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Ancient Monuments Laboratory
Report 34/98

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Summary

Dendrochronological analysis was undertaken on 18 samples from the nave roof and integral bell turret, and the bell tower at St Nicholas' Church, Warndon. Three timbers from the nave roof/bell turret crossmatched to give a chronology spanning the period AD 1348-1424. The felling date ranges produced suggest a construction phase in the early- or mid-fifteenth century for the nave roof and bell turret. Four timbers from the bell tower crossmatched to produce a chronology which dated to the period AD 1391-1498. Three of these had bark edge and produced precise felling dates for the winter or early spring of AD 1497/8 and AD 1498/9. This suggests that the bell tower was constructed shortly after felling at the turn of the century. The bell tower timbers were notable as they contained distinctive periodic bands of very narrow growth rings.

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TREE-RING ANALYSIS OF OAK TIMBERS FROM ST NICHOLAS' CHURCH, WARNDON, WORCESTERSHIRE

Introduction

This document is a technical archive report on the tree-ring analysis of timbers from St Nicholas' Church, Warndon, Worcestershire (NGR SO 88785688, Fig 1). It is beyond the dendrochronological brief to describe the building in detail or to undertake the production of detailed drawings. As part of a multifaceted and multidisciplinary study of the building, elements of this report may be combined with detailed descriptions, drawings, and other technical reports at some point in the future to form either a comprehensive publication or an archive deposition on the building. The conclusions presented here may therefore have to be modified in the light of subsequent work.

The church of St Nicholas', Warndon, a Grade I Listed Building, lies 3.7km north-east of Worcester. It has recently been the subject of a detailed building recording study by the Hereford and Worcester County Archaeological Service (Brown 1991). It is a single-celled church that has a wagon roof with a bell turret at its west end and an added timber-framed bell tower (Fig 2). Brown (1991) identified six principal structural phases in the historical development of the church, the earliest of which is thought to be of twelfth century date. The wagon roof and bell turret, associated with phase 3, are thought to be of late-fourteenth or early-fifteenth century date (Brown 1991; RCHME 1987), though it has been suggested that they date to either the fifteenth or sixteenth century. Structural analyses have indicated that the bell turret is integral to the nave roof rather than a later insertion. The bell tower, associated with phase 4, is thought to date to the late fifteenth or early sixteenth century (Brown 1991; RCHME 1987). The timber-framed bell tower is a rare survival in Worcestershire and is one of only five in the county, the others being at Cotheridge, Dormston, Kington, and Pirton (Brown 1991). The bell frame within the tower is made up of four trusses, all of type 3.B (Pickford 1993), with a braced king post and a short head. There is evidence of extensive use of secondary timber in this bell frame (Eisel 1998). The timber-framing of the re-set porch on the north wall of the church is also thought likely to have been reused (Brown 1991).

The building has recently been in receipt of an English Heritage grant-aided repair programme and tree-ring analysis was subsequently commissioned by English Heritage in order to both contribute to the production of a monograph on the structure and to inform future management decisions. The aims of the analysis were to provide dating evidence for the nave roof and

integral bell turret, and the bell tower. The bell frame and timber-framing of the porch, both thought to contain much reused timber, were excluded from the brief for the dendrochronological survey.

Methodology

The timbers in the accessible areas of the nave roof and integral bell turret, and the bell tower 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

The nave roof and bell turret

Examination of the timbers in the nave roof and bell turret showed that most were unsuitable for dating purposes since they clearly contained insufficient numbers of rings for dendrochronological dating purposes. Many of these timbers were derived from fast-grown young trees. The sampling strategy applied, by necessity, included timbers that might otherwise have been rejected as borderline. Where suitable timbers could be located their sampling was made difficult both by the physically cramped conditions and by the presence of shakes which often caused the cores to fragment. The sapwood had frequently not survived and where it had it was prone to disintegration during coring.

A total of eight samples (numbered **11-18** inclusive) were obtained: two (**11** and **12**) from posts in the bell turret; and six from the limited number of accessible rafters in the nave roof, three on the north side (**13-15**) and three on the south side (**16-18**). Details of the samples and their locations are provided in Table 1 and Fig 3. Four samples were rejected before measurement: sample **14** disintegrated during coring; whilst **11**, **15**, and **17** had insufficient rings. The remaining four samples (**12**, **13**, **16**, and **18**) were considered suitable for measurement, though sample **16** contained a band of very narrow rings in the middle of its ring sequence.

Two possible matches were identified, both statistically and visually, between samples **12** and **18**, and samples **16** and **18** (Table 2). However the *t*-value produced between **12** and **16** at the relative position suggested by the matches with **18** was only 2.61. Consequently these three sequences and that from the other measured sample, **13**, were compared individually with reference chronologies. No consistent results were obtained for **13** but **12**, **16**, and **18** all matched consistently well with a wide range of dated reference chronologies at the same relative positions indicated by the possible intra-site matches identified (Table 3). The ring sequences from samples **12**, **16**, and **18** were combined to form a 77-year master curve, **WARNDON1**, which dates to AD 1348-1424 inclusive (Tables 3 and 4).

The bell tower

Examination of the timbers in the bell tower showed that these were generally longer lived than those used in the nave roof and bell turret and hence more suited to dendrochronological analysis. Unlike the timbers in the nave roof and bell turret, these timbers were generally of halved or quartered conversion and the sapwood, complete to the bark edge, had frequently survived in a suitable state for successful coring. These timbers were also marked by the presence of shakes though to a lesser extent than in the nave roof and bell turret.

Ten timbers (numbered **1-10** inclusive) were sampled. Details of the samples and their locations are provided in Table 1 and Figs 4-7. Only one sample was rejected as it had fragmented badly during coring. The majority of the ring sequences were dominated by periodic bands of narrow rings. Three groups of matching ring sequences were found: **1**, **3**, **4**, and **5** (Table 5); **2** and **7**, which gave a *t*-value of 5.27, and **6** and **10**, which gave a *t*-value of 11.19 and may be from the same tree. The matching timbers from each of these groups were combined to form three mean sequences **WARNDON2**, **WSN2/7**, and **WSN6/10**.

The three mean sequences and the remaining unmatched sequence **8** were tested against a wide range of dated reference chronologies. No conclusive results were found for **WSN2/7**, **WSN6/10**, or **8** but **WARNDON2** matched a variety of reference chronologies and was dated to the period AD 1391-1498 inclusive (Tables 6 and 7). The results of the comparisons between each of the individual ring sequences which were combined to produce **WARNDON2** and a range of reference chronologies are also presented due to the low level statistical crossmatching between some of them.

The overlap between **WARNDON1** and **WARNDON2** is only 34 years and neither the statistical or visual comparison indicate a good match. These two mean curves have therefore not been combined to produce a single site master curve.

Interpretation

The nave roof and bell turret

Of the three dated timbers from this section (Fig 8), **12** is a post from the bell turret and the other two are rafters from the nave roof. Sample **12**, with a heartwood-sapwood boundary dating to AD 1401, was felled during the period AD 1411-56. The two rafters, both of which retained some sapwood rings, have a combined felling date range of AD 1429-59. Assuming

that the dated timbers are associated with the initial construction of the nave roof and bell turret a early- or mid-fifteenth century date is implied.

The bell tower

All the dated timbers from the bell tower had sapwood and three were complete to bark edge (Fig 8). The latter were all felled in winter/early spring, but samples **4** and **5** were felled in AD 1497/8, whilst sample **3** was felled in AD 1498/9. Sample **1** was felled during the period AD 1486-1526 and therefore could be contemporary with the late fifteenth-century felling date indicated by the other three timbers. Assuming that the dated timbers are associated with the initial erection of the tower, a construction date of AD 1498/9 or shortly afterwards is implied.

Discussion

The early- or mid-fifteenth century date implied from the dendrochronological results for the nave roof and integral bell turret is marginally later than suggested by Brown (1991) and RCHME (1987) for phase 3 but the turn of the fifteenth-century date implied for the bell tower supports the late fifteenth or early sixteenth-century date proposed by Brown (1991) and RCHME (1987) for phase 4. The bell turret appears to have become redundant less than a century after its construction.

It is commonplace to assume use of freshly felled 'green' timber for building projects (Rackham 1990, 67; Charles and Charles 1995) so the identification of two different precise felling dates for timbers from the bell tower suggest that some short term stockpiling took place prior to construction.

The low level of successfully dated timbers is disappointing. In the nave roof and bell turret the problem is caused by the predominant use of short-lived whole trunks with too few rings for dating purposes. This is exacerbated by the common occurrence of shakes in the timbers which severely hamper successful coring. In the bell tower the timbers, usually either quartered or halved, are derived from longer-lived trees but the recurrent periodic bands of narrow rings (Fig 9) have reduced their dating potential. The cause of such narrow rings is probably local in character and could be due to either insect attack (cockchafers are often regarded as capable of causing such cycles, see Schweingruber 1987, 222) or some form of cyclical management regime.

Acknowledgements

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Figure 1: Map showing location of St Nicholas' Church, Warndon

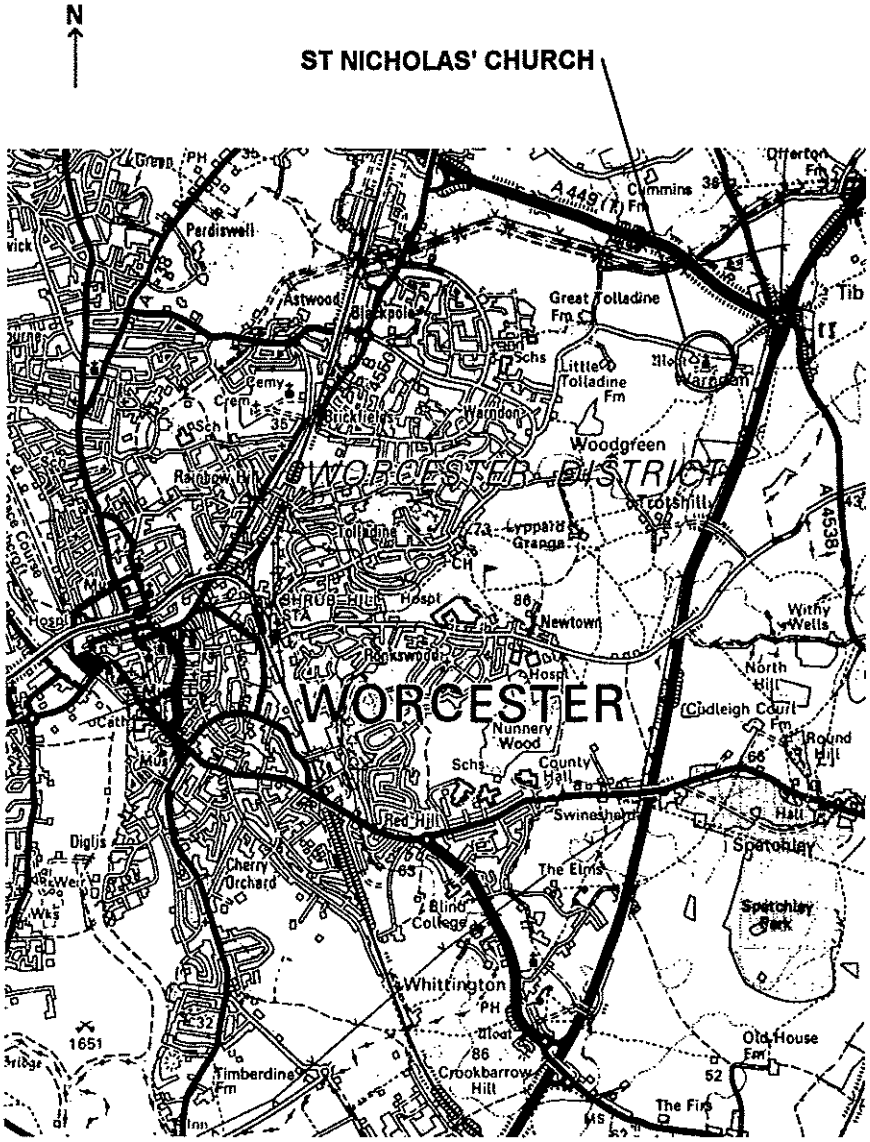

Figure 2: Plan of St Nicholas' Church, Warndon, after Hereford and Worcester Archaeology Unit

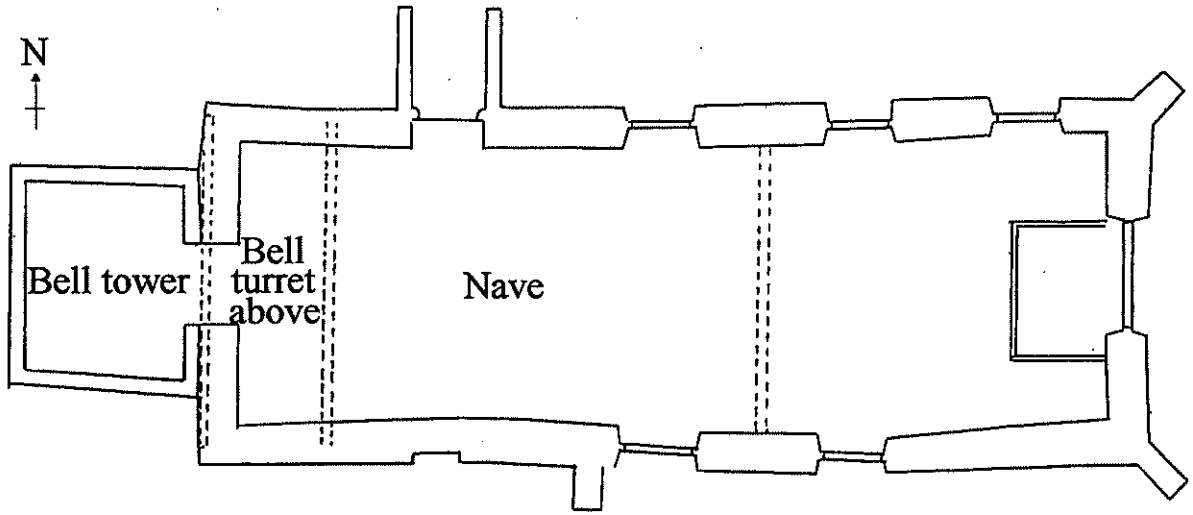

Figure 3: Plan of the bell turret at St Nicholas' Church, Warndon, showing approximate location of samples **11-18** inclusive, after Hereford and Worcester Archaeology Unit.

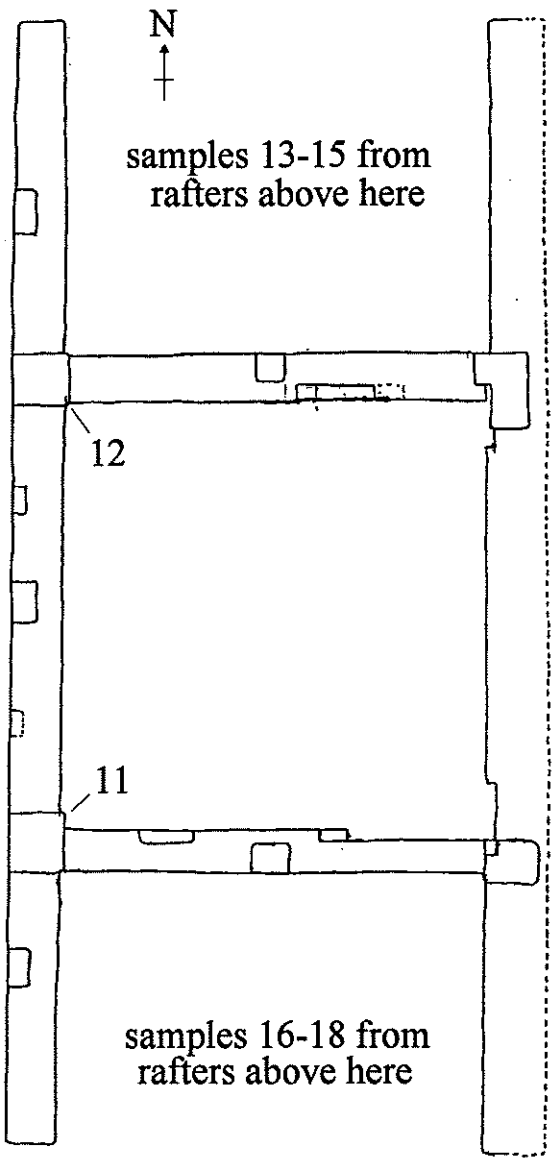

Figure 4: External north elevation of the bell tower at St Nicholas' Church, Warndon, showing approximate location of samples **1-2** inclusive, after Hereford and Worcester Archaeology Unit.

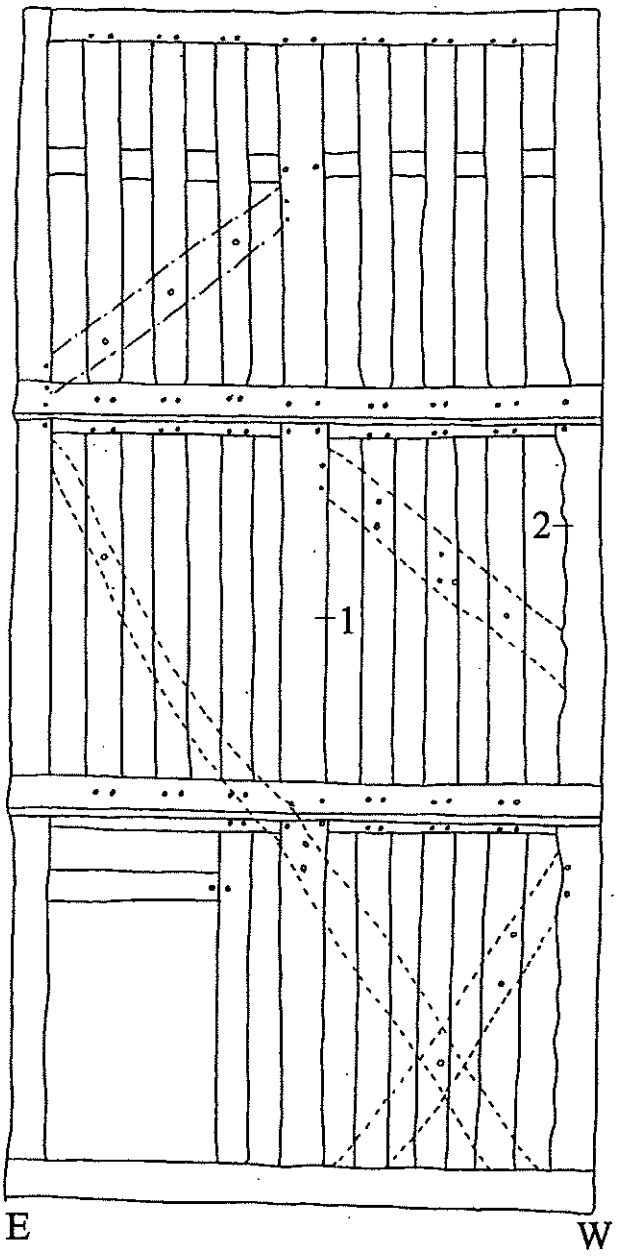

Figure 5: External south elevation of the bell tower at St Nicholas' Church, Warndon, showing approximate location of samples **4-5** inclusive, after Hereford and Worcester Archaeology Unit.

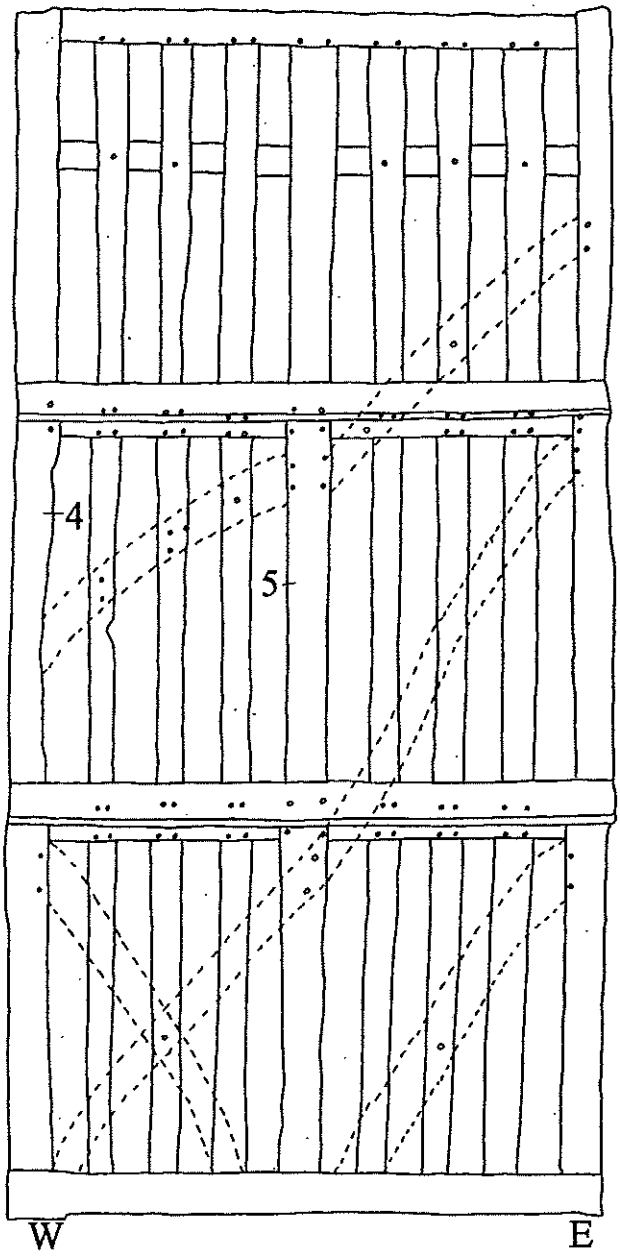

Figure 6: External west elevation of the bell tower at St Nicholas' Church, Warndon, showing approximate location of samples **2-6** inclusive, after Hereford and Worcester Archaeology Unit. Note sample **7** is from the collar above, not visible in this external elevation.

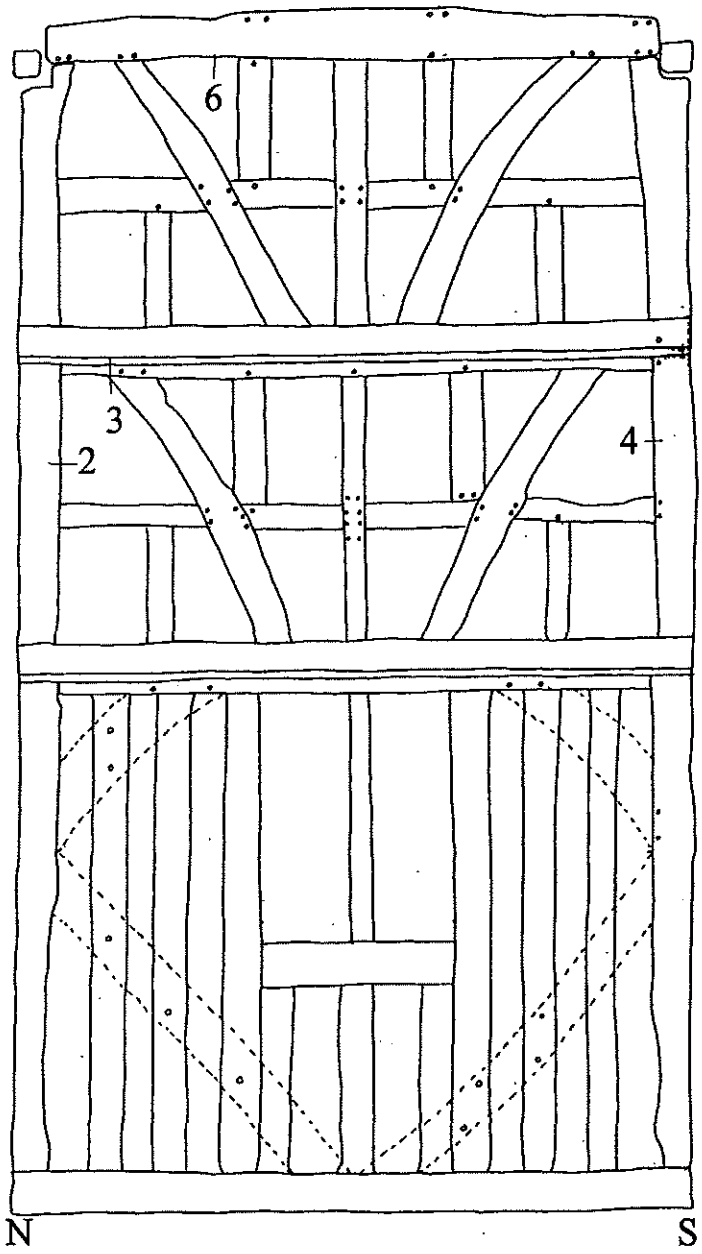

Figure 7: Internal east elevation of the bell tower at St Nicholas' Church, Warndon, showing approximate location of samples **8-10** inclusive, after Hereford and Worcester Archaeology Unit.

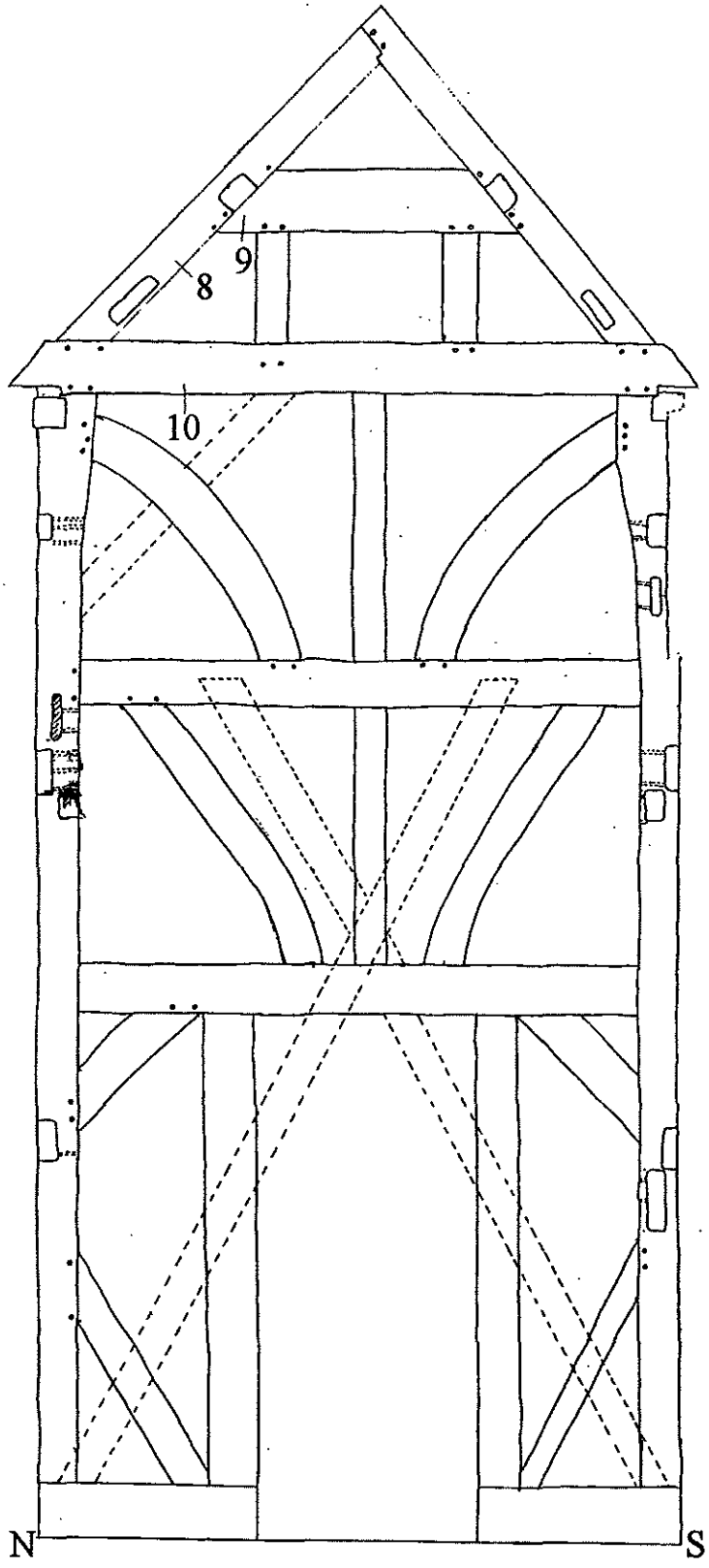

Figure 8: Bar diagram showing the relative positions of the dated ring sequences from the nave roof and integral bell turret, and the bell tower from St Nicholas' Church, Warndon.

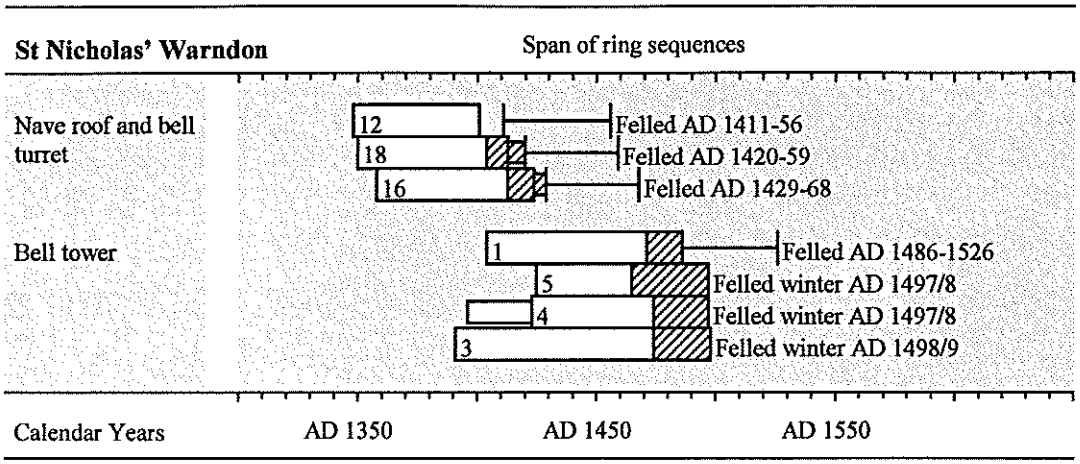

Figure 9: Ring sequences from the bell tower showing the periodic bands of narrow rings obtained from samples **1**, **6**, and **7**. Note there is no crossmatching between these three ring sequences. The vertical scale is logarithmic; the 1 mm level is shown for each graph.

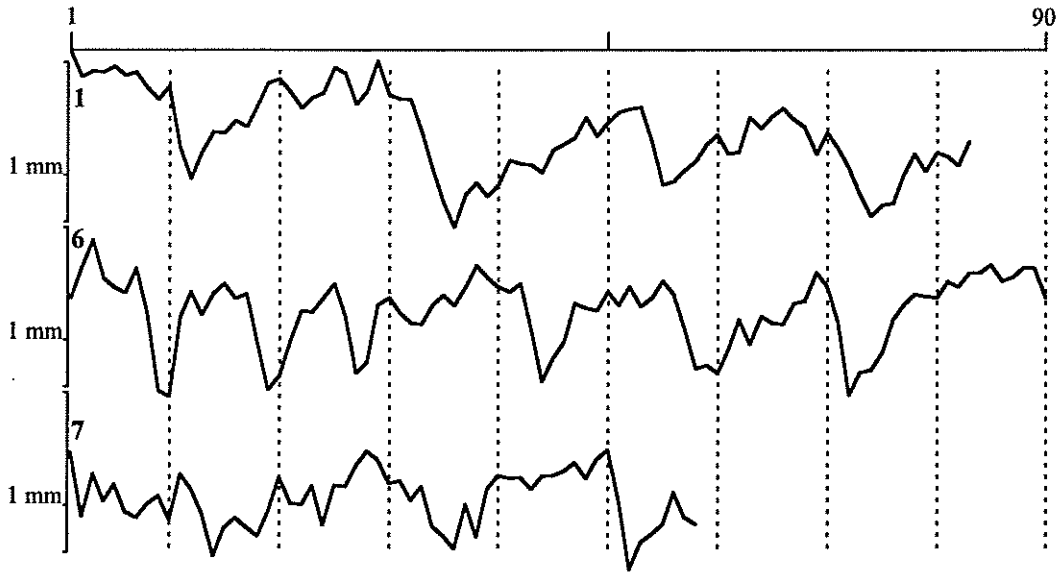

Table 1 Details of samples from St Nicholas' Church, Warndon

Core	Location	Timber	Total rings	Sapwood rings	mm/year	Date of sequence	Felling date
1	Bell tower, first floor	North centre post	83	15	2.09	AD 1404-1486	AD 1486-1526
2	Bell tower, first floor	North-west corner post	91	27Bw	1.54	undated	-
3	Bell tower, first floor	West middle rail, supports floor of bellframe	108	24Bw	1.22	AD 1391-1498	winter AD 1498/9
4	Bell tower, first floor	South-west corner post	+75	23Bw	1.30	AD 1423-1497	winter AD 1497/8
5	Bell tower, first floor	South centre post	73	32Bw	1.33	AD 1425-1497	winter AD 1497/8
6	Bell tower, upper level	West tiebeam	90	23?B	1.64	undated	-
7	Bell tower, upper level	West collar	58	26Bw	1.16	undated	-
8	Bell tower, upper level	North-east principal rafter	82	5	1.57	undated	-
9	Bell tower, upper level	East collar	+31	21Bw	1.55	undated	-
10	Bell tower, upper level	East tiebeam	+67	-	1.80	undated	-
11	Nave roof bell turret	South-west post	too few rings	-	-	undated	-
12	Nave roof bell turret	North-west post	54	h/s	2.93	AD 1348-1401	AD 1411-56
13	Nave roof	North rafter, second from tower	90	23Bw	1.01	undated	-
14	Nave roof	North rafter, third from tower	disintegrated	-	-	undated	-
15	Nave roof	North rafter, fourth from tower	too few rings	-	-	undated	-
16	Nave roof	South rafter, fourth from tower	67	11+5	1.17	AD 1358-1424	AD 1429-68
17	Nave roof	South rafter, third from tower	too few rings	-	-	undated	-
18	Nave roof	South rafter, second from tower	64	9+7	1.26	AD 1350-1413	AD 1420-59

Key:
Bw = bark edge present, outer ring complete; ?B = possible bark edge; h/s = heartwood/sapwood boundary; + = additional unmeasured rings

Table 2 *t*-values between individual dated timbers from WARNDON1. - indicates a *t*-value less than 3.0.

	16	18
12	-	4.14
16		4.21

Table 3 example *t*-values between WARNDON1 and its individual components against independent reference sequences. - indicates a *t*-value less than 3.0.

		12	16	18	WARNDON1
Region	Chronology				
Devon	Exeter, Bowhill (Hillam 1991)	6.74	4.24	6.68	9.21
Gloucestershire	Gloucester, Mercers Hall (Howard *et al* 1996)	8.26	6.08	6.30	10.59
Herefordshire	Hereford, Booth Hall/High Town (Boswijk and Tyers 1997)	6.62	3.88	3.07	7.16
	Hereford City Project (Tyers 1996a)	6.73	4.23	4.99	7.90
	Kings Pyon barn (Groves and Hillam 1993)	4.47	3.40	3.20	5.17
Staffordshire	Burton-on-Trent, Sinai Park (Tyers 1997b)	3.58	5.73	3.73	5.76
Worcestershire	Droitwich, Upwich 2 (Groves and Hillam 1997)	6.60	4.36	3.65	7.66
	Lower Sapey (Tyers 1995)	3.21	3.96	3.38	6.77
	Worcester, Commandery (Pilcher pers comm)	6.34	-	3.40	4.90
Wales	Welsh Border (Siebenlist-Kerner 1978)	4.01	5.97	5.39	7.27

Table 4 Ring-width data from site master WARNDON1, dated AD 1348-1424 inclusive.

Year	Ring widths (0.01mm)										No of samples									
AD 1348								461	395	156								1	1	2
AD 1351	244	159	201	227	220	185	246	257	290	177	2	2	2	2	2	2	2	3	3	3
	165	362	354	350	175	235	242	202	332	266	3	3	3	3	3	3	3	3	3	3
	185	205	209	229	186	231	208	162	218	200	3	3	3	3	3	3	3	3	3	3
	153	168	133	163	117	173	142	111	102	75	3	3	3	3	3	3	3	3	3	3
	97	61	64	52	49	70	53	83	104	113	3	3	3	3	3	3	3	3	3	3
AD 1401	132	80	170	150	142	123	106	133	186	132	3	2	2	2	2	2	2	2	2	2
	121	159	141	252	181	160	135	67	41	65	2	2	2	1	1	1	1	1	1	1
	95	75	128	98							1	1	1	1						

Table 5 *t*-values between individual dated timbers from WARNDON2. - indicates a *t*-value less than 3.0.

	3	4	5
1	-	-	7.84
3		3.40	3.86
4			3.25

Table 6 example *t*-values between WARNDON2 and its individual components against independent reference sequences. - indicates a *t*-value less than 3.0.

		1	**3**	**4**	**5**	**WARNDON2**
Region	Chronology					
Devon	Exeter, Bowhill (Hillam 1991)	-	4.77	-	3.98	5.78
Gloucestershire	Gloucester, Mercers Hall (Howard *et al* 1996)	-	5.44	4.72	3.68	6.27
Hampshire	Romsey Abbey (Hillam and Groves 1994)	3.04	-	4.93	3.88	6.01
Herefordshire	Hereford City Project (Tyers 1996a)	-	5.43	4.56	5.55	6.01
	Kings Pyon barn (Groves and Hillam 1993)	3.53	4.69	-	3.34	5.79
	Staplow (author unpubl)	3.21	4.42	3.58	3.60	5.73
	Tupsley (Tyers 1997c)	4.15	3.08	3.87	5.54	6.54
London	Hays Wharf (Tyers 1996b and c)	-	4.32	3.98	4.52	6.28
Staffordshire	Burton-on-Trent, Sinai Park (Tyers 1997b)	-	5.01	4.00	3.17	4.96
Worcestershire	Lower Sapey (Tyers 1995)					4.87
Wales	Border (Siebenlist-Kerner 1978)	-	3.90	4.26	5.04	5.02

Table 7 Ring-width data from site master WARNDON2, dated AD 1391-1498 inclusive.

Year	**Ring widths (0.01mm)**										**No of samples**									
AD 1391	197	177	179	188	203	242	188	219	162	148	1	1	1	1	1	1	1	1	1	1
AD 1401	192	131	193	368	292	256	255	299	317	292	1	1	1	2	2	2	2	2	2	2
	253	204	239	136	138	119	138	172	180	214	2	2	2	2	2	2	2	2	2	2
	235	280	323	285	268	229	240	282	248	168	2	2	3	3	4	4	4	4	4	4
	214	299	200	198	217	158	136	95	62	73	4	4	4	4	4	4	4	4	4	4
	90	81	95	128	107	96	99	118	121	113	4	4	4	4	4	4	4	4	4	4
AD 1451	174	141	160	187	162	161	143	97	89	95	4	4	4	4	4	4	4	4	4	4
	84	92	107	83	112	153	138	164	184	149	4	4	4	4	4	4	4	4	4	4
	117	97	124	127	158	99	66	54	59	76	4	4	4	4	4	4	4	4	4	4
	89	90	92	91	98	138	117	97	123	156	4	4	4	4	4	4	3	3	3	3
	128	86	86	61	62	97	90	97			3	3	3	3	3	3	3	1		