RESEARCH DEPARTMENT REPORT SERIES no. 74-2008 ISSN 1749-8775

CHURCH OF ST MABENA, ST MABYN, CORNWALL
DENDROCHRONOLOGICAL ANALYSIS OF OAK TIMBERS

SCIENTIFIC DATING REPORT

Ian Tyers

ARCHAEOLOGICAL SCIENCE

ENGLISH HERITAGE

Research Department Report Series 74-2008

CHURCH OF ST MABENA
ST MABYN
CORNWALL

DENDROCHRONOLOGICAL ANALYSIS OF OAK TIMBERS

Ian Tyers

NGR: SX 0418 7320

ISSN 1749-8775

The Research Department Report Series incorporates reports from all the specialist teams within the English Heritage Research Department: Archaeological Science; Archaeological Archives; Historic Interiors Research and Conservation; Archaeological Projects; Aerial Survey and Investigation; Archaeological Survey and Investigation; Architectural Investigation; Imaging, Graphics and Survey, and the Survey of London. It replaces the former Centre for Archaeology Reports Series, the Archaeological Investigation Report Series and the Architectural Investigation Report Series.

Many of these are interim reports which make available the results of specialist investigations in advance of full publication. They are not usually subject to external refereeing, and their conclusions may sometimes have to be modified in the light of information not available at the time of the investigation. Where no final project report is available, readers are advised to consult the author before citing these reports in any publication. Opinions expressed in Research Department reports are those of the author(s) and are not necessarily those of English Heritage.

Requests for further hard copies, after the initial print run, can be made by emailing:
Res.reports@english-heritage.org.uk
or by writing to:
English Heritage, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD
Please note that a charge will be made to cover printing and postage.

SUMMARY

A tree-ring dating programme was commissioned on timbers in the church of St Mabena, St Mabyn, Cornwall. The results identified that timbers in three areas of roof were datable by tree-ring dating techniques, with all three areas using timbers felled during the late-fifteenth or early sixteenth centuries. This dating programme was commissioned to exploit scaffolding access during grant aided repairs. This report archives the dendrochronological results.

CONTRIBUTORS

Ian Tyers

ACKNOWLEDGEMENTS

The sampling and analysis of timbers at the church of St Mabena, St Mabyn, Cornwall was funded by English Heritage (EH). Practical help and valuable discussions were provided by Francis Kelly, Historic Buildings Inspector South West Region (EH). Graham Howarth from Ryearch Ltd kindly facilitated access during the repair works.

ARCHIVE LOCATION

Cornwall and Scilly Historic Environment Record
Historic Environment Service
Kennall Building, Old County Hall
Station Road
Truro TR1 3AY

DATE OF INVESTIGATION

2008

CONTACT DETAILS

Dendrochronological Consultancy Ltd, 65 Crimicar Drive, Sheffield S10 4EF
Ian Tyers; ian@dendro.co.uk

CONTENTS

INTRODUCTION

This document is a technical archive report on the tree-ring analysis of timbers within three roofs of the church of St Mabena, St Mabyn, Cornwall (NGR SX 0418 7320). St Mabyn is a settlement on the north-western edge of Bodmin Moor, *c* 7km north of Bodmin, and *c* 5km east of Wadebridge. In 2008 grant-aided repairs to the north aisle roof, the nave, and chancel roofs, and the valley gutter between the nave/chancel and the north aisle of this Grade I listed parish church required the insertion of a large scaffold support structure, and a temporary weatherproof roof. A request was made to investigate if this allowed adequate access to the timbers to undertake sampling of the building. This report describes the results of the dendrochronological analysis of samples from three areas of roof in the church.

The church lies in the historic core of the settlement (Fig 1), and the existing church is thought to date from the later fifteenth century. The church has visually similar wagon roofs in the nave, chancel, north and south aisles, and porch (Fig 2). The nave has overall dimensions of *c* 18m length, and *c* 5.5m width, and contains 39 more or less identical trusses, it abuts a chancel roof of *c* 7m length and *c* 5.5m width with a further 22 trusses. The north aisle has overall dimensions of *c* 23m length, and *c* 5m width, and contains 49 more or less identical trusses. The porch has overall dimensions of *c* 2.5m length, and *c* 3.5m width, and contains seven again more-or-less identical trusses. Each truss in these roofs contains two straight common rafters, a collar purlin, and upper and lower curved braces on each side to form the wagon roof. There are some small ashlar pieces, usually angled, and some surviving fragments of outer wall plates (Fig 3). The inner wall plates carry decorative mouldings on the inside, and there are sets of carved bosses mostly every third truss inside as well. The roofs have evidently had problems of damp before the current repairs, as there are several campaigns of repairs documented in the nineteenth century and the chancel roof clearly has been extensively modified in the relatively recent past; it contains softwood common rafters and the present collar purlins are turned 90° from their original alignment. All the ancient timberwork throughout is in oak, and these oaks are derived from a mixture of whole trees and quartered trees, although the chancel roof is dominated by fast-grown whole trees.

The original timbers exhibit clear evidence for trestle sawing, and retain a series of scribed carpenters' numbers in Roman numerals. This report arbitrarily assigned truss numbers for each discrete area of roof, running from I at the east end of each of the east-west roofs, and from the north end of the porch (Fig 2).

METHODOLOGY

Tree-ring dating employs the patterns of tree-growth to determine the calendar dates for the period during which the sampled trees were alive. The amount of wood laid down in any one year by most trees is determined by the climate and other environmental factors. Trees over relatively wide geographical areas can exhibit similar patterns of growth, and

this enables dendrochronologists to assign dates to some samples by matching the growth pattern with other ring-sequences that have already been linked together to form reference chronologies.

The building was visited in May 2008 during the repair work. An assessment of the dendrochronological potential of timbers in five areas of the church had been requested by Francis Kelly. This assessment aimed to identify whether oak timbers with sufficient numbers of rings for analysis existed in any part of the structure. This assessment concluded that the timbers in the chancel roof, and the limited number of surviving timbers in the church tower were unsuitable for sampling and analysis. In contrast, the north side of the north aisle roof and the north side of the nave roof both contained some suitable material, particularly the common rafters and their lower curved wagon braces, whilst the much smaller porch also appeared to be constructed from suitable material. Access to timbers on the south sides of both roofs, and sampling of the collars was considered impractical because of Health and Safety issues. Throughout the building the survival of bark-edge was non-existent and survival of sapwood was negligible.

The selected 23 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 ring sequences in the cores were revealed by sanding.

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

Standard dendrochronological analysis methods (eg English Heritage 1998) were applied to each suitable sample. The complete sequence of the annual growth rings in the suitable samples were measured to an accuracy of 0.01mm using a micro-computer based travelling stage. The sequence of ring widths were then plotted onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition, cross-correlation algorithms (eg Baillie and Pilcher 1973) were employed to search for positions where the ring sequences were highly correlated (Tyers 2004a). Highly correlated positions were checked using the graphs and, if any of these were satisfactory, new composite sequences were constructed from the synchronised sequences. Any *t*-values reported below were derived from the original CROS algorithm (Baillie and Pilcher 1973). A *t*-value of 3.5 or over is usually indicative of a good match, although this is with the proviso that high *t*-values at the same relative or absolute position need to have been obtained from a range of independent sequences, and that these positions were supported by satisfactory visual matching.

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

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

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

'early spring', where only the initial cells of the new growth have begun – this is equivalent to a period in March/April, when the oaks begin leaf-bud formation;

'later spring/summer' where the early wood is complete but the late wood is evidently incomplete, which is equivalent to May-through-September of a normal year, and

'winter' where the latewood is complete and this is roughly equivalent to September-to-March (of the following year) since the tree is dormant throughout this period and there is no additional growth put on the trunk.

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

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

Reused timbers can only provide tree-ring dates for the original usage date, not their reuse. Identifying reused timbers requires careful timber recording which notes the presence of features which are not functional in the structure. It is always possible that some timbers exhibit no evidence of earlier usage, and are thus 'hidden reused' timbers.

The dendrochronological impact of this problem is particularly acute where only single timbers have been dated from a structure.

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

RESULTS

In May 2008 timbers of three separate roofs were cored; these cores were labelled 1–23 inclusive. Fifteen timbers were sampled in the north aisle roof, six in the nave roof, and two in the porch roof. Each sample was assessed for the wood type, the number of rings it contained, and whether the sequence of ring widths could be reliably resolved. This assessment confirmed that all the sampled timbers were oak (*Quercus* spp.) and that 22 (the exception was sample 3, which had too few rings) were suitable for dendrochronological analysis. The details of these samples are provided in Table 1.

The samples were prepared for analysis, measured, and then compared with each other. A group of nine timbers from the north aisle roof were found to cross-match each other strongly (Table 2), whilst a group of four samples from the nave roof and the two samples from the porch were also found to form an internally consistent group (Table 3). Each cross-matched group was then combined into a single composite data set. These were compared with each other without identifying any significant correlation between them. These two composite data sets were then compared with medieval and later tree-ring data from throughout England and Wales. Both the composite sequences were found to cross-match against medieval data from sites in the South-West region. This cross-matching provided consistent calendar dates for both sequences (Table 4), and also coincided with a weak match between the two sequences. A summary of the results for the component samples of these two chronologies are provided in Table 1 and Figure 4. The other seven individual series failed to provide any consistent dating evidence. The measurement data for all the measured samples are listed in Appendix 1.

DISCUSSION

Both the composite sequences were found to strongly match composite sequences obtained from buildings in Cornwall and Devon as well as to a lesser extent to other series from across the South-West and other English regions. Although there is still relatively little replicated contemporaneous medieval tree-ring data from the south-western counties of England, it is most likely that this timber was derived from the immediate vicinity of St Mabyn. This cross-dating indicated a late-fifteenth or early sixteenth-century date for all the datable timbers.

The tree-ring analysis dates the rings present in the cores. The correct interpretation of those dates relies upon the characteristics of the final rings in them. No sapwood survived on any of the timbers, previous problems of water entry into the roofs had presumably ensured this, but almost all the samples were targeted at timbers with surfaces that appeared to be their original heartwood/sapwood boundaries. Making allowances for minimum and maximum likely amounts of missing sapwood provides individual felling date ranges for each of the datable timbers. Figure 4 and Table 1 includes the interpreted felling date ranges for each of the datable samples.

The mathematical combination of estimated sapwood distributions is statistically complex. Whatever method is used would indicate these roofs are utilising timbers felled in the later fifteenth and/or early sixteenth centuries. The calculation of common felling periods for the three roofs suggests construction dates of AD 1513–35 for the north aisle, AD 1485–1514 for the nave, and AD 1487–1523 for the porch. It is therefore most likely that the nave and porch are broadly contemporaneous, with the north aisle roof likely to have been a slightly later addition. Given the uncertainty of the correct sapwood estimate to utilise in this area, the use of robust combinatorial methods or alternative statistical approaches might sacrifice a broad and indicative date for a narrower one of potentially spurious precision. The obvious conclusion is that the north aisle was probably built a short period after the nave, porch, and perhaps the chancel were built. This extensive campaign of building presumably reflects a period of economic strength in the parish.

REFERENCES

Arnold, A, Howard, R, and Litton, C, 2006 *Church of St Martin, East Looe, Cornwall: tree-ring analysis of roof timbers*, EH Res Dep Rep Ser, 46/2006

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

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

Groves, C, 2005 *Dendrochronological Research in Devon: Phase I*, Centre for Archaeol Rep, 56/2005

Howard, R E, Laxton, R R, and Litton, C D, 1996 *Tree-ring analysis of timbers from Mercer's Hall, Mercer's Lane, Gloucester*, Anc Mon Lab Rep, 13/96

Howard, R E, Laxton, R R, and Litton, C D, 1998 *Tree-ring analysis of timbers from Naas House, Lydney, Gloucestershire*, Anc Mon Lab Rep, 36/98

Nayling, N, 1999 *Tree-ring analysis of timbers from the White House, Vowchurch, Herefordshire*, Anc Mon Lab Rep, 73/1999

Tyers, I, 2004a *Dendro for Windows program guide 3rd edn*, ARCUS Rep, 500b

Tyers, I, 2004b *Tree-ring analysis of oak timbers from Holy Cross Church, Crediton, Devon*, Centre for Archaeol Rep, 32/2004

Tyers, I, 2004c *Tree-ring analysis of oak timbers from Pendennis Castle, Near Falmouth, Cornwall*, Centre for Archaeol Rep, 38/2004

FIGURES

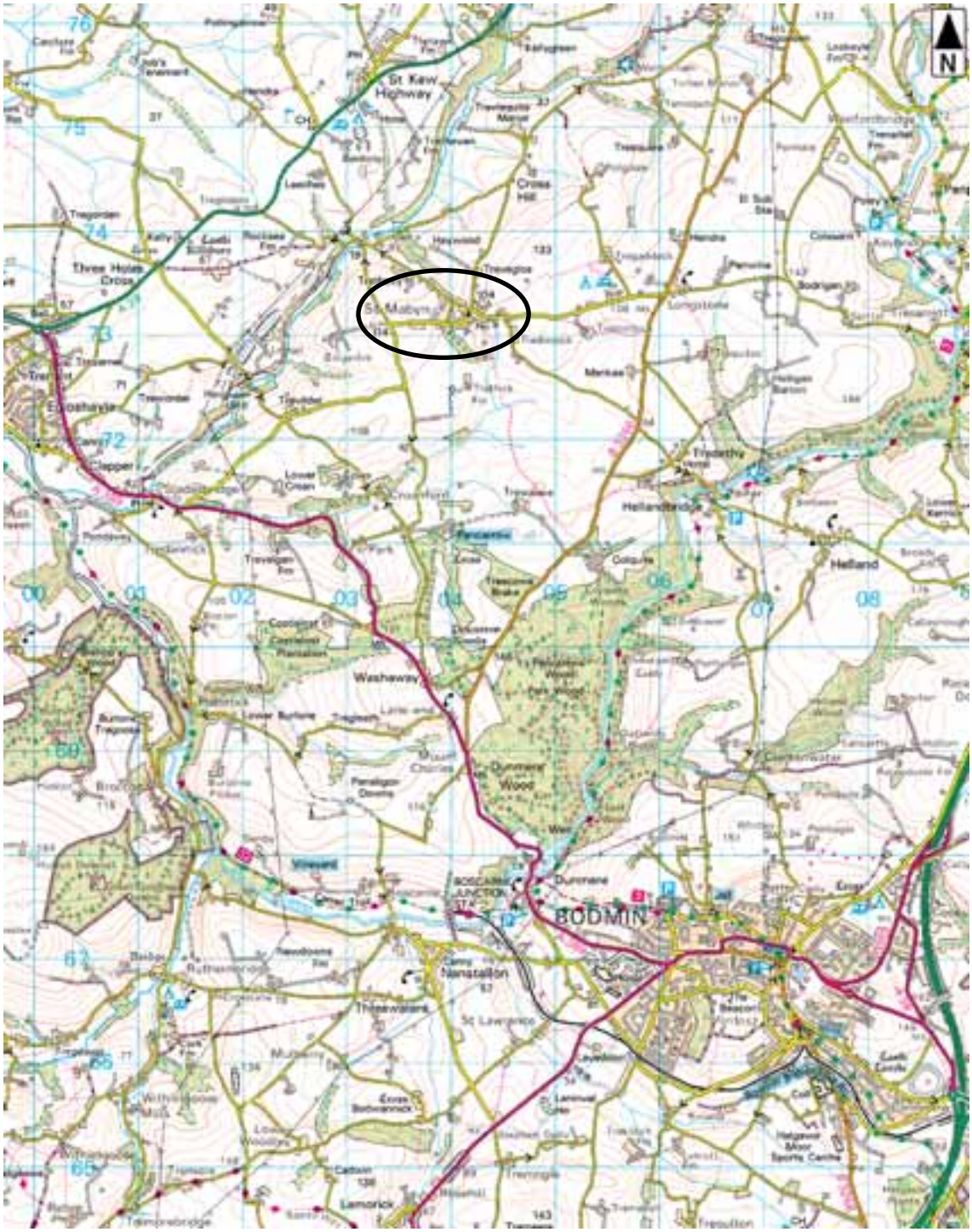

Figure 1. Location of the church of St Mabena, St Mabyn, Cornwall (circled). © Crown Copyright. All rights reserved. English Heritage 100019088. 2007

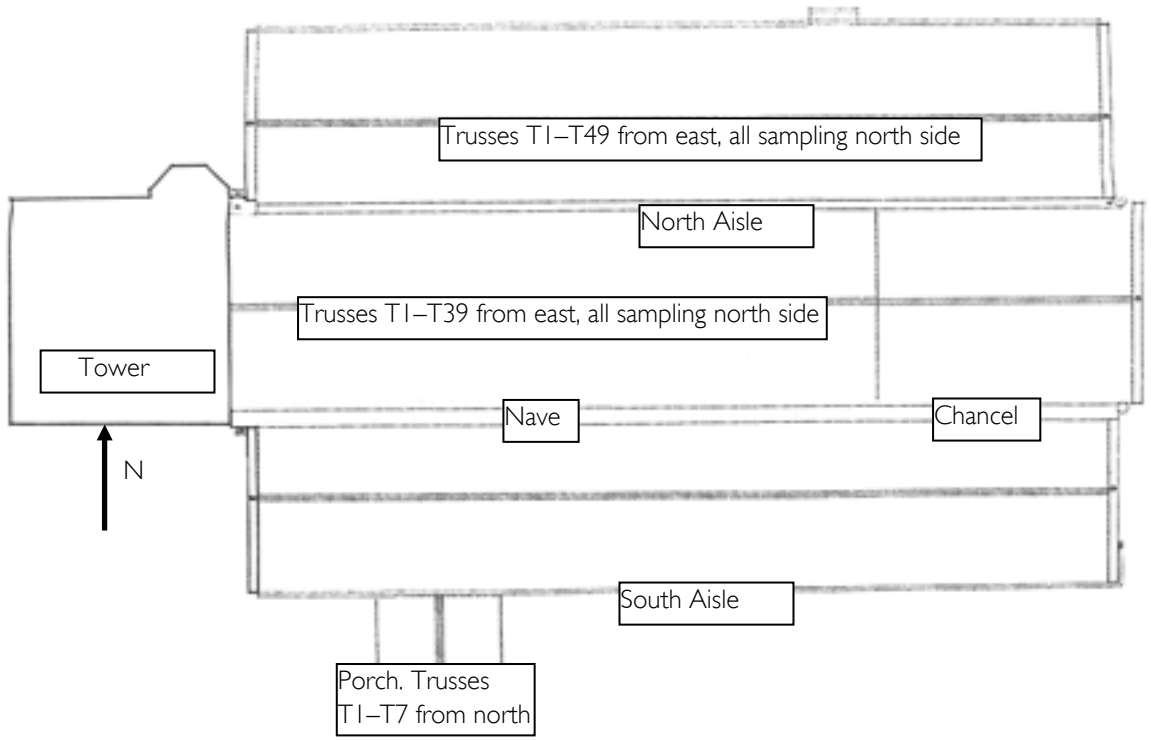

Figure 2. Plan of the church of St Mabena, St Mabyn, Cornwall. The truss numbering schemes followed in this report, and the location of the sampled areas are shown. Based on a plan by Bazeley, Miller-Williams and Corfield, Architects, supplied by English Heritage 2008

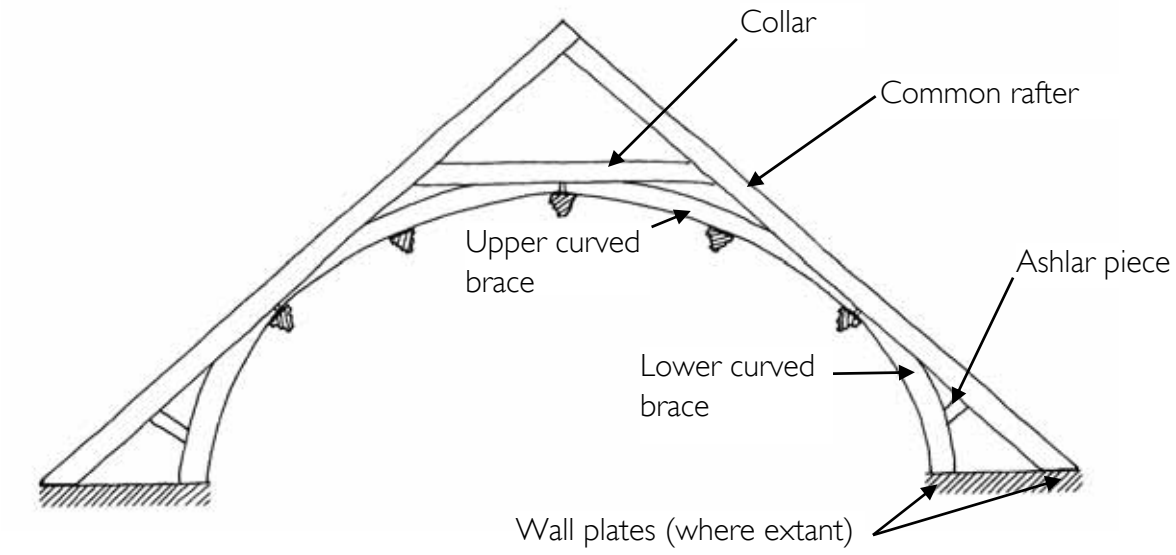

Figure 3. Sketch of a typical truss from the church of St Mabena, St Mabyn, Cornwall, showing the nomenclature followed in this report

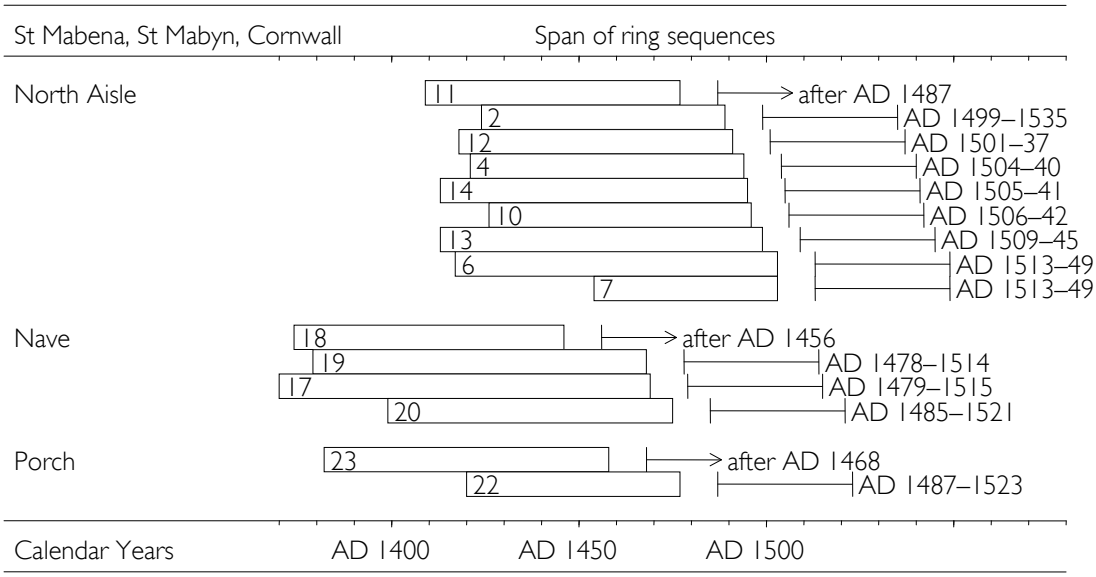

Figure 4. Bar diagram showing the absolute dating positions of the 15 dated tree-ring sequences for samples from the church of St Mabena, St Mabyn, Cornwall. The interpreted felling dates are also shown for each sample.

KEY White bars are oak heartwood.

TABLES

Table 1. Details of the 23 samples from timbers from the church of St Mabena, St Mabyn, Cornwall.

Sample	Location	Rings	Sap	Date of measured sequence	Interpreted result
1	Aisle T17 N brace	94	H/S	undated	-
2	Aisle T16 N rafter	66	H/S	AD 1424–89	AD 1499–1535
3	Aisle T11 N rafter	*c* 45	H/S	unmeasured	-
4	Aisle T9 N brace	74	H/S	AD 1421–94	AD 1504–40
5	Aisle T7 N rafter	63	H/S	undated	-
6	Aisle T1 N brace	87	H/S	AD 1417–1503	AD 1513–49
7	Aisle T5 N rafter	50	H/S	AD 1454–1503	AD 1513–49
8	Aisle T3 N rafter	51	H/S	undated	-
9	Aisle T20 N rafter	61	-	undated	-
10	Aisle T31 N rafter	71	H/S	AD 1426–96	AD 1506–42
11	Aisle T36 N rafter	69	-	AD 1409–77	after AD 1487
12	Aisle T46 N rafter	74	H/S	AD 1418–91	AD 1501–37
13	Aisle T44 N rafter	87	H/S	AD 1413–99	AD 1509–45
14	Aisle T40 N rafter	83	H/S	AD 1413–95	AD 1505–41
15	Aisle T33 N brace	51	H/S	undated	-
16	Nave T9 N rafter	74	H/S	undated	-
17	Nave T10 N rafter	100	H/S	AD 1370–1469	AD 1479–1515
18	Nave T22 N rafter	73	-	AD 1374–1446	after AD 1456
19	Nave T23 N rafter	90	H/S	AD 1379–1468	AD 1478–1514
20	Nave T26 N rafter	77	H/S	AD 1399–1475	AD 1485–1521
21	Nave T29 N rafter	54	H/S	undated	-
22	Porch T4 W brace	58	H/S	AD 1420–77	AD 1487–1523
23	Porch T5 E brace	77	-	AD 1382–1458	after AD 1468

KEY Aisle; North Aisle wagon roof truss numbers T1–T49 from east, Nave wagon roof truss numbers T1–39 from east (note there are also 22 trusses in the chancel roof), Porch wagon roof truss numbers T1–T7 from north. Braces are lower curving braces, Rafters are common rafters. N north, E east, W west, H/S is heartwood/sapwood edge.

Table 2. The t-values (Baillie and Pilcher 1973) between 9 sampled north aisle timbers from the church of St Mabena, St Mabyn, Cornwall.

	4	6	7	10	11	12	13	14
2	-	-	6.07	-	-	9.37	-	-
4		4.95	-	6.04	-	-	6.92	7.75
6			4.01	-	7.53	-	5.29	4.82
7				-	3.37	3.53	3.78	-
10					-	-	5.12	12.18
11						-	4.48	3.51
12							3.10	-
13								6.29

Table 3. The t-values (Baillie and Pilcher 1973) between 4 sampled nave and 2 sampled porch timbers from the church of St Mabena, St Mabyn, Cornwall.

	18	19	20	22	23
17	-	4.89	3.23	3.01	5.05
18		4.80	3.65	-	5.01
19			7.78	6.39	6.67
20				3.92	4.42
22					-

Table 4. Showing example t-values (Baillie and Pilcher 1973) between the two composite sequences constructed from the church of St Mabena, St Mabyn, Cornwall and oak reference data. These two composite chronologies overlap and cross-match (t-value 3.98)

Reference chronology	St Mabyn 1 AD 1370–1477	St Mabyn 2 AD 1409–1503
Cornwall, Goldophin House Godolphin Cross (Tyers and Tyers in prep)	5.49	5.09
Cornwall, Pendennis Castle nr Falmouth (Tyers 2004c)	6.02	7.03
Cornwall, St Martins Church East Looe (Arnold *et al* 2006)	5.23	8.58
Devon, Crediton Holy Cross church (Tyers 2004b)	5.22	7.28
Devon, Prowse barn Sandford (Groves 2005)	5.69	5.64
Gloucestershire, Gloucester Mercers Hall (Howard *et al* 1996)	4.73	5.68
Gloucestershire, Naas House Lydney (Howard *et al* 1998)	5.49	5.22
Herefordshire, White House Vowchurch (Nayling 1999)	4.86	5.81

APPENDIX 1

smc1

265	273	227	206	160	99	103	125	106	132
139	139	152	134	163	110	118	139	209	104
142	177	156	145	88	100	109	110	90	124
147	161	130	84	68	93	59	79	76	56
64	58	86	76	100	88	104	94	59	60
68	46	58	88	60	56	70	52	47	56
69	96	90	64	56	64	51	85	81	91
88	75	88	72	78	76	62	78	57	74
80	94	108	100	70	76	87	108	87	100
111	113	74	114						

smc2

184	237	251	138	278	149	122	206	171	173
292	179	143	188	153	220	232	133	175	193
110	179	182	153	281	170	151	211	139	171
219	138	178	179	217	127	199	236	186	147
122	210	227	247	346	190	209	155	168	193
125	255	175	131	128	120	88	177	141	130
143	152	113	132	122	135				

smc4

342	242	322	255	359	326	194	314	218	217
246	368	244	133	249	182	317	289	308	205
250	184	147	114	106	142	97	139	147	114
140	165	234	291	219	293	251	268	197	166
105	118	146	124	206	241	280	248	156	227
250	258	207	183	134	135	152	118	138	116
142	106	91	84	56	64	71	53	54	77
83	61	85	84						

smc5

158	121	139	118	169	134	132	129	163	107
124	120	138	127	123	114	133	138	129	130
131	109	134	120	108	111	112	89	84	118
102	98	87	101	123	89	136	124	109	119
92	136	140	151	117	91	89	97	124	126
117	162	116	80	102	78	79	108	102	94
108	86	111							

smc6

173	161	108	164	186	111	148	90	89	93
84	123	88	89	92	127	92	61	88	78
132	100	72	58	86	72	89	89	113	106
82	88	75	97	79	65	70	68	65	68
67	122	85	137	85	94	92	88	105	129
124	127	105	99	96	94	110	100	100	83
96	85	85	89	164	125	160	216	160	126
144	144	131	156	183	134	160	138	118	206
161	127	162	150	134	131	133			

smc7

440	272	440	308	410	229	408	358	332	245
290	364	283	249	344	140	177	133	115	127
106	149	180	148	165	152	133	203	148	159
179	142	110	115	93	107	126	110	80	83
98	81	118	139	93	161	161	136	105	94

smc8

355	301	314	287	240	129	129	138	134	109
108	99	95	133	89	150	132	142	122	125
132	125	167	110	96	98	97	150	192	187
177	136	156	156	157	139	181	179	166	236
255	258	282	200	165	202	133	115	165	152
133									

smc9

315	283	369	240	248	226	232	220	204	207
204	227	210	151	166	149	168	156	72	114
93	100	125	141	62	115	148	123	132	86
87	102	144	168	175	158	177	211	199	177
225	225	190	219	218	166	183	145	111	137
161	99	179	152	118	156	100	92	142	86
113									

smc10

241	105	149	121	132	140	177	144	179	229
178	193	153	149	125	126	128	127	95	113
132	95	129	127	109	111	112	114	130	99
116	127	169	150	234	163	185	188	163	236
198	233	147	85	123	134	99	101	112	97
114	104	101	113	91	138	113	111	79	51
63	72	47	46	57	68	64	54	54	55
66									

smc11

640	315	260	386	275	366	244	227	346	331
171	206	228	139	241	121	88	115	101	186
86	88	68	215	77	86	154	135	359	122
90	90	69	65	75	102	126	77	51	50
57	63	78	49	37	48	42	59	58	126
44	90	72	85	74	63	94	81	107	123
71	59	49	56	54	64	70	91	88	

smc12

128	101	116	149	103	158	127	115	114	76
94	63	71	99	98	83	100	138	109	121
94	104	135	84	114	189	96	180	173	133
232	174	121	151	94	161	193	105	111	121
161	110	151	157	126	128	105	147	163	182
199	143	163	115	97	118	94	147	142	107
99	103	71	110	100	80	113	151	95	91
83	95	83	91						

smc13

232	288	241	176	198	187	140	200	190	129
177	184	203	186	150	203	140	175	183	298
215	195	247	199	268	215	195	152	169	143
108	106	116	112	116	167	150	126	122	116
116	137	89	124	117	187	127	165	143	146
133	146	140	133	144	121	97	128	110	96
124	82	92	129	118	108	111	103	115	102
94	97	78	95	107	62	79	88	89	72
86	99	85	118	89	73	99			

smc14

205	171	168	167	277	252	160	229	207	154
215	143	169	225	121	155	113	109	131	163
138	164	227	189	206	153	143	106	121	99
92	82	103	116	93	142	131	108	106	106
113	107	90	97	93	144	139	170	127	138
154	131	169	156	155	120	84	126	126	114
101	100	69	73	92	83	88	69	116	109
96	89	64	84	105	75	58	87	85	85
80	87	101							

smc15

278	256	238	198	236	230	152	174	307	174
176	175	246	242	221	173	201	126	200	105
77	93	68	74	130	151	141	173	123	133
169	157	179	213	226	197	306	222	224	265
297	225	280	268	257	243	208	249	201	207
189									

smc16

399	154	216	180	201	156	227	187	212	143
193	185	160	161	183	109	143	158	66	168
147	117	115	149	220	183	212	185	171	112
106	125	134	199	131	127	167	231	106	134
82	93	107	100	105	138	170	202	247	163
187	90	128	95	94	74	125	163	237	227
112	166	119	146	155	170	226	208	209	161
127	111	107	85						

smc17

410	262	261	324	371	224	219	175	191	241
177	188	182	153	186	122	172	182	149	119
133	123	81	72	72	91	85	72	79	95
85	84	88	157	160	106	104	89	105	172
225	247	247	143	181	126	129	107	129	107
86	104	68	112	134	102	135	123	135	131
115	133	123	80	69	68	60	57	67	48
35	45	56	54	67	92	98	77	94	72
58	74	83	61	67	63	63	54	83	55
60	62	49	63	37	54	57	54	56	73

smc18

475	254	345	353	238	228	300	204	293	567
610	267	396	260	211	176	114	270	127	130
138	190	165	192	139	154	179	125	164	236
189	170	205	177	186	222	116	121	168	117
172	165	136	120	218	77	121	109	95	291
194	208	253	204	235	213	158	180	191	161
171	192	286	206	100	105	108	104	79	53
64	133	125							

smc19

194	189	234	227	186	195	130	164	204	186
140	110	162	115	97	96	129	121	137	161
166	125	111	126	228	150	116	160	142	122
166	135	121	165	125	148	120	102	122	107
87	59	67	75	112	112	92	114	86	118
110	78	103	115	96	124	158	143	145	103
69	101	76	68	79	79	100	128	106	116
99	98	95	124	88	94	90	112	115	129
107	113	142	115	127	103	116	119	156	160

smc20

184	231	166	127	239	202	182	165	147	127
184	143	113	136	123	152	124	114	148	149
117	84	92	90	106	101	79	80	63	77
83	51	62	69	77	83	99	95	86	55
46	50	63	63	68	69	74	77	74	50
59	73	76	130	85	79	76	91	94	95
70	93	118	92	116	108	154	128	126	134
138	114	127	92	101	111	147			

smc21

315	372	207	157	138	60	36	36	37	59
76	68	74	78	122	147	155	152	125	107
113	109	180	292	244	162	199	279	171	179
112	174	275	245	281	171	92	179	244	130
288	213	244	194	305	124	200	124	137	205
178	220	186	178						

smc22

101	94	83	169	161	118	147	166	255	233
196	186	362	239	407	487	369	256	231	116
225	205	205	163	184	197	171	181	195	170
149	172	175	132	131	91	159	114	167	89
164	186	166	169	110	147	110	172	164	122
198	117	82	90	91	140	130	132		

smc23

89	84	73	50	84	101	77	69	69	79
68	64	56	79	91	99	103	118	120	70
71	166	126	75	106	98	80	96	68	82
84	97	118	74	62	63	74	57	45	46
46	81	75	46	62	55	63	50	48	62
57	69	66	92	64	84	39	40	30	35
39	37	48	67	62	69	76	84	40	53
50	64	51	68	105	89	90			






ENGLISH HERITAGE RESEARCH DEPARTMENT

English Heritage undertakes and commissions research into the historic environment, and the issues that affect its condition and survival, in order to provide the understanding necessary for informed policy and decision making, for sustainable management, and to promote the widest access, appreciation and enjoyment of our heritage.

The Research Department provides English Heritage with this capacity in the fields of buildings history, archaeology, and landscape history. It brings together seven teams with complementary investigative and analytical skills to provide integrated research expertise across the range of the historic environment. These are:

* *Aerial Survey and Investigation*
* *Archaeological Projects (excavation)*
* *Archaeological Science*
* *Archaeological Survey and Investigation (landscape analysis)*
* *Architectural Investigation*
* *Imaging, Graphics and Survey (including measured and metric survey, and photography)*
* *Survey of London*

The Research Department undertakes a wide range of investigative and analytical projects, and provides quality assurance and management support for externally-commissioned research. We aim for innovative work of the highest quality which will set agendas and standards for the historic environment sector. In support of this, and to build capacity and promote best practice in the sector, we also publish guidance and provide advice and training. We support outreach and education activities and build these in to our projects and programmes wherever possible.

We make the results of our work available through the Research Department Report Series, and through journal publications and monographs. Our publication Research News, which appears three times a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities. A full list of Research Department Reports, with abstracts and information on how to obtain copies, may be found on www.english-heritage.org.uk/researchreports

For further information visit www.english-heritage.org.uk

ENGLISH HERITAGE