DENDROCHRONOLOGICAL ANALYSIS OF OAK TIMBERS FROM 6 HIGH STREET, WARMINSTER, WILTSHIRE, ENGLAND

Tree-Ring Services Report: BAHB/32/14

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SUMMARY

6 High Street lies on the north side of the street. The building is of three bays. The second truss from the west shows evidence of partitioning above the collar and some smoke blackening. The gabled roof is of clasped-purlin construction with two tiers of in-line butt purlins. The collars are slightly cambered. The windbraces are curved and the rafters lie flatways. The wall-framing consisted of large rectangular panels with jowled posts, and one straight down brace was evident. The front of the building was jettied.

Tree-ring series from four of seven samples taken from 6 High Street were matched together to form a 95-year site chronology which spans AD 1406 to AD 1500. Sapwood was identified on all four of the samples dated and a mean felling-date range indicates that construction is most likely to have occurred between AD 1499 and AD 1531. Cross-matching is sufficiently high to indicate that the timbers dated were probably locally sourced.

KEYWORDS

Dendrochronology, 16th Century, Wiltshire, Warminster.

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INTRODUCTION

The increased interest in Britain's past was evinced by such television programmes as "Time Team" and "The House Detectives". Today, more and more people wish to know precisely when ancient buildings were constructed in order to better understand the history of the land in which we live. However, although there is some ability to date a building on stylistic grounds, a precise date is rarely known except when there is a date-stone or documentary evidence.

The advent of dendrochronology (tree-ring dating) is changing this scenario, at least for buildings with timbers containing sufficient rings for analysis. The science is simple in concept. The width of a tree's growth rings varies from year to year, so that each series of years has a unique pattern of narrow and wide rings. We now know in detail the pattern of rings shown by oak trees in England for at least the last 2000 years, and there is some work in progress on other species. Small cores of wood taken from the structural timbers of a building show the pattern of rings laid down during the lifetime of the trees from which the timbers were cut. If this pattern is then compared with "master chronologies" it is often possible to identify the felling date of the trees with astonishing accuracy. Where bark is present, it is possible to give a precise year, sometimes even the season of the year. We know that oak for building was almost always used "green", (unseasoned, not having been felled and prepared until required), so construction dates can be determined in which we can place considerable confidence.

Recording Timber-Framed Buildings

National trends in building activity inevitably conceal regional differences that can only be explained by detailed local studies. The Royal Commission on the Historical Monuments of England (RCHME) has analysed 53 medieval buildings in Kent (Pearson 1994). Hampshire County Council has analysed well over 100 buildings in the county (Roberts 2003). These projects utilize the specific dates provided by tree-ring analysis to refine the typological and stylistic dating of buildings.

Harris (1978) provides a useful introduction to the study of timber-framed buildings, while Brunskill (2000) details the study of vernacular architecture. Alcock's (1996) glossary provides illustrative drawings which are particularly useful in facilitating the naming of timbers in a building.

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Figure 1: Area location map

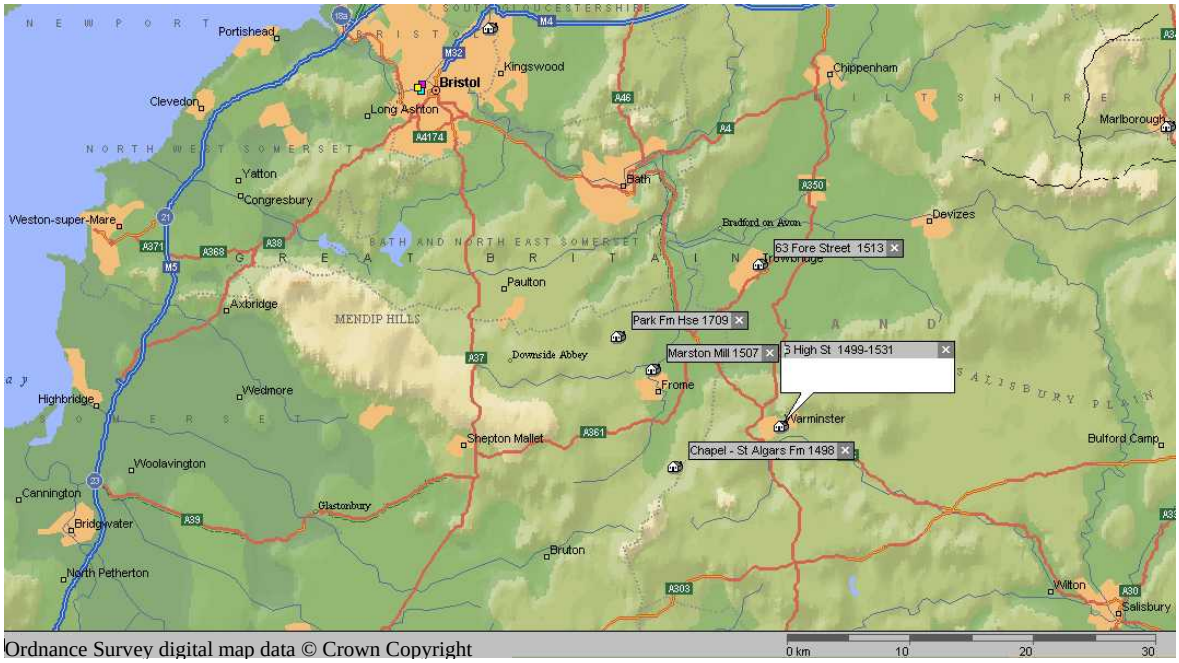
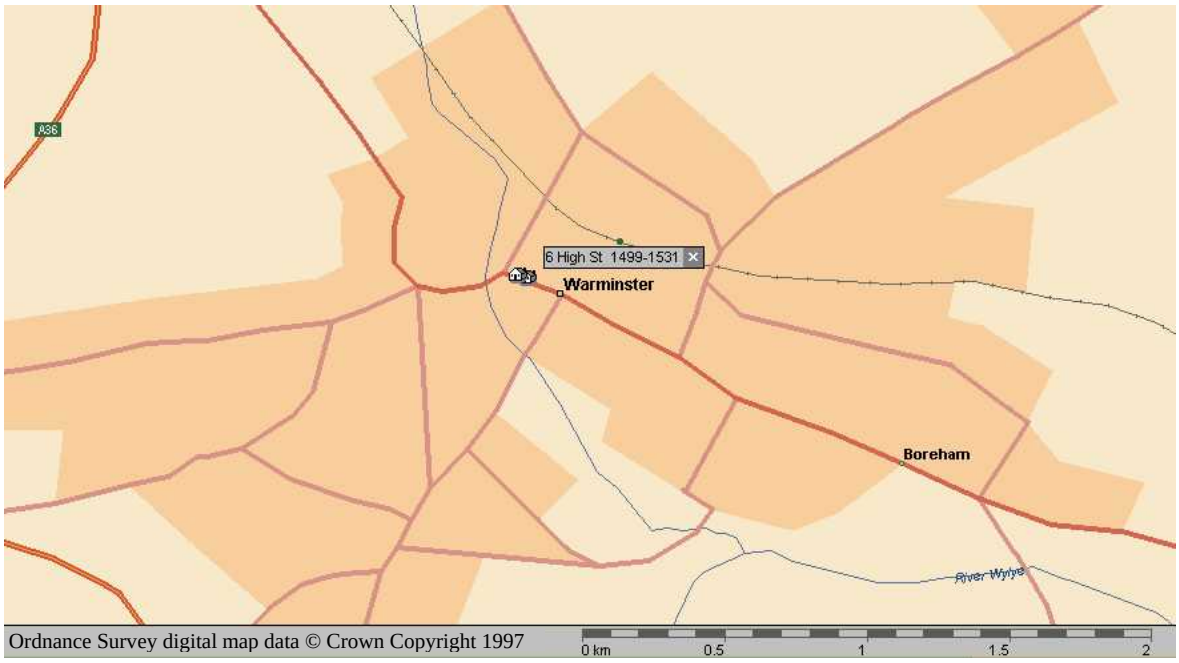


Figure 2: Site location map



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6 High Street (NGR: ST 8538 4512)

6 High Street lies on the north side of the street. The building is not listed as timber-framed, but was identified as substantially timber-framed by Dorothy Treasure of the Wiltshire Buildings Record in 1999.

The building is of three bays. The second truss from the west shows evidence of partitioning above the collar and some smoke blackening. The gabled roof is of clasped-purlin construction with two tiers of in-line butt purlins. The collars are slightly cambered. The windbraces are curved and the rafters lie flatways. The wall-framing consisted of large rectangular panels with jowled posts, and one straight down brace was evident. The front of the building was jettied.

Photo 1: 6 High Street – south aspect

Objective of the Analysis

The objective of this analysis was to provide dendrochronological evidence to date the primary phase of construction.

Dendrochronological Assessment

6 High Street was visited on the 19th November 2014. Oak timbers with more than 50 rings, traces of sapwood or bark, and accessibility were the main considerations. All the rafters were accessible from the attic. While many of the common rafters appeared to have been replaced, the principal rafters appeared to be original and contained sufficient rings to attempt sampling. While the majority of the wall-framed timbers were inaccessible, access was possible in the west end bay of the building. While full sapwood was found on three timbers, this was considered too friable to be successfully recovered by core sampling.

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METHODOLOGY

Methods employed by Tree-Ring Services in general are those described in English Heritage guidelines (Hillam 1998). Part 2 of the Guidelines is designed for large projects in conjunction with other specialist disciplines and is not applicable to the type of privately commissioned dendrochronological analysis generally conducted by Tree-Ring Services and is therefore not used. Details of the methods employed for the analysis of this building are described below.

Sampling and Preparation

Whenever possible, timbers with more than 50 annual growth rings are selected for sampling. This is necessary to provide a pattern of rings of sufficient length to be unique to the period of time when the parent tree was growing. Sections are immediately labelled on site, ready for subsequent analysis.

Tree-ring series are revealed through sanding with progressively finer grits to a 600 abrasive grit finish to produce results suitable for measuring, see **Photo 2**. When required, for example where bands of narrow rings occur, further preparation is performed manually.

Photo 2: An example of the tree-ring series revealed through the sanding of cores

Measuring and Cross-matching

Tree-ring series are measured under a ×20 stereo microscope to an accuracy of 0.01mm using a microcomputer-based travelling stage. All samples are measured from the centremost ring to the outermost. Samples considered unsuitable for dating purposes are then rejected. These include samples with disturbed ring series which cannot be measured due to knots or bands of extremely narrow rings, and those samples with fewer than 40 rings.

Samples of fewer than 50 rings are sometimes rejected from dendrochronological analysis because their ring patterns may not be unique (Hillam *et al.* 1987). Although this is certainly true of all ring series of fewer than 30 rings, which should not be used in dating (Mills 1988), samples with 30 to 50 rings may be dated in some circumstances (Hillam 1998). Because samples taken by Tree-Ring Services are often from listed structures, it has been felt wise to maximize the recorded amount of data, and series of 40–50 rings are included in analysis and considered for dating, usually when they match well with a number of other series. Samples are measured twice and the two sets of measurements cross-matched and plotted visually as a check. Where series match satisfactorily they are averaged and the resulting series are used in subsequent analysis. Series containing fewer than 50 rings are suffixed ‘-S’, and series from managed trees ‘-M’ to help indicate that additional caution must be exercised in dating.

Cross-correlation algorithms are then employed to search for the positions where tree-ring series correlate and therefore possibly match. All statistical correlations are reported as *t*-values derived from the original CROS73 algorithm (Baillie and Pilcher 1973). A value

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of 3.5 or over is usually indicative of a good match as it represents the value of *t* which should occur by chance only once in every 1000 mismatches (Baillie 1982), and the higher the *t*-value the closer to congruency in the cross-matching. However, due to the remaining small risk of high *t*-values being produced by chance, all indicated correlations are further checked to ensure that corroborative high results are obtained at the same relative position against a range of independent tree-ring series. Visual comparisons of series are also employed to support or reject possible cross-matches and serve as a means of identifying measuring errors.

Timber Groups

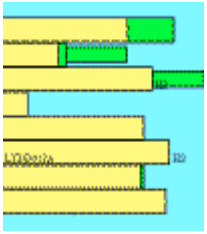
A further element of the tree-ring analysis of buildings and archaeological assemblages is the grouping of timbers within the sampled material. Inspection of *in situ* timbers may indicate that samples derive from a common timber, while common arrangements of anatomical features (knots & branching) may also indicate that samples are derived from a single tree.

Tree-ring analysis is used to support suggestions of same-tree groups between samples based on a combination of information. Timbers derived from the same tree are generally expected to have *t*-values over 10, although lower *t*-values may be produced when different radii measured from the same tree are compared. Tree-ring series producing *t*-values of 10 or above are examined to identify same-tree groups. Good comparisons of visual matching, growth rates, short and longer-term growth patterns, are combined with pith information, sapwood boundaries, bark and anatomical anomalies, to help decide whether timbers are likely to come from the same tree. Where timbers are assessed as deriving from the same tree, to avoid bias the series are averaged to produce a single tree-ring series before inclusion in the final site chronology, but inevitably some same-tree samples go undetected by dendrochronology.

Chronology Building and Cross-dating

The process of cross-matching compares all tree-ring series against one another and those found to cross-match satisfactorily together are combined to create an average series. The site mean(s) and individual ring series which remain unmatched with the site mean are then tested against a range of established reference series (reference chronologies). Significant *t*-values replicated against a range of series at the same position with satisfactory visual matching are similarly used to establish cross-matches with reference chronologies. Where cross-matching is established against dated reference chronologies, calendar dates can be assigned to the site series. The dates of the first and last rings of dated series are produced as date spans. These dates should not be confused with felling dates.

Felling Dates



Series dated by the cross-dating process provide calendar year dates for the final tree-ring present in the measured timber sample. The interpretation of these dates then relies upon the nature of the final rings in the series. Where bark survives intact on a sample a felling date is given as the date of the last ring measured on the tree-ring series. Based on the completeness of the final ring it is sometimes even possible to distinguish between spring, summer or winter fellings, corresponding to

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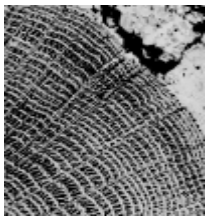
approximately March to May, June to September and October to February, respectively. Where timbers were felled in either spring or summer and the final ring is incomplete and therefore not measured, allowance has to be made for the one-year discrepancy between the end of a measured series and the actual year of felling.

Sapwood Estimates

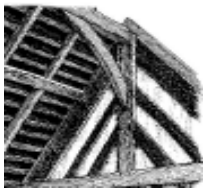


Where bark is missing from oak samples, as long as either sapwood or the heartwood/sapwood boundary have been identified, an estimated felling-date range can be calculated using the maximum and minimum number of sapwood rings that were likely to have been present. Sapwood estimates have varied over time with different data sets, geographical location and researchers. A general trend identified is that the number of sapwood rings in oak decreases from north to south and from west to east across Europe.

However, simply not enough is yet understood about sapwood variations and the mechanisms responsible for them. A generally accepted sapwood estimate of between 10 and 55 rings for British and Irish oaks (at 95% confidence) was given in 1987 (Hillam *et al.* 1987). Analysis of the increased data set available ten years later indicates a range of 10 to 46 rings to be more appropriate for England (Tyers 1998). Currently, as research in areas improves, sapwood estimates are refined and new estimates applied. Therefore, when dendrochronological dates are produced, the reference to the sapwood estimate used in its calculation should always follow.

This report applies a sapwood estimate of a minimum of 9 and maximum of 41 annual rings, which means that 19 out of every 20 trees examined is expected have between 9 and 41 sapwood rings. This sapwood estimate is currently applied to most of the south-east region and has been arrived at by Oxford Dendrochronology Laboratory (Haddon-Reece *et al.* 1990, Miles 1997). Felling-date ranges have been calculated by adding the sapwood estimate of minimum and maximum missing rings to the date of the heartwood/sapwood boundary. Felling-date ranges have been refined by the presence of surviving sapwood where appropriate, see **Table 2**. Where samples ending in heartwood were dated, "felled after dates" have been calculated by adding the minimum expected number of missing sapwood rings to the samples' final ring dates. These dates represent the earliest probable felling dates. However, the actual felling date of a tree may be decades later due to an unknown number of missing heartwood rings.

Felling Groups



It is common to find that timbers used in the construction or repair of smaller buildings, or identifiable parts of larger buildings, date into groups whose felling dates occur within a narrow range of years. These groups are called associated fellings. Where they are identified the average heartwood/sapwood boundary of the component timbers is used to calculate an overall estimated period of felling. Close location association and a short (21 years at most) range of heartwood-sapwood boundary dates are normally used to define these groups. The estimates do not assume that trees within a group were felled at the same time. However, evidence published by the Nottingham University Tree-Ring Dating Laboratory indicates that the range estimate encompasses the possible different individual felling dates (English Heritage 2001). Where bark is present within a group of timbers and other evidence does not dispute the date, it is assumed that all the trees within a felling group were felled in the same year.

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Date of Construction

It is vitally important to understand that dendrochronological analysis provides dates for when trees were felled and not necessarily when their timbers were used. Green or freshly felled wood is, however, far easier to work and it is standard practice to assume that medieval timbers were felled as required and used green (Rackham 1990, Miles 1997). However, the use of previously felled timbers in vernacular construction was not uncommon, with short-term stockpiling of usually not more than 1 to 2 years (Miles 1997), and the use of leftovers or re-used timbers may certainly give rise to differences between felling dates and the date of construction where samples are analysed in isolation. A number of samples having a close range of felling dates are required from different elements of a building either to strongly indicate a single date of construction or to identify separate phases of construction.

Tree-Ring Services - Methods and Criteria

Tree-ring analysis and graphics are achieved via a dendrochronological programme suite developed by Ian Tyers of Sheffield University (Tyers 1999). Location maps are produced using *Microsoft AutoRoute Express GB 98 Auto Street Navigator*, which uses Ordnance Survey digital map data © Crown Copyright 1997. Alcock's (1996) timber-framed building nomenclature has been adopted throughout to facilitate regional comparisons.

For the analysis of a building an initial assessment is conducted with the owner and recommendations in line with English Heritage guidelines on sampling strategies made, (i.e., that a minimum of 8 to 10 samples are obtained per building or per phase). However, the final decision concerning the number of samples taken for analysis rests with the individuals who commission the analysis. It is generally beyond the scope of an analysis to describe a building in detail or to undertake the production of detailed drawings. Without the benefit of other specialist disciplines there is always the danger that re-used timbers may be inadvertently selected, and the conclusions presented in a report may be modified in the light of subsequent work.

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RESULTS

A total of seven cores were taken from 6 High Street on the 19th November 2014. The main timber trusses of the building were labelled from 1 in the south-west corner to 4A in the north-east corner. Sampling locations are indicated on a sketch plan of the building (see **Appendix I**) and the locations of cores taken are also shown in the photographs below.

Photo 3: Cores BAHB01 (left) & BAHB02 (right)

Photo 4: Cores BAHB03 (right) & BAHB04 (left)

Photo 5: Cores BAHB05 (right) & BAHB06 (left)

Photo 6: Core BAHB07

In the laboratory, the seven samples taken were all confirmed as oak (*Quercus* spp). One series containing less than 30 rings was rejected from further analysis at this stage.

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Three series that contained less than 50 rings were identified by the suffix '-S'. One sample, BAHB01, was taken from where the sapwood was complete, but the end 20mm of sapwood broke off. Six series were of sufficient length to be considered for cross-matching. Four series were found to match together (see **Table 1**), and were combined to form an 95-year site chronology named WARMT-HB.

Table 1: Cross-matching between the four series from 6 High Street, which form the site chronology WARMT-HB

Filenames	Start dates	End dates	BAHB03	BAHB04-S	BAHB06
BAHB02-S	AD1431	AD1472	4.20	\	3.76
BAHB03	AD1406	AD1494		4.51	4.74
BAHB04-S	AD1459	AD1500			3.22
BAHB06	AD1438	AD1495			

KEY: - = *t*-values less than 3.00. \ = overlap < 30 years.

This site chronology was found to produce consistently high *t*-values against reference chronologies (**Table 2**) and to visually cross-match (**Figure 3**), with the first ring of the series at AD 1406 and the final ring of the series at AD 1500.

Table 2: Dating evidence for site chronology WARMT-HB against reference chronologies

WARMT-HB dated AD 1406 TO AD 1500					
File	**Start Date**	**End Date**	***t*-value**	**Overlap (yr.)**	**Reference chronology**
TROWB-FS#	AD1378	AD1512	6.68	95	63 Fore Street - Trowbridge - Wiltshire (Moir 2013)
WILT-26	AD1053	AD2006	5.99	95	Wiltshire area reference chronology (Author, unpublished)
BAMM05$	AD1395	AD1506	5.82	95	Bresummer - Marston Mill - Frome - Somerset (Moir 2014)
LYDNEY	AD1360	AD1591	5.81	95	Nass House - Lydney - Gloucestershire (Howard *et al.* 1998)
SINAI	AD1227	AD1750	5.62	95	Sinai Park - Staffordshire (Tyers 1997)
MOTTISFT	AD1388	AD1538	5.43	95	Mottisfont Abbey - Romsey - Hampshire (Miles 1996)
CAPEL-TE	AD1366	AD1571	5.35	95	Temple Elfande - Capel - Surrey (Moir 2003a)
SOMERST36	AD1095	AD2011	5.30	95	Somerset area reference chronology (Author, unpublished)
COOLHAM	AD1416	AD1548	5.26	85	Coolham Barn - Billingshurst - West Sussex (Moir 2002)
RUSPR-AV	AD1382	AD1580	5.02	95	Averys - Rusper - West Sussex (Moir 2003b)
TIDWORTH#	AD1363	AD1512	4.80	95	Holy Trinity Church - North Tidworth - Wiltshire (Bridge 2009)
HUBS04	AD1384	AD1532	4.73	95	West purlin - 2 Bridge Street - Hungerford - Berks (Moir 2011)

KEY: **Bold** = indicates a composite reference chronology consisting of multiple site chronologies. # = a component of the WILT-26 reference chronology. $ = a component of the SOMERST36 reference chronology.

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Series BAHB01 AND BAHB05-S failed to cross-match and therefore remain undated at this time.

INTERPRETATION

Felling Dates

The sapwood allowance used to calculate the felling dates now discussed is presented in **Table 3**, and the bar diagram (see **Figure 3**) helps to demonstrate the findings visually.

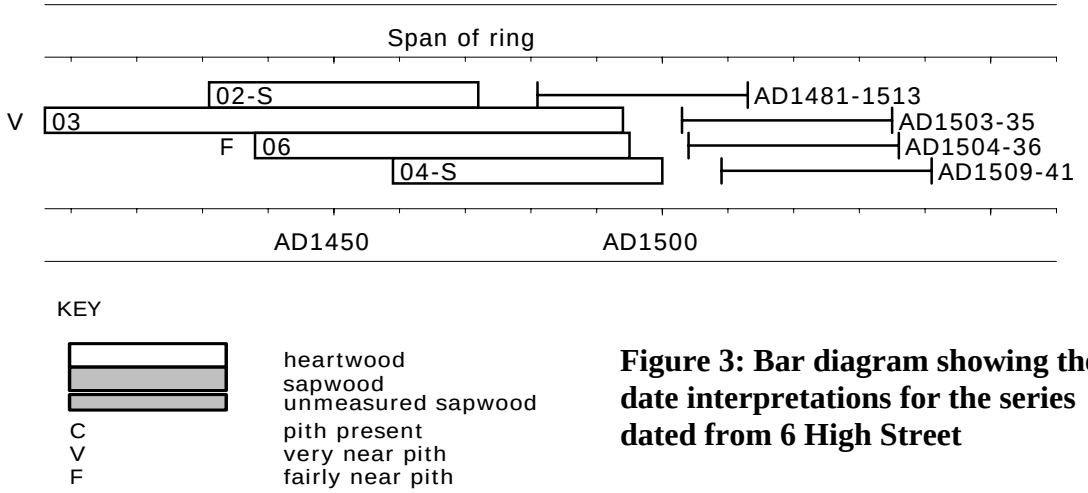

Figure 3: Bar diagram showing the date interpretations for the series dated from 6 High Street

6 High Street produces four felling-date ranges. A mean felling-date range for these four samples is calculated to be AD 1499 to AD 1531. This evidence indicates that construction of 6 High Street is most likely to have occurred between AD 1499 and AD1531.

Timber analysis

Cross-matching against individual buildings (including a building in Trowbridge) and the Wiltshire county reference chronology is sufficiently high to indicate that the timbers dated are likely to have been sourced locally.

CONCLUSIONS

Tree-ring series from four of seven samples taken from 6 High Street were matched together to form a 95-year site chronology which spans AD 1406 to AD 1500. Sapwood was identified on all four of the samples dated and a mean felling-date range indicates that construction is most likely to have occurred between AD 1499 and AD 1531. Cross-matching is sufficiently high to indicate that the timbers dated were probably locally sourced.

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Table 3: Summary of dendrochronological analysis

Sample	Timber and Position	Timber Conversion	Timber Dimensions (mm)	Rings	Sapwood	Average Growth Rate (mm/yr)	Sequence Date Range	Felling Date Range	Rings to Pith		Age Estimate
BAHB01	South principal rafter - truss 3	B2	230 x 120	65	+HS	2.26				10	93
BAHB02-S	North principal rafter - truss 3	B2	240 x 110	42	+HS	1.42	AD1431-AD1472	AD1481-1513	>	15	75
BAHB03	North principal rafter - truss 2	B2	250 x 120	89	+HS	1.62	AD1406-AD1494	AD1503-35		5	112
BAHB04-S	South principal rafter - truss 2	B2	200 x 100	42	+HS	2.52	AD1459-AD1500	AD1509-41	>	15	75
BAHB05-S	Post 2A	A2	280 x 230	42	+HS	1.90				10	70
BAHB06	North wallplate - bay 1	A2	170 x 180	58	+HS	2.04	AD1438-AD1495	AD1504-36		10	86
BAHB07	Post 1	?	0 x 0	29	+HS					10	57

KEY	
+	= additional information not measured on the core
(+)	= unmeasured heartwood rings at the beginning or end of the core
HS	= heartwood/sapwood boundary
?B	= probable bark
¼B	= spring bark
½B	= summer bark
Bw	= winter bark
A2	= boxed heartwood & trimmed
B2	= halved & trimmed
C2	= quartered & trimmed
E2	= tangential & trimmed

Note: Timber dimensions were generally taken at the core sample location and are not necessarily the maximum dimensions of the timber.

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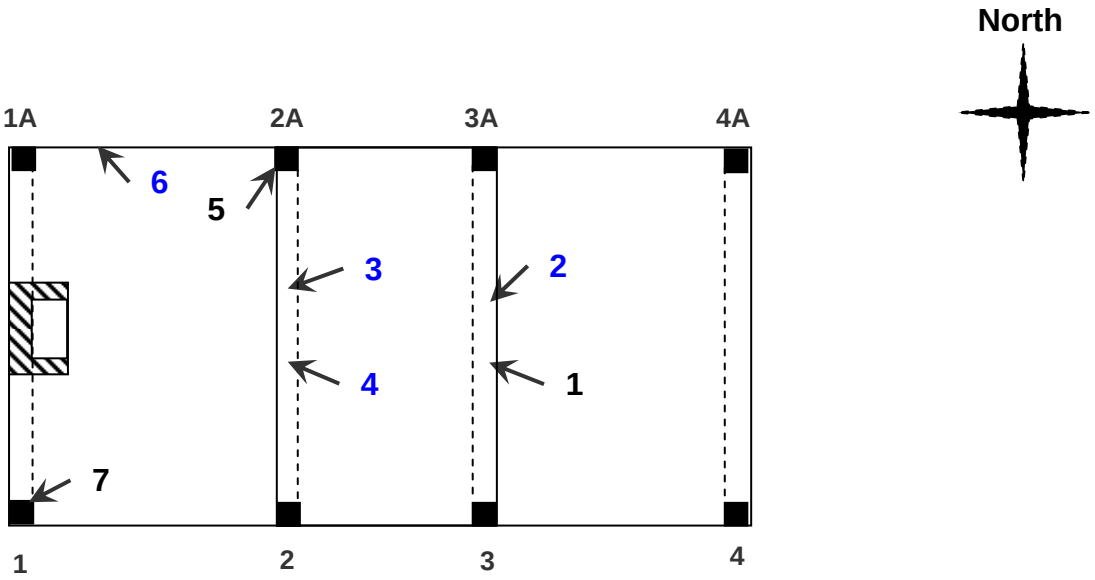
APPENDIX I: Plan of 6 High Street (Not to scale)



KEY:
Numbers identify location of the cores taken.
Blue = dated to AD 1499-1531
Grey = Undated cores

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