Ancient Monuments Laboratory
Report 12/96

THE TREE-RING ANALYSIS OF FIVE BELLFRAMES FROM THE COUNTY OF ESSEX.

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Summary

Dendrochronological analysis of five Essex bellframes is described. Seventeen bellframes had previously been assessed for their suitability for dendrochronological analysis (Tyers 1993a; 1995a), and three had already been analysed (Tyers 1995b). 57 samples were obtained from a further five bellframes that were selected for extensive sampling and analysis. The analyses were commissioned as part of a wide-ranging survey of surviving bellframes in the county.

Dates were obtained for timbers from the primary phase of one bellframe, the primary phase of one belfry, and the later modification phases of two bellframes. The results have helped illuminate the developmental sequence of surviving bellframe types.

This study has reaffirmed that tree-ring dating of timbers from buildings in Essex is difficult. This appears primarily due to the use of fast growing young trees which are less suited to the technique. A particular problem with this study has been the limited numbers of trees used to build most extant bellframes. Nevertheless, data have been produced which will add to the research currently underway to create a long, well replicated, county based chronology, and which may help to date more bellframes in the future.

Author's address :-

I Tyers
SHEFFIELD DENDROCHRONOLOGY LABORATORY
Archaeological Science Research School
Dept. Archaeology, Sheffield University
Sheffield
S10 2TN

THE TREE-RING ANALYSIS OF FIVE BELLFRAMES FROM THE COUNTY OF ESSEX

Introduction

The analyses discussed in this report are an integral part of a wide-ranging survey of bellframes within the county of Essex. This survey, funded by English Heritage and Essex County Council, has located every bellframe in Essex and examined a number of methods for undertaking similar surveys in other counties (Cligman and Watkin in prep). The aim of the dendrochronological analysis was to provide an objective base to supplement both the stylistic assessment and the documentary research on the construction dates of the bellframes. The production of dates for bellframes in the county would allow comparison of dates obtained both with the standard typology (Pickford 1993) and with other well dated examples in other areas, and hence allow a better understanding of the development of fashions in bellframe design. The analyses were not restricted purely to the original construction phase of individual bellframes, but included repairs and alterations plus timbers from the belfries. This is for two reasons. Firstly, relatively few trees appear to have been used in the construction of any one bellframe, and therefore a sampling programme designed to obtain sequences from additional trees should increase the chances of obtaining a date. Secondly, the analysis of timbers associated with repairs and modifications to bellframes allows comparison of these events with the dates of insertion of new bells. From a dendrochronological point of view an equally important aim of this study was the provision of data of aid the creation of a long and well replicated county tree-ring chronology.

As an earlier part of this survey three bellframes have been analysed (Tyers 1995b). This revealed a number of methodological difficulties with the original sampling strategy. As a result this part of the survey has concentrated on a single bellframe type from a fairly restricted geographical area.

The opportunity to undertake tree-ring analyses of bellframes in Essex was regarded from the outset as something of a mixed blessing. Tree-ring analyses in Essex, along with some other counties in England such as Devon, Cornwall, Cambridgeshire, Suffolk, and Norfolk, has proved immensely difficult. Many buildings have been sampled but it is only recently that successful results have been obtained (eg Tyers 1993b). The challenge of the bellframe survey was attempting to successfully date a large number of structures each containing perhaps only a handful of trees, none of which were of large scantling. The survey provided a great opportunity to obtain extensive new sets of tree-ring data from the county.

Methodology

A list of all the surviving timber bellframes in Essex was produced (Watkin pers comm). The numbers and distributions of the three most common types of timber bellframe that survive in the county were examined. The short headed bellframes (Pickford 1993, Type 3) were observed to lie mostly in a fairly restricted geographical area. Arrangements were made to visit most of these with a view to assessing their potential for tree-ring analysis. Any that were selected were also intended to be the subject of detailed recording programmes and documentary research. The dendrochronological assessment involved attempting to identify the numbers and accessibility of suitable oak timbers that could be reasonably expected to provide dating evidence for the original construction and any later modifications of the bellframe. In each case a minimum of six suitable oak timbers were sought from the original elements of the bellframe and belfry, and from subsequent modifications. If suitable timbers were located, additional notes were made of more practical issues such as the availability of power supply, ease and safety of accessibility, the diversity of the timbers, and the likelihood of inconvenience being caused to the church by either our presence or the debris dendrochronological sampling inevitably leaves behind. Such factors are clearly of great importance during the assessment and selection process.

Once individual bellframes were clearly identified as suitable, the various levels of official permission to sample were sought and, once these were obtained, the practical arrangements were made for access to the church for the day required for the sampling exercise.

At each selected bellframe, sampling of the prioritised timbers was undertaken using a 15mm diameter core borer attached to an electric drill. Cores were taken in such a direction as to maximise the numbers of rings present in the core. The core holes were left unfilled. For each successful core the ring sequence within was revealed by sanding the core in the horizontal plane of the original parent tree.

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 purpose built travelling stage attached to a computer system. 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 each assemblage were compared with each other and those that were found to cross-match were combined to form a site master curve. This master curve and the remaining unmatched ring sequences were then 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.

These tree-ring dates can initially only date the rings present in the timber. Their interpretation 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 that may be missing. It is important to appreciate that this *tpq* may be many decades prior to the real felling date, although efforts are obviously made during sample selection to ensure that timbers are likely to include rings near the original outer surfaces of the trees. 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. Alternatively, if bark-edge survives, then a felling date can be directly utilised from the date of the last surviving ring. It is sometimes possible to distinguish between either late-summer/winter felling and late-spring/early summer-felling on the basis of the completeness of the final ring: the former has a complete ring, the latter is incomplete. The sapwood estimates applied through-out 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 are national figures applicable to oaks from throughout the British Isles (Hillam *et al* 1987). There is increasing evidence to suggest that there is some degree of regional variation in sapwood number within Britain and it is probable that regional sapwood estimates may ultimately refine the broad ranges given here.

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 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, either in buildings or on 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 and extremely similar longer term growth trends or anatomical anomalies within the timbers. High *t* values are not 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 link.

Description of each sampled bellframe and the results of the analyses undertaken

For this phase of the project samples have been obtained from five bellframes and associated belfries. A map provides locations of these (Fig 1, bellframes 1-5), as well as bellframes visited as part of the assessment which were not selected for further study (Fig 1 and Table 1a). Bellframes examined during earlier parts of this project (Tyers 1993, 1995a) are also highlighted (Fig 1 and Table 1b-c). Rather than provide separate descriptions, assessments, results, and discussion sections with each covering information from several bellframes, a single section for each individual bellframe has been produced that covers the tree-ring dates, the interpretation of those dates, and other information where relevant. The order of the bellframes is based upon the alphabetical order of their parish name. In an attempt to reduce confusion each bellframe for which any sampling and analysis has been undertaken has been assigned a suffix for all the tables and figures relating to it. Thus Little Totham has been assigned suffix 2 and relevant data will be found in Tables 2.2, 3.2, 4.2, and 5.2, whilst relevant diagrams will be found in Figures 2.2, and 3.2. This numbering system is adhered to strictly. There is for example no table 4.1 and 5.1 since no dating evidence or chronology was produced for Doddinghurst.

Doddinghurst 'All Saints'

NGR TQ58939902, (Fig 1; bellframe 1), Table and Figure Suffix 1, survey no 122.

This bellframe consists of four trusses, labelled A-D with A easternmost (Fig 2.1). The bellframe is integral with the timber belfry and therefore presumably of the same date (Watkin pers comm).

All the structural timbers were oak (*Quercus* spp.). Twelve samples, numbered **1** to **12**, were obtained from the bellframe and the belfry (Fig 2.1 and Table 2.1). Samples **4** and **9** were unusable as they fragmented badly during extraction, whilst samples **10** and **12** contained too few rings for reliable analysis. The eight suitable samples were measured and the sequences compared with each other. No cross-matching was identified between any of this material.

None of the data was found to date when compared with an extensive collection of reference data.

Little Totham 'All Saints'
NGR TL88401035, (Fig 1; bellframe 2), Table and Figure Suffix 2, survey no 288.

This bellframe consists of four trusses, labelled A-D with A easternmost (Fig 2.2). The bellframe is not integral with the timber belfry and therefore may not be contemporaneous (Watkin pers comm).

All the structural timbers were oak (*Quercus* spp.). Eleven samples, numbered **1** to **11**, were obtained from the bellframe and the belfry (Fig 2.2 and Table 2.2). Samples **2** and **10** contained too few rings for reliable analysis. The nine suitable samples were measured and the sequences compared with each other. Samples **5**, **6**, **7**, **8**, and **11** were found to cross-match (Table 3.2), and a master chronology was created by combining the data (Fig 3.2). This chronology was found to match to an extensive range of reference chronologies (Table 4.2), and is dated AD 1380 to AD 1517 inclusive. The chronology, LTOTHAM, is listed in Table 5.2. The remaining measured samples (**1**, **3**, **4**, and **9**) have failed to produce any visually and statistically acceptable matches and are thus undated by the technique.

The interpretation of these results is relatively straightforward. All five samples are from major belfry elements; all end at the heartwood/sapwood boundary, and all end at either AD 1516 or AD 1517. Using a sapwood estimate of 10 - 55 rings (Hillam *et al* 1987), a combined felling date range of AD 1527 to AD 1571 is produced. Use of green timber would be expected (Rackham 1990, 69) and thus the construction date for the belfry probably falls within this range. Only two trees are present in the dated material. Samples **5**, **6**, and **7** are derived from one tree, and samples **8** and **11** from another tree. No timber from the bellframe has been found to cross-match; the later replacement of one of the truss heads has also failed to cross-match.

Mountnessing 'St Giles'
NGR TQ64769661, (Fig 1; bellframe 3), Table and Figure Suffix 3, survey no 320.

This bellframe consists of four trusses, labelled A-D with A easternmost (Fig 2.3). The bellframe is not integral with the timber belfry and they may therefore be of different dates.

All the structural timbers were oak (*Quercus* spp.). Fourteen samples, numbered **1** to **14**, were obtained from the bellframe and the belfry (Fig 2.3 and Table 2.3). Sample **1** fragmented badly

during extraction, and samples **6** and **7** had too few rings for reliable analysis. The eleven suitable samples were measured and the sequences compared with each other. Two samples from the original bellframe timbers (**2** and **8**) were found to match (Fig 3.3a and Table 3.3a). A further group of four samples from original bellframe timbers (**3**, **4**, **5**, and **14**) were also found to match each other but not the first group (Fig 3.3b and Table 3.3b). It is possible that both of these groups are derived from individual trees. New master sequences were constructed from these groups. However, neither of these cross-match to an extensive range of reference chronologies. Sample **10**, from the replaced head of truss A, was found to date to AD 1747 to AD 1899 inclusive (Fig 4.3 and Table 3.3c). The undated chronologies, MOUNTNS1 and MOUNTNS2, and the data from sample **10** are listed in Tables 5.3a, 5.3b, and 5.3c. The remaining measured samples (**9** and **11** - **13** inclusive) have failed to produce any visually and statistically acceptable matches and are thus undated by the technique.

Sample **10** has no surviving sapwood and thus felling after AD 1909 is indicated. This result shows the replacement of the head on Truss A occurred after AD1909 and probably in the first half of the twentieth century. No dating evidence was obtained for the bellframe or the belfry.

Ramsden Cray 'St Mary the Virgin'
NGR TL70809339, (Fig 1; bellframe 4), Table and Figure Suffix 4, survey no 358.

This bellframe consists of three trusses; these are referred to here as the North, Middle and South Truss (Fig 2.4). The bellframe is not integral with the timber belfry and they may therefore be of different date.

All the structural timbers were oak (*Quercus* spp.). Ten samples, numbered **1** to **10**, were obtained from the bellframe and the belfry (Fig 2.4 and Table 2.4). Samples **6**, **7**, **8**, and **10** fragmented badly during extraction and no further use could be made of them. The six suitable samples were measured and the sequences compared with each other. Two separate pairs of samples were linked on the basis of their internal cross-matching (Fig 3.4a-b and Table 3.4a-b). Two master chronologies were constructed by combining the data. One of these chronologies was found to match to an extensive range of reference chronologies (Table 4.4a). This chronology, RAMCRAY1, composed of samples **4** and **5**, was dated to AD 1639 - 1711 inclusive. The chronologies, RAMCRAY1 and the undated RAMCRAY2 constructed from samples **1** and **2**, are listed in Tables 5.4a-b. The remaining measured samples, **3** and **9**, have failed to produce any visually and statistically acceptable matches and are thus undated by the technique.

The two dated samples are from replacement heads. No sapwood is present and thus felling and use after AD 1721 is indicated. No dating evidence was obtained for the bellframe or the belfry.

Woodham Walter 'St Michael'
NGR TL80900672, (Fig 1; bellframe 5), Table and Figure Suffix 5, survey no 492.

This bellframe consists of four trusses, labelled A-D with A westernmost (Fig 2.5). The bellframe is probably integral with the timber belfry and thus they are probably contemporary.

All the structural timbers were oak (*Quercus* spp.). Ten samples, numbered **1** to **10**, were obtained from the bellframe and the belfry (Fig 2.5 and Table 2.5). Sample **4** fragmented badly during extraction and no further use could be made of it. The nine suitable samples were measured and the sequences compared with each other. Three samples (**1**, **2**, and **6**) were found to cross-match and a new master chronology was constructed by combining the data (Fig 3.5 and Table 3.5). This chronology was found to match to an extensive range of reference chronologies (Table 4.5) and is dated to AD 1276 - 1372 inclusive. The chronology, WOODWALT, is listed in Table 5.5. The remaining measured samples (**3**, **5**, and **7-10** inclusive) have failed to produce any visually and statistically acceptable matches and are thus undated by the technique.

All three dated samples are from primary elements of the bellframe, and all three are heartwood only. Adding the minimum expected sapwood number indicates felling and use occurred after AD 1382.

Conclusion

The results of the analysis of eight bellframes appear disappointing. Nevertheless, new data has been obtained and one bellframe has been successfully dated. It is difficult to draw conclusions but in the terms of the pilot survey it is clear that dendrochronological analysis can be undertaken on bellframes, sometimes with success. In all probability analyses on this scale in most other areas of Britain would have yielded many more results. Analyses of bellframes outside Essex have generally proved more successful. Twyning in Gloucestershire (Tyers 1996a), Sutton in the Isle, Cambridgeshire (Tyers 1995c), and Romsey Abbey, Hampshire (Hillam and Groves 1994), have all been analysed and useful results produced. Each of these bellframes has been of a somewhat larger size, and thus with greater numbers of timbers, also of greater scantling. Dendrochronology thus has a vital part to play as an important component of any future national survey.

Substantial quantities of new data were obtained during the study. Some of which has consolidated and lengthened the Essex county tree-ring sequence (Fig 4). Results for some of the currently undated sequences may be produced as more Essex buildings are examined in the future.

Acknowledgements

The analysis reported here was funded by English Heritage. I wish to thank Elphin Watkin for his unfailing help, practical assistance, and encouragement. My colleagues Cathy Groves and Jennifer Hillam provided immeasurable assistance and useful comment to early drafts of this report.

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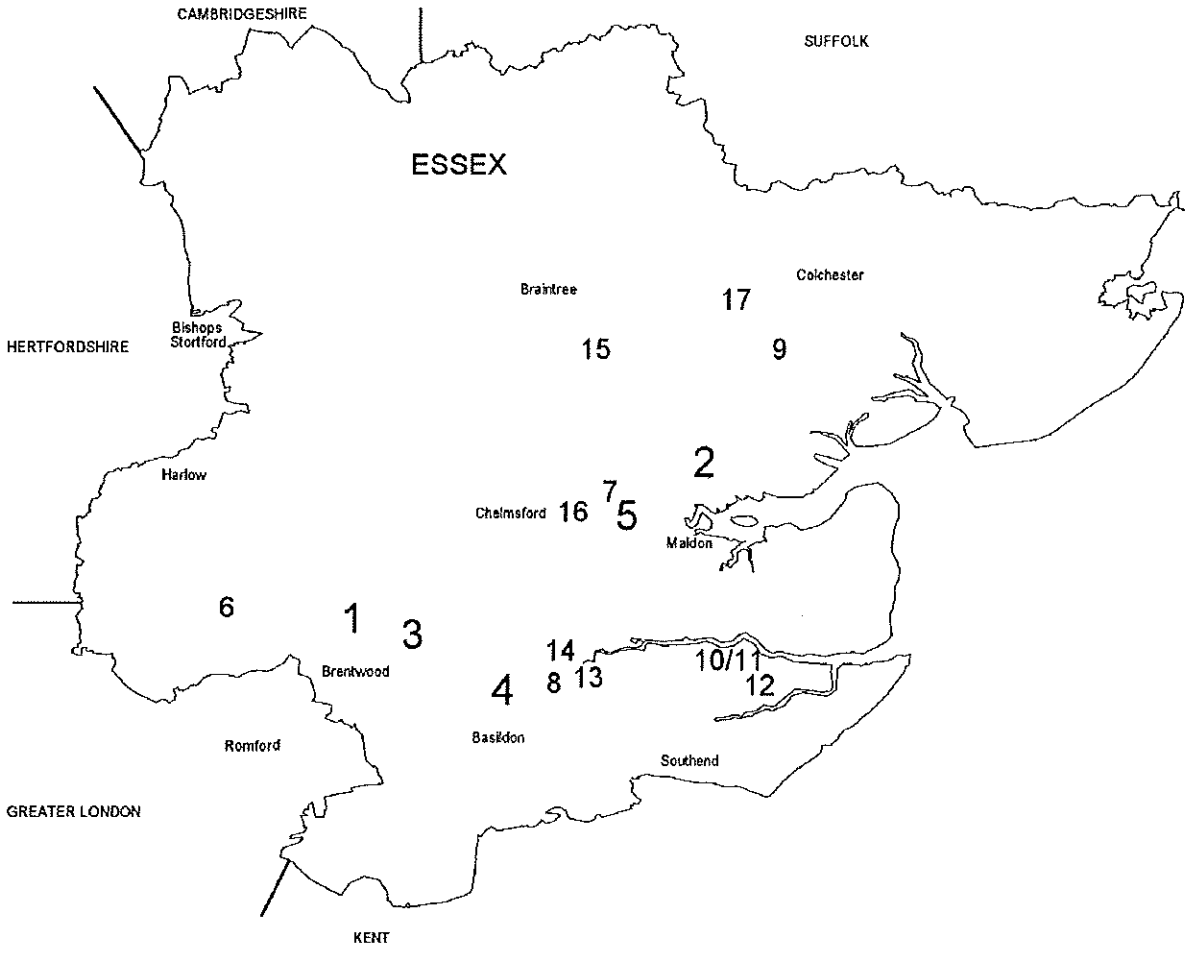
Figure 1

Map of Essex showing location of bellframes discussed in the text



Key

1 Doddinghurst
2 Little Totham
3 Mountnessing
4 Ramsden Cray
5 Woodham Walter

For frames 6-17 see Table 1.

Figure 2.1

Doddinghurst (after Watkin pers comm): tower (a), plan of frame showing trusses (b), typical truss (c)

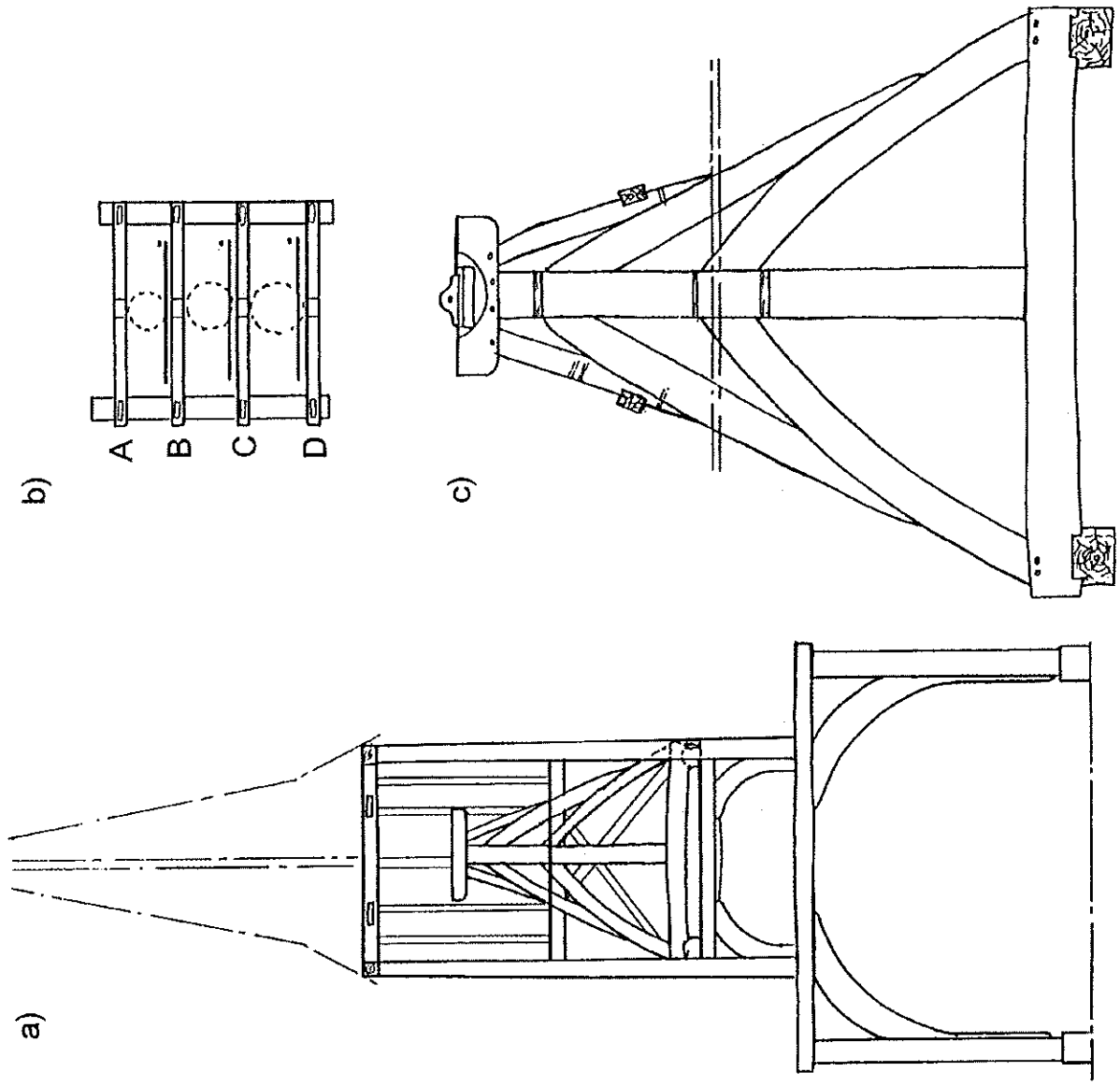


Figure 2.2

Little Totham (after Watkin pers comm): tower (a), plan of frame showing trusses (b), typical truss (c)

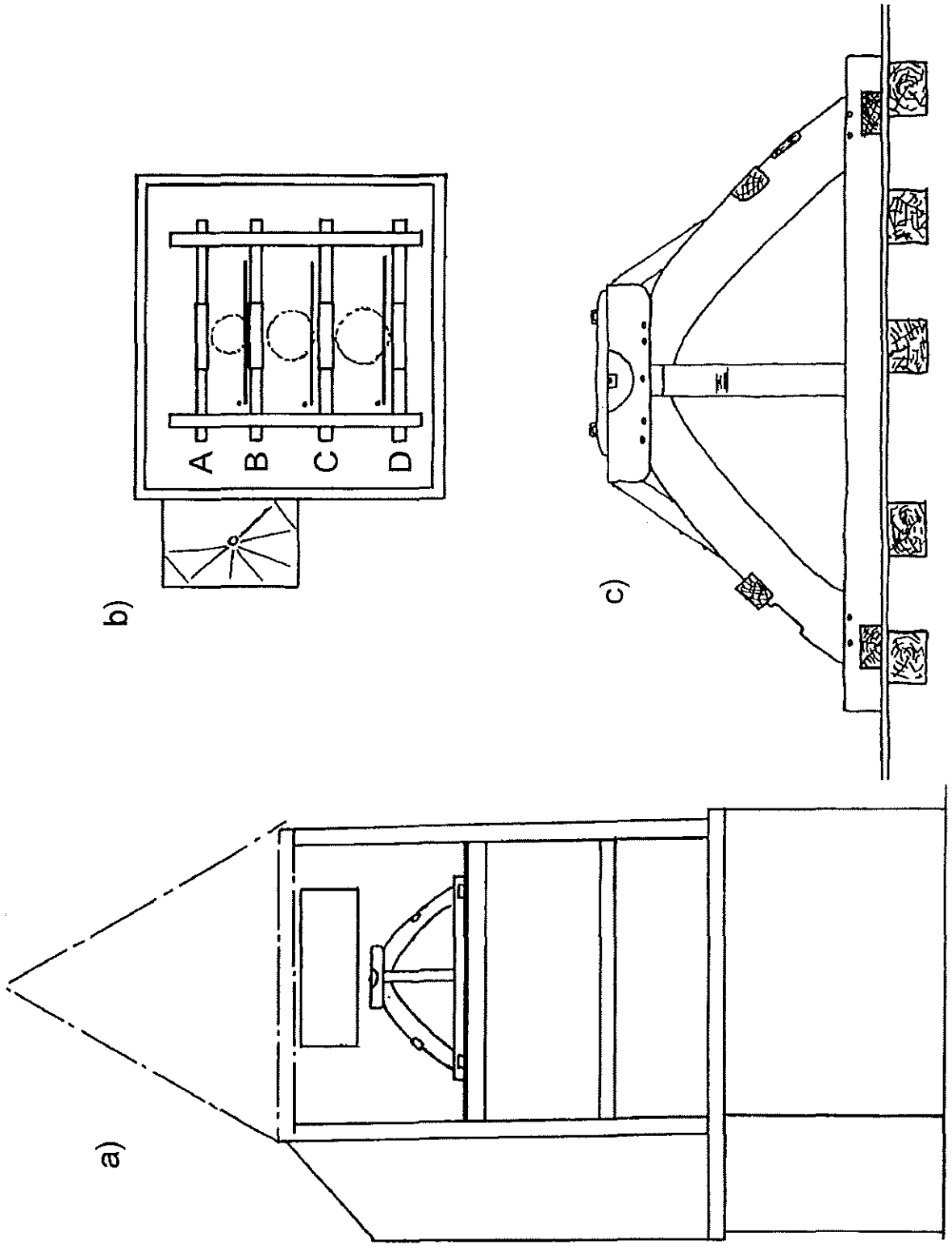


Figure 2.3

Mountnessing (after Watkin pers comm): tower (a), plan of frame showing trusses (b), typical truss (c)

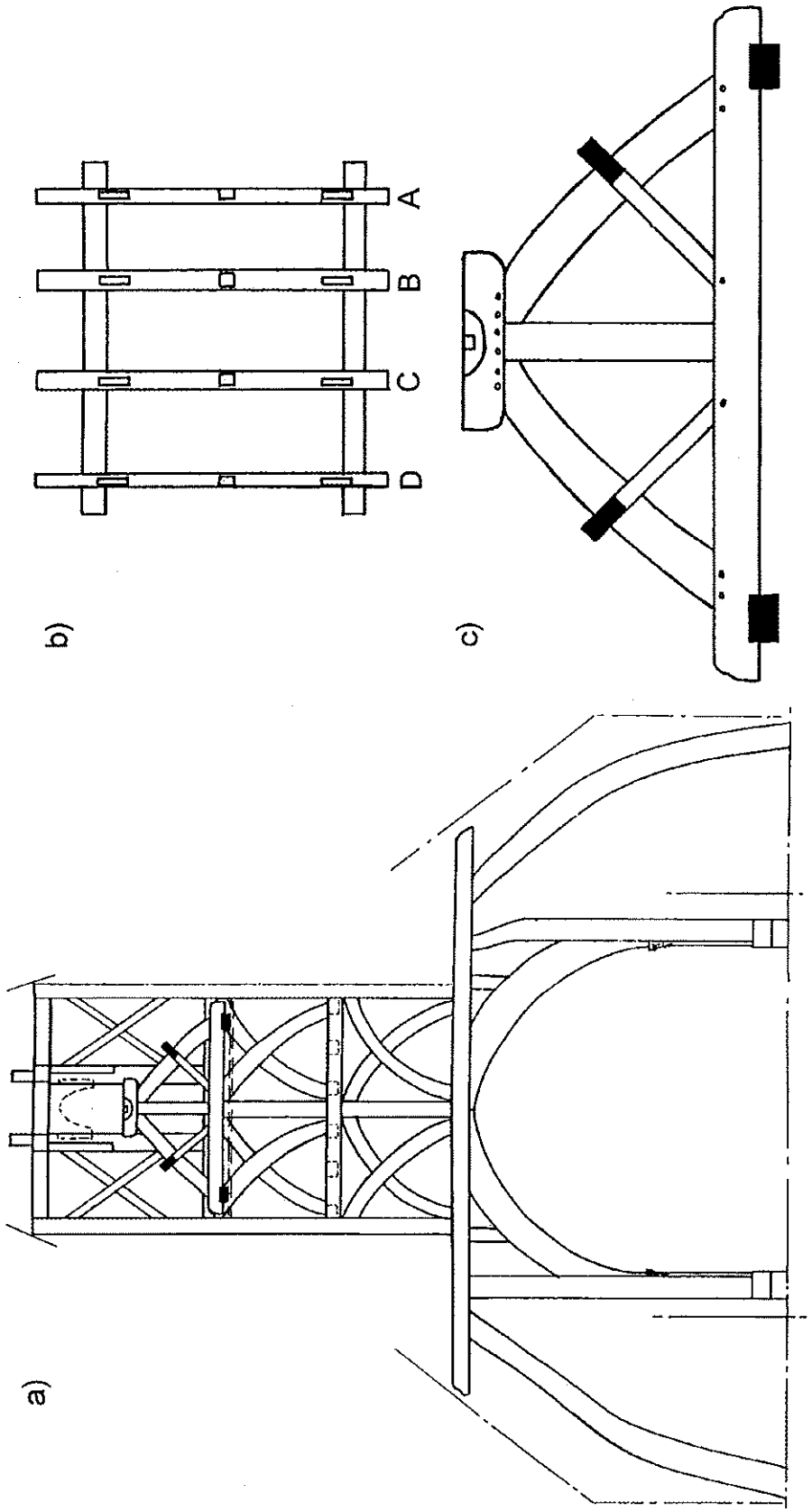


Figure 2.4

Ramsden Cray (after Watkin pers comm): tower (a), plan of frame showing trusses (b), typical truss (c)

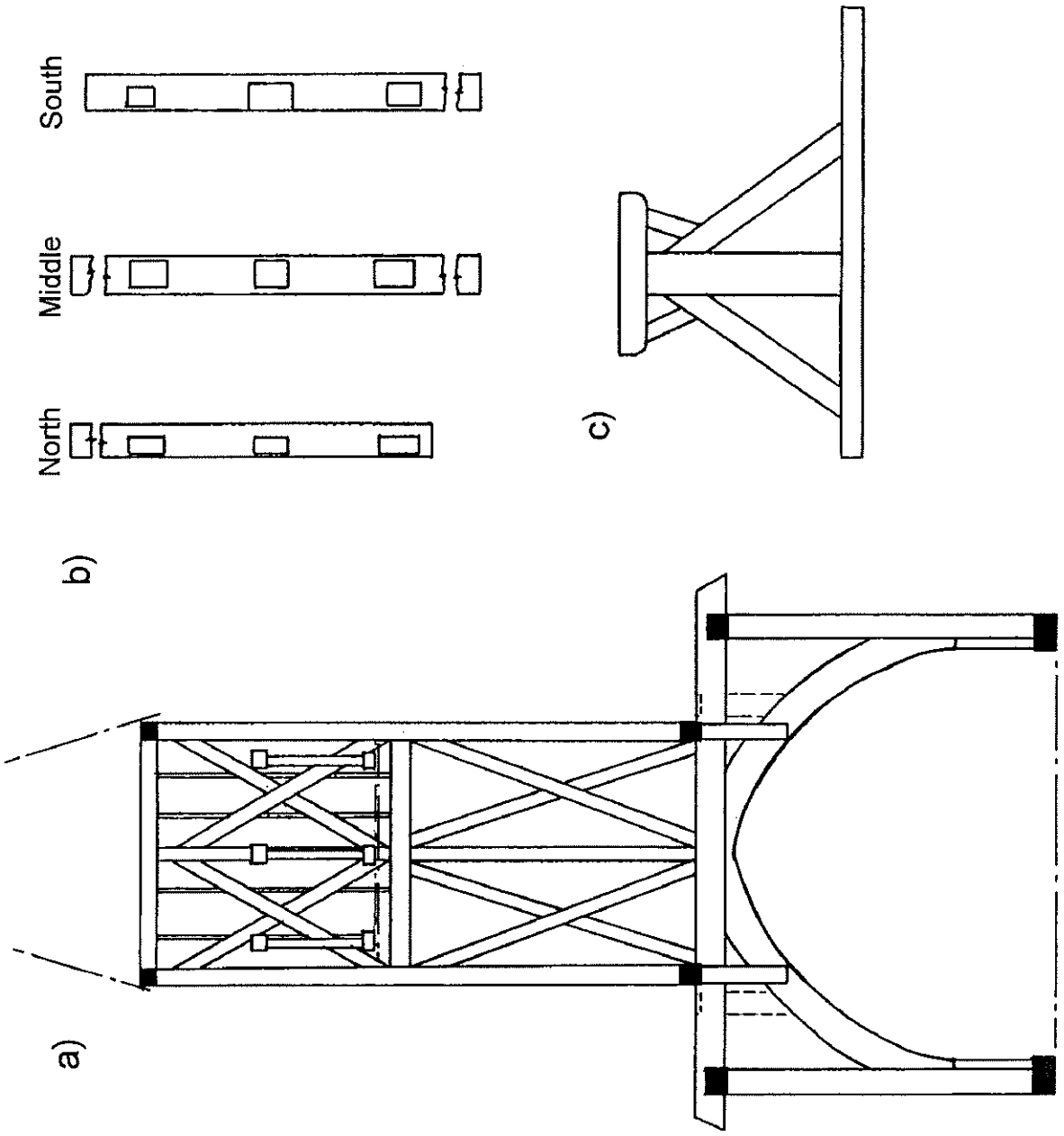


Figure 2.5

Woodham Walter (after Watkin pers comm): tower (a), plan of frame showing trusses (b), typical truss (c)

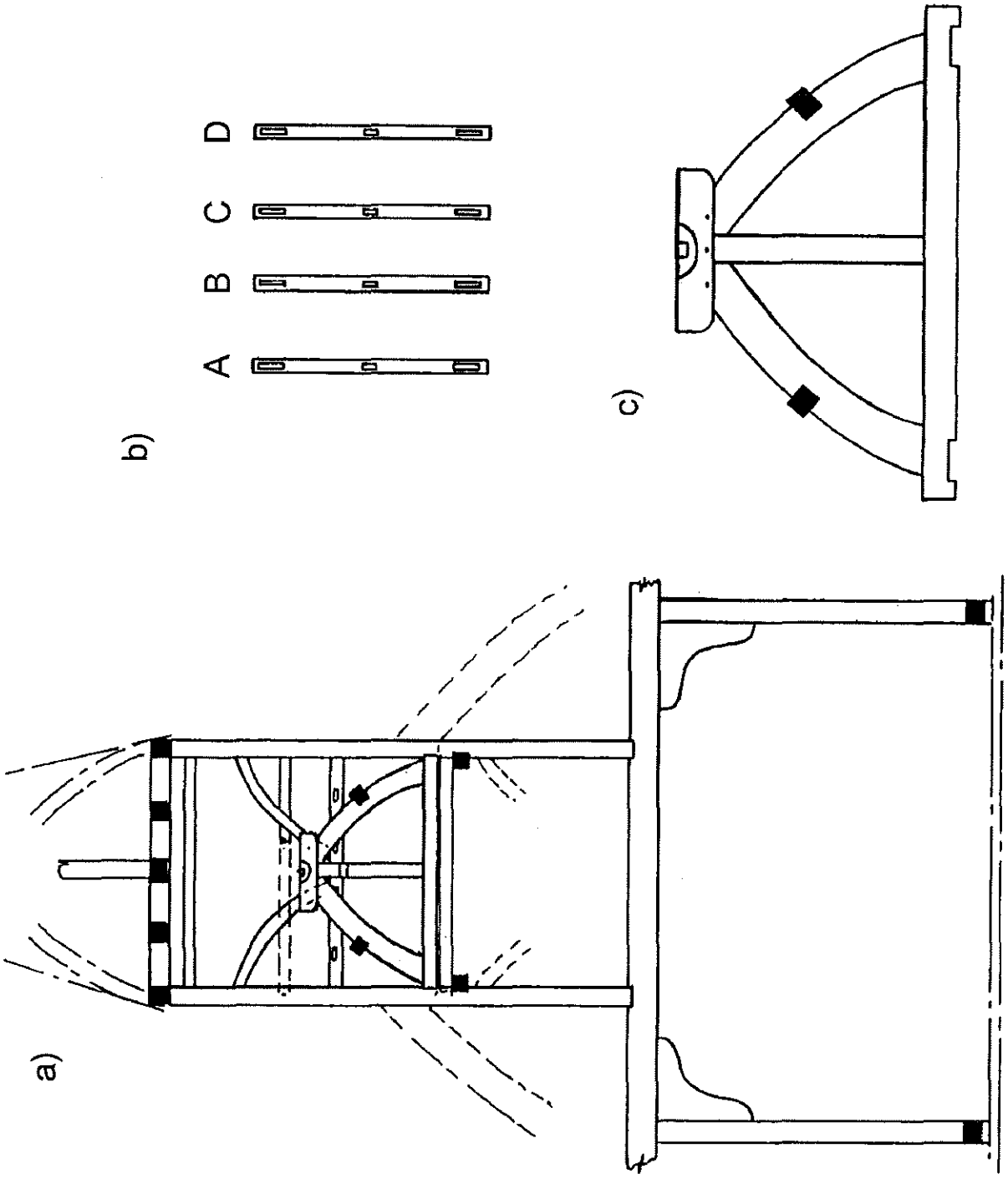


Figure 3.2

Bar diagram showing the relative positions of the dated sequences from Little Totham

White bars - heartwood rings; HS - heartwood/sapwood boundary

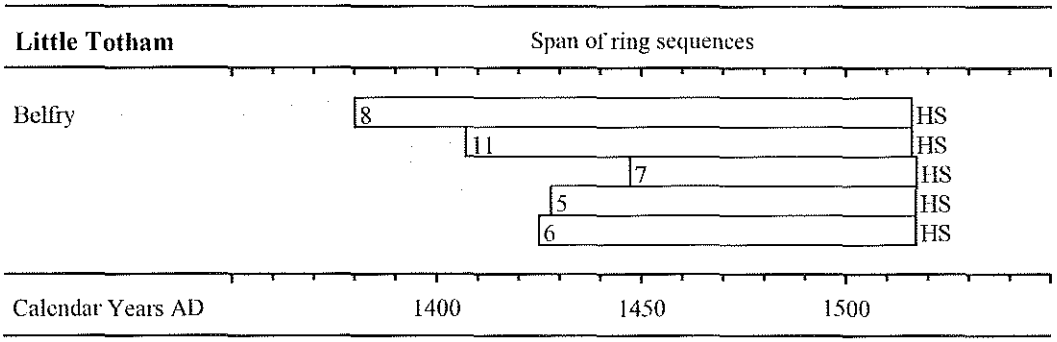


Figure 3.3a-b

Bar diagram showing the relative positions of the undated sequences from Mountnessing. Note there is no link, and thus no relationship between the two groups.

White bars - heartwood rings; hatched bars - sapwood rings

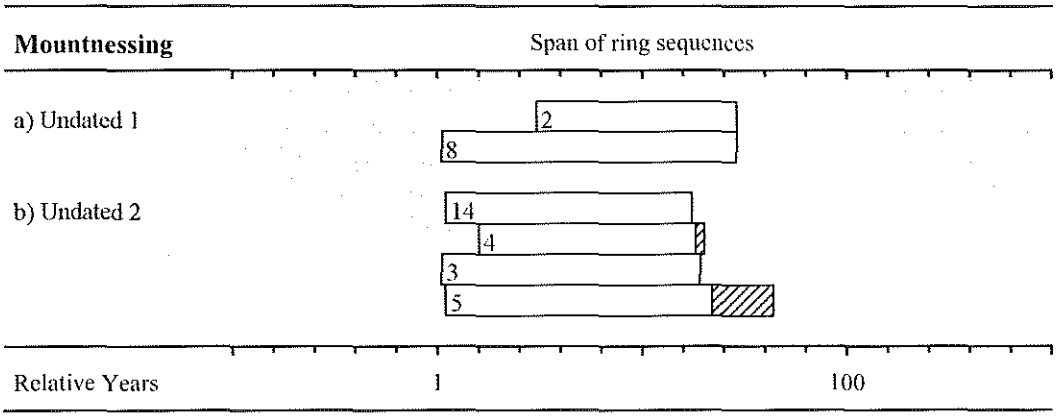


Figure 3.3c

Bar diagram showing the position of sample 10 from Mountnessing.

White bars - heartwood rings

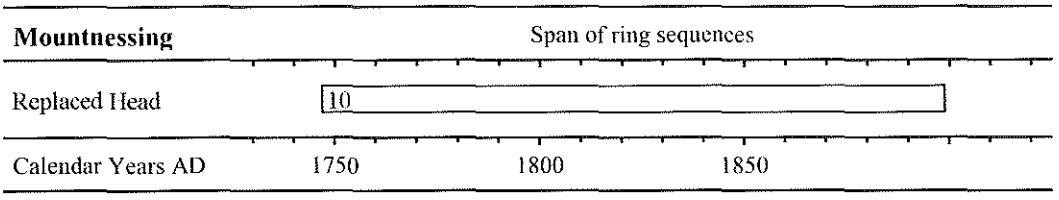


Figure 3.4a

Bar diagram showing the relative positions of the undated sequences from Ramsden Cray

White bars - heartwood rings; hatched bars - sapwood rings

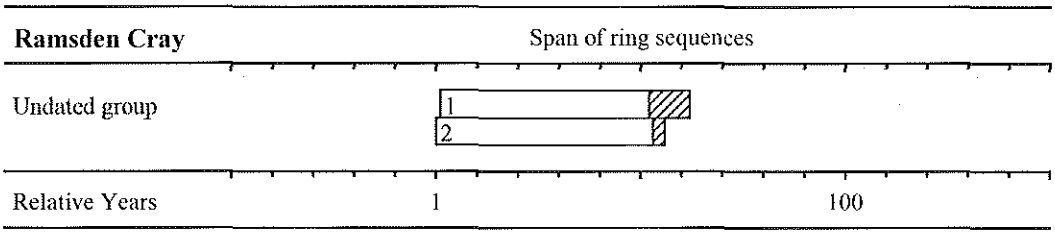


Figure 3.4b

Bar diagram showing the relative positions of the dated sequences from Ramsden Cray

White bars - heartwood rings

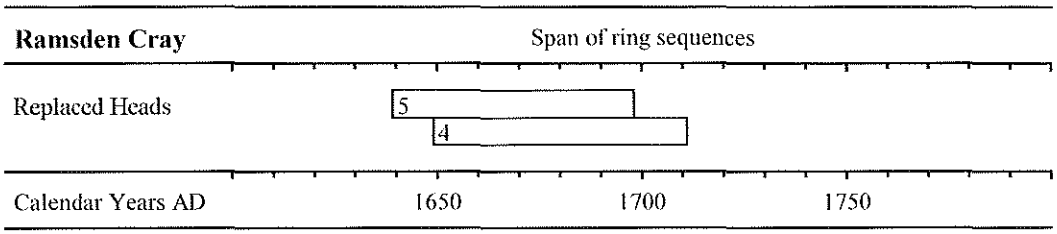


Figure 3.5

Bar diagram showing the relative positions of the dated sequences from Woodham Walter

White bars - heartwood rings

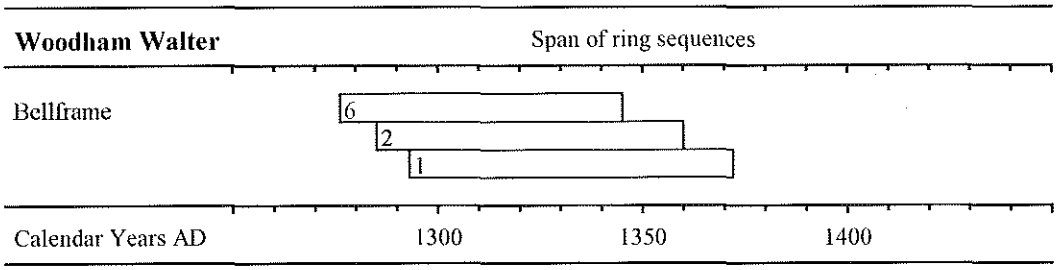
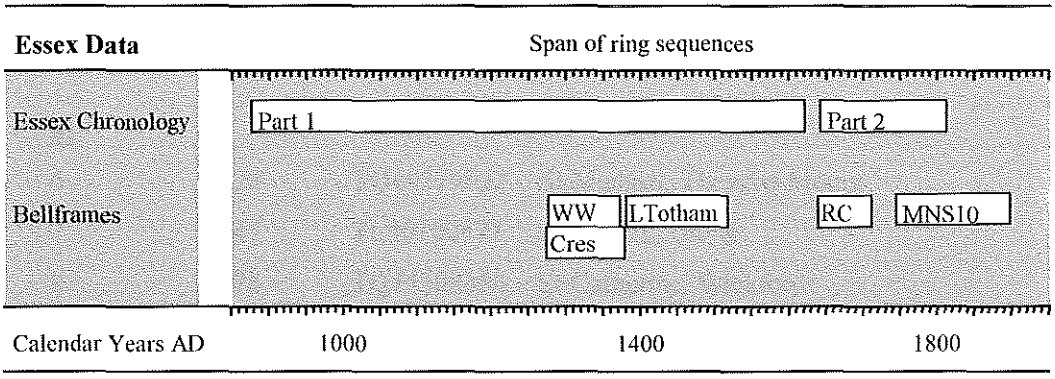


Figure 4

Bar diagram showing the extent of Essex tree-ring data, and the positions of new data produced during the Bellframes survey.



Key

WW	Woodham Walter
LTotham	Little Totham
Cres	Cressing
RC	Ramsden Cray
MNS10	Mountnessing sample 10

Table 1

Summary of bellframes assessed for this part of the project but not selected for further study (a); other bellframes assessed earlier but not selected (b), and bellframes analysed earlier in the project (c).

Map number	Survey number	NGR	Description
a)			
6	428	TQ49279922	St Michael, Theydon Mount
7	447	TL80100877	All Saints, Ulting
8	478	TQ75509350	St Catherine, Wickford
b)			
9	38	TL94351990	St Mary, Birch
10/11	3/4	TQ89709450	St Nicholas, Canewdon (Two Frames)
12	340	TQ92619306	St Peter, Paglesham
13	360	TQ78059334	St Nicholas, Rawreth
14	372	TQ75369441	St Mary, Runwell (Frame Missing)
c)			
15	116	TL79452041	All Saints, Cressing (6 samples, 2 dated from belfry, chronology dates AD 1274 - AD 1378, probably built between AD 1388 and *c* 1410)
16	262	TL76440807	St Mary the Virgin, Little Baddow (3 samples, no matching, no dates)
17	307	TL89142375	St Andrew, Marks Tey (9 samples, two matching pairs, no dates)

Table 2.1

List of samples from Doddinghurst

Core	Origin of core	Analysis undertaken	Wood type	Total Rings	Sap Rings	mm/year	Result	Date of sequence
1	Belfry SW Corner Post	Tree-ring sequence measured	Oak	105	23	1.74	Undated	-
2	Belfry S Top Plate	Tree-ring sequence measured	Oak	62	14	2.53	Undated	-
3	Truss B Southern Lower Brace	Tree-ring sequence measured	Oak	79	0	2.17	Undated	-
4	Truss C Southern Lower Brace	Species Identification only	Oak				-	-
5	Truss C Southern Upper Brace	Tree-ring sequence measured	Oak	58	0	3.10	Undated	-
6	Truss C Sill	Tree-ring sequence measured	Oak	65	0	2.68	Undated	-
7	Truss B Sill	Tree-ring sequence measured	Oak	56	0	3.81	Undated	-
8	Belfry S outer X brace rail	Tree-ring sequence measured	Oak	59	0	3.11	Undated	-
9	Belfry N outer X brace rail	Species Identification only	Oak				-	-
10	Belfry N outer X brace rail	Species Identification only	Oak				-	-
11	Belfry N upper E X brace	Tree-ring sequence measured	Oak	52	0	3.19	Undated	-
12	Belfry Lower NW Corner Post	Species Identification only	Oak				-	-

Table 2.2

List of samples from Little Totham

Core	Origin of core	Analysis undertaken	Wood type	Total Rings	Sap Rings	mm/year	Result	Date of sequence
1	Truss A Head - replacement	Tree-ring sequence measured	Oak	66	0	1.95	Undated	-
2	Truss B Head	Species Identification only	Oak				-	-
3	Truss C Head	Tree-ring sequence measured	Oak	50	0	3.36	Undated	-
4	Truss D North Brace	Tree-ring sequence measured	Oak	61	0	1.92	Undated	-
5	Belfry NW Corner post	Tree-ring sequence measured	Oak	90	0	2.35	Dated	AD1428 - AD1517
6	Belfry SW Corner post	Tree-ring sequence measured	Oak	93	0	1.89	Dated	AD1425 - AD1517
7	Belfry SE Corner post	Tree-ring sequence measured	Oak	71	0	2.09	Dated	AD1447 - AD1517
8	Belfry S Upper post	Tree-ring sequence measured	Oak	137	0	1.76	Dated	AD1380 - AD1516
9	Belfry N-S beam below frame	Tree-ring sequence measured	Oak	76	14	2.29	Undated	-
10	Bellframe N Bearer	Species Identification only	Oak				-	-
11	Belfry W Rail below frame	Tree-ring sequence measured	Oak	110	0	1.45	Dated	AD1407 - AD1516

Table 2.3

List of samples from Mountnessing

Core	Origin of core	Analysis undertaken	Wood type	Total Rings	Sap Rings	mm/year	Result	Date of sequence
1	Truss A N Main Brace	Species Identification only	Oak				-	-
2	Truss A S Main Brace	Tree-ring sequence measured	Oak	50	0	2.63	Undated	-
3	Truss B S Transom Strut	Tree-ring sequence measured	Oak	64	0	2.59	Undated	-
4	Truss C S Transom Strut	Tree-ring sequence measured	Oak	56	2	1.99	Undated	-
5	Truss D S Main Brace	Tree-ring sequence measured	Oak	81	15	2.85	Undated	-
6	Truss C N Transom Strut	Species Identification only	Oak				-	-
7	Truss D Head	Species Identification only	Oak				-	-
8	Truss C Head	Tree-ring sequence measured	Oak	73	0	3.00	Undated	-
9	Truss B Head	Tree-ring sequence measured	Oak	86	11	1.97	Undated	-
10	Truss A Head	Tree-ring sequence measured	Oak	153	0	1.56	Dated	AD1747 - AD1899
11	Belfry N Window W Durn	Tree-ring sequence measured	Oak	73	0	2.91	Undated	-
12	Belfry W NW X-brace	Tree-ring sequence measured	Oak	65	22	2.46	Undated	-
13	Belfry NW Corner Post	Tree-ring sequence measured	Oak	103	16	1.98	Undated	-
14	Bellframe S E-W Bearer	Tree-ring sequence measured	Oak	61	0	2.22	Undated	-

Table 2.4

List of samples from Ramsden Cray

Core	Origin of core	Analysis undertaken	Wood type	Total Rings	Sap Rings	mm/year	Result	Date of sequence
1	S Truss King Post	Tree-ring sequence measured	Oak	62	10	2.79	Undated	-
2	N Truss King Post	Tree-ring sequence measured	Oak	57	3	3.02	Undated	-
3	C Truss Head	Tree-ring sequence measured	Oak	57	0	3.00	Undated	-
4	N Truss Head	Tree-ring sequence measured	Oak	63	0	2.56	Dated	AD1649 - AD1711
5	S Truss Head	Tree-ring sequence measured	Oak	60	0	1.94	Dated	AD1639 - AD1698
6	C Truss Sill	Species Identification only	Oak				-	-
7	Belfry SE Corner Post	Species Identification only	Oak				-	-
8	Belfry N E-W Tiebeam	Species Identification only	Oak				-	-
9	Belfry E N-S Tiebeam	Tree-ring sequence measured	Oak	60	5	3.33	Undated	-
10	Belfry SE Corner Post (repeat)	Species Identification only	Oak				-	-

Table 2.5

List of samples from Woodham Walter

Core	Origin of core	Analysis undertaken	Wood type	Total Rings	Sap Rings	mm/year	Result	Date of sequence
1	Truss A N Brace	Tree-ring sequence measured	Oak	80	0	1.50	Dated	AD1293 - AD1372
2	Truss A S Brace	Tree-ring sequence measured	Oak	76	0	1.64	Dated	AD1285 - AD1360
3	Truss A Head	Tree-ring sequence measured	Oak	53	0	2.32	Undated	-
4	Truss A King Post	Species Identification only	Oak				-	-
5	Truss B S Brace	Tree-ring sequence measured	Oak	99	0	1.08	Undated	-
6	Truss B N Brace	Tree-ring sequence measured	Oak	70	0	2.32	Dated	AD1276 - AD1345
7	Truss C Head	Tree-ring sequence measured	Oak	70	2	2.26	Undated	-
8	Truss D S Brace	Tree-ring sequence measured	Oak	99	0	1.39	Undated	-
9	Nave Roof N Ashlar	Tree-ring sequence measured	Oak	81	0	1.87	Undated	-
10	Nave Roof N Wall Plate	Tree-ring sequence measured	Oak	94	0	1.96	Undated	-

Table 3.2

Correlation between the dated material from Little Totham. (- = *t*-value below 3.0)

		***t*-values**		
sample		**sample**		
	6	*7*	*8*	*11*
5	10.1	8.3	3.4	5.2
6		7.5	-	3.6
7			4.2	3.9
8				6.9

Table 3.3a

Correlation between samples 2 and 8 from Mountnessing.

	***t*-values**
sample	**sample**
	8
2	7.4

Table 3.3b

Correlation between the four cross-matched but undated samples from Mountnessing.

		***t*-values**	
sample		**sample**	
	4	*5*	*14*
3	7.1	6.7	6.1
4		4.5	6.5
5			3.2

Table 3.4a

Correlation between samples 1 and 2 from Ramsden Cray.

	t-values
sample	**sample**
	2
1	14.5

Table 3.4b

Correlation between samples 4 and 5 from Ramsden Cray.

	t-values
sample	**sample**
	5
4	6.1

Table 3.5

Correlation between the dated material from Woodham Walter

	t-values	
sample	**sample**	
	2	*6*
1	5.7	3.3
2		4.9

Table 4.2

Dating of the master curve from Little Totham. *t*-values with dated reference chronologies. All the reference curves are independent.

Area	Reference chronology	*t*-values
Essex	Nether Hall (Tyers unpubl)	5.3
	Rookwood Hall Barn (Tyers and Hibberd 1993)	4.9
Berkshire	Windsor Castle Kitchen (Hillam in prep)	5.6
Hampshire	Alton (Hillam 1978)	4.2
Kent	Kent master (Laxton and Litton 1989)	6.1
	Longport House (Tyers unpubl)	4.2
London	Queen Elizabeth Hunting Lodge (Tyers and Hibberd 1993)	4.5
	Southwark Boats chronology 3 (Tyers forthcoming)	5.1
	Sutton House (Tyers and Hibberd 1993)	5.1

Table 4.3

Dating of sample 10 from Mountnessing. *t*-values with dated reference chronologies. All the reference curves are independent.

Area	Reference chronology	*t*-values
Essex	Tilbury Fort (Groves 1993)	5.7
	Thaxted Church (Tyers 1990)	4.6
Berkshire	Reading1 (Groves *et al* forthcoming)	4.8
Hampshire	Winchester (Barefoot 1975)	5.9
London	Hampstead Heath (Tyers unpubl)	5.1
Norfolk	Blickling (Pilcher and Baillie 1980)	4.3
Nottinghamshire	Sherwood (Briffa *et al* 1986)	4.7
Wiltshire	Savenake (Briffa *et al* 1986)	6.1

Table 4.4

Dating of the master curve, RAMCRAY1, from Ramsden Cray. *t*-values with dated reference chronologies. All the reference curves are independent.

Area	Reference chronology	*t*-values
Essex	Thaxted Church 3 (Tyers 1990)	4.8
	Coggeshall Kings Mill (Tyers unpubl)	4.2
	Cressing Barley 3 (Tyers 1993b)	4.2
Berkshire	Windsor Castle 12053 (Hillam in prep)	6.2
Buckinghamshire	Claydon House (Tyers 1995d)	5.2

Table 4.5

Dating of the master curve from Woodham Walter. *t*-values with dated reference chronologies. All the reference curves are independent.

Area	Reference chronology	*t*-values
Essex	Cressing Temple Church (Tyers 1995b)	5.5
	Fyfield Hall (Pilcher pers comm)	5.0
Buckinghamshire	Bletchley (Bridge 1987)	6.3
	Northall (Sheffield Dendrochronology Lab unpubl)	4.4
Berkshire	Reading (Groves *et al* forthcoming)	4.7
Gloucestershire	Twyning (Tyers 1996a)	5.0
Hereford/Worcs	Hereford, 14 Church St (Tyers 1996b)	4.7
London	Harmondsworth Barn (Tyers and Hibberd 1993)	5.4
	Southwark Boats chronology 3 (Tyers forthcoming)	4.9
	Sutton House (Tyers and Hibberd 1993)	4.2
	Trig Lane (Tyers 1992)	4.5
Norfolk	Kings Lynn Guildhall (Tyers 1996c)	5.4
Oxfordshire	Bayllols (Haddon-Reece and Miles 1992)	5.2

Table 5.2

Ring-width data of the site master curve for oaks from Little Totham, LTOTHAM, dated AD 1380 - 1517 inclusive.

year	ring widths (0.01mm)										number of trees per year									
AD 1380										223										1
	139	103	122	102	211	261	319	303	125	70	1	1	1	1	1	1	1	1	1	1
	99	118	232	169	202	321	192	272	399	334	1	1	1	1	1	1	1	1	1	1
AD 1401	382	348	125	167	182	419	146	151	221	148	1	1	1	1	1	1	2	2	2	2
	152	213	228	147	142	127	105	129	100	189	2	2	2	2	2	2	2	2	2	2
	145	106	93	129	191	183	167	253	241	201	2	2	2	2	3	3	3	4	4	4
	181	214	169	146	216	177	222	229	187	209	4	4	4	4	4	4	4	4	4	4
	229	307	276	157	202	204	284	180	307	257	4	4	4	4	4	4	5	5	5	5
AD 1451	242	190	139	187	156	161	154	173	120	122	5	5	5	5	5	5	5	5	5	5
	188	195	203	186	203	158	114	160	193	206	5	5	5	5	5	5	5	5	5	5
	194	158	152	202	267	207	151	177	232	221	5	5	5	5	5	5	5	5	5	5
	236	202	210	203	178	201	275	273	242	222	5	5	5	5	5	5	5	5	5	5
	147	160	165	205	174	209	175	119	122	142	5	5	5	5	5	5	5	5	5	5
AD 1501	109	104	112	121	113	156	184	144	162	170	5	5	5	5	5	5	5	5	5	5
	146	131	165	246	225	183	185				5	5	5	5	5	5	3			

Table 5.3a

Ring-width data of the undated master curve, MOUNTNS1, for oaks from Mountnessing.

year	ring widths (0.01mm)										number of trees per year									
1	515	568	705	637	497	317	454	679	591	511	1	1	1	1	1	1	1	1	1	1
	500	453	387	390	405	408	311	366	314	291	1	1	1	1	1	1	1	1	1	1
	298	259	247	294	385	391	409	426	355	279	1	1	1	2	2	2	2	2	2	2
	283	236	405	270	367	417	324	270	264	345	2	2	2	2	2	2	2	2	2	2
	263	304	306	266	223	286	201	184	283	204	2	2	2	2	2	2	2	2	2	2
51	194	231	343	247	203	185	138	189	160	176	2	2	2	2	2	2	2	2	2	2
	227	197	150	161	192	143	161	191	188	205	2	2	2	2	2	2	2	2	2	2
	142	154	114								2	2	2							

Table 5.3b

Ring-width data of the undated master curve, MOUNTNS2, for oaks from Mountnessing.

year	ring widths (0.01mm)										number of trees per year									
1	340	643	550	393	264	508	475	450	343	314	1	3	3	3	3	3	3	3	3	4
	332	292	426	275	417	221	210	258	364	221	4	4	4	4	4	4	4	4	4	4
	436	415	370	414	388	378	378	193	218	161	4	4	4	4	4	4	4	4	4	4
	199	83	114	95	163	168	171	219	138	119	4	4	4	4	4	4	4	4	4	4
	184	239	305	185	314	220	279	296	246	151	4	4	4	4	4	4	4	4	4	4
51	243	130	131	107	135	133	159	195	131	155	4	4	4	4	4	4	4	4	4	4
	164	200	149	211	182	147	226	228	169	117	4	4	3	3	2	1	1	1	1	1
	146	92	86	68	66	68	63	80	125	121	1	1	1	1	1	1	1	1	1	1
	147	120									1	1								

Table 5.3c

Ring-width data from sample 10 at Mountnessing dated AD 1747 - 1899 inclusive.

year	ring widths (0.01mm)									
AD 1747							277	230	126	190
AD 1751	317	290	231	350	351	335	282	355	283	259
	291	257	322	306	185	181	189	296	184	175
	159	98	80	126	178	193	199	182	176	191
	207	185	145	101	67	50	70	108	143	142
	130	140	122	92	113	68	96	122	149	124
AD 1801	99	60	70	92	141	146	137	131	111	78
	74	121	150	132	151	180	152	152	152	90
	72	94	125	114	108	96	103	103	121	86
	70	74	88	117	142	129	120	96	112	104
	150	243	193	238	265	295	298	313	243	205
AD 1851	211	142	136	71	64	123	221	220	245	211
	247	185	140	148	155	193	195	153	198	224
	248	169	155	159	136	125	138	129	163	138
	105	106	109	122	97	76	73	59	69	82
	101	101	67	82	67	99	101	102	111	

Table 5.4a

Ring-width data of the site master curve for oaks from Ramsden Cray, RAMCRAY1, dated AD 1639 - 1711 inclusive.

year	ring widths (0.01mm)										number of trees per year									
AD 1639									124	105									1	1
	84	63	187	162	113	127	201	281	233	198	1	1	1	1	1	1	1	1	2	2
AD 1651	147	159	78	231	261	162	183	176	131	194	2	2	2	2	2	2	2	2	2	2
	252	219	308	220	185	205	371	456	297	268	2	2	2	2	2	2	2	2	2	2
	431	271	358	200	194	195	420	426	299	413	2	2	2	2	2	2	2	2	2	2
	246	366	266	181	209	165	177	282	210	213	2	2	2	2	2	2	2	2	2	2
	182	174	253	201	151	157	203	336	234	206	2	2	2	2	2	2	2	2	1	1
AD 1701	199	142	226	210	108	156	146	103	203	135	1	1	1	1	1	1	1	1	1	1
	107										1									

Table 5.4b

Ring-width data of the undated site master curve for oaks from Ramsden Cray, RAMCRAY2.

year	ring widths (0.01mm)										number of trees per year									
1	498	738	359	575	592	414	570	408	423	365	1	2	2	2	2	2	2	2	2	2
	643	290	310	353	295	266	167	233	317	395	2	2	2	2	2	2	2	2	2	2
	418	314	277	310	354	347	572	281	256	332	2	2	2	2	2	2	2	2	2	2
	320	324	191	166	195	204	201	207	219	152	2	2	2	2	2	2	2	2	2	2
	162	186	176	208	212	242	282	213	233	125	2	2	2	2	2	2	2	2	2	2
51	134	115	114	170	163	154	166	163	153	295	2	2	2	2	2	2	2	1	1	1
	275	217	160								1	1	1							

Table 5.5

Ring-width data of the site master curve for oaks from Woodham Walter, WOODWALT, dated AD 1276 - 1372 inclusive.

year	ring widths (0.01mm)										number of trees per year									
AD 1276						297	486	376	552	512						1	1	1	1	1
	398	444	445	341	443	396	350	291	325	286	1	1	1	1	2	2	2	2	2	2
	287	251	318	399	256	136	118	140	115	156	2	2	3	3	3	3	3	3	3	3
AD 1301	230	184	145	212	197	223	290	344	331	326	3	3	3	3	3	3	3	3	3	3
	219	212	222	267	355	328	223	151	175	127	3	3	3	3	3	3	3	3	3	3
	140	143	125	126	114	89	118	118	150	107	3	3	3	3	3	3	3	3	3	3
	91	63	78	72	82	64	71	63	86	94	3	3	3	3	3	3	3	3	3	3
	92	91	83	91	109	118	124	96	110	126	3	3	3	3	3	2	2	2	2	2
AD 1351	127	113	129	110	99	91	107	76	89	89	2	2	2	2	2	2	2	2	2	2
	60	101	185	234	205	213	145	157	170	190	1	1	1	1	1	1	1	1	1	1
	159	167									1	1								