Ancient Monuments Laboratory
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TREE-RING ANALYSIS OF OAK TIMBERS FROM THE BELL TOWER OF THE CHURCH OF ST MARY MAGDALEN, MAGDALEN LAVER, ESSEX

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Summary

Tree-ring analysis of oak timbers from the bell tower of St Mary Magdalen, Magdelen Laver was undertaken to date the belfry and surrounding outer wall. The belfry was thought to be of fifteenth century date and the outer wall a sixteenth century addition. the results of the tree-ring analysis indicate that the belfry was constructed after AD 1525 and that the outer wall was built in, or shortly after, AD 1534/5. Contrary to expectation the results indicate that the structure could be the product of a single building campaign or to have taken on;y a few years to complete.

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Introduction

This document is a technical archive report on the tree-ring analysis of timbers from the bell tower of the Church of St Mary Magdalen, Magdalen Laver, Essex (TL513084). 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 at Magdalen Laver is a grade II* listed building. The earliest part of the church, the nave, is thought to date from the eleventh century. The church was altered in the fourteenth century, and the timber-framed roof may date from this period. The bell tower is located at the west end and appears to contain several phases of construction (Fig 1). The belfry is thought to have been built as a free-standing tower in the fifteenth century, replacing an earlier bell turret. It has four principal posts capped by a pyramidal roof. Scissor bracing has been used in the side walls and arch bracing in the upper stage. A protective outer wall was built around the lower part of the belfry, forming narrow aisles on the north, south, and west sides. Since this is structurally independent of the belfry this is thought to be a later addition.

Tree-ring analysis of timbers from the belfry and outer wall was undertaken in order to date the construction of the two structural elements of the bell tower. The dendrochronological dating, funded by English Heritage (EH), was requested by the local EH inspector, Ian Harper, to help inform decisions relating to the ongoing restoration program at the church.

Methodology

The timbers from both the lowest level and the first floor stage of the belfry as well as the outer wall were carefully examined in an attempt to identify those timbers with the most suitable ring sequences for analysis. Those with more than 50 annual rings and some survival of the original sapwood and bark-edge were sought.

A selection of the most promising timbers from both parts of the structure were sampled using a 15mm diameter corer attached to an electric drill. The cores were taken from the timbers in the most suitable direction for maximising the numbers of rings for subsequent analysis. The core holes were left open. The ring sequences in the cores were 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.

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 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 early spring; 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, both in buildings and archaeological sites, 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. High *t*-values are not by themselves necessarily indicative of two series being derived from a single tree. Conversely low *t*-values do not necessarily exclude the possibility. It is the balance of a range of information that provides the evidence.

Results

Twenty one samples were obtained from the belfry and outer wall, all were oak (*Quercus* spp.) sample location and other details are provided in Table 1. Seven cores were obtained from the ground-floor level of the belfry (Fig 1). The first floor of the belfry was assessed but no samples were obtained because the timbers were all from fast grown trees which did contain enough rings. There was no safe access to the upper stage of the belfry. Fourteen samples were taken from the outer wall surrounding the lower stage of the belfry (Fig 2). Large whole, halved, and quartered timbers were used for the principal posts and tiebeams throughout the belfry structure. The scissor braces in the belfry and studs in the outer walls were made from smaller halved and quartered timbers.

After preparation three samples, **7**, **10**, and **12**, were found to be unsuitable for analysis because they did not have enough rings. The remaining eighteen timbers were analysed and contained between 54 and 154 rings.

The measured samples were compared against each other and sixteen timbers were found to crossmatch, forming a site chronology MLAVER (Table 2: Fig 3). Ring width data from the chronology are presented in Table 3. Within this group, five 'same-tree' pairs (**1+4**, **5+6**, **9+18**, **13+15**, **14+17**) were identified. Each pair was averaged together prior to inclusion in the site chronology. MLAVER was tested against reference curves for the last millennia and was dated to AD 1411-1534 inclusive (Table 4). Although crossmatching between **1**, **4**, and **16**, and the other samples was not strong, independent testing against reference curves indicates that they are contemporary. For example, **4** matched a chronology from St Aylotts, Essex (Tyers 1996a) with $t = 5.18$ and **16** matches Hays Wharf, London with $t = 4.68$ (Tyers 1996d; 1996e). Two samples (**2** and **19**) could not be dated against MLAVER or independently by comparison with reference chronologies.

Interpretation

The chronology MLAVER includes timbers from both the belfry and the outer wall.

Three samples from the belfry had sapwood or heartwood/sapwood boundary. The range of heartwood/sapwood boundaries obtained from these (Fig 3a) are consistent with timbers that were felled at the same time (Baillie 1982, 57). Unfortunately the lack of bark edge dates from the belfry prevents an exact date being determined but a felling date range of AD 1527 to AD 1562 can be calculated from the dated timbers. This can be refined slightly because timber **3** was complete to bark edge but the sample lost *c* 7 mm of the outer sapwood during coring because of the woodworm damage. The last ring of this sample dates to AD 1525. It is possible to roughly estimate the number of rings missing by using the average growth rate of the measured rings in the sample (overall sequence 2.18mm/year, last 20 years 1.17 mm/year, last 10 years 1.15 mm/year). This suggests that the felling date of this tree was most probably less than decade after AD 1525. Combining this with the evidence from the other dated belfry samples suggest the structure was probably erected with timber felled between AD 1527 and AD 1535.

Seven samples from the outer wall had sapwood and an additional three may have retained the heartwood/sapwood boundary. Two samples had sequences complete to bark edge. The final

ring on sample **16**, from a post, only had spring cells which indicates that this tree was felled in late spring or early summer of AD 1532. On sample **17**, a stud, the last ring included both spring and summer growth indicating that the tree was felled during the dormant period between autumn AD 1534 and early spring AD 1535. The range of heartwood/sapwood boundaries obtained from the outer wall (Fig 3) are consistent with timbers that were felled at broadly the same time (Baillie 1982, 57). The presence of timbers felled a couple of years apart in the same structure suggests that some of the trees were felled and stored before use either in, or not long after, AD 1534/5.

Discussion

Tree-ring analysis indicates that the belfry and outer wall of the bell tower at the church of St. Mary Magdalen, Magdalen Laver date to the early sixteenth century. This is later than the fifteenth-century date suggested by Hewett (1982) although it agrees Pevsner and Radcliffe's (1965) interpretation of the whole structure.

The lack of bark edge data from the belfry itself prevents the precise chronological relationship between the two areas from being ascertained. The dates obtained from the belfry are derived from both major and minor structural elements all linked by a coherent sequence of carpenters marks. This evidence suggests that the unexpectedly late date obtained is not due to either an unrecognised later repair or extensive late reconstruction. On the other hand the lack of a coherent structural relationship between the belfry and the outer wall certainly indicates they are of different construction programmes. Thus although the tree-ring results suggest it is possible that the belfry and the outer wall were constructed at the same time in, or soon after, AD 1534/5 it seems more likely the tower was built a few years earlier and then rapidly enclosed by the outer wall. The presence of a timber in the outer wall felled two years earlier than another in the same structure implies some timbers may have been stored prior to use. It is even possible this timber may be a leftover offcut from the belfry construction. During analysis, two 'same-tree' pairs from the belfry and three pairs from studs in the outer wall were identified. There was no identified intermixing of timbers derived from 'same-tree' pairs between the two structures.

The occurrence of several 'same-tree' pairs in the belfry and outer wall may indicate that few trees were used in the construction of the bell-tower. The timber is primarily young, fast-grown, and of large scantling, which appears to be characteristic of other Essex belfry assemblages (Tyers 1996b). Tree-ring analysis of several bell frames and belfries from Essex

has been undertaken as part of a county wide project. This is intended to assist in establishing a regional chronology, as well as providing independent data to supplement the stylistic interpretation and documentary evidence on bell frame construction (Tyers 1996b). The analysis of the belfry at the church of St Mary Magdalen, Magdalen Laver, has provided a useful contribution to this study, producing a robust and well replicated site chronology.

Conclusion

Tree-ring analysis of oak timbers from the bell tower of the church of St Mary Magdalen, Magdalen Laver, has produced a 117-year chronology, MLAVER. This was dated to AD 1411 to AD 1534 inclusive. The results indicate that the belfry was built after AD 1525 whilst at least one timber for the outer wall was felled in AD 1534/5. The tree-ring results cannot determine if the belfry and bell tower were built in two phases, but within a few years of each other, or in a single phase around AD 1534/5. Other structural information may assist in refining this interpretation. The construction of the MLAVER chronology has contributed new data to the regional Essex chronology project.

Acknowledgements

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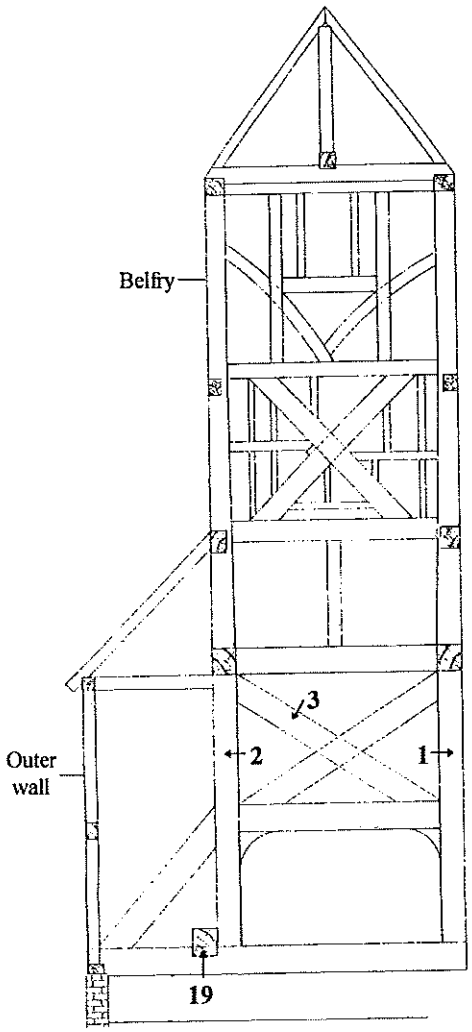
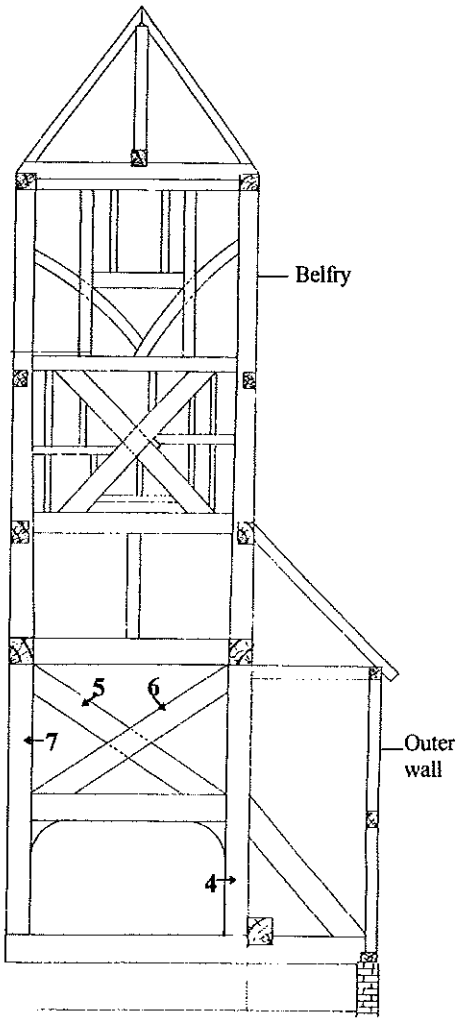
Figure 1: location of the samples obtained from the ground floor of the belfry

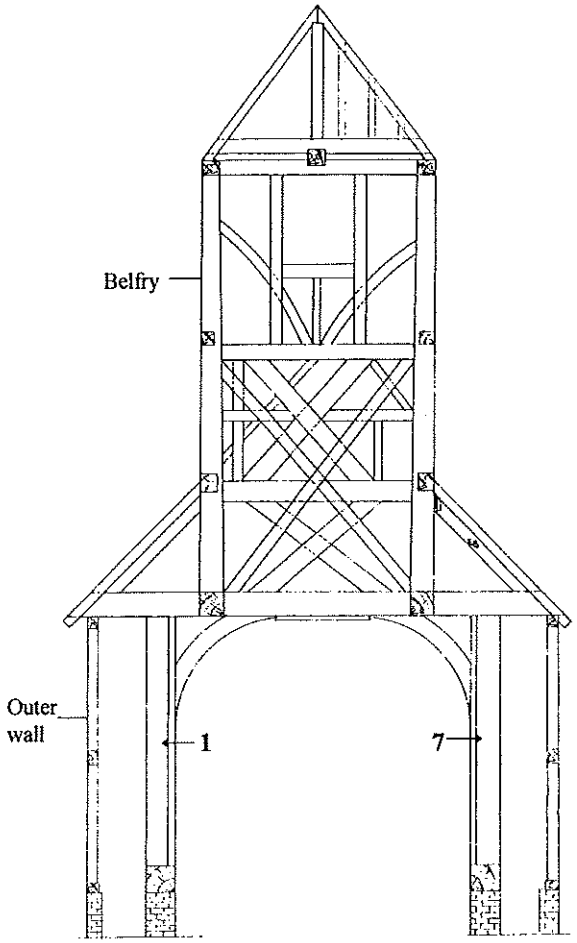
a) Looking North



b) Looking South



c) Looking East



d) Looking West

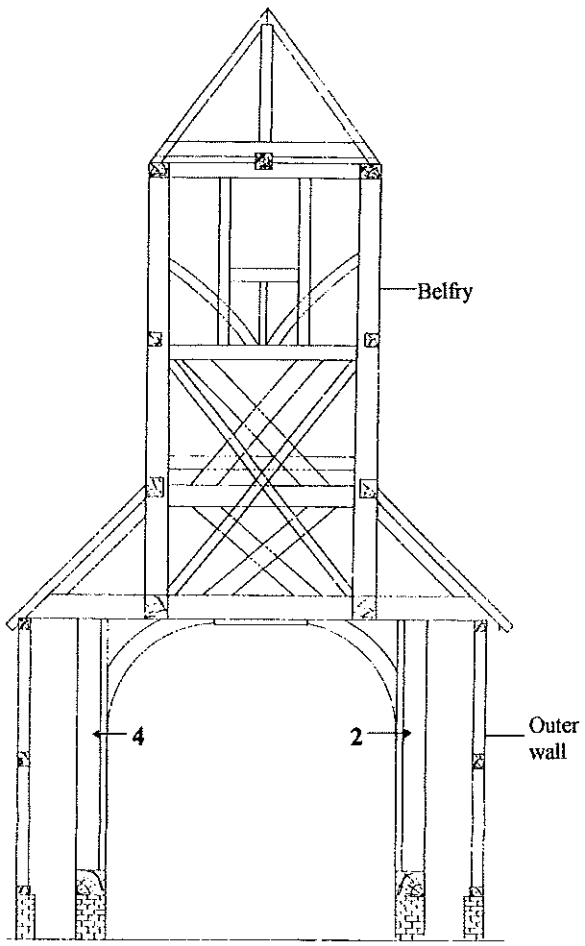
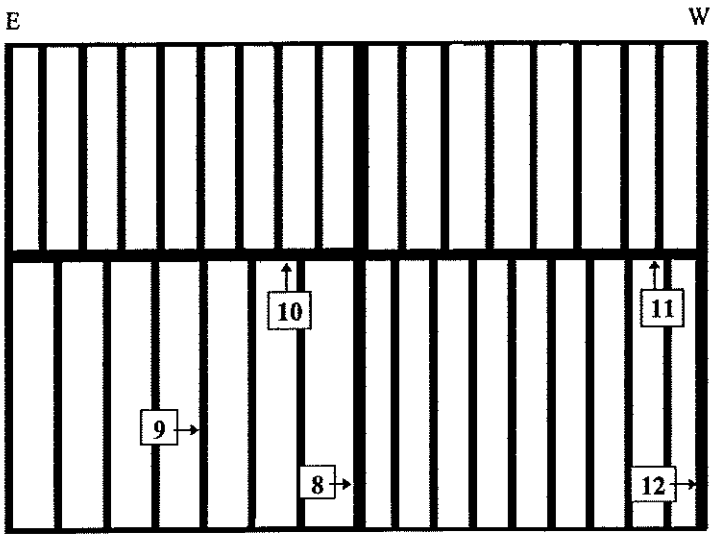
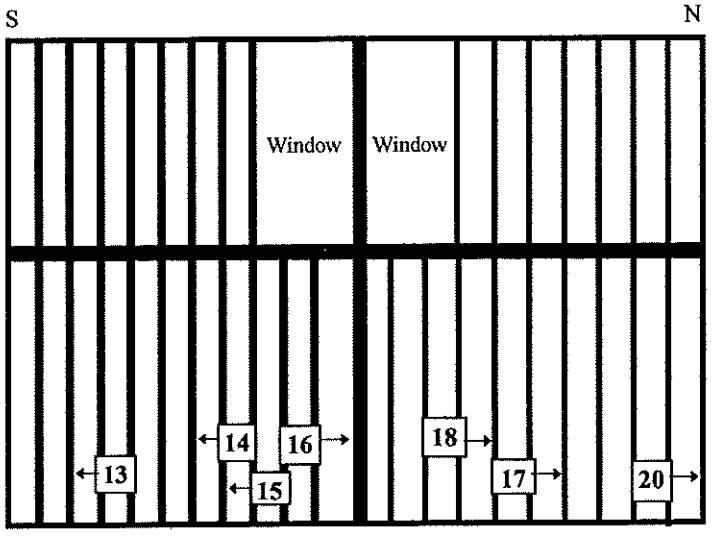


Figure 2: location of the samples from the outer wall of the Church of St Mary Magdalen, Magdalen Laver. Note: E = east; W = west; N = north; S = south. The plans are not to scale.

a) South Wall



b) West Wall



c) North Wall

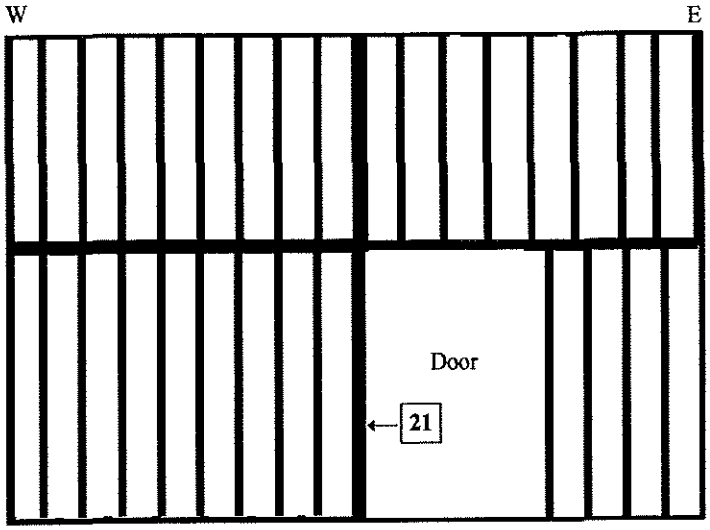
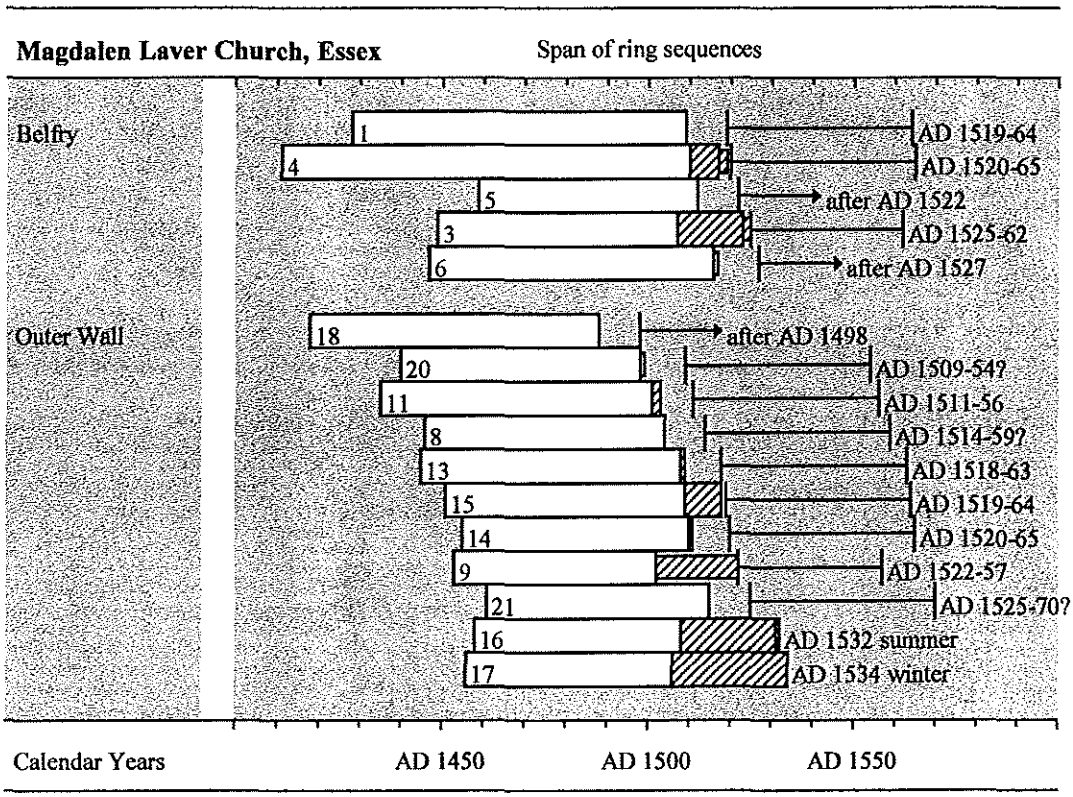


Figure 3: bar diagram showing the relative positions of the dated samples. The felling date ranges at the end of each bar are calculated using a sapwood estimate of 10-55 (Hillam *et al* 1987) and are the same as listed in Table 1.



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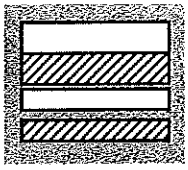

heartwood
sapwood
unmeasured heartwood
unmeasured sapwood

Table 1: list of samples obtained from the church of St Mary Magdalen, Magdalen Laver, Essex

Core	Origin	Location	No. of rings	Sapwood rings	mm/year	Date of sequence (AD)	Interpreted Felling Date (AD)
Belfry							
1	North-east corner post	Belfry	82	h/s	3.20	1428-1509	1519-1564
2	North-west corner post	Belfry	113	16 ?b	2.90	undated	
3	North cross brace	Belfry	75	16+2 [1]	2.18	1449-1523	1525-1562
4	South-west corner post	Belfry	107	7+2 [1]	2.87	1411-1517	1520-1565
5	South cross brace	Belfry	54		3.10	1459-1512	after 1522
6	South cross brace	Belfry	70+1 [2]		2.86	1447-1516	after 1527
7	South-east corner post	Belfry	too few rings		-	-	-
19	West baseplate	Belfry	154		1.41	undated	-
Outer wall							
8	Centre post	South wall	59	?h/s	2.12	1446-1504	1514-1559?
9	Stud	South wall	50	h/s+20 [1]	1.77	1453-1502	1522-1557
10	Intermediate tiebeam (east)	South wall	too few rings	-	-	-	-
11	Intermediate tiebeam (west)	South wall	69	2	1.89	1435-1503	1511-1556
12	South-west corner post	South wall	too few rings	-	-	-	-
13	Stud	West wall	65	1	2.13	1445-1509	1518-1563
14	Stud	West wall	57	1	2.43	1455-1511	1520-1565
15	Stud	West wall	68	9	2.05	1451-1518	1519-1564
16	Centre post	West wall	73	23+1 bs [1]	1.80	1458-1531	1532
17	Stud	West wall	79	28 bw	1.58	1456-1534	1534/5
18	Stud	West wall	71		2.28	1418-1488	after 1498
20	North-west corner post	North wall	59+1 [2]	?h/s	2.88	1440-1498	1509-1554?
21	Centre post	North wall	55	?h/s	2.06	1461-1515	1525-1570?

Key: h/s = heartwood/sapwood boundary; ?h/s = possible heartwood/sapwood boundary; bs = bark edge, felled summer; bw = bark edge, felled winter; ?b = possible bark-edge, + = additional unmeasured rings, [1] additional unmeasured but counted sapwood rings present on the sample, [2] additional unmeasured but counted heartwood rings present on the sample. The felling date ranges are calculated using a sapwood estimate of 10-55 (Hillam *et al* 1987).

Table 2: *t*-value matrix for the matching sequences, arranged by sampling area. Values less than 3.0 are not given. Samples **1-6** are from the belfry. Samples **8-21** are from the outer wall. 'Same-tree' matches have been highlighted in bold.

	3	**4**	**5**	**6**	**8**	**9**	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**20**	**21**
1	-	**15.42**	-	-	4.51	-	-	3.53	3.76	3.82	-	3.01	-	-	-
3		-	4.95	7.39	5.99	5.52	3.63	6.05	5.15	6.51	-	5.49	4.00	5.92	4.80
4			-	-	3.79	-	-	-	3.02	3.03	-	-	-	-	-
5				**10.02**	6.60	3.23	3.93	3.67	3.91	-	-	-	-	3.30	4.26
6					6.38	4.51	3.91	5.91	6.61	7.02	-	4.48	3.82	3.75	5.46
8						6.04	4.29	5.30	4.87	5.20	4.19	3.89	4.37	7.14	5.56
9							9.92	5.79	4.37	6.50	-	3.97	**10.18**	5.27	3.28
11								4.98	4.77	4.97	-	3.57	9.26	4.78	3.30
13									8.65	**10.22**	-	8.20	4.82	4.97	4.19
14										8.82	-	**10.03**	3.30	4.81	5.57
15											-	7.62	4.73	4.07	5.04
16												-	3.72	3.19	3.64
17													-	5.01	3.94
18														3.04	-
20															5.15

Table 3: Ring-width data from site master MLAVER, dated AD 1411 to AD 1534

Year	Ring widths (0.01mm)										Number of samples									
AD 1411	378	422	362	414	489	440	525	343	271	318	1	1	1	1	1	1	1	2	2	2
	403	250	320	338	370	386	494	554	319	332	2	2	2	2	2	2	2	3	3	3
	294	425	389	423	370	394	284	150	105	122	3	3	3	3	4	4	4	4	4	5
	166	166	222	215	218	263	257	316	333	348	5	5	5	5	6	7	8	8	9	9
AD 1451	375	279	270	343	319	354	345	308	268	393	10	10	11	11	12	13	13	14	15	15
	274	282	290	188	305	272	250	290	294	299	16	16	16	16	16	16	16	16	16	16
	213	261	216	241	346	218	198	205	245	256	16	16	16	16	16	16	16	16	16	16
	301	252	233	239	227	215	237	206	205	214	16	16	16	16	16	16	16	16	15	15
	155	159	170	197	162	233	216	142	174	162	15	15	15	15	15	15	15	15	14	14
AD 1501	141	158	139	150	160	169	145	136	139	149	14	14	13	12	11	11	11	11	11	9
	158	152	142	156	166	135	98	117	106	88	9	8	7	7	7	6	5	4	3	3
	82	102	95	91	76	110	103	85	88	84	3	3	3	2	2	2	2	2	2	2
	124	83	101	100							2	1	1	1						

Table 4: Dating the MLAVER chronology, AD 1411-1534. *t*-values with independent reference chronologies.

Area	Reference chronology	*t*-values
Berkshire	Windsor Castle (Hillam forthcoming)	6.45
Essex	Queen Elizabeth's Hunting Lodge (Tyers and Hibberd 1993)	7.61
Herefordshire	Hereford (Tyers 1996c)	7.10
Kent	Longport Farmhouse (Tyers *et al* 1997)	6.46
London	Broomfield House (Bridge 1997a)	7.93
	Bruce Castle (Bridge 1997b)	6.57
	Hays Wharf (Tyers 1996d; 1996e)	7.25
Staffordshire	Sinai Park (Tyers 1997b)	6.77
Sussex	Cowfold Barn (Tyers 1990)	5.69