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Summary

Dendrochronological analysis of the rafters and ashlar pieces from the roof of St George's Guildhall, Kings Lynn, Norfolk, has shown that the main construction phase is early fifteenth century. Analysis of timbers from a possibly inserted floor suggests that these are either contemporary with the main construction phase, or are possibly from shortly afterwards. No useful results have been obtained from analysis of timbers from a presumed later roof truss.

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Introduction

This document is a technical archive report on the tree-ring analysis of timbers from St George's Guildhall, King's Lynn. It is beyond the dendrochronological brief either to describe the building in detail or to undertake the production of detailed drawings. As part of a multifaceted and multidisiplinary study of the buildings it is likely that 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 archive deposition on the buildings. The conclusions presented here may therefore have to be modified in the light of subsequent work.

The purpose of the study was to carry out dendrochronological analyses of timber elements from St George's Guildhall, King St, Kings Lynn, Norfolk (NGR TF616202). The building is due to be the subject of a major programme of restoration and this analysis was commissioned by Philip Walker (English Heritage Inspector) to complement other survey work. The building is owned by the National Trust (NT), and currently used as an arts centre.

Descriptions of the building and its history are provided in the NT guidebook (Richards 1992). Three groups of timbers were of considered to be important to the understanding of the development of the building. The main roof consists of at least 47 common rafter trusses with scissor bracing (Fig 1). There are also an unknown number of similar trusses above the western stage area to which access is prohibited. The second group of timbers are from a dismantled king post truss preserved in a store within the building complex. This truss is thought to be one of several inserted under the main roof when structural problems resulted in the north wall leaning and the roof sagging (Fig 1). The locations of these inserted trusses can still be identified in the main roof since the decorated inner wall plates were cut back to allow the alignment of the vertical posts. Additional fragments of one of these trusses apparently still survive in the stage area. The precise original location of the dismantled truss is unknown. The final group of timbers is a series of massive north-south beams supporting the hall floor and forming the roof of both the undercroft and the main east-west access corridor (Fig 1). These timbers may be part of the original structure, or the floor may have been inserted at some later date.

Methodology

The building was visited and all the timbers were assessed for suitability. An assessment visit is designed to ensure that enough timbers have sufficient rings to warrant a full sampling visit.

This is not always the case with buildings since many timbers have less than 50 annual rings and are thus unsuitable for analysis. An important aspect of assessment visits is to ensure that suitable timbers are accessible in the appropriate direction to enable the maximum number of rings to be extracted from them. Although most timbers at the Guildhall appeared to be suitable, a large proportion of them were of marginal use since they only contained 50-60 rings. Due to the great height of the roof and difficulties of placing scaffold towers on the sloping floor of the theatre, sampling access to the upper elements of the trusses was impossible. Thus the sampling was restricted to the lower ends of the rafters and their associated ashlar pieces. Numbers for each of the rafter trusses were assigned by counting from the first complete truss at the east end of the building. The dismantled king post truss was easily accessible and each element could be moved to assist the sampling. The large floor beams were readily accessible, but only in the east-west corridor. Access to the beams from the undercroft, currently used as a restaurant, was considered impractical. However, since the corridor is the principal thoroughfare in the building, due consideration had to be given to both the visual impact of the sampling programme and to the safety of the public. Numbers were assigned to these beams by counting from the east end of the building. Following assessment, sampling was arranged and samples were taken using a 15mm diameter hollow corer attached to an electric drill. The cores were taken within all the timbers at positions which maximised the numbers of rings obtained and, where possible, included sapwood or the outer-most heartwood rings.

In the laboratory the ring sequences in the cores were revealed by sanding them in the original horizontal plane of the parent tree. The complete sequences of growth rings in the cores were measured to an accuracy of 0.01mm using a micro-computer based travelling stage. 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.

Any tree-ring dates can obviously only date the rings present in the timber. The correct interpretation of those dates relies upon the nature of the final rings in the individual samples. 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. 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. Alternatively, if bark-edge survives, then a felling date can be directly utilised from the date of the last surviving ring. 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 figures are applicable to oaks from the British Isles (Hillam *et al* 1987). 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

Original roof

Eight samples were obtained from this group of timbers, numbered **1** to **8** (Table 1). Two samples were unsuitable for analysis: sample **4** had too few rings; sample **7** fragmented badly during coring. The remaining six were suitable for analysis and five of these were found to cross-match (Fig 2a; Table 2a). These were combined together to form a new composite sequence. This master curve was then tested against a range of reference chronologies, using the normal matching criteria: high *t*-values, replicated values against a range of chronologies at the same position, and satisfactory visual matching. The sequence was found to match to an extensive range of chronologies (Table 3a), and is dated AD 1309 to AD 1397 inclusive. The master chronology, KLYNN_SG, is listed in Table 4a. Sample **6** failed to match the other material or to date independently. Four of the dated samples included some sapwood.

The average growth rates and quality of the cross-matching demonstrate the material is remarkably similar and it seems probable that all of the parent trees of this phase was derived from a single, presumably local, woodland. The original trees were of great height, since the rafters are around 7m in length, and they are still of reasonable scantling at the upper ends. Visual inspection shows that there is a marked uniformity in scantling within the 94 visible rafters, and also, although the extant lengths are shorter, there is little variation within the 94 visible scissor braces. There are very few knots visible on all this material, all of which appears to be derived from single whole trees. The large number of trees required, and their overall similarity suggests that a fairly large area of even-aged woodland was exploited to produce the timbers for the roof of this building.

The king post truss

Four samples were obtained from this truss, numbered **9** to **12** inclusive (Table 1). All samples were suitable for measurement. Samples **10** and **11** were cross-matched (Fig 2b, Table 2b), and appear to be derived from a single tree. However neither the chronology made from these data, nor the sequences from sample **9** and **12**, provided any replicated and significant matching to any of the other samples obtained from the site, or to the dated reference chronologies available at the laboratory. Thus no sample from this phase was successfully dated.

Relatively few timbers were available for sampling or inspection, which prevents reliable conclusions being drawn about the nature of the parent woodland from this assemblage.

The floor beams

Seven samples were obtained from this material, numbered **13** to **19** inclusive (Table 1). Sample **16** was of sufficient length that it passed through the middle of the tree and thus two radii could be obtained from the core. Samples **13**, **15**, **17**, and **18** were unsuitable for further analysis because of serious fragmentation of the cores during sampling (see below). Samples **14**, **16**, and **19** were measured. The two radii from **16** were combined to form a single sequence. The sequences were compared, but none was found to cross-match any other. The individual sequences were then compared with the extensive reference chronologies available in the laboratory. Sample **19** was found to match a number of chronologies (Fig 2a; Table 3b). Neither this nor any of the other material matches the sequences obtained from the other sampled phases.

These timbers are of exceptional length (at least 10m), and of massive scantling, with at least four of these timbers being greater than 400mm square at the sampled ends. Inspection of the timbers from the undercroft suggests that they are not all aligned with their butt ends to the south, nor are they placed with the butts at alternate ends. At least some of the timbers of smaller scantling at the corridor end (eg **15** and **17** and the two rejected beams) may have their butt ends to the north. The beams, where they are visible in the undercroft, appear markedly more knotty than those used for the rafters. The impression of this group is that the timbers are more diverse than those in the hall roof. It seems inevitable that these trees were derived from a different type of woodland than that exploited for the main roof timbers.

Interpretation

Original roof

The latest ring obtained from this material was from sample **2** at AD 1397, whilst the four heartwood/sapwood transitions in date order are: AD 1375, AD 1379, AD 1381, and AD 1384. These are sufficiently close that these results can be safely combined to produce a single felling date range for this entire group. If the material was used green, which appears to be normal practice at this period (Rackham 1990, 69), the tree-ring analysis indicates the construction of the roof occurred between AD 1397 and AD 1430.

The king post truss

No dating evidence was obtained from the analysis

The floor beams

The date of the latest measured ring on sample **19** is AD 1408. The measured sequence includes six sapwood rings. An additional band of sapwood was too compressed and distorted to measure, or even count, with any great reliability. There are at least a further 9 sapwood rings present in this section. The felling date range calculated for this sample is AD 1417 to AD 1457 inclusive. It is important to appreciate that, although the date of the sequence is regarded as reliable, the interpretation of it is difficult since only a single dated timber was obtained. There are no obvious signs of reuse on any of this group of beams. Hence, if the material was used green, the tree-ring analysis indicates the construction of this phase was between AD 1417 and AD 1457.

Discussion

The provision of date ranges for two of the three sampled phases is something of an achievement. East Anglian timber framed buildings have generally proved difficult and many are not suitable for tree-ring techniques. There are currently remarkably few tree-ring chronologies available for Norfolk.

The phasing of the construction of the building is obviously complex. Documentary evidence (quoted in Richards 1992) suggests that the plot on which the building stands was acquired by the Guild of St George in AD 1406, and that the building was certainly in use by AD 1444. Dates between *c* AD 1410 and *c* AD 1430 are favoured on architectural grounds. The insertion of the king post trusses was thought to have occurred around AD 1500. The floor and the massive supporting beams may have been inserted during this remodelling, or they may be an original feature of the building.

The result obtained from the rafters and ashlar pieces is clearly compatible with prior expectations. The failure to obtain any samples complete to the bark-edge prevents a precise felling date from being obtained. This situation could be rectified by additional sampling during the forthcoming restoration work when access to the rafters, scissor braces, and collars should be easier.

The failure to date any element of the single king post truss available for sampling is a disappointment. The paucity of data is probably a contributory factor, since only four of the seven timbers had sufficient rings for sampling, and two of these appear to be derived from a single parent tree.

The results for the large floor beams have proved disappointing since first appearances suggested that they were highly suited for dating purposes. Sampling supports this notion, but difficulties in extracting intact cores has prevented successful analysis of almost every timber. The cores that were obtained had far fewer rings than might be expected from such large timbers which emphasises the lack of relationship between size of timber and number of rings. The trees were characterised by knottiness and twisting which probably reduces the quality of the data for dendrochronology.

The dated timber is mostly embedded in the eastern wall of the building and there is therefore some doubt about its association with the rest of the floor beam material. Clearly it is of the same massive size, at least on its exposed face, as the other beams. Assuming it is contemporary the interpretation suggests that the floor is either contemporary with the construction of the hall roof or that it was inserted within the first few decades of the building's life.

Despite the proximity of the quay, and previous identification by dendrochronology of large quantities of imported oak from many sites on the eastern seaboard of England, all the dated material from the Guildhall appears to be of local origin. It should be noted that the undated material has been also been checked against other European reference data sets with no success.

Conclusion

The tree-ring analysis of samples from St George's Guildhall, Kings Lynn, has demonstrated conclusively that the extant roof of the hall is early fifteenth-century in date. A date from a single timber suggests that the massive beams supporting the floor are either contemporary with the hall roof or slightly later in date. Analysis of the king post trusses, presumed to be later insertions and now mostly removed, has failed to obtain any useful dating information.

Since lack of access to some of the timbers may have hampered production of a precise felling date for the original roof structure, it may be worthwhile assessing more of this structure specifically for surviving bark-edge when the timbers become available during the restoration program. If any timbers are removed during restoration, they should be retained for analysis.

Acknowledgements

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Figure 1

Sketch cross-section (not to scale) of St George's Guildhall, Kings Lynn, showing a typical scissor brace roof truss *in situ*, a reconstruction of a king post truss in position, and the location of a typical north-south tie-beam supporting the floor. Based in sketches produced during the tree-ring sampling of the building.

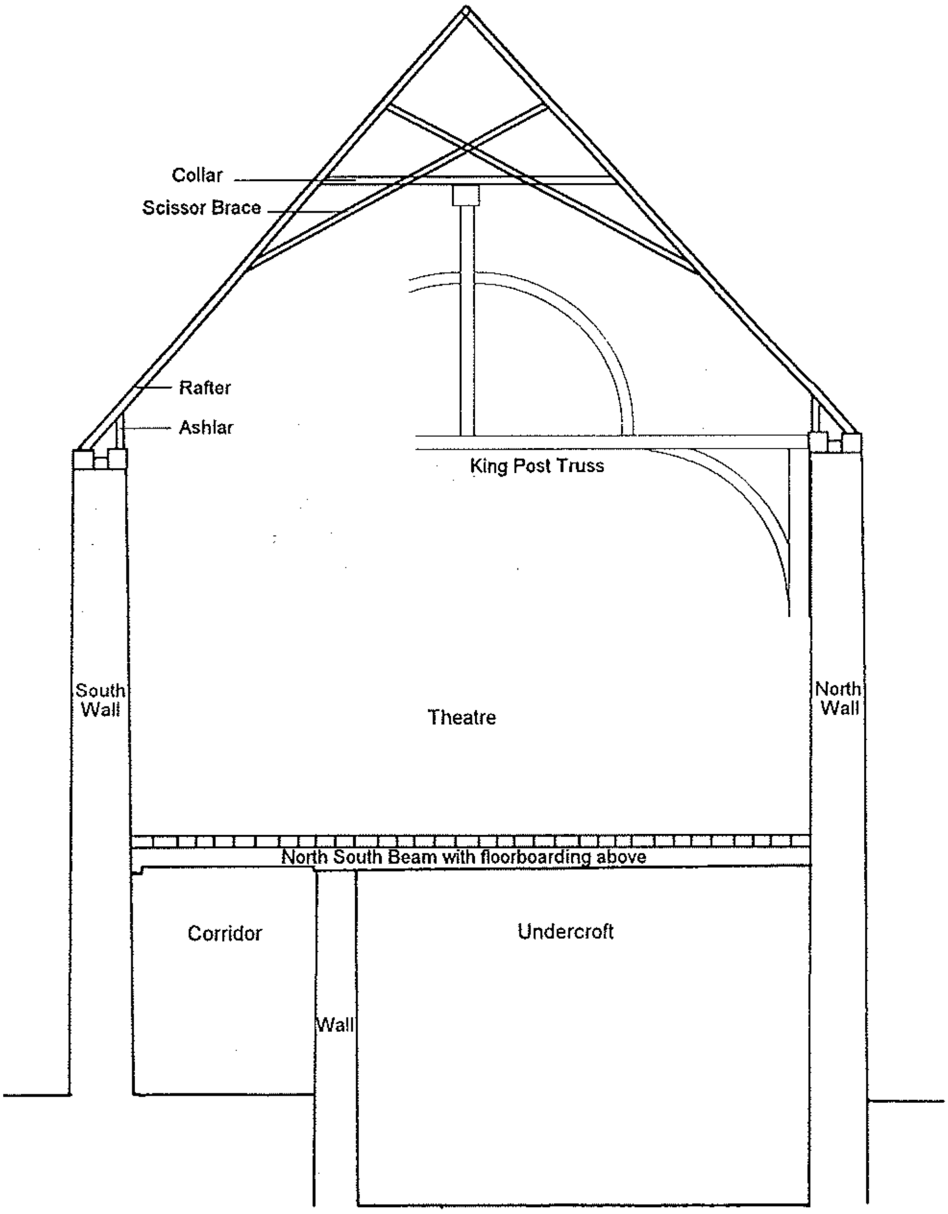
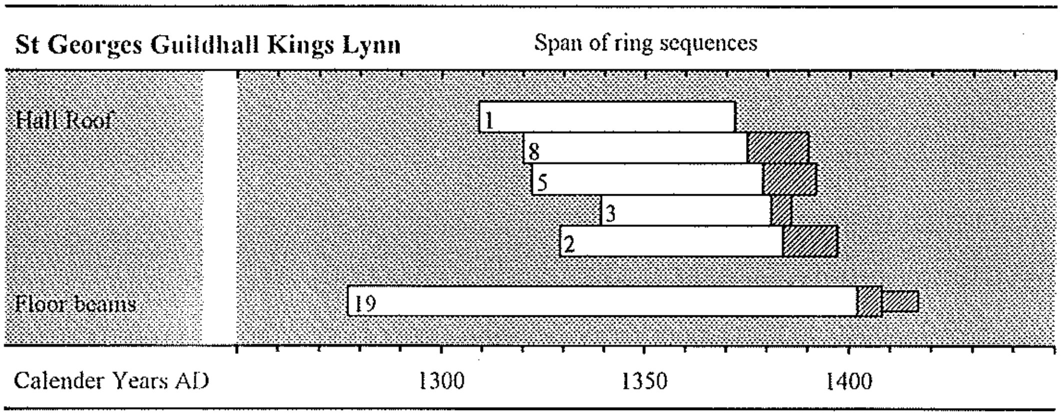


Figure 2

a. Bar diagram showing the relative positions of the dated sequences from the roof, and the single dated timber from the floor tie-beams.

White bars - heartwood rings; hatched bars - sapwood rings; narrower hatched bar - unmeasured sapwood rings



b. Bar diagram showing the relative positions of the two matched, but undated, sequences from the king post truss.

White bars - heartwood rings; hatched bars - sapwood rings

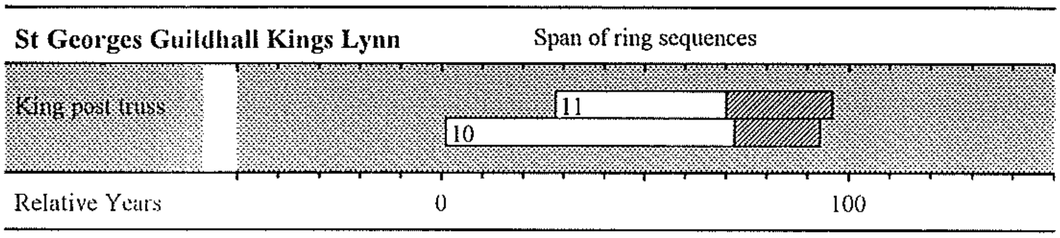


Table 1

List of samples.

Core	Origin of core	Analysis undertaken	Wood type	Total Rings	Sap Rings	mm/year	Result	Date of sequence
1	Truss 13 S Rafter	Tree-ring sequence measured	Oak	64	0	1.37	Dated	AD1309 - AD1372
2	Truss 12 S Ashlar	Tree-ring sequence measured	Oak	69	13	1.88	Dated	AD1329 - AD1397
3	Truss 13 S Ashlar	Tree-ring sequence measured	Oak	48	5	1.70	Dated	AD1339 - AD1386
4	Truss 15 S Ashlar	Species identification only	Oak				-	-
5	Truss 18 S Rafter	Tree-ring sequence measured	Oak	71	13	1.61	Dated	AD1322 - AD1392
6	Truss 19 S Rafter	Tree-ring sequence measured	Oak	56	18	1.80	Undated	-
7	Truss 12 N Ashlar	Species identification only	Oak				-	-
8	Truss 12 N Rafter	Tree-ring sequence measured	Oak	71	15	1.78	Dated	AD1320 - AD1390
9	later truss tie-beam	Tree-ring sequence measured	Oak	65	0	3.08	Undated	-
10	later truss brace 1	Tree-ring sequence measured	Oak	93	21	1.87	Undated	-
11	later truss brace 2	Tree-ring sequence measured	Oak	69	26	1.37	Undated	-
12	later truss ?post	Tree-ring sequence measured	Oak	106	0	1.49	Undated	-
13	N-S floor beam 8	Species identification only	Oak				-	-
14	N-S floor beam 6	Tree-ring sequence measured	Oak	108	0	1.42	Undated	-
15	N-S floor beam 5	Species identification only	Oak				-	-
16	N-S floor beam 4	Tree-ring sequence measured	Oak	77	0	2.11	Undated	-
17	N-S floor beam 3	Species identification only	Oak				-	-
18	N-S floor beam 2	Species identification only	Oak				-	-
19	N-S floor beam 1	Tree-ring sequence measured	Oak	132	6	1.77	Dated	AD1277 - AD1408

Table 2

a. Correlation between the dated material from the rafters and ashlar pieces.

sample	*t*-values samples *2*	*3*	*5*	*8*
1	4.2	4.1	4.3	6.2
2		5.3	7.2	7.7
3			4.8	5.1
5				6.2

b. Correlation between the two braces from the king post truss

sample	*t*-values samples *11*
10	8.4

Table 3

a. Dating of the master curve constructed from timbers in the roof at St George's. *t*-values with dated reference chronologies. All the reference curves are independent.

Area	Reference chronology	*t*-values
Essex	Cressing Temple Barley Barn 2 (Tyers unpubl)	6.3
	Cressing Temple Wheat Barn 2 (Tyers unpubl)	5.0
Hereford and Worcester	14 Church St, Hereford (Tyers 1996)	6.8
Kent	St Mary Cray (Tyers 1990)	4.5
London	Harmondsworth Barn (Tyers and Hibberd 1993)	5.1
	Sutton House (Tyers and Hibberd 1993)	5.3
	Trig Lane (Tyers 1992)	4.9

b. Dating of the sequence from sample 19. *t*-values with dated reference chronologies. All the reference curves are independent.

Area	Reference chronology	*t*-values
Berkshire	Reading (Groves *et al* forthcoming)	5.1
Buckinghamshire	Northall (Sheffield Dendrochronology Laboratory unpubl)	6.3
Essex	Thaxted Church 2 (Tyers 1990)	5.2
	Cressing Temple Wheat Barn 2 (Tyers unpubl)	3.6
London	Harmondsworth Barn (Tyers and Hibberd 1993)	6.1
Oxfordshire	Oxford; Zacharias's (Haddon-Reece *et al* 1988)	4.9

Table 4

a. Ring-width data from the master curve, KLYNN_SG, dated AD 1309 - AD 1397 inclusive.

year	ring widths (0.01mm)										number of trees per year									
AD 1309									249	260									1	1
	346	291	186	232	271	331	313	255	229	174	1	1	1	1	1	1	1	1	1	2
	229	260	285	206	180	149	245	228	260	227	2	3	3	3	3	3	3	3	4	4
	193	222	214	307	279	202	170	160	204	216	4	4	4	4	4	4	4	4	5	5
	202	165	130	171	193	180	197	163	174	197	5	5	5	5	5	5	5	5	5	5
AD 1351	202	155	170	156	123	143	156	134	134	101	5	5	5	5	5	5	5	5	5	5
	87	104	180	190	172	151	119	84	130	193	5	5	5	5	5	5	5	5	5	5
	171	178	163	116	125	117	127	135	136	125	5	5	4	4	4	4	4	4	4	4
	126	123	129	84	105	121	118	122	116	102	4	4	4	4	4	4	3	3	3	3
	95	93	103	118	148	177	114				2	2	1	1	1	1	1			

b. Ring-width data from sample 19, dated AD 1277 - AD 1408 inclusive.

year	ring widths (0.01mm)									
AD 1277							349	332	410	423
	284	139	84	119	136	148	159	163	217	233
	242	198	246	205	179	137	121	139	127	113
AD 1301	160	203	216	231	169	76	65	78	90	79
	107	118	141	194	232	186	139	97	159	154
	228	186	165	178	142	115	154	136	183	106
	101	110	148	186	180	198	146	142	185	172
	136	141	206	215	207	194	170	159	176	231
AD 1351	217	137	142	143	153	187	183	101	205	173
	119	145	183	135	115	122	153	165	152	160
	136	163	129	181	171	177	164	230	166	209
	218	234	202	153	210	196	219	250	238	231
	217	152	235	202	178	218	177	243	170	255
AD 1401	208	201	186	202	134	233	173	171		