

Centre for Archaeology Report 5/2002

**Tree-Ring Analysis of Timbers from Chethams Library and
School, Long Millgate, Manchester**

Ian Tyers

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ISSN 1473-9224

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Summary

Chethams Library and School is located in the centre of Manchester. The building was founded in AD 1421 as the domestic premises of the priests college serving the adjacent parish church, which is now Manchester Cathedral. Following suppression of the college during the reign of Edward VI it was acquired by the Stanleys, Earls of Derby, and used as a residence. The building was confiscated during the civil war and it was acquired by the executors of Humphrey Chetham (d AD 1653) in AD 1654. It was converted into a school for poor boys and a public library using the Chethams bequest by AD 1656 and AD 1661 respectively. Both organisations continue to occupy this remarkable building.

Tree-ring sampling of parts of the structure was commissioned to inform repair decisions. The results indicate that almost all the accessible timber structure throughout the cloistral ranges includes fifteenth century material. The high levels of decoration have removed most of the sapwood and detailed differences in chronology have mostly proved impracticable to identify, although there are hints of differences in construction date between a number of areas. Two sixteenth century timbers have been identified in one area of the cloisters, perhaps indicating Stanley-era modifications.

Keywords

Dendrochronology
Standing Building

Author's address

Sheffield Dendrochronology Laboratory, Archaeology & Archaeological Science Research School, Department of Archaeology & Prehistory, University of Sheffield, West Court, 2 Mappin Street, Sheffield, S1 4DT.
Telephone: 0114 222 5107. Email: i.tyers@sheffield.ac.uk

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TREE-RING ANALYSIS OF TIMBERS FROM CHETHAMS LIBRARY AND SCHOOL , LONG MILLGATE, MANCHESTER

Introduction

This document is a technical archive report on the tree-ring analysis of oak timbers from Chethams Library and School, Long Millgate, Manchester, formerly Greater Manchester but now part of the Unitary Authority of Manchester (Figs 1 and 2; NGR SJ 839 989). It is beyond the dendrochronological brief to describe the buildings in detail or to undertake the production of detailed drawings.

Chethams School and Chethams Library effectively occupy parts of the same building. This was originally laid out as a series of priests lodgings (or sets) arranged around the cloistral garth, with a large hall to the east side of the cloister, and probably the senior lodgings on the south side. Most of the divisions on the south and west upper floors between the lodgings, presumably timber framed, are now gone and this provides the Library with a generally open aspect. The Library occupies the west and south sides of the cloistral range, and the School has most of the northern range, and the hall to the eastern side, as well as the extensive run of medieval buildings running east towards the gatehouse (Fig 3). The many later buildings within the complex are all school buildings. The three sides of the cloistral ranges and the hall are stone walled, with oak roofs that have similar truss designs and mostly similar mouldings. The roofs are of crown-post type with arched-braced collar/tiebeams and exceedingly short crown-posts (Fig 4), there are common rafter trusses with collars and simple bracing between the main trusses (Hartwell 2001). Most of the roofs appear to have been lath and plastered over at some stage, although this is now mostly removed. In the central area of the north cloistral range the present roof is a later restoration, in this case after a second world war incendiary explosion. There is some possibility that other parts of the roofs may be derived from other periods of reconstruction.

The ground-floor ceilings of the three cloistral ranges consists of a grid of large slightly cranked transverse moulded beams connecting with similarly moulded central joists and wall beams, all in oak. Here there is plain plasterwork, perhaps later in date, that hides the smaller joists except where there has been subsequent movement in the structure. The mouldings on the hall roof timbers and the ceiling beams of the cloistral ranges are similar. The southern ground-floor cloistral range ceiling has been thought to be of a slightly different date (Hartwell pers comm).

Around the garth side of the three cloistral ranges there is a ground-floor walkway, ceiled by a grid of oak slightly cranked moulded transverse beams, plain longitudinal joists, and moulded

wall beams. The mouldings of these are similar to both the hall and cloistral range mouldings. Throughout the walkway areas there are numerous signs of secondary insertions and repairs. There is a second floor to the walkway structure with a different roof line to the main building, however at no point within the complex is the roof of the walkway readily accessible and where it can be seen it is usually a recent replacement. Unfortunately in most areas it is boarded under and impossible to access. At two points, the north-west corner running west, and the south-west corner running south, the ground-floor inner walkway provides points of egress to the outside of the ranges. This is achieved by going through the ranges themselves at ground-floor level. In both cases, the structure visible in the corridor ceilings may structurally be either part of the cloistral ceiling or part of the walkway ceiling structure.

The complex is listed grade I. It should be noted that one of the school blocks is of the AD 1870s by Alfred Waterhouse. Waterhouse is known to have undertaken sympathetic restoration of the west cloistral range around the same period, further sympathetic restoration in AD 1883-95 by Heywood and Heywood also occurred. The degree of intervention into the original, or any other period, fabric at these times provided something of an unknown quantity for the sampling programme outlined here. A tree-ring dating programme of the timbers of the hall, and cloistral ranges, excluding the south west corner (Wardens lodgings and Audit room) and excluding the north east range down to and including the gatehouse (Buttery, Kitchen, Bakehouse, Dormitories, and Gatehouse) was requested by Marion Barter, English Heritage Historic Buildings Architect, to help inform future repair decisions.

Methodology

The general methodology and working practises used at the Sheffield Dendrochronology Laboratory are described in English Heritage (1998). The methodology used for this building was as follows.

The sampling reported here was undertaken over a period of a week. A survey undertaken before this had identified those areas of the complex where oak timbers with suitable ring sequences for analysis survived. Those with more than 50 annual rings and some survival of the original sapwood and bark-edge were sought, although the level of decoration throughout has reduced the presence of both significantly. The dendrochronological sampling programme attempted to obtain cores from as broad a range of timbers, in terms of structural element types, scantling sizes, and carpentry features, as was possible within the terms of the request and with due regard to safety on site. The hall timbers were accessed with a scaffold tower kindly provided by and erected by the School. The cloistral ceiling and roof timbers, and the cloistral walkway ceiling timbers were all accessed by short ladders.

The most promising timbers were sampled using a 15mm diameter corer attached to an electric drill. The cores were taken as closely as possible along the radius of the timbers so that the maximum number of rings could be obtained for subsequent analysis. The core holes were filled and stained throughout the normally accessible areas and the private apartments. The core holes in timbers in the book stack areas were left open to try to ensure they are well ventilated. The ring sequences in the cores were revealed by sanding.

Two additional timbers were collected and removed whole to the laboratory, these are two diamond pattern grilles, normally to be found suspended from nails in the cloister walkways. They are thought to be shutters for the cloister windows, although what period they are from is uncertain. Both are broken and have been mended with glues, screws and metal strips, on one or more occasions. One is complete, whilst the other has a corner missing. The ring sequences were recovered from the ends of the boards by direct measurement after removal of overlying grime and knifing the edge of the boards to reveal the ring sequences. Both have now been returned to the site, and are in store awaiting conservation treatment.

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 1999a). The ring sequences were plotted onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition a cross-correlation algorithm (Baillie and Pilcher 1973) was employed to search for positions where the ring sequences were highly correlated. These positions were checked visually 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 only date 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 sapwood rings which are 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. The sapwood estimates applied throughout this report are a minimum of 10 and maximum of 46 annual rings, where these figures indicate the 95% confidence limits of the range (Tyers 1998,a). These figures are applicable to oaks from England and Wales. Alternatively, if bark-edge survives, then a felling date can be directly utilised from the date of the last surviving ring. 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 re-use 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

Forty seven core samples were obtained in February AD 2001. The sampling attempted to identify and core suitable timbers from the potentially different areas of the ranges and walkway ceilings in order to provide results that may indicate whether they were contemporary. It was apparent at the time of sampling that sapwood survival was poor in the building, principally because of the amount of deep carved decoration. It is thus self evident that small differences in date between different areas of the complex are unlikely to be identified by this analysis, instead major differences in the dates of construction or reconstruction are the main focus of the report. Overall 43 of these samples were analysed,

the remainder being either too short or too fragmented to analyse. In addition there are the two cloister shutter boards. The results are discussed initially for each area.

Hall

Access to the timbers in this area was entirely by scaffold tower. This, fully extended, could reach the collars but not the purlins above that in the central bay. Reduced in height by a couple of tiers it provided access to the wall plates and lower arch braces against the walls. The presence of a large chandelier in the middle of the hall prevented access to timbers on the central truss (truss 3). A screen at the north end prevents access with the scaffold tower to the north wall truss (truss 1), the hall stage and above it the dais canopy likewise prevents tower access to the southern wall truss. During sampling no original truss numbers were identified that formed a sequence. The trusses were therefore assigned numbers from north to south. A total of sixteen timbers were selected as most suitable for sampling (Table 1). There was limited survival of sapwood throughout the decorated timbers in this part, although the need to produce curving arch braces from straighter trees yielded some signs of outermost rings at opposite ends of these timbers. The plain common rafters, braces, and upper purlins included several with clear survival of the heartwood/sapwood boundary but there was no survival of bark-edge in this area. The densely packed structure above the tiebeams meant that sampling locations could not always be optimal here. Several timbers with a different surface treatment and clearly visible band saw marks were thought to be fairly recent (nineteenth- or twentieth-century repairs) and these were avoided for sampling purposes. The samples were numbered **1-16** inclusive. Two of the samples (numbers **4** and **13**) when examined in the laboratory were rejected due to them having badly fragmented during sampling. In total therefore 14 samples were measured from this area and the resultant series were then compared with each other. Ten sequences were found that matched together to form one internally consistent group (Fig 5; Table 2). A 226-year interim site mean chronology was calculated, named CHET_H.

Cloister walkway ceiling

Several timbers along the north side of the cloister walkway were sampled, along with a single timber from the south-side walkway. Both this latter, and one of the former, were thought to be potentially later modifications to the structure. Access in this area was undertaken with a short folding ladder. During sampling no original carpentry numbers were identified. The transverse beams were therefore used to define number bays around the cloister starting from the hall doorway. A total of seven timbers were selected as most suitable for sampling (Table 1). As with the hall there was limited survival of sapwood throughout the decorated timbers in this part, but as before the plainer timbers, in this area that is the joists, included several with clear survival of the heartwood/sapwood boundary and one with

survival of bark-edge. The proximity of the joists to the walls sometimes meant that sampling locations could not be optimal. In some instances the inability to fit equipment into the spaces precluded sampling in otherwise suitable timbers. As with other areas any timbers with a different surface treatment or clearly visible band saw marks were avoided for sampling purposes. The samples were numbered **17-22** inclusive and **28**. One of the samples (number **17**) when examined in the laboratory was rejected due to it having badly fragmented during sampling. In total therefore six samples were measured from these areas and the resultant series were then compared with each other and the CHET_H sequence. Four sequences were found that matched together to form one internally consistent group (Fig 5; Table 3). A 157-year interim site mean chronology was calculated, named CHET_CW.

Cloister range/walkway corridors

Several timbers from both the north-west walkway corridor ceiling and the south-west walkway corridor ceiling were sampled. Access in this area was again undertaken with a short folding ladder. During sampling no original carpentry numbers were identified. A total of five timbers were selected as most suitable for sampling (Table 1). As before there was limited survival of sapwood throughout the decorated timbers, but again the plainer joist timbers included some with clear survival of the heartwood/sapwood boundary. The awkward access to the closely packed joists meant that sampling locations could not always be optimal here. Several timbers with a different surface treatment and clearly visible band saw marks were thought to be fairly recent (nineteenth- or twentieth-century repairs) and these were avoided for sampling purposes. The samples were numbered **23-27** inclusive. All of the samples when examined in the laboratory were measured from this area. The resultant series were then compared with each other, and the two interim sequences constructed from the hall and cloister walkway areas. All five sequences were found to match together to form one internally consistent group (Fig 5; Table 4). A 170-year interim site mean chronology was calculated, named CHET_COR.

Cloister north range roof

Timbers were sampled in the Headmistress's private first-floor accommodation. These rooms are derived from parts of four original priests sets on the north cloistral range. The eastern end of this is where the second world war incendiary device destroyed much of the original roof, and it is quite clear when examining this that this area has timbers with quite different surface treatments and toolmarks. At the west end of this range the roof timbers were readily accessible, although again no original carpentry numbers were identified. A total of four timbers originally in a single lodging were selected as most suitable for sampling (Table 1). As before there was limited survival of sapwood throughout these timbers. The presumably plainer rafters etc, were not accessible above a lath and plaster ceiling. The samples were

numbered **29-32** inclusive. All of the samples were measured from this area and the resultant series were then compared with each other and the three interim sequences. All four sequences were found to match together to form one internally consistent group (Fig 5; Table 5). A 190-year interim site mean chronology was calculated, named CHET_NR.

Cloister range west ceiling

Timbers in the book stacks under the west range of the Library were sampled. Access in this area was undertaken with a short folding ladder. During sampling no original carpentry numbers were identified. A total of six timbers originally within two different lodgings were selected as most suitable for sampling (Table 1). As before there was limited survival of sapwood throughout these timbers although the long lengths required clearly provided some difficulties for the original builders in this respect. Here the plainer timbers were not generally accessible. It is known Waterhouse was involved in enlarging windows in this area (Hartwell pers comm). This has evidently involved changing the dual purpose decorated wall beams/window lintels since they have different surface treatments and different surface tooling. These were avoided for sampling purposes. The samples were numbered **33-38** inclusive. All of the samples were measured from this area and the resultant series were then compared with each other and the previously constructed interim series. All the sequences were found to match together to form one internally consistent group (Fig 5; Table 6). A 163-year interim site mean chronology was calculated, named CHET_WC.

Cloister range south ceiling

Timbers in the controlled book stores under the south range of the Library were sampled. Access in this area was undertaken with a short folding ladder. During sampling no original carpentry numbers were identified. A total of seven timbers originally in a single lodging were selected as most suitable for sampling (Table 1). As before there was limited survival of sapwood throughout these timbers although here again the long lengths required and the deep carving clearly provided some difficulties for the original builders in this respect. Here the plainer timbers were not generally suitable nor accessible. The samples were numbered **41-47** inclusive. One of the samples (number **47**) when examined in the laboratory was rejected due to it having badly fragmented during sampling. In total therefore six samples were measured from this area and the resultant series were then compared with each other and the previously constructed interim series. All these sequences were found to match together to form one internally consistent group (Fig 5; Table 7). A 158-year interim site mean chronology was calculated, named CHET_SC.

'Scriptorium' roof

The hall bay, immediately south of the chimney/inglenook was specified as an area for sampling. In the ground-floor section of this the mouldings of some timbers, presumably mostly hidden above the plaster work, are visible. However the grain direction and growth rates of these could not be reliably identified. Above this bay lies a room known as the 'scriptorium' although actually of unknown original purpose. It may not be contemporary with the room below, and the roof seems likely to have had later modifications since there are lines in the plaster apparently reflecting earlier arrangements. Two timbers were selected from here in order to investigate whether either the rather curious east side truss, or the current rafters were potentially original to the building (Table 1). As before there was limited survival of sapwood on these timbers. These samples were numbered **39** and **40**. Both of the samples were measured and the resultant series were then compared with each other and the previously constructed interim series. Both sequences were found to match to the interim series in a highly consistent fashion (Fig 5; Table 8) A 107-year interim site mean chronology was calculated, named CHET_HB.

Cloister Shutters

Both boards were cleaned and measured at both ends, the slow growing slightly tangential ring sequences were particularly awkward to recover due to the somewhat brittle nature of these timbers. The boards were numbered **48** and **49** (Fig 6; Table 1). The four series derived from both ends of both boards cross-match really well (Table 9), undoubtedly both boards are derived from a single long lived tree. A composite single series named **48+49** was calculated from the series. This does not match the various interim site means produced.

Dating the interim site means

The eight interim sequences, and the six remaining unmatched samples were then compared with each other. This identified that the seven structural interim series correlated (Table 10). A new composite series CHETHAM was constructed from these correlated interim sequences. This new series, and the residual unmatched material, was then compared with dated reference chronologies from throughout the British Isles and northern Europe. A single well correlated position was identified for the CHETHAM sequence. Table 11 shows some example correlations of the CHETHAM mean sequences at its identified dating position, AD 1185 – AD 1428 inclusive. Two of the unmatched samples, and the shutter sequence correlate consistently with later medieval series although they do not match each other especially well. Table 12 shows some example correlations for the two structural series at their identified dating positions. Table 13 shows some example correlations of the shutter sequence **48+49** at its identified dating position. The remaining four series, all relatively short, failed to correlate with any reference data and remain undated by this analysis.

Discussion

The early fifteenth century.

The 244-year chronology CHETHAM is dated AD 1185 to 1428 inclusive. It was created from 37 timbers from the hall and cloistral ranges at Chethams. One of the cloistral walkway samples (sample **22**) is definitely complete to bark-edge, in this case an incomplete ring for AD 1429 indicates felling occurred in the spring of that year. Ten other dated samples retain either incomplete sapwood or the identifiable heartwood/sapwood boundaries. The AD 1429 dating of a walkway timber suggests this area of the complex was built some eight years after the license to convert the parish church into a collegiate church was granted. This area was thus still apparently under construction after the death of the founding rector and lord of the manor (Thomas de la Warre d AD 1426). However the absence of surviving sapwood on most of the timbers has resulted in most of the sampled areas having felling date ranges that cover the period from *c* AD 1410 (ie before the license) through to the AD 1440s (Fig 7). It is not suggested here that any of the extant structure predates the license in AD 1421, instead the lack of sapwood prevents dendrochronology from proving that it cannot predate the license. The combined felling date ranges for each area are sufficiently broad that precise interpretation of the sequence of construction of the complex is impossible to achieve reliably. The results do convincingly indicate that much of the structure remains intact from the foundation of the collegiate church. The one tentative indication of phasing of construction is derived from the south range ceiling which appears to predate the cloister walkway since the latest likely felling of sample **42** is AD 1424. This may indicate that the walkways were later than some part of the cloistral accommodation, or that the senior lodgings were amongst the earliest completed parts of the complex.

Observations during sampling revealed extensive and clear signs of warping of the timbers after being converted from the trunks into usable beams. Similarly the mouldings show characteristic distortions clearly due to warping after carving. Both these indicate the use of green timber throughout the fifteenth century framing of these ranges and implies the felling dates and felling date ranges identified are likely to be coterminous with the construction dates of these areas. Overall it is clear that construction dates for all areas in the second quarter of the fifteenth century is indicated by these results.

Later timbers

Two later dated samples appear to indicate the first bay of the cloister walkway nearest the hall has been modified in the later sixteenth or early seventeenth centuries (Figs 6, 8). The undated sample from a decorated wall plate from the hall (sample **16**) shows some similarities in colour and growth rates to these two samples and may indicate all these timbers relate to

the otherwise undated insertion of the chimney and other modifications on the west side of the hall.

The two cloister shutters are of late seventeenth- or early eighteenth-century date. In strict terms they date from sometime after AD 1679 but since they are already quite long lived (235 years plus the missing centre and at least the missing sapwood), and they are quite broad for a single radius (0.35m), it seems unlikely they have been cut from a significantly older or bigger tree. Assuming they are original to the building they are the only evidence currently obtained for works of the Chethams period.

Conclusion

Analysis of a series of 47 cores from structural timbers in the Chethams cloistral ranges and hall has resulted in the production of estimated felling date ranges for a number of separate areas of the complex. These show that almost the entire structure retains significant fifteenth-century structural elements. The presence of identified sixteenth- or seventeenth-century timbers in only one small area suggests the degree of reconstruction after firstly its dissolution and secondly after the civil war were not as extensive as had been thought, at least in these areas of the property. Timbers recognised as from the more recent repairs were excluded from the analysis. The tree-ring chronology is a well replicated sequence which appears to be a useful contribution to the regional data series. The high levels of correlation between samples from different areas as well as the consistent overall slow growth rates interspersed by periods of extremely slow growth appears to imply a limited range of woodland sources was used for the original construction of the complex. Two shutters are identified as late seventeenth-century objects.

Acknowledgements

The sampling and analysis programme was funded by English Heritage. Marian Barter, Alex Bayliss, and Peter Marshall all from English Heritage provided useful discussion. Clare Hartwell provided an incredible amount of useful information through her draft reports and her observations during sites visits. Her willingness to guide me through the complexities of the structure and the obscurities of its development have helped ensure the sampling has been aimed at the most useful timbers whenever practicable. Michael Powell, Fergus Wilde, and Anne Leslie from the Library all helped during the assessment visits and over the long week of sampling through their combined enthusiasm and deep mines of information, their coffee making, and their skills with the fire alarm systems proved invaluable. Dave Mulligan, Ged, and Eddy all helped with scaffold towers, keys, and other practical issues too numerous to mention. The School also generously provided use of accommodation on site which made some of the practical aspects of the work easier. The School Headmistress Mrs Moreland

kindly allowed access to her rooms in her absence, Mrs Woods, Domestic Services Manager, facilitated the use of on-site accommodation. Colin Jackson, Sheffield University Finance Department, and Cyril Barratt, Bursar from Chethams School, kindly liaised over the issues of third party insurance cover in this building. Sue Stallibrass, English Heritage Regional Science Advisor currently based in Liverpool University, kindly came out to site to try to understand some of the practical issues involved in sampling timbers within buildings and to discuss the sort of information likely to be forthcoming. My colleague Cathy Groves provided useful discussion of the results and conclusions.

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Figure 1 Location of Chetham Library and School within England and Wales, based upon Ordnance Survey map (<http://www.ordsvy.gov.uk/freegb/index.htm>) with the permission of The Controller of Her Majesty's Stationery Office, © Crown Copyright 1999

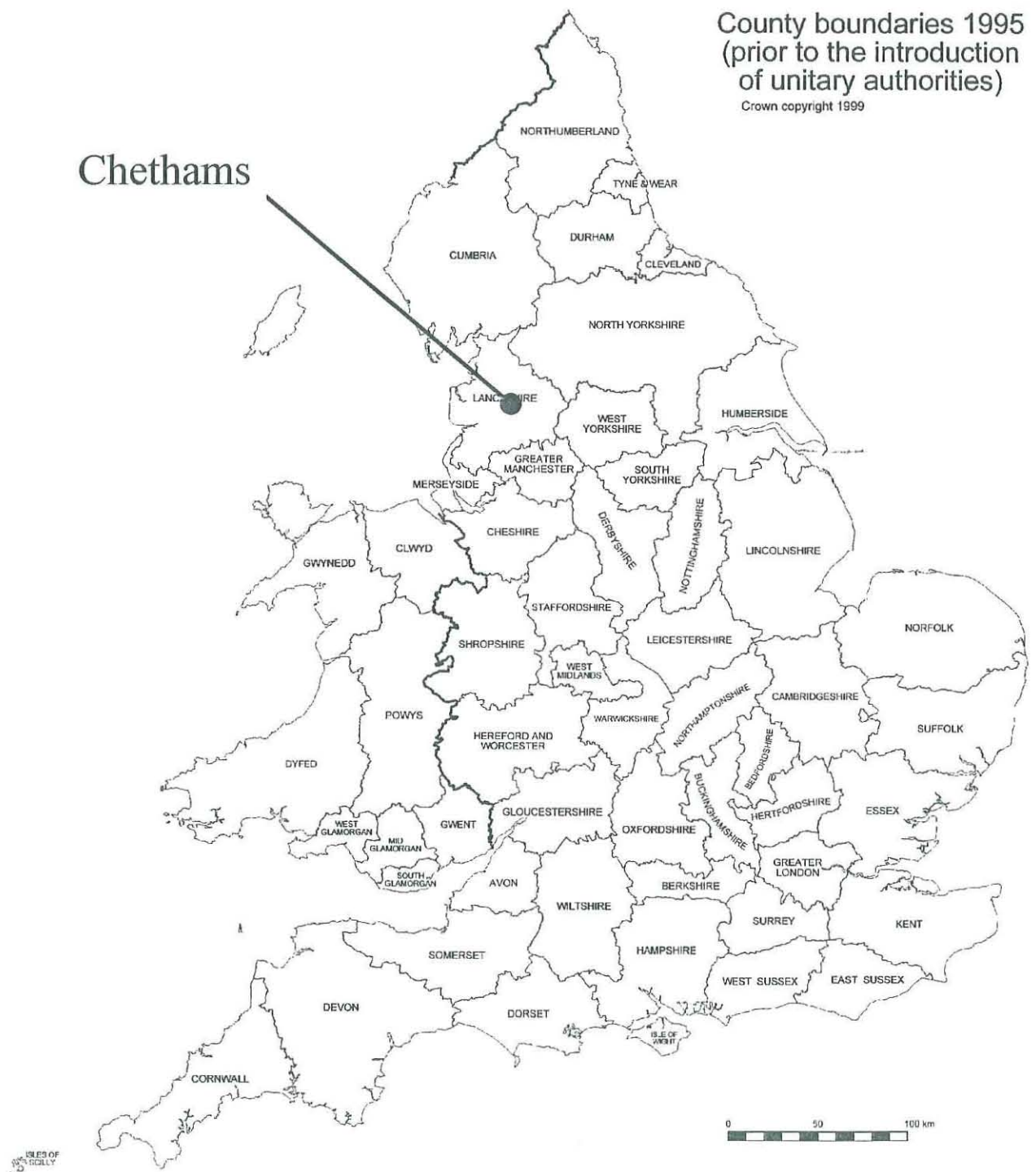


Figure 2 Location of Chethams Library and School based upon Ordnance Survey 1:1250

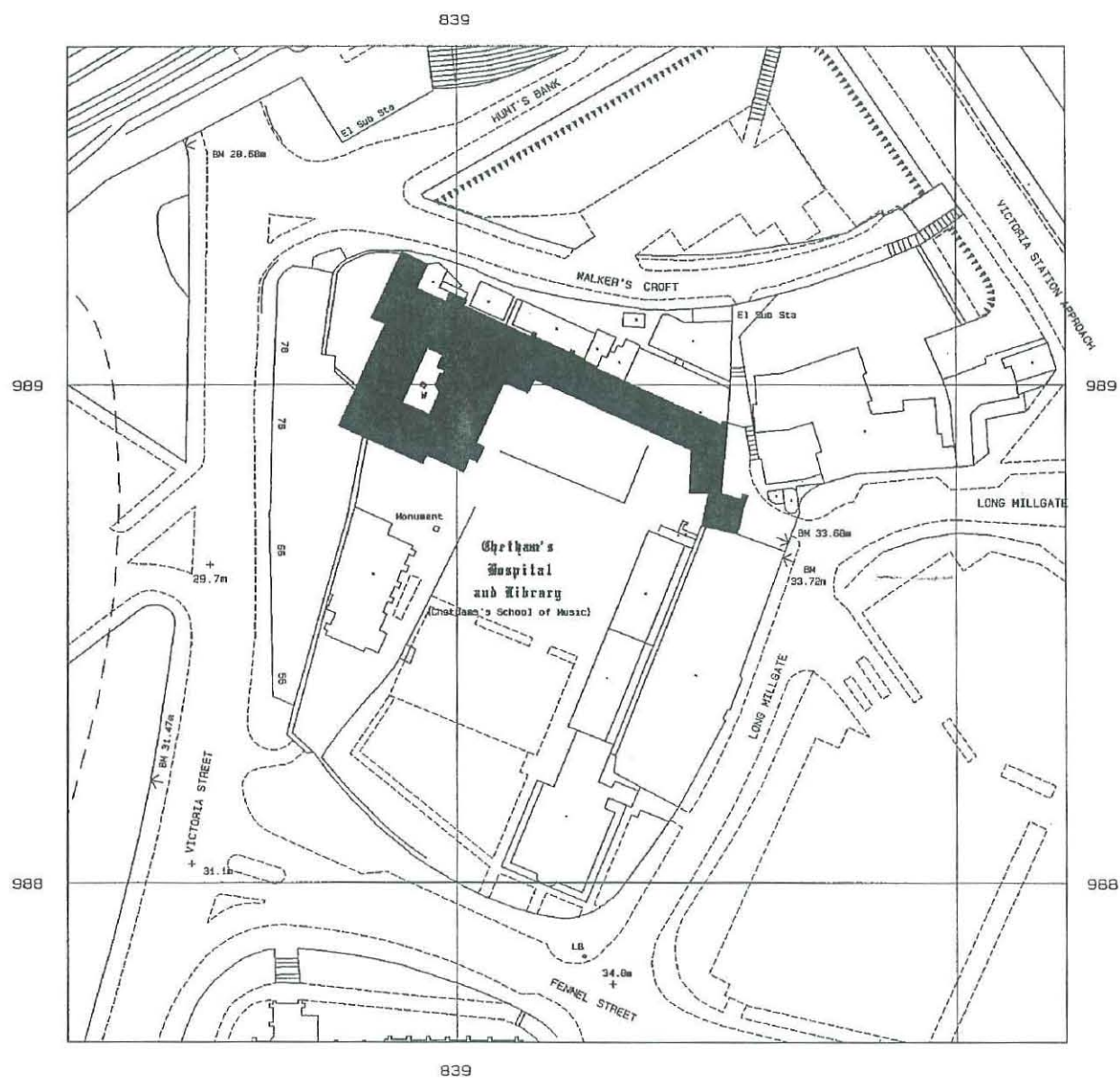


Figure 3 Plan of the Chethams Library and School complex (after Waterhouse 1878), showing the principal areas of sampling discussed in the report.

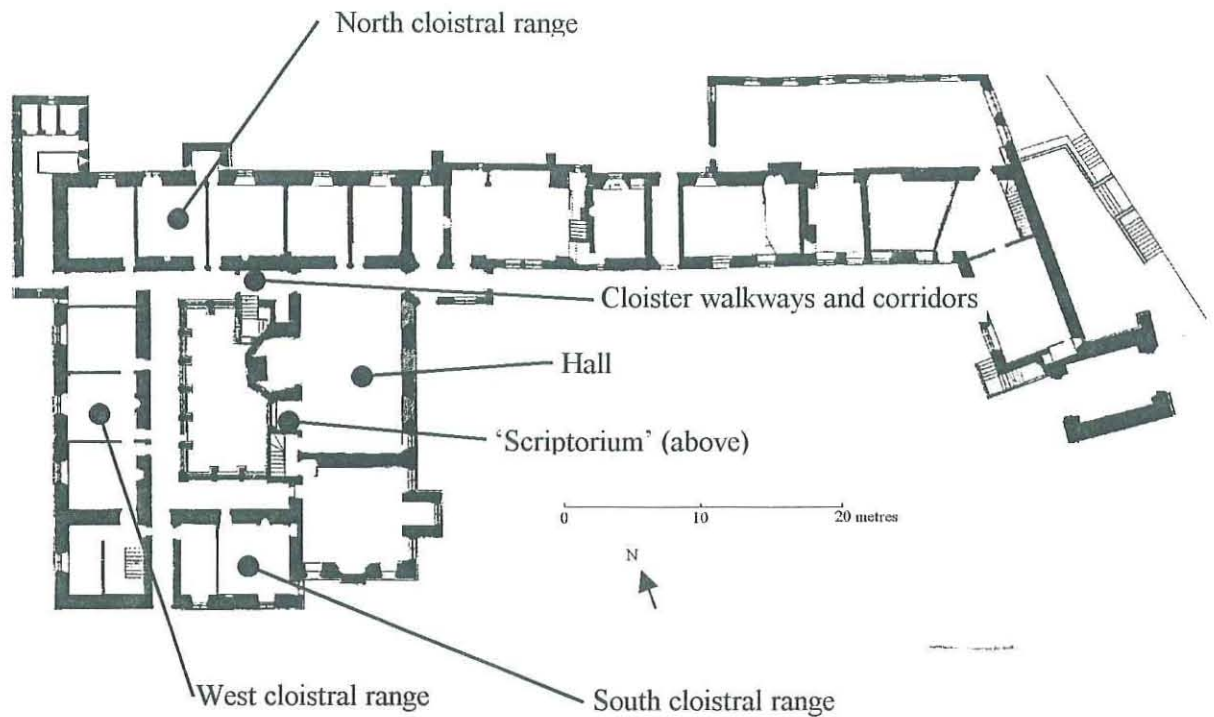


Figure 4 Typical roof truss (after an undated drawing by P Page kindly supplied by Clare Hartwell), showing the nomenclature followed in Table 1.

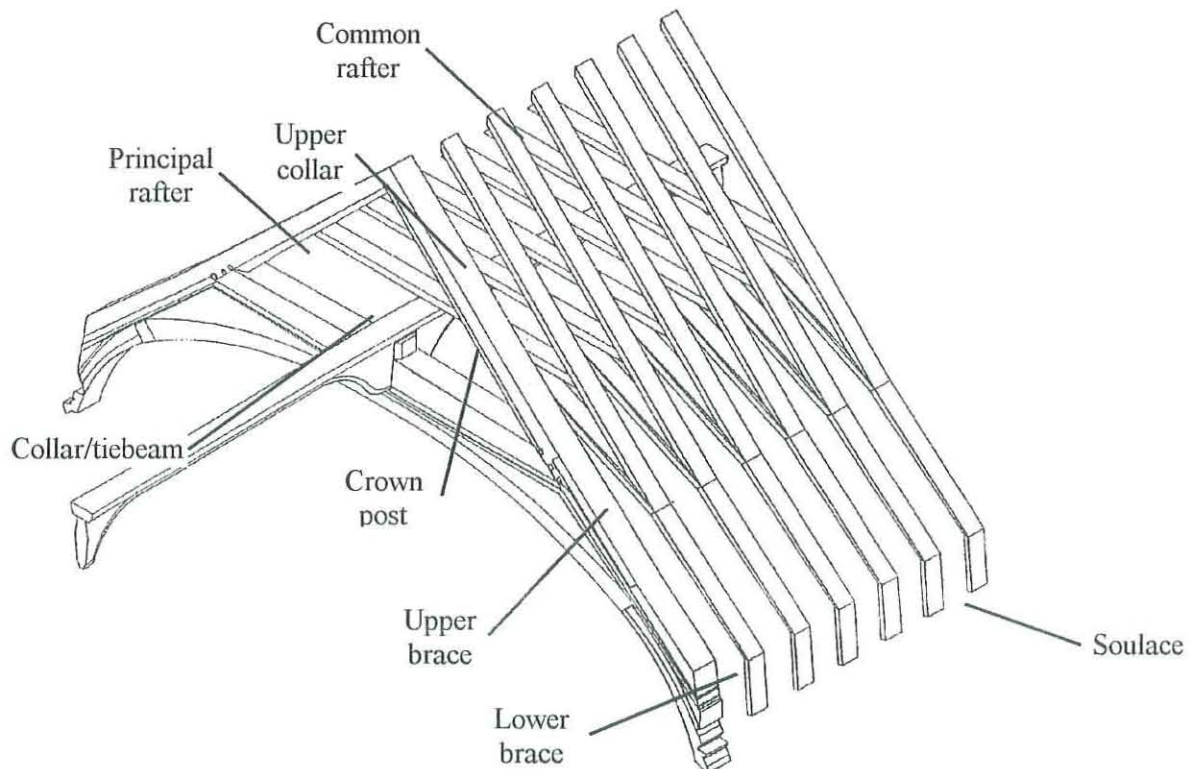
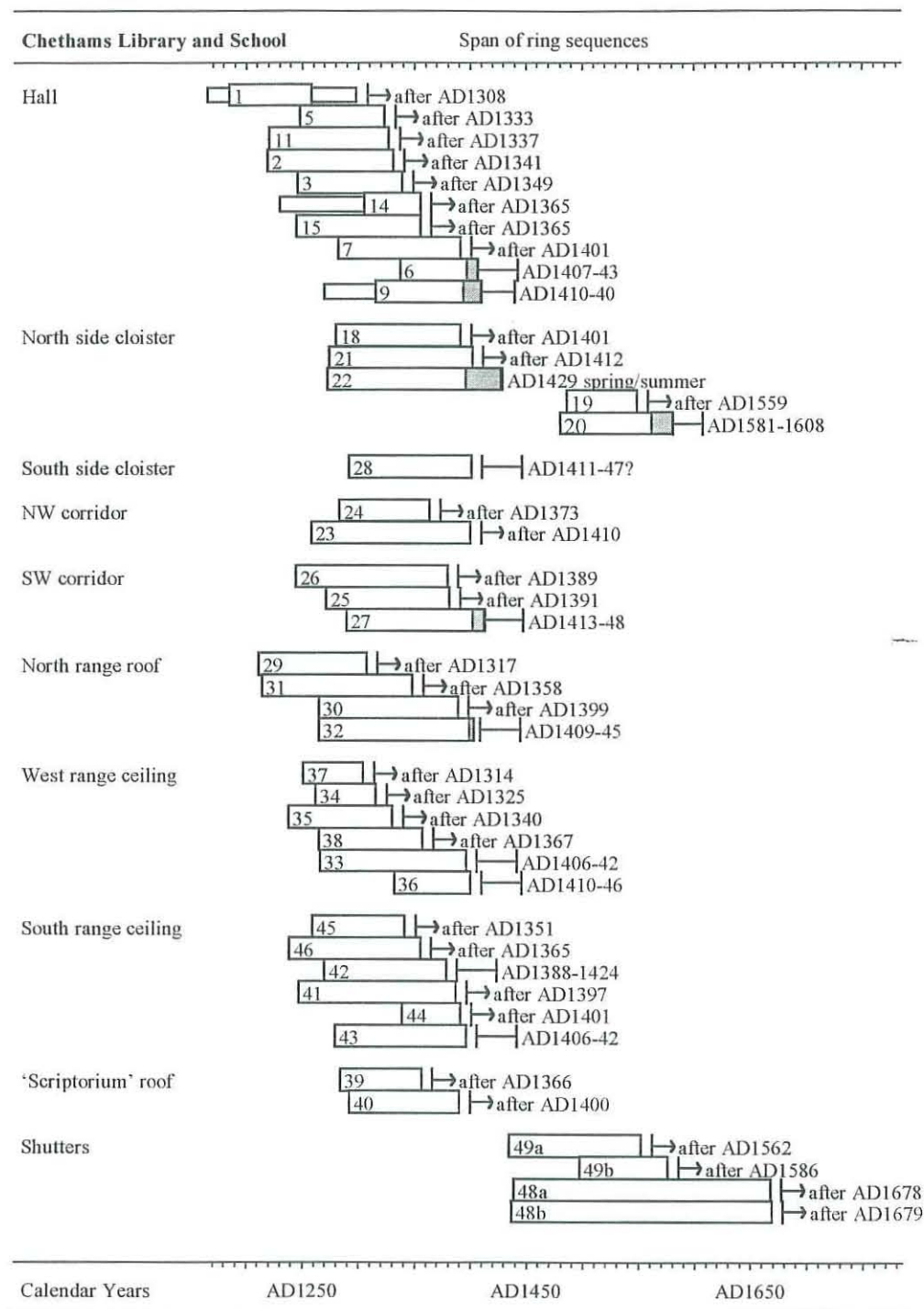


Figure 5 Bar diagram showing the chronological positions of the dated timbers from Chethams Library and School. The felling period for each sequence is also shown



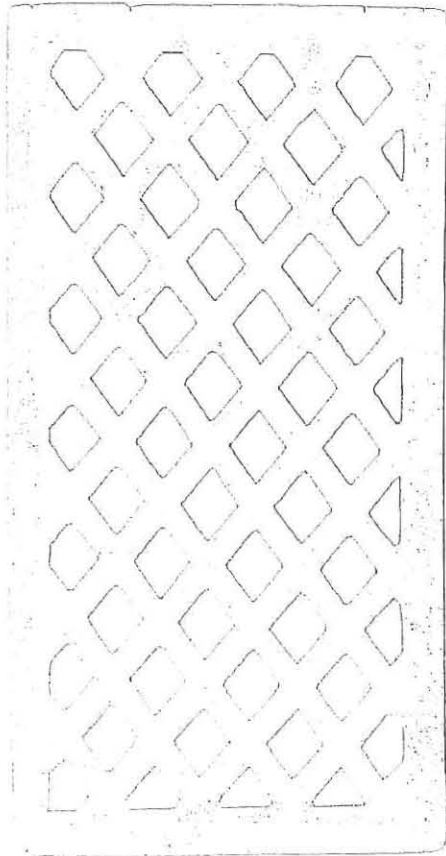
KEY



heartwood
sapwood

Figure 6 The shutter samples **48** and **49**, both boards are approximately 690mm high, 355mm wide, and 15mm thick. The grain pattern in **49** is highly distorted compared to **48** due to the presence of a large knot, this may have encouraged its subsequent breakage. Curiously although both boards have clear marking out lines scribed on this face, both have been marked out with the same systematic inaccuracy (for example the left hand column of diamond cut-outs gets less complete down both the boards).

48



49

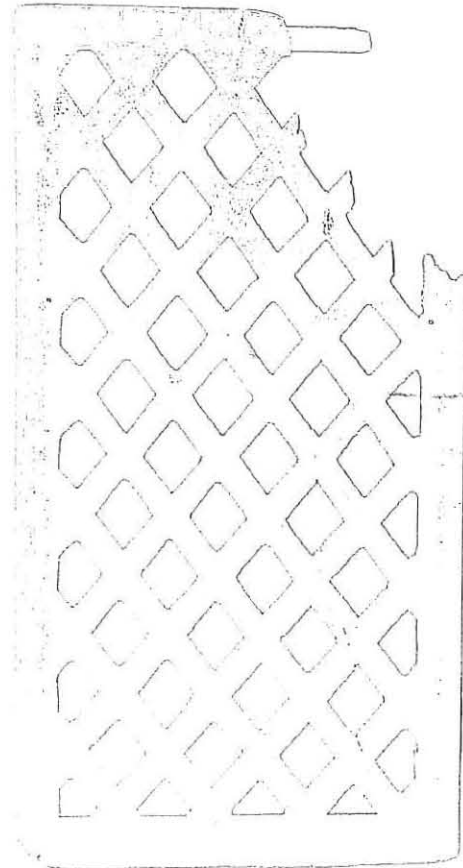


Figure 7 Summary of the results for each area of the complex.

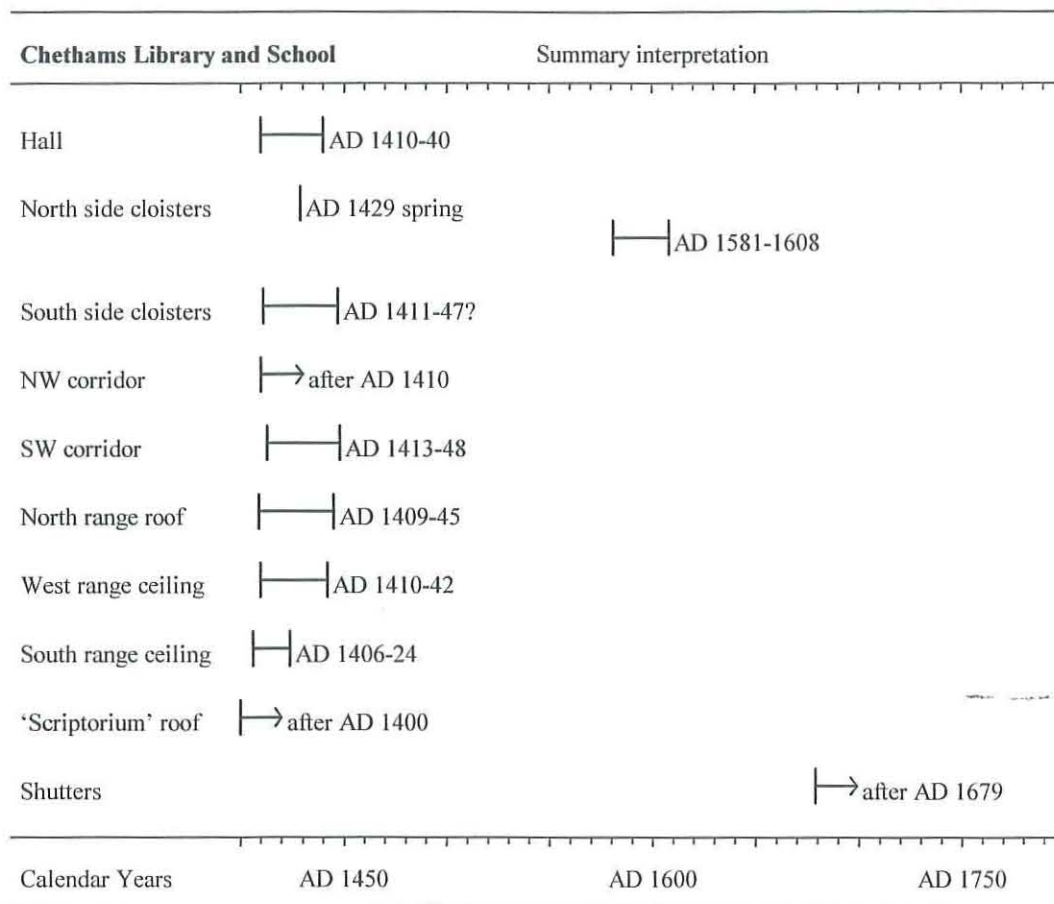


Table 1

List of samples obtained from Chethams Library and School, Manchester, data from each core is listed in Appendix 1.

Core No	Origin of core	Total rings	Sapwood rings	ARW mm/year	Date of sequence	Felling period
HALL						
1	Truss 4 west upper brace	20+74+40	-	1.04	AD 1185-AD 1258	after AD 1308
2	Truss 4 east upper brace	113	-	0.96	AD 1219-AD 1331	after AD 1341
3	Truss 4 west principal rafter	94	-	1.60	AD 1246-AD 1339	after AD 1349
4	Bay 3 west common rafter	-	-	-	Not measured	-
5	Truss 4 collar/tiebeam	76	-	1.57	AD 1248-AD 1323	after AD 1333
6	Bay 3 west soulace	71	10	1.18	AD 1337-AD 1407	AD 1407-43
7	Bay 3 west common rafter	110	-	1.00	AD 1282-AD 1391	after AD 1401
8	Truss 4 east principal rafter	53	-	1.63	undated	-
9	Bay 1 upper collar	45+96	16	0.88	AD 1315-AD 1410	AD 1410-40
10	Truss 2 crown post	68	-	1.30	undated	-
11	Truss 2 west upper brace	107	-	1.26	AD 1221-AD 1327	after AD 1337
12	Truss 2 east lower brace	75	-	1.56	undated	-
13	Truss 4 east lower brace	-	-	-	Not measured	-
14	Truss 4 west lower brace	75+51	-	1.06	AD 1305-AD 1355	after AD 1365
15	Truss 2 west lower brace	111	-	1.29	AD 1245-AD 1355	after AD 1365
16	Bay 1, west wall plate	71	-	2.32	undated	-
CLOISTER WALK - NORTH						
17	Joist 1 bay 2 from Hall	-	-	-	Not measured	-
18	Joist 3, same bay	112	-	1.13	AD 1280-AD 1391	after AD 1401
19	Joist 3 bay 1 from Hall	64	-	1.66	AD 1486-AD 1549	after AD 1559
20	Post, left of stairs	102	19	1.52	AD 1480-AD 1581	AD 1581-1608
21	Joist 1, bay 4 from Hall	129	-	1.18	AD 1274-AD 1402	after AD 1412
22	Joist 1, bay 5 from Hall (corner)	157	32+Bs	0.71	AD 1272-AD 1428	AD 1429 spr
CORRIDOR - NORTH WEST						
23	East wall spine beam	143	-	1.55	AD 1258-AD 1400	after AD 1410
24	West wall joist	81	-	1.29	AD 1283-AD 1363	after AD 1373
CORRIDOR - SOUTH WEST						
25	West wall beam	111	-	0.95	AD 1271-AD 1381	after AD 1391
26	Central spine beam	136	-	1.16	AD 1244-AD 1379	after AD 1389
27	Central joist, north bay	125	11	1.60	AD 1289-AD 1413	AD 1413-48

Table 1 (cont)

Core No	Origin of core	Total rings	Sapwood rings	ARW mm/year	Date of sequence	Felling period
CLOISTER WALK - SOUTH						
28	Western of paired beams	111	h/s?	0.75	AD 1291-AD 1401	AD 1411-47?
CLOISTER RANGE - NORTH						
29	Truss 2 north upper brace	97	-	1.41	AD 1211-AD 1307	after AD 1317
30	Truss 2 north lower brace	125	-	1.24	AD 1265-AD 1389	after AD 1399
31	Truss 2 south upper brace	135	-	1.19	AD 1214-AD 1348	after AD 1358
32	South east stud/storey post	139	4	0.88	AD 1265-AD 1403	AD 1409-45
CLOISTER RANGE - WEST						
33	Ceiling east-west beam	131	h/s	1.80	AD 1266-AD 1396	AD 1406-42
34	Ceiling north-south beam	54	-	1.27	AD 1262-AD 1315	after AD 1325
35	Ceiling north-south beam	93	-	1.52	AD 1238-AD 1330	after AD 1340
36	Ceiling east-west beam	69	h/s	1.42	AD 1332-AD 1400	AD 1410-46
37	Ceiling north-south beam	54	-	2.49	AD 1251-AD 1304	after AD 1314
38	Ceiling north wall plate	93	-	1.52	AD 1265-AD 1357	after AD 1367
HALL - 'Scriptorium'						
39	East truss south vertical post	73	-	1.47	AD 1284-AD 1356	after AD 1366
40	Rafter south east corner	99	-	1.57	AD 1292-AD 1390	after AD 1400
CLOISTER RANGE - SOUTH						
41	Ceiling north-south beam	141	-	1.78	AD 1247-AD 1387	after AD 1397
42	Ceiling south wall plate	109	h/s	0.94	AD 1270-AD 1378	AD 1388-1424
43	Ceiling east-west beam	118	h/s	1.20	AD 1279-AD 1396	AD 1406-42
44	Ceiling east wall plate	53	-	1.76	AD 1339-AD 1391	after AD 1401
45	Ceiling north wall plate	83	-	1.46	AD 1259-AD 1341	after AD 1351
46	Ceiling east-west beam	117	-	1.06	AD 1239-AD 1355	after AD 1365
47	Ceiling south wall plate	-	-	-	Not measured	-
CLOISTER SHUTTERS						
48	Shutter - complete	233	-	1.46	AD 1437-AD 1669	after AD 1679
49	Shutter - broken	142	-	1.92	AD 1435-AD 1576	after AD 1586

KEY

Total rings = all measured rings, figures in *italics* indicate detached or un-measurable sections of the cores. Sapwood rings: h/s heartwood/sapwood boundary, ?h/s possible heartwood/sapwood boundary, Bs bark spring felled. ARW = average ring width of the measured rings (mm/year)

Table 2

t-value matrix for the timbers forming the interim Chethams Library and School chronology
 CHET_H. KEY: \ = no overlap, - = *t*-values under 3.0

Hall	2	3	5	6	7	9	11	14	15
1	5.24	\	\	\	\	\	-	\	\
2		5.43	3.79	\	-	-	6.64	3.83	4.62
3			-	\	-	-	-	4.93	-
5				\	3.47	\	3.31	3.43	-
6					3.25	4.40	\	4.82	3.48
7						3.94	-	5.08	5.66
9							\	-	4.04
11								-	7.27
14									6.17

Table 3

t-value matrix for the timbers forming the interim Chethams Library and School chronology
 CHET_CW. KEY: - = *t*-values under 3.0

Cloister walkways	18	21	22	28
CHET_H	5.02	6.96	4.56	7.32
18		9.82	-	4.67
21			3.64	3.72
22				3.32

Table 4

t-value matrix for the timbers forming the interim Chethams Library and School chronology
 CHET_COR. KEY: - = *t*-values under 3.0

Cloister corridors	23	24	25	26	27
CHET_H	7.52	4.33	5.75	9.16	8.64
CHET_CW	4.64	3.44	-	6.14	5.46
23		-	5.09	7.65	5.95
24			4.59	3.95	-
25				4.78	-
26					5.48

Table 5

t-value matrix for the timbers forming the interim Chethams Library and School chronology
CHET_NR. KEY: - = *t*-values under 3.0

North range roof	29	30	31	32
CHET_H	5.44	5.83	8.35	6.44
CHET_CW	-	4.51	3.56	3.45
CHET_COR	-	4.80	4.34	5.78
29		3.97	8.38	-
30			5.46	4.77
31				3.26

Table 6

t-value matrix for the timbers forming the interim Chethams Library and School chronology
CHET_WC. KEY: \ = no overlap, - = *t*-values under 3.0

West range ceiling	33	34	35	36	37	38
CHET_H	7.64	4.23	7.40	5.59	5.64	8.01
CHET_CW	8.30	3.67	4.17	4.81	3.10	4.48
CHET_COR	5.02	5.20	4.45	7.06	4.30	10.27
CHET_NR	5.34	3.71	4.55	4.13	3.75	5.79
33		3.06	7.32	4.84	3.79	3.32
34			4.00	\	5.21	4.29
35				\	5.42	-
36					\	3.43
37						3.13

Table 7

t-value matrix for the timbers forming the interim Chethams Library and School chronology
CHET_SC. KEY: \ = no overlap, - = *t*-values under 3.0

South range ceiling	41	42	43	44	45	46
CHET_H	9.81	6.82	7.76	5.30	4.45	6.39
CHET_CW	7.32	4.51	5.24	-	4.16	6.60
CHET_COR	7.71	6.90	6.97	4.82	4.47	8.48
CHET_NR	5.94	-	6.88	3.02	-	3.15
CHET_WC	9.31	5.52	5.92	5.22	3.18	6.82
41		4.40	5.53	5.12	4.31	5.92
42			3.41	-	6.59	3.70
43				3.25	-	9.25
44					\	3.30
45						-

Table 8

t-value matrix for the two timbers from the gallery forming the interim Chethams Library and School chronology CHET_HB.

Hall Bay	39	40
CHET_H	7.67	6.08
CHET_CW	6.22	6.43
CHET_COR	6.28	5.98
CHET_NR	4.31	4.69
CHET_WC	6.25	7.56
CHET_SC	5.37	6.56

Table 9

t-value matrix for the sequences from the shutters forming the interim Chethams Library and School chronology 48+49.

Shutters	48b	49a	49b
48a	12.73	12.45	7.82
48b		8.94	8.07
49a			4.60

Table 10

t-value matrix for the interim Chethams Library and School area sequences.

Interim groups	CW	COR	NR	WC	SC	HB
CHET_H	7.82	11.35	9.33	12.39	11.96	8.41
CHET_CW		5.84	5.41	9.13	8.10	7.79
CHET_COR			6.08	11.96	10.92	7.61
CHET_NR				7.41	6.39	5.96
CHET_WC					11.33	9.79
CHET_SC						7.71

Table 11

Dating the Chethams chronology CHETHAM. Example *t*-values with independent reference chronologies.

Reference Chronology	CHETHAM AD 1185 - AD 1428
East Midlands regional master (Laxton and Litton 1988)	8.16
Greater Manchester, Eccleston Hall St Helens (Groves 1993)	5.19
Lancashire, Witches Tower Lancaster Castle (Groves and Hillam 1995)	5.52
N Yorkshire, York Merchant Adventurers Hall (Howard <i>et al</i> 1992)	5.48
Shropshire, Ightfield Hall Barn (Groves 1997)	5.36
Staffordshire, Sinai Park nr Burton (Tyers 1997)	6.96
W Yorkshire, Wakefield John Bunny House (Morgan 1988)	5.56
Worcestershire, Crowle Court Barn (Hillam 1997)	6.01
Worcestershire, Droitwich Upwich (Groves and Hillam 1997)	7.25
Yorkshire East, Hull HMC94 coffin 1790 (Tyers 1998)	5.86

Table 12

Dating the two later samples from the cloister walkways. Example *t*-values with independent reference chronologies.

Reference Chronology	19 AD 1486-1549	20 AD 1480-1581
Derbyshire, Kent House Ridgeway (Groves and Hillam 1990)	4.73	3.08
East Midlands regional master (Laxton and Litton 1988)	5.23	6.15
Greater Manchester, Hall I' Th' Wood Bolton (Groves 1999)	4.09	5.40
Herefordshire, Hereford Farmers Club (Tyers 1996)	4.15	4.38
Lancashire, Lightshaw Hall Golborne (Groves 1998)	4.67	4.44
Shropshire, Ightfield Hall Barn (Groves 1997)	3.37	6.36
Staffordshire, Black Ladies nr Brewood (Tyers 1999b)	3.41	5.41
Staffordshire, Sinai Park nr Burton (Tyers 1997)	4.94	5.63
Worcestershire, Droitwich Upwich (Groves and Hillam 1997)	4.40	4.21
Yorkshire West, Wakefield Golden Cock (Hillam and Groves 1992)	5.09	3.15

Table 13

Dating the combined series from the shutters. Example *t*-values with independent reference chronologies.

Reference Chronology	48+49 AD 1435-1669
Derbyshire, Bretby Hall Bretby (Howard <i>et al</i> 1999)	4.99
Derbyshire, Kent House Ridgeway (Groves and Hillam 1990)	5.88
East Midlands regional master (Laxton and Litton 1988)	6.48
Greater Manchester, Market Place Stockport (Tyers 1999c)	5.20
Herefordshire, Kings Pyon barn (Groves and Hillam 1993)	4.95
Herefordshire, Pembridge belltower (Tyers 1999d)	5.85
Staffordshire, Black Ladies nr Brewood (Tyers 1999b)	6.75
Staffordshire, Sinai Park nr Burton (Tyers 1997)	4.86
Yorkshire South, Stanington Whitehouse Farm (Hillam 1983)	5.21
Yorkshire West, Thorpe Barn Finthorpe (Boswijk 1997)	4.87

$$100 = 1\text{mm}$$

118	134	133	117	148	173	148	118	160	127
149	166	162	135	110	113	132	116	126	91
149	104	81	110	90	84	121	93	94	114
116	132	124	93	97	107	95	105	76	71
104	124	119	170	116	102	80	84	74	74
94	73	89	102	93	78	71	89	81	79
70	82	89	76	93	90	96	55	61	72
71	87	69	60						

183	189	212	192	118	110	147	183	180	270
235	219	177	156	116	103	115	128	182	144
163	123	107	95	102	107	111	142	128	108
145	125	129	72	89	100	98	88	88	75
54	73	78	103	96	88	104	61	52	60
62	104	119	90	102	71	61	59	52	45
74	87	88	84	95	95	102	81	79	48
84	83	120	83	91	76	66	48	60	59
52	64	46	29	34	34	53	57	47	51
72	60	68	58	35	44	76	96	97	103
54	60	59	64	61	60	80	101	93	90
87	79	64							

286	257	184	245	289	233	121	259	270	247
192	224	204	161	204	169	228	141	160	139
125	78	121	141	174	199	141	261	278	301
236	247	186	289	336	256	273	293	309	173
198	183	119	232	251	194	215	276	197	148
153	128	117	128	164	77	56	83	93	93
107	100	92	113	88	74	79	74	110	150
118	117	115	49	73	81	84	141	140	153
85	95	96	79	111	117	100	75	65	82
67	98	95	114						

402	558	373	496	256	319	287	363	281	246
228	273	372	189	174	151	144	167	182	164
137	188	146	185	188	222	196	168	156	145
131	110	116	123	153	149	148	169	189	99
62	109	114	164	182	189	146	82	79	86
62	50	47	52	49	56	53	79	112	87
92	123	98	94	69	61	72	90	99	133
113	59	45	53	48	85				

106	127	124	134	125	136	116	96	120	92
106	155	164	108	109	113	160	139	173	117
148	130	114	80	97	74	119	117	82	105
117	158	159	118	142	158	114	121	107	94
94	114	94	78	87	108	97	70	113	141
136	128	110	89	110	104	106	103	109	109
99	119	154	152	152	107	157	157	107	97
88									

CHET18

187	204	219	185	191	208	194	160	150	124
139	153	158	192	144	119	86	79	80	72
88	86	79	75	89	110	136	131	142	132
121	58	59	55	67	98	98	68	75	45
51	45	55	93	107	126	100	73	107	73
70	73	130	103	93	100	89	71	106	89
100	114	133	86	125	135	103	114	110	92
74	81	154	138	117	106	81	80	52	90
89	108	150	136	130	73	69	102	106	83
62	120	165	131	148	117	148	133	163	158
136	148	125	92	112	126	145	135	167	148
123	104								

CHET19

236	329	238	224	250	180	185	310	353	306
366	357	257	189	218	179	243	192	203	305
247	188	186	206	196	175	199	184	144	115
116	102	121	140	116	188	159	108	123	116
133	128	116	94	83	94	81	68	55	71
50	71	65	74	101	104	80	144	148	160
162	91	104	120						

CHET20

306	297	260	296	274	333	280	265	192	140
144	114	89	99	142	250	305	120	107	111
131	85	108	131	174	271	186	212	154	202
209	273	171	232	125	96	110	143	149	153
165	177	172	147	177	129	127	136	188	165
114	165	148	144	127	124	116	185	113	126
134	111	70	146	128	143	142	121	145	153
176	165	110	149	169	101	65	93	83	173
112	121	100	101	119	80	60	88	87	131
132	155	129	155	89	100	101	124	85	142
170	132								

CHET21

376	263	346	239	161	107	195	273	236	268
247	215	177	146	120	173	189	200	208	225
147	98	72	74	52	53	54	60	43	46
53	87	85	86	78	84	56	51	47	42
47	76	77	73	47	45	43	54	50	87
104	108	80	78	99	84	75	80	111	88
119	113	99	71	122	131	144	151	152	107
104	171	101	149	128	162	72	108	173	118
129	119	121	105	83	85	132	129	156	134
157	80	70	105	110	93	69	112	135	114
138	83	83	100	108	113	111	109	91	76
65	95	133	132	139	119	99	109	70	112
130	125	109	123	151	119	133	126	119	

CHET26

193	241	254	245	246	309	282	265	155	243
287	216	187	230	202	194	198	163	173	141
113	137	165	112	151	170	148	123	132	109
100	84	98	114	103	87	121	112	88	78
137	91	93	62	77	109	124	108	113	106
65	77	73	104	77	59	63	69	49	37
42	48	54	60	66	90	54	82	49	47
61	103	102	78	100	75	57	45	45	76
86	107	90	113	101	55	61	84	100	92
51	119	108	100	122	152	201	140	134	108
87	112	58	94	125	135	84	89	88	105
105	133	93	100	93	79	56	63	86	138
133	91	73	88	82	159	88	126	162	130
150	115	131	135	144	120				

CHET27

258	301	290	353	277	258	148	184	216	182
134	146	149	87	92	94	133	144	142	108
159	165	164	202	145	147	217	194	227	257
129	97	90	120	142	131	167	144	142	142
118	150	132	126	167	138	179	176	161	184
199	240	238	236	152	129	184	149	172	210
187	123	93	176	154	167	218	203	156	174
109	89	107	146	168	174	175	122	118	135
162	117	112	213	206	171	127	111	142	135
166	150	145	130	112	115	99	128	212	173
200	146	168	102	109	106	159	138	137	172
146	166	121	150	134	244	151	184	140	164
116	151	145	190	170					

CHET28

113	157	160	137	103	88	81	67	70	71
51	46	60	64	80	102	77	98	129	66
112	66	73	99	133	164	134	101	63	42
37	43	53	58	91	78	78	80	74	74
52	81	74	47	66	54	57	52	79	74
83	69	55	55	93	44	74	77	86	67
56	81	107	85	87	64	59	55	57	43
44	47	81	64	33	37	38	36	38	45
49	66	70	81	73	63	71	73	141	64
73	65	52	58	63	95	105	119	109	73
52	75	48	49	77	89	72	92	74	79
91									

CHET29

375	257	267	245	266	292	257	216	198	197
248	190	134	130	138	167	153	152	190	233
150	123	94	93	163	133	179	170	186	145
105	129	173	167	156	133	159	150	220	124
257	155	159	141	140	182	136	101	153	122
125	186	123	131	140	113	74	124	121	148
189	210	173	141	89	88	65	79	141	111
130	119	122	131	154	122	72	68	82	88
99	110	106	77	56	61	69	57	65	67
74	53	47	47	76	78	58			

CHET30

118	183	88	97	73	126	174	157	146	149
107	116	89	103	148	213	133	130	135	170
179	120	104	79	101	155	223	175	127	106
92	72	76	82	65	71	72	52	48	51
89	83	98	123	117	127	109	84	94	95
137	153	88	82	76	68	85	80	94	123
140	88	172	118	88	113	100	127	97	90
161	84	116	138	149	175	141	232	88	103
119	116	118	149	152	100	81	126	127	133
115	123	120	94	91	84	90	207	154	155
167	128	117	130	146	108	144	178	128	135
127	136	119	132	200	200	147	159	145	141
142	159	225	227	211					

CHET31

175	135	177	145	162	198	199	247	201	122
156	198	241	214	277	261	214	100	94	85
95	145	69	129	111	222	152	110	91	123
114	118	97	185	140	198	121	173	96	80
82	132	100	93	56	80	111	99	224	121
115	127	165	122	126	134	159	192	182	147
113	63	67	59	59	122	115	145	131	162
173	163	168	100	52	97	103	111	139	156
112	47	49	49	57	64	56	68	40	35
50	64	81	97	75	92	74	59	45	52
69	70	102	90	102	53	48	55	61	60
86	126	91	211	117	94	101	104	134	121
80	105	69	89	107	81	138	170	181	120
117	169	132	116	208					

CHET32

260	326	249	281	197	196	267	242	285	226
219	216	244	137	182	178	185	147	119	125
127	104	85	93	98	157	151	130	104	60
76	70	109	82	69	72	75	46	48	70
97	91	112	84	104	89	76	66	62	99
95	86	68	74	54	46	45	50	71	66
100	72	110	80	77	69	66	54	56	63
55	50	43	58	79	101	68	79	74	55
83	56	60	84	76	67	76	74	67	70
89	54	74	80	61	48	53	63	63	71
60	45	38	37	47	30	39	36	41	45
45	44	36	39	44	50	48	45	39	51
50	49	48	50	52	42	48	56	41	45
47	57	40	56	67	73	69	49	57	

CHET33

265	242	313	372	520	687	569	566	397	357
333	386	247	214	226	279	279	275	266	239
298	246	208	235	278	307	288	301	246	204
169	176	128	131	132	119	109	102	130	174
160	158	161	186	170	162	141	155	183	214
281	223	204	166	114	152	143	151	163	202
159	175	133	177	121	146	139	136	131	119
88	116	119	174	155	132	150	121	132	184
143	132	161	145	80	95	139	171	177	180
161	173	115	110	83	135	141	150	132	82
67	78	76	75	74	76	149	121	149	121
90	133	150	166	117	141	94	102	90	113
136	148	148	136	132	106	121	85	98	113
139									

CHET34

295	165	140	180	224	168	212	155	198	204
211	217	199	208	139	188	109	91	115	94
83	87	114	79	95	83	90	112	115	108
121	138	90	69	94	82	66	62	86	80
62	63	67	87	85	136	108	144	146	142
119	76	122	130						

CHET35

146	147	140	146	131	167	129	137	179	188
151	206	182	212	92	131	221	244	229	244
257	268	394	291	299	202	211	212	255	196
174	167	194	263	227	251	226	216	214	232
181	126	211	184	216	228	204	160	196	180
98	126	174	191	175	210	150	120	78	95
72	81	85	72	69	54	92	93	97	117
96	116	94	109	67	65	88	114	97	85
86	54	47	51	57	57	57	93	67	100
84	84	73							

CHET36

219	232	150	221	213	146	226	270	207	175
198	187	144	262	180	238	255	214	96	102
103	115	130	161	150	143	144	176	109	115
197	197	184	142	116	122	78	103	69	79
147	187	176	96	100	93	124	140	114	99
104	133	111	99	131	104	126	123	96	93
90	77	75	95	91	79	108	113	123	

CHET37

251	109	293	432	415	381	453	349	492	453
283	353	167	149	277	292	195	298	283	460
476	274	410	261	349	329	355	214	174	293
267	201	224	366	205	237	262	131	235	227
221	212	225	144	87	79	88	95	99	110
69	57	43	65						

CHET42

155	170	160	213	152	117	135	146	129	152
151	141	156	145	177	127	158	122	136	132
171	134	136	177	135	122	118	154	126	142
113	115	91	87	83	94	90	92	103	105
87	94	64	85	88	116	103	90	94	99
79	68	46	75	71	87	88	84	78	70
68	55	67	96	52	58	51	48	54	75
55	68	57	59	62	72	44	54	59	60
47	69	74	66	77	97	74	93	92	90
61	96	61	94	95	48	65	42	44	51
50	60	88	64	94	64	55	51	52	

CHET43

184	166	173	157	116	163	111	105	110	121
149	145	168	203	159	125	97	116	118	107
100	81	115	52	65	63	81	80	71	100
114	105	123	98	55	87	78	82	89	82
65	53	38	46	49	62	98	67	82	73
69	74	60	77	80	72	75	82	88	193
147	147	136	142	101	82	146	88	134	201
171	115	84	78	138	144	179	115	168	148
130	90	90	101	99	146	133	121	103	109
127	109	129	170	150	193	198	172	155	171
224	251	180	187	147	99	149	168	190	204
141	103	129	122	99	108	110	142		

CHET44

181	124	138	157	167	117	196	160	129	173
209	121	134	115	136	153	121	98	121	130
133	96	116	120	215	181	140	160	178	139
206	202	184	273	256	242	167	205	213	237
323	284	230	222	186	196	143	220	230	247
201	147	140							

CHET45

389	541	299	293	257	334	308	265	221	229
342	372	320	246	259	222	123	139	146	103
111	129	125	120	137	158	137	159	113	135
148	198	168	173	189	136	94	114	113	132
135	101	96	77	62	60	53	82	77	86
94	88	100	84	102	84	120	120	96	90
85	78	68	56	67	54	64	61	64	73
58	116	87	109	132	110	115	100	90	115
146	121	113							

CHET46

410	382	257	231	197	144	182	189	201	123
156	192	131	118	264	238	174	94	165	154
147	185	137	134	69	64	80	103	86	92
98	68	108	146	204	146	96	124	104	86
64	68	73	67	63	83	84	80	75	71
123	136	125	200	161	95	95	88	95	82
73	70	70	50	51	40	53	52	41	55
62	57	74	69	43	50	48	55	66	64
66	45	39	40	41	47	57	47	51	65
50	55	55	72	83	67	106	101	113	176
177	169	108	109	57	49	100	54	76	109
140	83	71	83	94	96	84			

CHET48A

176	248	216	132	148	239	143	117	133	141
126	139	208	146	132	163	124	126	141	107
94	119	147	128	127	181	159	134	220	253
177	170	134	125	176	128	200	240	179	180
253	165	154	140	154	151	201	206	284	275
242	239	187	173	178	251	211	381	258	232
170	150	152	201	143	122	131	151	164	245
255	192	248	222	141	95	83	125	88	103
101	112	154	146	147	175	209	184	193	170
156	111	129	109	93	106	167	129	112	117
100	104	87	83	123	105	175	104	148	143
94	93	110	86	124	106	107	87	75	70
96	141	117	109	102	102	109	87	96	123
94	96	107	119	105	143	119	111	85	54
53	107	109	110	101	172	142	117	120	89
153	112	101	175	193	205	308	182	171	162
175	117	134	127	176	152	145	153	166	138
121	150	155	130	146	90	115	115	176	145
140	169	142	168	187	168	140	194	162	179
182	152	91	113	103	89	146	97	102	132
120	110	131	108	103	92	86	107	98	91
106	100	126	107	111	172	177	220	195	171
181	173	168	156	139	138	200	159	172	158

CHET48B

161	187	153	142	214	163	171	191	170	127
133	146	134	149	164	135	131	156	120	155
129	122	71	98	135	112	106	115	101	120
162	198	150	123	113	107	177	159	240	322
209	222	127	123	123	171	144	157	186	175
211	292	252	252	272	221	160	341	284	370
293	285	215	193	219	241	161	137	143	156
161	186	268	188	270	244	199	143	144	135
141	150	116	101	142	126	116	120	130	177
179	156	137	136	155	143	119	119	165	144
117	117	124	111	87	73	106	87	157	88
118	155	128	109	134	106	135	113	106	93
63	59	97	114	106	120	98	116	90	78
71	72	70	95	107	97	96	146	109	95
67	52	80	139	112	106	122	166	148	131
103	87	122	116	130	144	147	122	150	165
136	144	127	108	120	115	143	152	168	174
184	156	113	160	156	124	115	97	97	116
147	131	152	154	142	195	218	169	148	194
146	170	150	139	129	117	100	114	143	101
101	128	121	113	127	125	107	79	93	99
93	71	82	80	93	89	93	134	133	174
192	135	166	221	157	194	193	230	249	278
239	131	123							

CHET49A

217	160	180	243	191	237	218	177	157	166
169	139	125	150	159	147	198	151	133	155
118	127	112	94	87	111	156	145	139	139
134	137	216	240	192	124	132	92	144	131
208	267	192	176	260	141	167	140	141	151
192	195	296	305	286	242	227	152	181	281
254	378	265	225	177	162	170	202	150	131
132	149	186	230	227	242	231	215	155	99
91	113	105	111	115	108	138	158	132	155
205	230	194	162	152	144	143	111	102	108
148	118	127	117	111	111	96	87	136	130
178	113	164	138	91	105	130	169		

CHET49B

492	549	501	490	364	620	554	471	421	282
308	275	418	282	384	322	235	170	152	197
177	198	198	215	276	218	268	312	370	393
432	325	211	203	213	221	231	224	355	329
380	405	287	357	152	110	250	155	356	191
209	183	150	164	228	173	257	243	177	135
80	72	138	193	207	166	159	162	110	110
105	146	93	131	173	139	156	256	151	120