the nottingham tree-ring dating laboratory

Dendrochronology, timber analysis, and historic building consultants

TUDOR HOUSE, MAIN STREET, THORPE BY WATER, RUTLAND

TREE-RING ANALYSIS OF TIMBERS

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SUMMARY

Analysis by dendrochronology of 19 samples obtained from the roof trusses of Tudor House has resulted in the production of two dated site chronologies.

The first site chronology, TBWASQ01, comprises eight samples, with at least one sample from each of truss 3, 4, 5, 6, and 7. This site chronology is 90 rings long, these rings dated as spanning the years 1487–1576. Interpretation of the sapwood on these eight samples would indicate that the timbers were all cut as part of a single programme of felling at some point between 1586 and 1611, and may well be the work recorded by the stone plaque dated '1597'.

The second site chronology, TBWASQ02, comprises six samples, three from truss 1 and three from 2. This site chronology is 91 rings long, these rings dated as spanning the years 1588–1678. Interpretation of the sapwood on these six samples would indicate that the timbers were again all cut as part of a single programme of felling, this taking place in 1678.

Three samples remain ungrouped and undated, while two final samples were not measured because they had too few rings for reliable analysis.

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Introduction

Tudor House, on Main Street in Thorpe by Water (SP 893 964, Figs 1a/b), is a Grade II*, L-plan building (Fig 2), constructed of coursed limestone rubble beneath a Collyweston slate roof. The gables of the front range roof are coped and there are two fine ashlar chimneys with pairs of square shafts, one to the west gable and another, two-thirds the way along to the east, between trusses T4 and T5. The house has a main front range of three-room plan and a one-room rear north-east wing, both of two and a half storeys. A rather later service wing to the rear north-west has been much reconstructed.

It appears that the original building was a lower house, comprising the central and eastern sections of the front range. Then, in 1597, a two-and-a-half storey rear north-east wing was built and the front range was raised to match. In the late seventeenth century, the west end was either added as a new build, or, (if it had been built earlier which is a possibility), it was rebuilt.

Extract description of the roofs from the buildings archaeology survey undertaken by Nick Hill and Robert Ovens

The roof structure to the west end of the front range has two quite slender A-frame trusses (T1 and T2), with two sets of high-set tenoned collars but without original tiebeams, this suggesting that the roof was designed to allow clear headroom. These trusses carry two sets of clasped purlins but have no ridge. The principal rafters have bridle joints at the apex while the purlins have straight-splayed scarf joints. These timbers are very neat and square-cut. The west truss (T1) has chiselled carpenter's marks: 'II' to the south side of the lower collar, and 'I' to the south side of the upper collar. The east truss (T2) has no carpenter's marks to the north, though the south side is covered by plating. The feet of the principal rafters are tenoned into heavy wall-plates.

The roof structure to the rest of the front block and to the rear wing is of different type. The central section has two trusses (T3 and T4), as does the east, (T5 and T6), while the rear wing has a single truss (T7) set at its junction with the front block with rafter couples, without trusses, beyond. The trusses have a high-set, slightly arched collars tenoned to the principal rafters.

Trusses T3 and T4 are of A-frame type, without tiebeams, though it is possible that the other trusses have tiebeams. Tenoned purlins are set high up at collar level to the south side between T3/T4 and T5/T6 to allow for former dormer windows, as well as to the cross-wall/T5 bay, to allow for a doorway from a spiral stairs; elsewhere the purlins are set lower. There are bridle joints to the apex of the principal rafters, but no ridge. Trusses T3 and T4 have the face side to the west, but appear to be without carpenter's marks in the three joint locations where evidence is visible. Truss T5 does, however, have the mark 'II' and T6 the mark 'I'. There are neat chamfers to the underside of the principal rafters and collar, with ogee stops.

At the level of the upper purlins a higher oak collar has been nailed onto the rafters to support a, perhaps original, ceiling. Cranked wind-braces are tenoned to the principal rafters, but simply lapped and nailed to the upper side of the lower purlins. The nailed joint detail is unusual, but clearly original. The continuity of the roof structure from the front block into the rear wing, including the valley construction, shows that both roofs are of the same date. The south section of the rear wing roof has slightly arched ceiling joists to the rafter couples, with flat joists to the north half. The rafter couples are simply supported on a long-span purlin, and have a plain-lapped upper collar, fixed only with nails, again an original detail.

Sampling

Sampling and analysis by tree-ring dating of the timbers within Tudor House were undertaken as part of a much larger Heritage Lottery Funded programme of research on the social, political and cultural history of the Manor of Lyddington. The Manor covers a number of small villages or hamlets in the area including Lyddington itself, Stoke Dry, and Thorpe by Water. Amongst the many other aims of this project the one most pertinent to this report is the survey, recording, and dating by dendrochronology of as many of the buildings of the parish as may prove suitable, it being hoped that a sustained programme of sampling will provide a substantial amount of tree-ring data.

Tudor House was initially identified as being of especial interest from an architectural perspective and one likely to provide suitable samples for dating. It was hoped that tree-ring dating might not only establish the date of its original construction, but also show the dates of its subsequent changes and possibly establish how much, if any, re-used older, or later inserted, material it contained.

With the aim of fulfilling this brief, core samples were obtained from a number of different timbers which appeared suitable for tree-ring dating by reason of having sufficient rings for reliable analysis, and by appearing to be pertinent to the construction and development of the house. Although there were other timbers potentially available for sampling most of these either appeared to have insufficient rings for dating, or appeared to be relatively modern (probably twentieth century) pieces inserted into the frame. Such timbers were not sampled.

Each sample was given the code TBW-A (for Thorpe by Water – site 'A'), and numbered 01–19. The sampled timbers are located on plans and sections made by Nick Hill and Robert Ovens as part of the historic survey and record of the house, these being given as Figures 3a–c. Details of the samples are given in Table 1, including the timber sampled and its location, the total number of rings each sample has, and how many of these, if any, are sapwood rings. The individual date span of each dated sample is also given. In this Table, following the schema of the survey report, the rear of the house is taken to be facing north, the front to be facing south. The trusses of the main range have been numbered from site west to east, followed by the single truss of the rear east wing.

The Nottingham Tree-ring Dating Laboratory would like to take this opportunity to thank the owners of Tudor House, Mr and Mrs Warman, for allowing tree-ring dating to be undertaken and cooperating so wholeheartedly with sampling. The Laboratory would also like to thank

Nick Hill and Robert Ovens for the use of their drawings in this report, and for their help in the interpretation and understanding of this building.

Tree-ring dating

Tree-ring dating relies on a few simple, but quite fundamental, principles. Firstly, as is commonly known, trees (particularly oak trees, the timber most commonly used in building construction until the introduction of pine from the late eighteenth century onwards) grow by adding one, and only one, growth-ring to their circumference each, and every, year. Each new annual growth-ring is added to the outside of the previous year's growth just below the bark. The width of this annual growth-ring is largely, though not exclusively, determined by the weather conditions during the growth period (roughly March–September). In general, good conditions produce wider rings and poor conditions produce narrower rings. Thus, over the lifetime of a tree, the annual growth-rings display a climatically influenced pattern. Furthermore, and importantly, all trees growing in the same area at the same time will be influenced by the same growing conditions and the annual growth-rings of all of them will respond in a similar, though not identical, way (Fig 4).

Secondly, because the weather over a certain number of consecutive years (the statistically reliable minimum calculated as being 54 years) is unique, so too is the growth-ring pattern of the tree. The pattern of a shorter period of growth, 20, 30**,** or even 40 consecutive years, might conceivably be repeated two or even three times in the last one thousand years, and is considered less reliable. A short pattern might also be repeated at different time periods in different parts of the country because of differences in regional micro-climates. It is less likely, however, that such problems would occur with the pattern of a longer period of growth, that is, anything in excess of 54 years or so. In essence, a short period of growth, anything less than 54 rings, is not reliable, and the longer the period of time under comparison the better.

Tree-ring dating relies on obtaining the growth pattern of trees from sample timbers of unknown date by measuring the width of the annual growth-rings. This is done to a tolerance of 1/100 of a millimeter. The growth patterns of these samples of unknown date are then compared with a series of reference patterns or chronologies, the date of each ring of which is known. When the growth-ring sequence of a sample 'cross-matches' repeatedly at the same date span against a series of different reference chronologies the sample can be said to be dated. The degree of cross-matching, that is the measure of similarity between sample and reference, is denoted by a '*t*-value'; the higher the value the greater the similarity. The greater the similarity the greater is the probability that the patterns of samples and references have been produced by growing under the same conditions *at the same time*. The statistically accepted fully reliable minimum *t*-value is 3.5.

However, rather than attempt to date each sample individually it is usual to first compare all the samples from a single building, or phase of a building, with one another, and attempt to cross-match each one with all the others from the same phase or building. When samples from the same phase do cross-match with each other they are combined at their matching positions to form what is known as a 'site chronology'. As with any set of data, this has the effect of reducing the anomalies of any one individual (brought about in the case of tree-rings by some non-climatic influence) and enhances the overall climatic signal. As stated above, it is the climate that gives the growth pattern its distinctive pattern. The greater the number of samples in a site chronology the greater is the climatic signal of the group and the weaker is the non-climatic input of any one individual.

Furthermore, combining samples in this way to make a site chronology usually has the effect of increasing the time-span that is under comparison. As also mentioned above, the longer the period of growth under consideration, the greater the certainty of the cross-match. Any site chronology with less than about 55 rings is generally too short for reliable dating.

Having obtained a date for the site chronology as a whole, the date spans of the constituent individual samples can then be found, and from this the felling date of the trees represented may be calculated. Where a sample retains complete sapwood, that is, it has the last or outermost ring produced by the tree before it was cut, the last measured ring date is the felling date of the tree.

Where the sapwood is not complete it is necessary to estimate the likely felling date of the tree. Such an estimate can be made with a high degree of reliability because oak trees generally have between 15 to 40 sapwood rings. For example, if a sample with, say, 12 sapwood rings has a last sapwood ring date of 1400 (and therefore a heartwood/sapwood boundary ring date of 1388), it is 95% certain that the tree represented was felled sometime between 1403 (1400+3 sapwood rings (12+3=15)) and 1428 (1400+28 sapwood rings (12+28=40)).

Analysis

Each of the 19 samples obtained from the roof timbers of this house was prepared by sanding and polishing. It was seen at this time that two of these, TBW-A11 and A14, had less than 30 rings, considerably fewer than the minimum required for providing meaningful data, and these were rejected from this programme of analysis. The annual growth ring widths of the remaining 17 samples were, however, measured, the data of these measurements then being compared with each other as described in the notes above. By this process two separate groups of cross-matching samples could be formed.

The first group comprises eight samples, these being derived from roof trusses 3, 4, 5, 6, and 7. The eight cross-matching samples were combined at their indicated off-set to form TBWASQ01, a site chronology with an overall length of 90 rings. This site chronology was then satisfactorily dated by repeated and consistent comparison with a large number of relevant reference chronologies for oak as spanning the years 1487 to 1576. The evidence for this dating is given in the *t*-values of Table 2.

The second group comprises six samples, with three of the samples from truss 1 and three from truss 2. These six samples were also combined at their indicated off-set positions to form TBWASQ02, a site chronology with an overall length of 91 rings. This site chronology was then also satisfactorily dated by repeated and consistent comparison with a large number of relevant reference chronologies as spanning the years 1588 to 1678. The evidence for this dating is given in the *t*-values of Table 3.

The relative position and date of the samples in the two dated site chronologies, TBWASQ01 and SQ02, are shown in the bar diagram Figure 5, where they are sorted not only by their site chronology, but also in respect of their source truss and in order of last measured ring date.

Both site chronologies were compared with the three remaining measured but ungrouped samples, but there was no further satisfactory cross-matching. The three remaining ungrouped samples were then compared individually with the full body of reference material, but again there was no further cross-matching or dating.

This analysis may be summarised as below:

Site chronology / samples	Number of samples	Number of rings	Date span	Felling date
TBWASQ01	8	90	1487–1576	1586–1611
TBWASQ02	6	91	1588–1678	1678
Undated	3	---	---	---
Unmeasured	2	---	---	---

Interpretation

Site chronology TBWASQ01

None of the eight samples in site chronology TBWASQ01 retains complete sapwood (the last ring produced by the tree immediately before it was cut down), and it is thus not possible to say precisely when any of the trees were felled. All the samples do, however, retain the heartwood/sapwood boundary (denoted by h/s in Table 1 and the bar diagram). This means that only the sapwood rings are missing. It will be seen from Table 1 and the bar diagram, Figure 5, that the relative position and the date of the heartwood/sapwood boundary on all eight samples is very similar, varying by only 12 years from relative position 78 (1564) on sample TBW-A15 to relative position 90 (1576), on sample TBW-A19. Such similarity in the boundary would strongly suggest that the trees represented by the eight samples were all cut at the same time as each other in a single episode of felling.

Given that the amount of sapwood on oak trees generally lies within known limits (the 95% probability interval being 15–40 sapwood rings), it is possible, in such a situation, to estimate a time-frame within which it is very likely that the felling of the timbers represented took place. As indicated in the notes on tree-ring dating above, this is done by calculating the simple average date of the heartwood/sapwood boundary on the samples that retain it and adding to this minimum and maximum number of sapwood rings (15–40). In this instance the average heartwood/sapwood boundary date on the eight samples is 1571, this giving an estimate felling date for the trees of 1586–1611.

The interpretation that all the trees of this group were cut at the same time as each other is further supported by the degree of cross-matching between a number of the samples, this being sufficiently high to suggest that some of the trees represented were growing very close to each other in the same copse or stand of woodland. Such trees were each affected in a similar way by the same growing conditions, this producing a very similar growth pattern in each tree. We find, for example, cross-matches with values of t=11.9 between samples TBW-A15 and 16, the north and south principal rafters respectively of truss 6, t=9.9 between samples TBW-A09 and A12, respectively the collars of trusses 3 and 4, or t=7.4 between samples TBW-A18 and A19, the principal rafters of truss 7. Had these trees been felled at very different times it is very unlikely that they would come to be used together in the same building. Indeed, given the level of cross-matching between some samples, and the fact that some of the principal rafters appear to be whole trees, it is likely that in some instances two beams have in fact been derived from a single tree.

Site chronology TBWASQ02

By contrast, three of the six samples in site chronology TBWASQ02, retains complete sapwood (this being denoted by upper case 'C' in Table 1 and the bar diagram). In each case, this last, complete, sapwood ring, and thus the felling of the tree represented, is dated to 1678. In this case the date and relative position of the heartwood/sapwood boundary on the five samples that retain it is even closer, varying by only two years from relative position 174 (1660) on sample TBW-A03, to relative position 176 (1662), on sample TBW-A06, this again emphasising the relationship between the similarity of this boundary and the felling date of the timbers. Likewise, the cross-matching between all the samples, including TBW-A04, which is without the heartwood/sapwood boundary and in theory could have been felled at any time after 1640, (the date of its last extant heartwood ring), is sufficiently high to suggest all the timbers have been derived from the same woodland source, and are again part of a single programme of felling.

Woodland sources

However, although the trees used for the two phases of felling found at Tudor House were each probably growing in the same respective woodland areas, it is not possible, with any great degree of precision or reliability, to say where these source woodlands might have been located. However, as may be seen from Tables 2 and 3, which lists the sites against which the two respective site chronologies have been cross-matched and dated, some of the highest t-values, ie, the greatest degrees of similarity, are found with reference data made up of timbers from nearby sites in Northamptonshire. Specifically, these are with Kirby Hall, probably less than four miles to the south of Thorpe by Water, and with Apethorpe Hall, about seven miles to the east. Although the source woodlands for these other buildings are themselves not known, it is likely that their timbers have come from the surrounding area, suggesting a similar general source for the timbers used at Tudor House.

Conclusion

Analysis of the timbers of Tudor House would clearly indicate that two phases of felling are represented by the roof trusses. An earlier phase, seemingly accounting for four of the trusses to the main range and the truss of the rear wing, have an estimated felling date between the very late-sixteenth century, after 1586, and the very early seventeenth century, before 1611. It will of course be noted that this estimated felling date range brackets the date, 1597, inscribed on the stone plaque at Tudor House, and it is quite likely that it is this work which is being recorded.

A later phase, represented by the two west-most trusses, is also found, these timbers being felled in 1678.

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Table 1: Details of tree-ring samples from Tudor House, Thorpe-by-Water, Rutland

Sample number	Sample location	Total rings	Sapwood rings*	First measured ring date (AD)	Heart/sap boundary (AD)	Last measured ring date (AD)
TBW-A01	North principal rafter, truss 1	61	h/s	1601	1661	1661
TBW-A02	South principal rafter, truss 1	61	h/s	1601	1661	1661
TBW-A03	Lower collar, truss 1	54	18C	1625	1660	1678
TBW-A04	North principal rafter, truss 2	53	no h/s	1588	------	1640
TBW-A05	South principal rafter, truss 2	67	17C	1612	1661	1678
TBW-A06	Lower collar, truss 2	55	16C	1624	1662	1678
TBW-A07	North principal rafter, truss 3	41	h/s	------	------	------
TBW-A08	South principal rafter, truss 3	45	h/s	------	------	------
TBW-A09	Lower collar, truss 3	61	h/s	1509	1569	1569
TBW-A10	North principal rafter, truss 4	49	h/s	------	------	------
TBW-A11	South principal rafter, truss 4	nm	---	------	------	------
TBW-A12	Lower collar, truss 4	55	h/s	1513	1567	1567
TBW-A13	North principal rafter, truss 5	50	h/s	1524	1573	1573
TBW-A14	South principal rafter, truss 5	nm	---	------	------	------
TBW-A15	North principal rafter, truss 6	76	h/s	1489	1564	1564
TBW-A16	South principal rafter, truss 6	79	h/s	1487	1565	1565
TBW-A17	Lower collar, truss 6	52	h/s	1524	1575	1575
TBW-A18	East principal rafter 7	54	h/s	1522	1575	1575
TBW-A19	West principal rafter 7	54	h/s	1523	1576	1575

*h/s = the sample has the heartwood/sapwood boundary, i.e., only the sapwood rings are missing

nm = sample not measured

C complete sapwood is retained on the sample; the last measured ring date is the felling date of the tree represented

Table 2: Results of the cross-matching of site chronology TBWASQ01 and the reference chronologies when the first ring date is 1487 and the last ring date is 1576

Reference chronology	*t*-value	
Kirby Hall, Northants	7.9	(Arnold and Howard forthcoming)
St Leonard's Church, Apethorpe, Northants	7.5	(Arnold and Howard 2008)
Newnham Hall Farm, Newnham Murren, Oxon	6.3	(Arnold and Howard 2006 unpubl)
Eastcote House, Hillingdon, Middex	5.9	(Arnold and Howard 2012)
Court House, Shelsley Walsh, Worcs	5.7	(Arnold *et al* 2008b)
Hilltop Farm, Staunton Harold, Leics	5.7	(Arnold *et al* 2008c)
Stoneleigh Abbey, Stoneleigh, Warwicks	5.7	(Howard *et al* 2000)
England, London	5.6	(Tyers and Groves 1999 unpubl)

Table 3: Results of the cross-matching of site chronology TBWASQ02 and the reference chronologies when the first ring date is 1588 and the last ring date is 1678

Reference chronology	*t*-value	
Kirby Hall, Northants	9.7	(Arnold and Howard forthcoming)
Wren Wing, Easton Neston, Northants	8.5	(Arnold *et al* 2008b)
Gatehouse, Kenilworth Castle, Warwicks	7.0	(Arnold and Howard 2007)
Wheatsheaf, Cropwell Bishop, Notts	6.5	(Arnold *et al* 2008a)
The Hall, South Luffenham, Leics	6.0	(Arnold *et al* 2002 unpubl)
Potterdike House, Newark, Notts	5.6	(Arnold *et al* 2002)
East Midlands Master Chronology	5.6	(Laxton and Litton 1988)
Church Farm, Hayton, Notts	5.5	(Arnold *et al* 2008a)

Site chronologies TBWASQ01 and TBWASQ02 are composites of the data of the relevant cross-matching samples as seen in the bar diagram Figure 5. This composite data produces 'average' tree-ring patterns, where the overall climatic signal of the growth is enhanced, and the possible erratic variations of any one individual sample are reduced. These 'average' site chronologies are then compared with several hundred reference patterns covering every part of Britain for all time periods. Each site chronology dates only at the time span indicated, each table giving only a small selection of the very best matches as represented by '*t*-values' (ie, degrees of similarity).

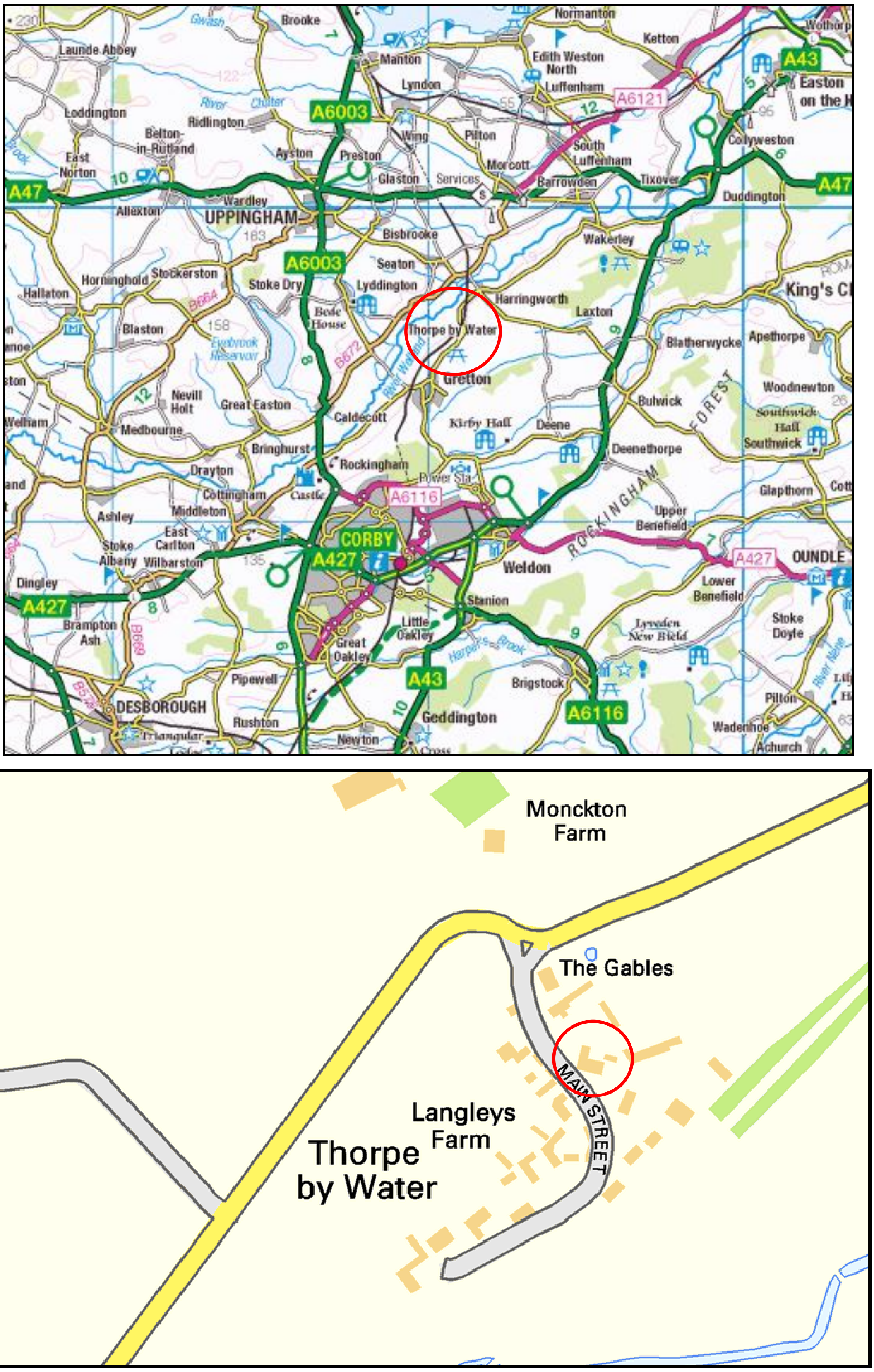


Figure 1a/b: Maps to show location of Thorpe by Water (top) and Tudor House (bottom)

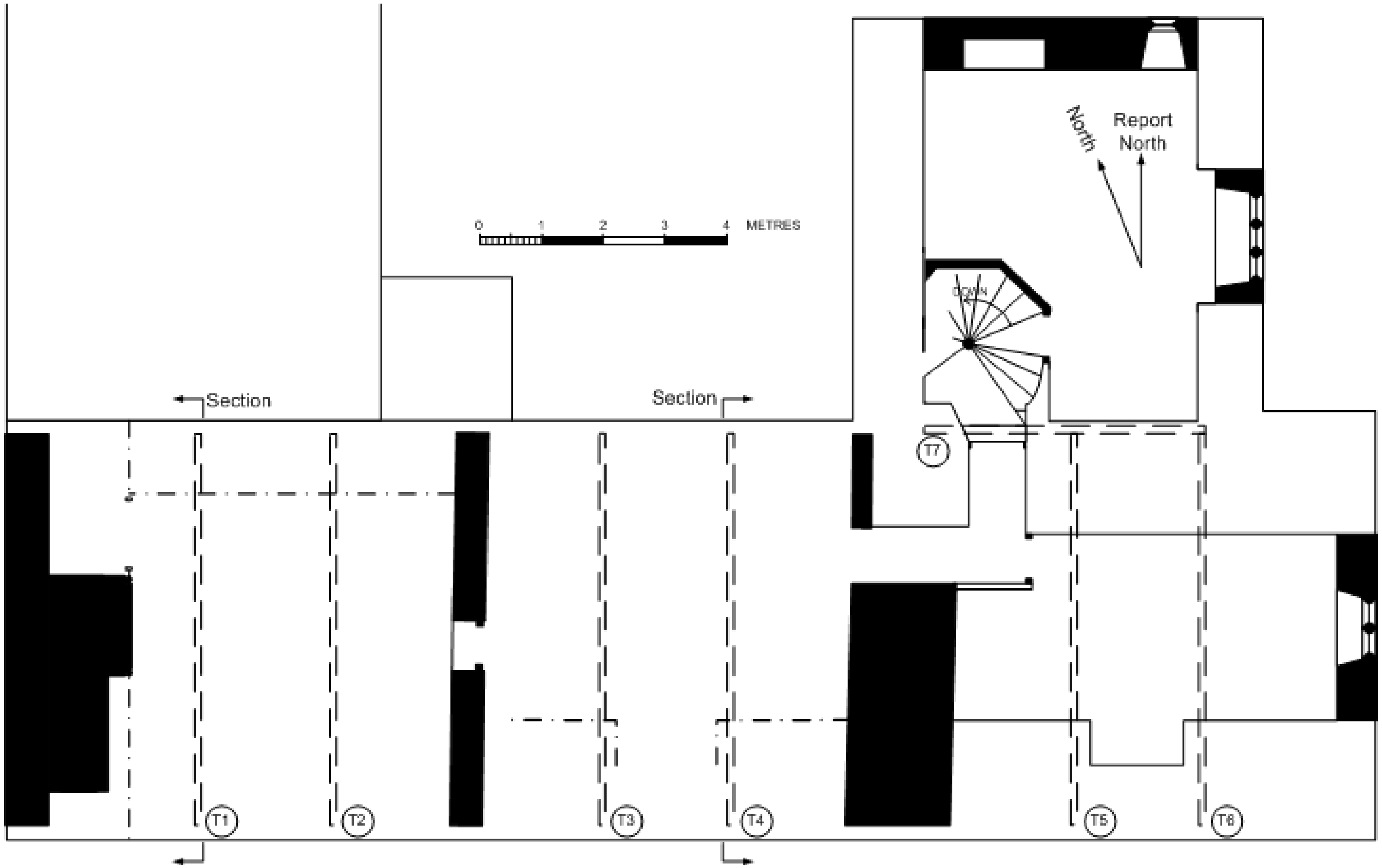


Figure 2: Plan of Tudor House at roof level to show position and arrangement of the trusses (after Nick Hill and Robert Ovens)

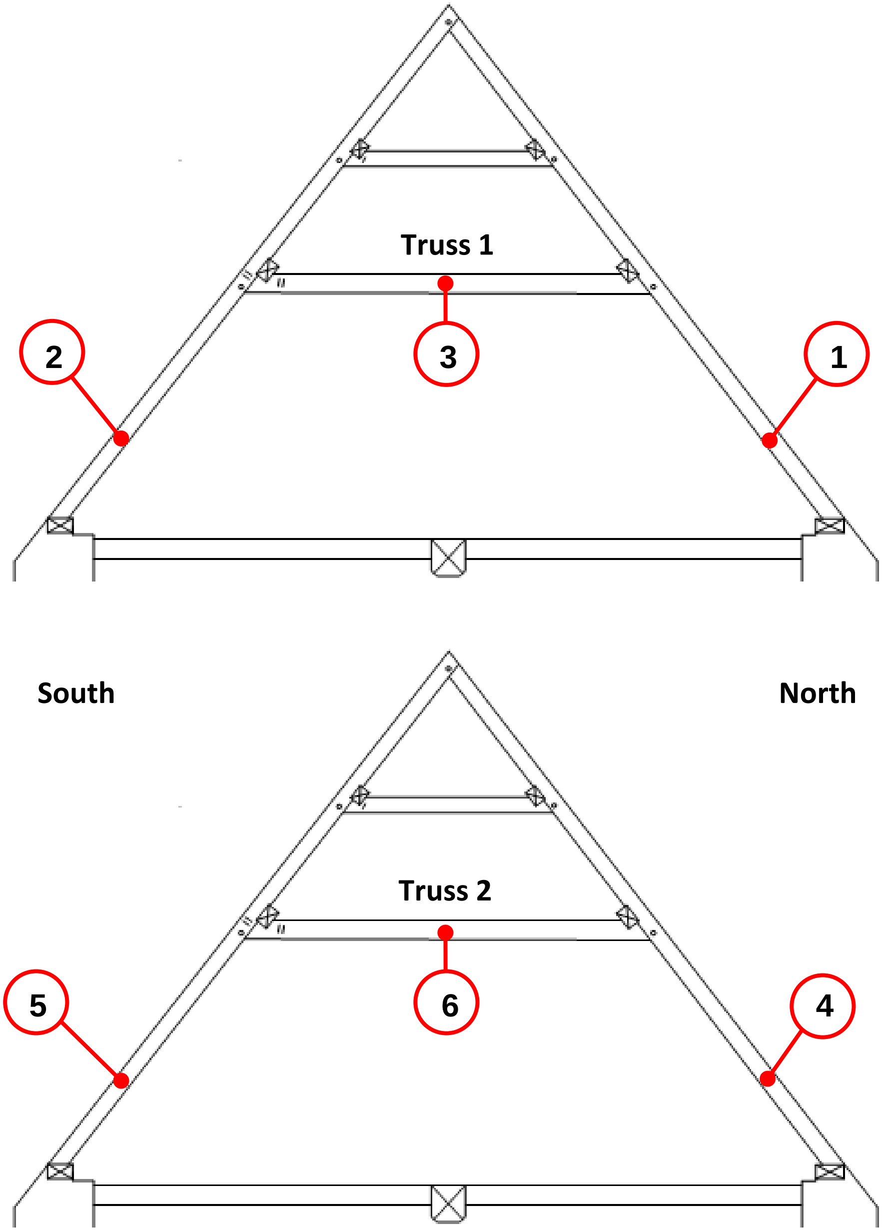


Figure 3a: Trusses 1 and 2 showing sampled timbers (after Nick Hill and Robert Ovens)

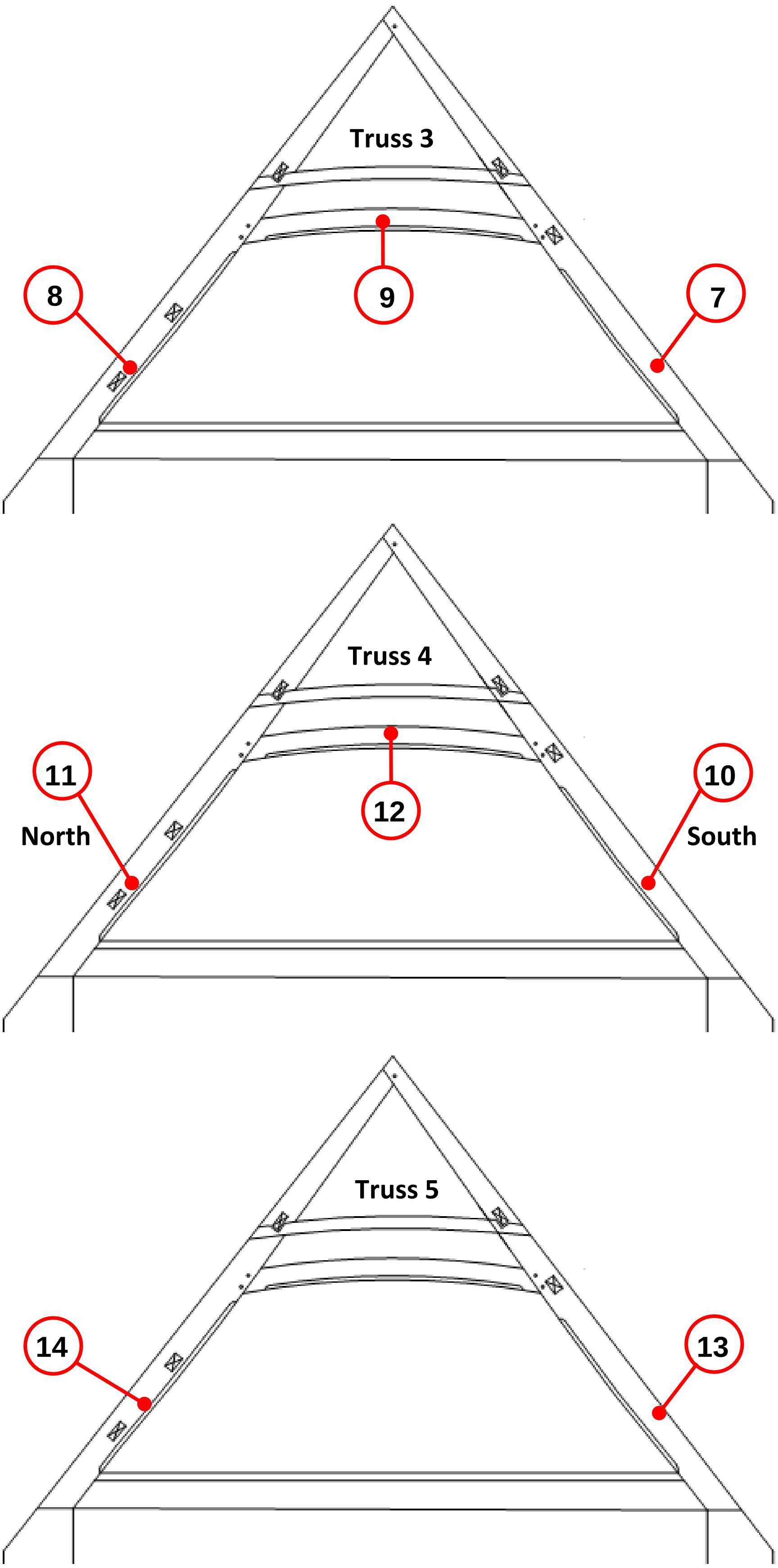


Figure 3b: Trusses 3–5 showing sampled timbers (after Nick Hill and Robert Ovens)

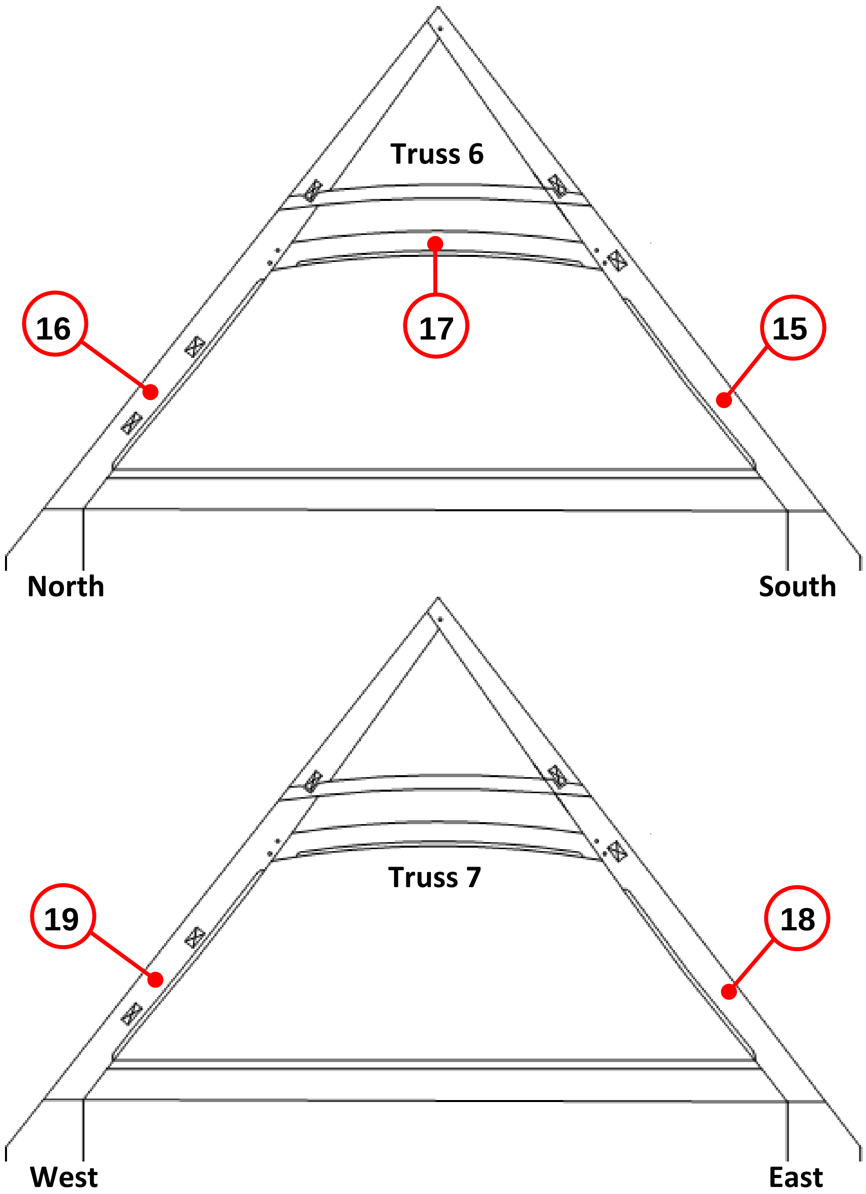


Figure 3c: Trusses 6 and 7 showing sampled timbers (after Nick Hill and Robert Ovens)

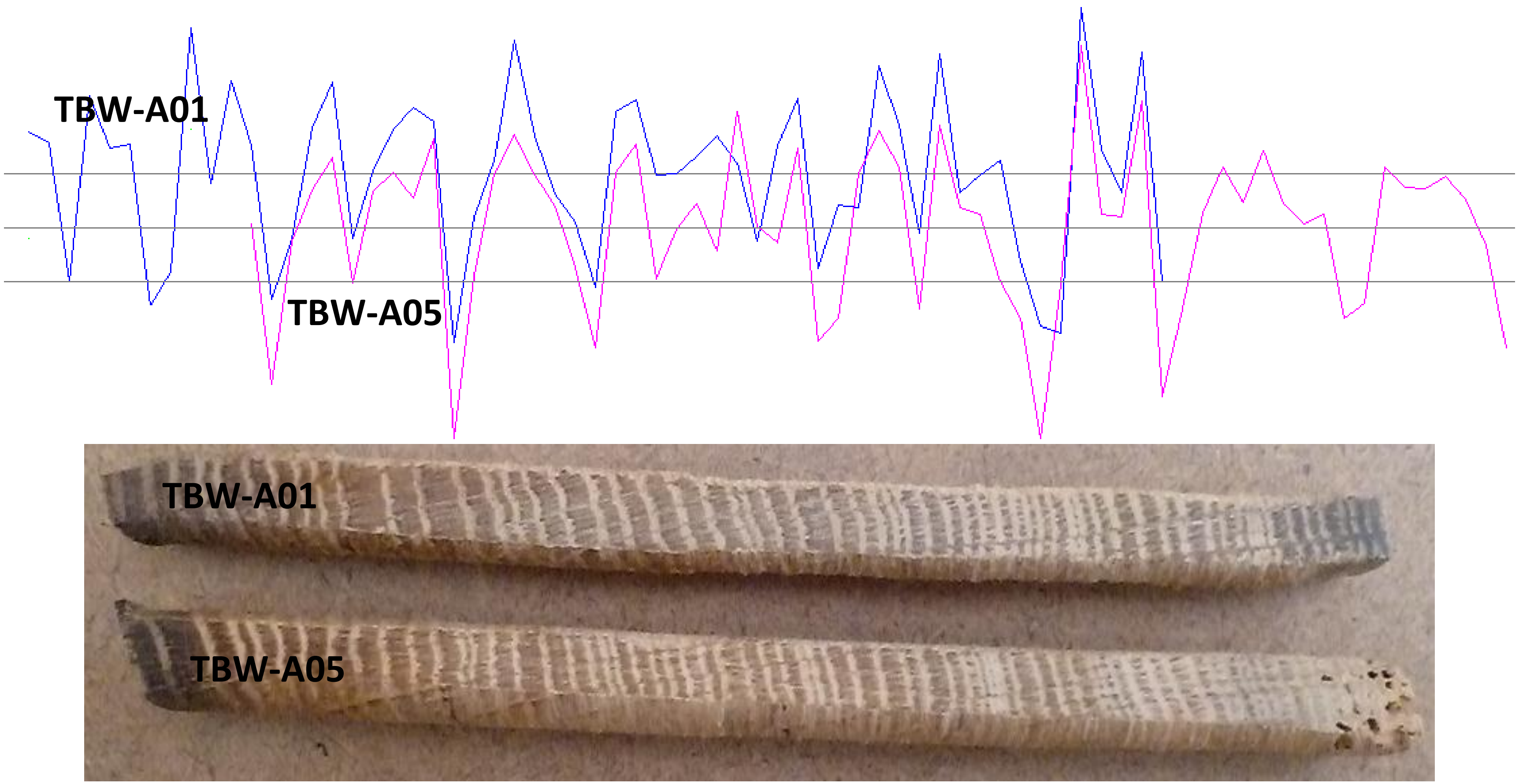
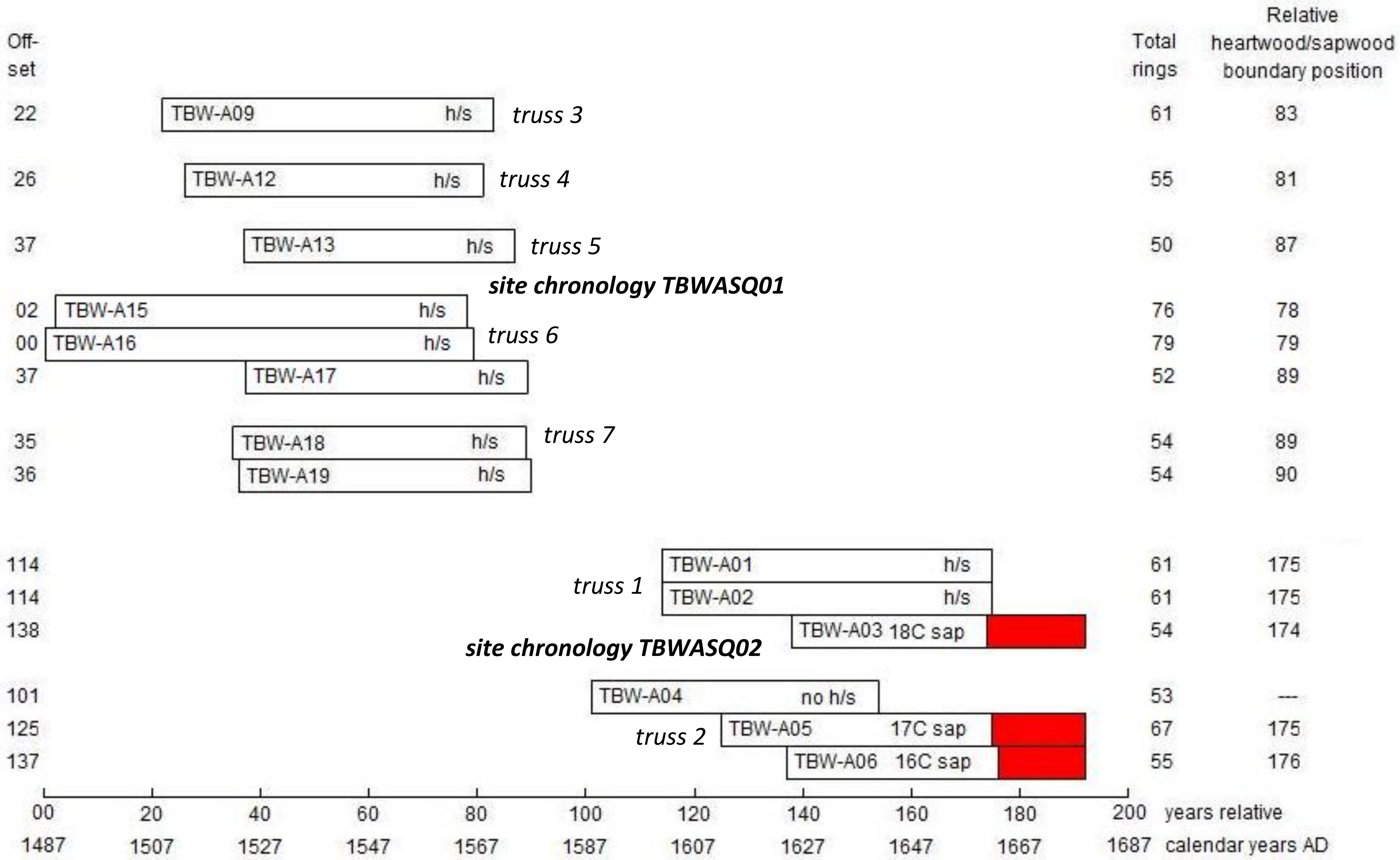


Figure 4: Graphic representation of the cross-matching of two samples, TBW-A01 and A05 from trusses 1 and 2 respectively. It can be seen from the graph that when cross-matched at the correct off-set positions, as here, the variations in width of the annual growth rings of these two samples correspond with a high degree of similarity. As the annual rings widths of one sample increase (represented by peaks in the graph), or decrease (represented by troughs), so too do the annual ring widths of the other sample. This similarity in growth pattern is a result of the two trees represented having grown in the same area *at the same time.* The growth ring pattern of two samples from trees grown at different times should never cross-match significantly at any position.



Blank bars [ ] = heartwood rings, shaded bars [ ] = sapwood rings

h/s = heartwood/sapwood boundary, i.e., only the sapwood rings are missing

C = complete sapwood is retained on the sample, the last measured ring date is the felling date of the tree represented

Figure 5 (above): Bar diagram of the samples in site chronologies TBWASQ01 and TBWASQ02 at positions indicated by their separate grouping. The samples in the two separate site chronologies are shown in the form of bars at positions where the ring variations of the samples within each group cross-match with each other. This similarity is produced by the trees represented within each site chronology growing, *at the same time* as each other. The samples are combined to form two 'site chronologies', each of which is dated by comparison with the 'reference' chronologies (Tables 2 and 3).

From this dating it can be clearly seen that the trees within each site chronology represent two very different periods of growth. Samples TBW-A05 and A06 in site chronology TBWASQ02 retain complete sapwood, the last ring produced by the trees they represented before they were cut down (indicated by upper case 'C'). The last growth ring, and thus the felling of each tree, has been dated to 1678. The relative position of the heartwood/sapwood boundary on all the other samples in this site chronology, would suggest that the trees they represent were felled in 1678 as well.

None of the samples in site chronology TBWASQ01 retains complete sapwood, and it is thus not possible to say precisely when any of the trees were felled. The samples do, however, retain the heartwood/sapwood boundary (denoted by h/s in Table 1 and the bar diagram). This means that only the sapwood rings are missing. The relative position and the date of the boundary on all eight samples is very similar, strongly suggesting that the trees represented by the eight samples were all cut at the same time as each other in a single episode of felling. The average date of the heartwood/sapwood boundary date on these eight samples is 1571, which, allowing for a minimum/maximum of 15/40 sapwood rings would give the timbers an estimate felling date for the trees of 1586–1611 (it may be noted that a stone plaque on the building is dated 1597).