	77	102	104	80	98	73	103
77	60	108	142	135	107	156	162	130	85
95	129	145	122	154	206	186	150	166	175
169	182	208	187	138	114	274	246	270	177
187	172	114	125	169	174	236	192	161	152
167	165	151	209	196	177	216	108		

chc14

372	310	385	370	291	414	287	231	305	243
184	252	239	239	260	236	279	268	153	214
242	172	247	234	201	248	279	277	197	190
189	344	204	186	223	201	249	206	151	164
182	155	128	146	129	160	162	225	161	116
152	113	120	132	146	131	116	171	121	114
97	112	134	142	194	175	138	137	121	195
172	141	158	140	183	144	150	144	115	118
163	145	146	158	143	161	198	187	165	147
161	147	162	114	152	169	177	147	157	165
137	129	173	146	130	109	94	98	122	

chc15

208	198	165	287	214	205	199	159	207	213
159	161	193	154	122	134	118	164	144	151
124	140	151	119	105	116	163	116	128	110
117	171	148	136	189	145	159	134	146	118
99	97	101	153	117	126	134	107	104	98
116	130	109	93	106	105	116	90	72	75
75	105	96	77	96	113	91	100	90	72
87	80	69	71	70	83	104	76	66	82
63	65	56	66	68	62	60	43	59	62
51	56	56	60	55	49	41	38	52	68
55	56	93	70	66	64	69	86	71	60
50	72	62							

chc16

261	278	257	292	367	213	297	238	237	342
271	234	255	193	237	146	191	177	321	207
262	218	173	265	265	174	112	124	128	145
129	104	166	179	167	198	133	117	117	107
99	108	161	160	173	128	114	111	128	138
111	130	163	109	71	64	96	112	102	151
115	147	171	106	119	83	131	146	144	152
202	219	182	120	95	62	75	70	67	61
60	154	163	127	120	121	79	83	104	152
165	142	131	68	150	118	86	136	148	150
198	111	70	84	103	109	114	150	228	172
145	83	136	147	150	105	99			

chc17

445	408	364	265	278	342	306	423	313	521
379	405	293	415	508	585	525	680	608	491
578	355	341	344	484	407	376	540	449	360
322	359	471	453	472	393	318	273	293	360
406	384	451	217	398	320	346	420	444	620
539	377	277	293	390	325	278	383	392	330
396	371	363	324	331	359	206	255	328	275
187	223	243	258	213					

chc18

337	314	424	383	417	561	532	403	486	336
560	477	371	525	467	416	472	609	394	400
271	507	362	421	534	528	494	340	562	488
452	422	505	614	377	484	423	502	436	329
212	381	261	237	267	253	319	208	149	156
187	195	197	258						

chc19

297	509	273	424	533	544	543	518	399	396
422	310	342	330	504	470	410	277	427	434
508	375	317	307	378	579	342	363	297	610
404	351	416	390	371	437	394	447	446	466
395	298	293	291	437	477	372	386	218	297
365	292	381	328	429	356	272	211	201	205
273	248	264	261	219	215	247	248	275	179
291	218	271	283	221	200	170	278	296	232

chc20

192	188	191	196	171	166	157	185	137	218
178	144	148	153	188	187	174	187	183	186
212	186	312	231	172	210	205	179	177	247
241	247	169	189	224	246	171	184	171	209
174	177	141	184	161	129	111	133	138	141
138	158								

chc21

95	163	206	193	149	119	176	185	133	96
128	126	140	141	150	183	214	273	394	347
372	277	265	250	181	357	242	306	234	332
287	406	396	318	310	285	234	348	245	179
194	201	230	199	175	161	203	125	189	180
137	121	188	208	177	168				

chc22

162	145	188	245	219	156	178	150	217	188
270	226	257	229	236	186	236	173	244	224
131	151	154	191	243	197	163	181	121	170
195	117	96	119	159	118	144	153	161	156
180	234	187	134	101	113	83	81	66	110
125	127	78	77	102	102	89	110	112	168
131	101	97	97	88	85	58	77	91	91
103	84	73	82	70	62	92	108	164	130
121	121	94	71	88	75				

chc24

183	162	227	202	223	207	152	157	153	147
146	164	147	119	132	121	148	171	166	145
139	155	166	127	106	122	111	147	132	128
141	146	134	168	174	160	176	229	165	161
165	168	263	175	224	213	272	291	189	171
195	201	243	221	156	167	187	198	200	166
162	179	132	198	167	132	123	158	178	181
188	192	175	167	176	223	280	215	163	171
177	156	176	244	227	208	144	154	204	190
156	184	176	194	173					

chc25

332	359	505	466	200	263	326	563	345	517
340	390	280	260	295	328	303	363	292	237
282	324	453	306	357	393	425	244	275	335
276	295	306	426	495	275	511	348	308	415
355	318	232	286	260	257	254	313	383	262
227	268	183	198						

chc26

343	424	342	494	395	281	225	262	289	308
199	465	432	405	267	159	227	270	393	276
294	316	220	331	393	357	261	213	273	361
340	310	220	254	240	159	159	188	214	327
258	239	292	277	143	180	234	166	304	263
235	295	168	183	175	151	151			

chc27

277	281	307	228	282	297	300	195	182	138
221	225	232	242	187	262	319	324	285	233
305	365	273	239	273	279	292	278	214	185
153	198	210	149	192	225	251	292	286	253
244	343	306	198	161	167	240	261	191	157
144	153	222	210	160	216	201	240	146	245
184	180	201	166	167	149	152	150	132	205
178	171	165	148	143	132	170	145	175	159
152	163	167	141	113	160	178	216	202	162
192	206	167	233	188	179	229	211	135	135
127	162	119	210	171	120	162	130		