ntrdl the nottingham tree-ring dating laboratory

TREE-RING ANALYSIS OF TIMBERS FROM
AVEBURY MANOR,
AVEBURY,
WILTSHIRE,

A J ARNOLD
R E HOWARD

TREE-RING ANALYSIS OF TIMBERS FROM AVEBURY MANOR, AVEBURY, WILTSHIRE

A J ARNOLD
R E HOWARD

SUMMARY

A total of 27 cores was obtained from the Manor House, Avebury, with timbers of the east range roof, the roof of the south extension of the east range, and the 'upper' and 'lower' roofs of the south range, being sampled, along with two ceiling timbers to the kitchen in the east range, and two timbers to the roof of the north extension of the east range. Three of these 27 samples, one from the east range roof, one from the kitchen, and one from the roof of the north extension, had too few rings and they were not analysed.

Of the 24 samples which were analysed, 21 (from all parts of the building) formed a single site chronology 204 rings long, these rings spanning the years 1393–1596. Two further samples, from the upper roof of the south range, form a second site chronology, but this cannot be dated. One other sample, from the roof of the north extension, remains a singleton and cannot be dated individually.

The earliest timber is a ceiling beam from the kitchen, this estimated to have been felled some time between 1555 and 1580. The next timbers are those of the east range roof, these having an estimated felling date in the period 1574–99. It is highly likely that all the other timbers, those to the south extension to the east range, and those to the 'upper' and 'lower' roofs of the south range itself, were cut as part of a single programme of felling in 1600.

NTRDL, 20 Hillcrest Grove, Sherwood, Nottingham, NG5 1FT
Telephone 0115 960 3833 (laboratory);
07980 305583 / 07913 427987 (Mobiles)
roberthoward@tree-ringdating.co.uk
alisonarnold@tree-ringdating.co.uk

Introduction

Avebury Manor (SU 098 699, Figs 1a/b) is built on, or close to, the site of a small Benedictine cell of St Georges de Boscherville, founded in 1114 and allocated to Fotheringhay College when it was dissolved in 1411. Fragmentary remains of this period, the capital of twin Norman

colonnettes, for example, possibly from the cloister, have been found in the grounds. The Manor House itself was begun in *c.* 1557 by William Dunch, auditor of Royal Mint, this phase being represented by the gabled, four bay, two storey with attic, central portion of the present east range (Fig 2a)

The east range was then extended southwards by four bays in an enlargement and major rebuild undertaken by sir James Mervyn in 1600–01, the southern extension forming a projecting wing forward of the new, not quite symmetrical, south range. The south range itself (Fig 2b) is of five bays, two storeys, with central porch with round arch on fluted pilasters and tall shaped gable containing niche and initials *'M J D 1601'*. A further, west, wing was then added to create a 'U'-shaped courtyard arrangement. At some uncertain date the east range was extended northward by a further four gabled bays (Fig 2c).

Internal alterations were made to the Manor *c.* 1730 for Sir Richard Holford, Master in Chancery. In the main south block the former hall was remodelled as a dining room with moulded dentilled cornice, corner panelled doors in eared architraves, and dentilled pediments. Beyond the cross passage the library was given bolection panelling and a heavy marble fire-surround. The upper floor of the south wing contains the Elizabethan Bedroom with early-seventeenth century panelling, plaster ceiling, and a robust fireplace of *c.* 1600 with its gadrooned surround, arabesque frieze, and carved wood over-mantel. There are also other seventeenth century panelled rooms, particularly, in respect of this report, the Queen Anne Bedroom with ceiling coved to a guilloche and dentilled raised central section (Fig 2d).

Subsequently, alterations were made in the early nineteenth century when much restoration work was carried out by Sir Walter Jenner, owner from 1907, Alexander Keiller, the antiquary, and others. An overall plan of the site is given in Figure 3, with elevation drawings being given in Figures 4a/b.

Sampling

Sampling and analysis by tree-ring dating of the timbers within Avebury Manor were commissioned as part of a major programme of investigation, survey, and recording undertaken by Anne Upson and Robert Davies of Wessex Archaeology on behalf of The National Trust, the owners of Avebury Manor (Wessex Archaeology, 2011). This was carried out under the direction of Dr Nicola Snashall, site archaeologist for The National Trust.

The purpose of tree-ring dating was to obtain dates for a number of different parts of the Manor. Firstly it was hoped that analysis would confirm the date of the original, central, portion of the east range and, there being some question mark about the extent of later alterations, determine if the present roof of this is the original. Secondly, although the sequence of construction is clear, it was hoped that tree-ring analysis would determine at what date the east range roof was extended southwards, there being no clear-cut stylistic or structural evidence to establish this with precision. Thirdly it was hoped that analysis would not only confirm the date of the main south range roof, but also establish if this roof was changed in connection with the insertion of the ceiling to the Queen Anne Bedroom as is

traditionally believed, there being some reason to question this assumption. Finally it was hoped that tree-ring dating would establish the date of the north extension of the east range.

With the aim of fulfilling this brief, core samples were obtained from 27 different suitable timbers, an attempt being made to distribute the samples throughout the building to ensure that any differences in date might be detected, and to ensure that any possible variations in construction might be identified. Each sample was given the code AVB-M (for Avebury Manor), and numbered 01–27. Six sample, AVB-M01–06, were taken from the central east range roof and six samples, AVB-M07–12, from the roof of the southern extension to the east range. A further six samples, AVB-M13–18, were obtained from the original 'lower' roof of the south range, with five samples, AVB-M19–23, being obtained from the 'upper' roof of the south range (the supposed alteration phase).

Two samples, AVB-M24 and M25, were then obtained from the two available suitable timbers to the ceiling of the kitchen in the east range, with two final samples, AVB-M26 and M27, being obtained from the only two oak timbers to the roof of the north extension to the east range (all the other roof timbers here being of elm).

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 the trusses, bays, and individual timbers, have been located on a site north–south/east–west basis as appropriate.

The Nottingham Tree-ring Dating Laboratory would like to take this opportunity to thank both Anne Upson and Bob Davis of Wessex Archaeology for their interpretation of the phasing of this building, for arranging access for sampling, and for the provision of plans and drawings used in this report. We would also like to thank Dr Nicola Snashall of the National Trust for her considerable assistance with sampling and for obtaining the necessary funds for analysis. Finally, we would like to thank Brian Holman, Head Gardner at Avebury Manor, for his cooperation and help in sampling the north extension, this being his private residence.

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 found preserved in archaeological excavations) 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 5).

Secondly, because the weather over any number of consecutive years is unique, so too is the growth-ring pattern of the tree. The pattern of a short 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. 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 millimetre. 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 relevant 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

All 27 samples obtained from the various timbers of Avebury Manor were prepared by sanding and polishing. It was seen at this time that three of these samples, AVB-M03, M25, and M27, had too few rings (ie, less than 50) for reliable dating and they were rejected from this programme of analysis. The annual growth rings of the remaining 24 samples were measured, however, and the data of these measurements were compared with each other as described in the notes above. By this comparative process two separate groups of cross-matching samples could be formed, the samples of each cross-matching as shown in the bar diagrams, Figures 6 and 7.

The first group, comprising 21 samples from a variety of locations in the building, were combined at their indicated off-set positions to form AVBMSQ01, a site chronology with an overall length of 204 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 1393–1596. The evidence for this dating is given in the *t*-values of Table 2.

The second group comprises two samples, both of them from truss 3 of the 'upper' south range roof (the supposed alteration phase). These two samples were combined at their indicated off-set positions to form AVBMSQ02, a site chronology with an overall length of 107 rings. This site chronology was then compared to a large corpus of reference data for oak, but there was no satisfactory cross-matching at any position and these two samples must, therefore, remain undated.

The single remaining measured but ungrouped sample was compared individually with the full corpus of reference data, but again there was no satisfactory cross-matching and this sample must also, remain undated.

Interpretation

Analysis of 24 of the 27 samples obtained from a range of locations at Avebury Manor has produced a single dated site chronology, AVBMSQ01, comprising 21 samples. This site chronology has a last measured ring date of 1596.

None of the dated samples in site chronology AVBMSQ01 retains complete sapwood on their respective cores, that is, none of them have the last growth ring produced by the trees they represent before they were cut down. As a result it is not possible to give an absolutely precise felling date for any of the timbers. Several samples, however, retain some sapwood, or at least the heartwood/sapwood boundary (meaning that only the sapwood rings are missing), and it is thus possible to give estimated felling date ranges for the timbers.

The earliest timber appears to be a ceiling beam from the kitchen, represented by sample AVB-M24, this having a heartwood/sapwood boundary date of 1540. Using the usual sapwood estimate for oaks in this area, 15–40 sapwood rings, would give this timber an estimated felling date in the range 1555–80.

The next phase of felling is found amongst the timbers of the east range roof. Taken together these samples have an average heartwood/sapwood boundary ring date of 1559. Using the same sapwood estimate as above, 15–40 rings, would give these timbers an estimated felling date in the range 1574–99.

It is likely that all the other dated timbers, those from the southern extension of the east range, and those from both the 'upper' and 'lower' roofs to the south range, are probably a little bit later. Within the samples from these roofs the timbers have an average heartwood/sapwood boundary date of 1572. Using the same sapwood estimate as above, 15–40 rings, would give the timbers an estimated felling date in the range 1587–1612.

Two of the samples from these roofs, however, AVB-M10 and M12, are from timbers with complete sapwood on them (ie they have the last growth rings produced by the trees before they were cut down), but from which, due to the soft and fragile nature of this part of the wood, small portions of the sapwood have been lost in coring. Under such circumstances, having noted at the time of sampling the amount of sapwood lost from the core, it is possible to estimate the likely number of sapwood rings the lost section might have contained. In the case of sample AVB-M10 the loss amounts to no more than about 6 millimetres, and on sample AVB-M12, only about 4 millimetres. Given that the last extant ring on sample AVB-M10 is dated to 1593, and that on AVB-M12 is dated to 1596, it is estimated that the trees represented was almost certainly felled in 1600. Given that the relative position and date of the heartwood/sapwood boundary on these two samples is very similar to that on the other samples from these two roof areas, it is very likely that all the trees used in their construction were felled at a very similar, if not identical, time.

This interpretation is supported by the fact there is highly significant cross-matching between a number of timbers in different roofs. This suggests that some beams in different roofs have been derived from the same trees, which have been split in half, ie, samples AVB-M11 (east range south extension) and AVB-M16 (south range lower roof). If the roofs had been built of timbers felled at different times, the heart/sap boundary would be wider (though probably consistent within each roof), and it would be unusual to find timbers from the same tree in different roofs.

Undated timber

One measured sample, AVB-M26, from the roof of the north extension to the east range, remains ungrouped and undated. It is possible that this sample, with only 59 rings, is slightly too short for reliable cross-matching, and it may also have some slight disturbance to its growth pattern. It is also possible that the tree represented has been grown at a time and/or place, or under a woodland management regime, that is not yet represented in the currently available reference material. If this timber were of a different date and or from a different place (and this cannot be proven by dendrochronology) it would in effect make it a singleton, and while such timbers can sometimes be dated, it is much more difficult than with well replicated groups of data.

Conclusion

From the results reported upon here it would thus appear that the only timber that might possibly belong to the original 1557 building is the ground floor ceiling beam to the kitchen in the east range, represented by sample AVB-M24, with an estimated likely felling date in the range 1555–80.

The present roof of the east range, however, would appear to be a replacement, the earliest likely felling date of the timbers used in its construction being 1572. It is possible, however, that these timbers were felled up to as late as 1599, and its replacement might be connected with the enlargement and major rebuild of 1600–01. Why it was necessary to replace the earlier, though still relatively recent, roof of 1557 is of course unknown, but may have been connected with a reconfiguration of the first floor rooms, and possibly with the creation of the east-facing gables.

It is also clear from the analysis undertaken here, that the enlargement of 1600–01 included the southern extension of the east range roof, as well as the southern range itself. Interestingly, and perhaps unexpectedly, both the 'lower', original trusses of this roof, as well as the 'upper', or replacement, trusses are of this date, perhaps suggesting the possibility that the original trusses have simply been reused in a raised position.

Bibliography

Arnold, A J, and Howard, R E, 2006 unpubl, Tree-ring analysis of timbers from Newnham Hall Farm, Newnham Murren, near Wallingford, Oxfordshire – Nottingham Tree-ring Dating Laboratory, unpublished computer file *CMGASQ01*

Arnold, A J, and Howard, R E, forthcoming *Apethorpe Hall, Apethorpe, Northamptonshire: Tree-Ring Analysis of Timbers*, Res Dep Rep Ser

Howard, R E, Laxton, R R, Litton, C D, and Simpson, W G, 1995 List 60 no 2a – Nottingham University Tree-ring Dating Laboratory Results: general list, Vernacular Architect, **26**, 47–53

Howard, R E, Laxton, R R, and Litton, C D, 1998 *Tree-ring analysis of timbers from 26 Westgate Street, Gloucester,* Anc Mon Lab Rep, **43/1998**

Hurford, M, Bridge, M, and Tyers, C, forthcoming *Dauntsey House, Dauntsey, Wiltshire: Tree-Ring Analysis of Timbers*, EH Res Dep Rep Ser

Laxton, R R, and Litton, C D, 1988 An East Midlands master tree-ring chronology and its use for dating vernacular buildings, University of Nottingham, Dept of Classical and Archaeol Studies, Monograph Series, **III**

Tyers, I, 2008 Hartlebury Castle, near Stourport on Severn, Worcestershire; Dendrochronological analysis of oak timbers, EH Res Dep Rep Ser, **76/2008**

Tyers, I, and Groves C, 1999 unpubl England London, unpubl computer file *LON1175,* Sheffield Univ

Wessex Archaeology 2011 *Avebury Manor, Avebury, Wiltshire; Historic Building Survey*, ref **78060.01**

Table 1: Details of tree-ring samples from Avebury Manor, Avebury, Wiltshire

Sample number	Sample location	Total rings	Sapwood rings*	First measured ring date (AD)	Heart/sap boundary (AD)	Last measured ring date (AD)
	East range roof					
AVB-M01	East principal rafter, truss 1	101	no h/s	1424	------	1524
AVB-M02	West principal rafter, truss 1	85	6	1477	1555	1561
AVB-M03	West lower purlin, truss 1–2	nm	---	------	------	------
AVB-M04	East principal rafter, truss 2	115	h/s	1448	1562	1562
AVB-M05	West principal rafter, truss 2	107	4	1453	1555	1559
AVB-M06	West principal rafter, truss 4	146	h/s	1419	1564	1564
	East range, south extension roof					
AVB-M07	West principal rafter, truss 1	122	h/s	1448	1569	1569
AVB-M08	Collar, truss 1	177	h/s	1393	1569	1569
AVB-M09	East principal rafter, truss 2	91	1	1490	1579	1580
AVB-M10	West principal rafter, truss 2	133	21c	1461	1572	1593
AVB-M11	West principal rafter, truss 3	142	h/s	1433	1574	1574
AVB-M12	East principal rafter, truss 4	125	26c	1472	1570	1596
	South range (lower) roof					
AVB-M13	North principal rafter, truss 1	111	h/s	1474	1584	1584
AVB-M14	South principal rafter, truss 1	74	h/s	1497	1570	1570
AVB-M15	North principal rafter, truss 4	137	7	1443	1572	1579
AVB-M16	South principal rafter, truss 4	142	no h/s	1413	------	1554
AVB-M17	Tiebeam, truss 4	112	h/s	1452	1563	1563
AVB-M18	Collar, truss 4	96	6	1484	1573	1579

Table 1: continued

Sample number	Sample location	Total rings	Sapwood rings*	First measured ring date (AD)	Heart/sap boundary (AD)	Last measured ring date (AD)
	South range (upper) roof					
AVB-M19	North principal rafter, truss 2	140	3	1430	1566	1569
AVB-M20	South principal rafter, truss 2	92	no h/s	1468	------	1559
AVB-M21	North (upper?) purlin, truss 2–3	153	2	1427	1577	1579
AVB-M22	North principal rafter, truss 3	90	19C	------	------	------
AVB-M23	South principal rafter, truss 3	106	18c	------	------	------
	East range, kitchen ceiling timbers					
AVB-M24	North ceiling beam (above fireplace)	133	9	1417	1540	1549
AVB-M25	South ceiling beam (to south wall)	nm	------	------	------	------
	East range, north extension roof					
AVB-M26	East purlin	59	10	------	------	------
AVB-M27	West purlin	nm	------	------	------	------

*h/s = the last measured ring on the sample is at the heartwood/sapwood boundary, ie, only the sapwood rings are missing
C = complete sapwood is retained on the sample
c = complete sapwood is found on the timber, but all or part of the sapwood has been lost from the sample in coring
nm = sample not measured

Table 2: Results of the cross-matching of site chronology AVBMSQ01 and relevant reference chronologies when the first ring date is 1393 and the last ring date is 1596

Reference chronology	*t*-value	
England, London	13.4	(Tyers and Groves 1999 unpubl)
Dauntesey House, Dauntsey, Wilts	13.1	(Hurford *et al* forthcoming)
26 Westgate Street, Gloucester	12.2	(Howard *et al* 1998)
Apethorpe Hall, Apethorpe, Northants	11.3	(Arnold and Howard forthcoming)
Lodge Park, Aldsworth, Glos	11.1	(Howard *et al* 1995)
Hartlebury Castle, Stourport on Severn, Worcs	11.0	(Tyers 2008)
Newnham Hall Farm, Newnham Murren, Oxon	11.0	(Arnold and Howard 2006 unpubl)
East Midlands Master Chronology	10.1	(Laxton and Litton 1988)

Site chronology AVBMSQ01 is a composite of the data of the 21 cross-matching samples from this site (Fig 6), this producing an 'average' tree-ring pattern, where the overall climatic signal of the combined ring growth is enhanced, and the possible erratic variations of any one individual sample are reduced. This 'average' site chronology is then compared with several hundred reference patterns covering every part of Britain for all time periods. As can be seen here, site chronology AVBMSQ01 matches only when its 204 rings span the years 1393–1596, the degree of similarity between it and the reference chronologies indicated in this instance by a set of particularly high '*t*-values' (ie, degrees of similarity).

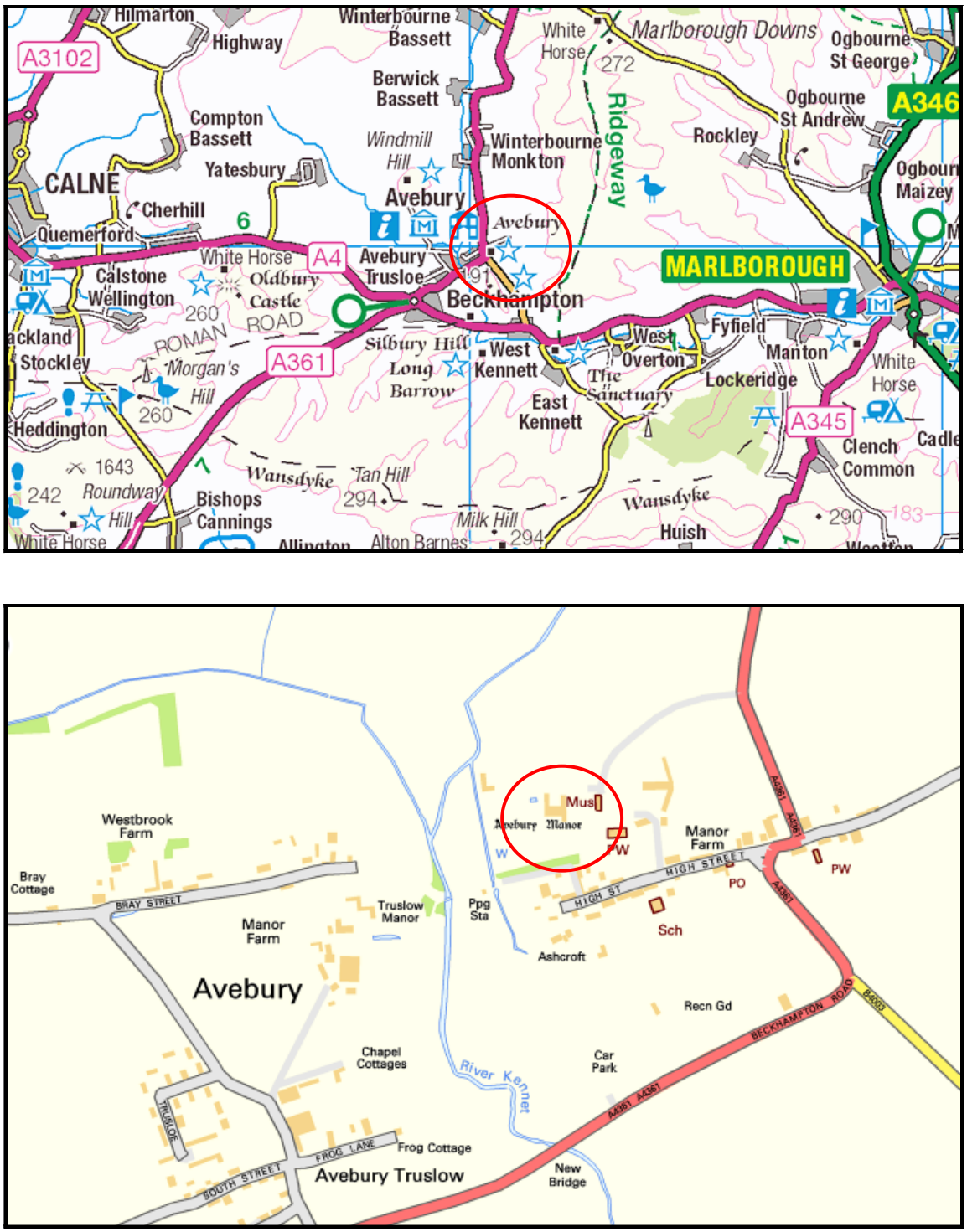

Figure 1a/b: Maps to show location of Avebury village (top) and Avebury Manor (bottom)

Figure 2a/b: Views of the east range and its southern extension (top), and the south range (bottom)

Figure 2c/d: View of the east range and the north extension (top), and the Queen Anne bedroom (bottom)

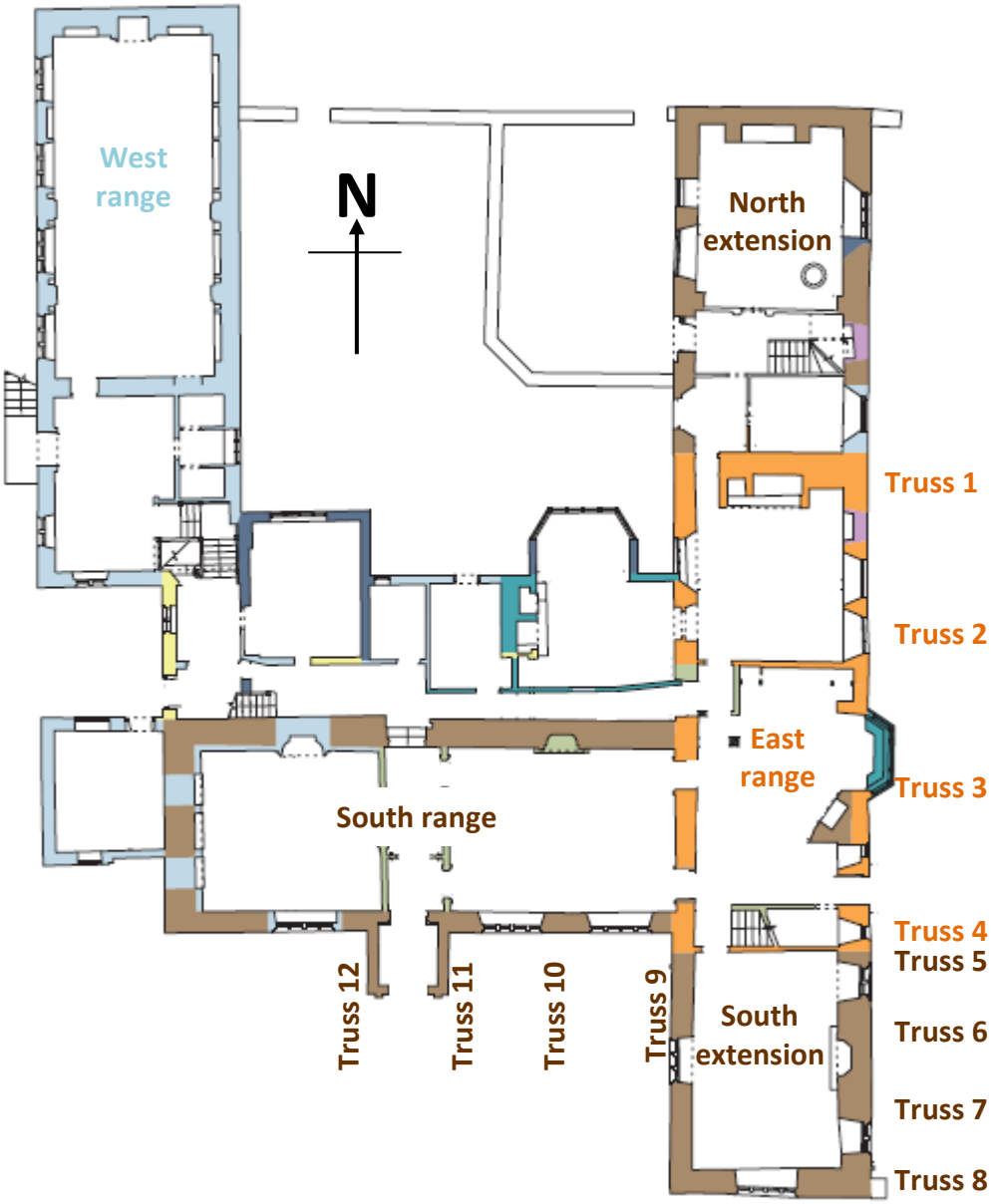

Figure 3: Plan of Avebury Manor to show layout and arrangement of the various ranges and the approximate position of the roof trusses (after Wessex Archaeology)

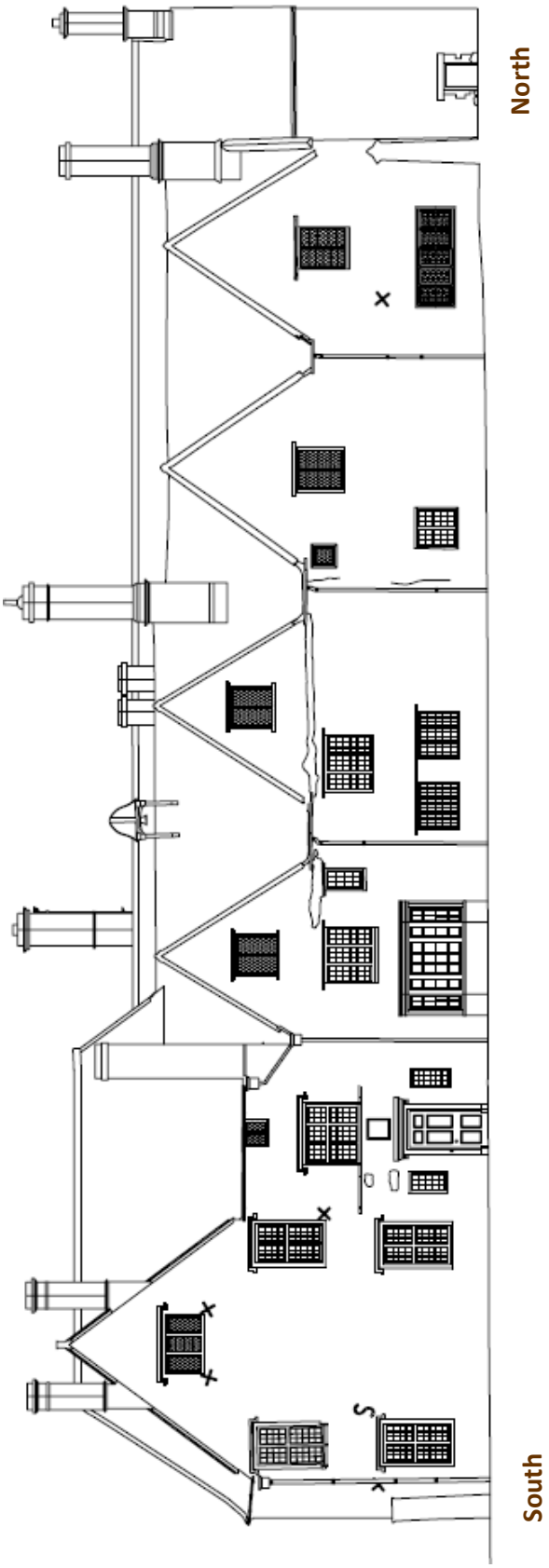

Figure 4a: East elevation of Avebury Manor (after Wessex Archaeology)

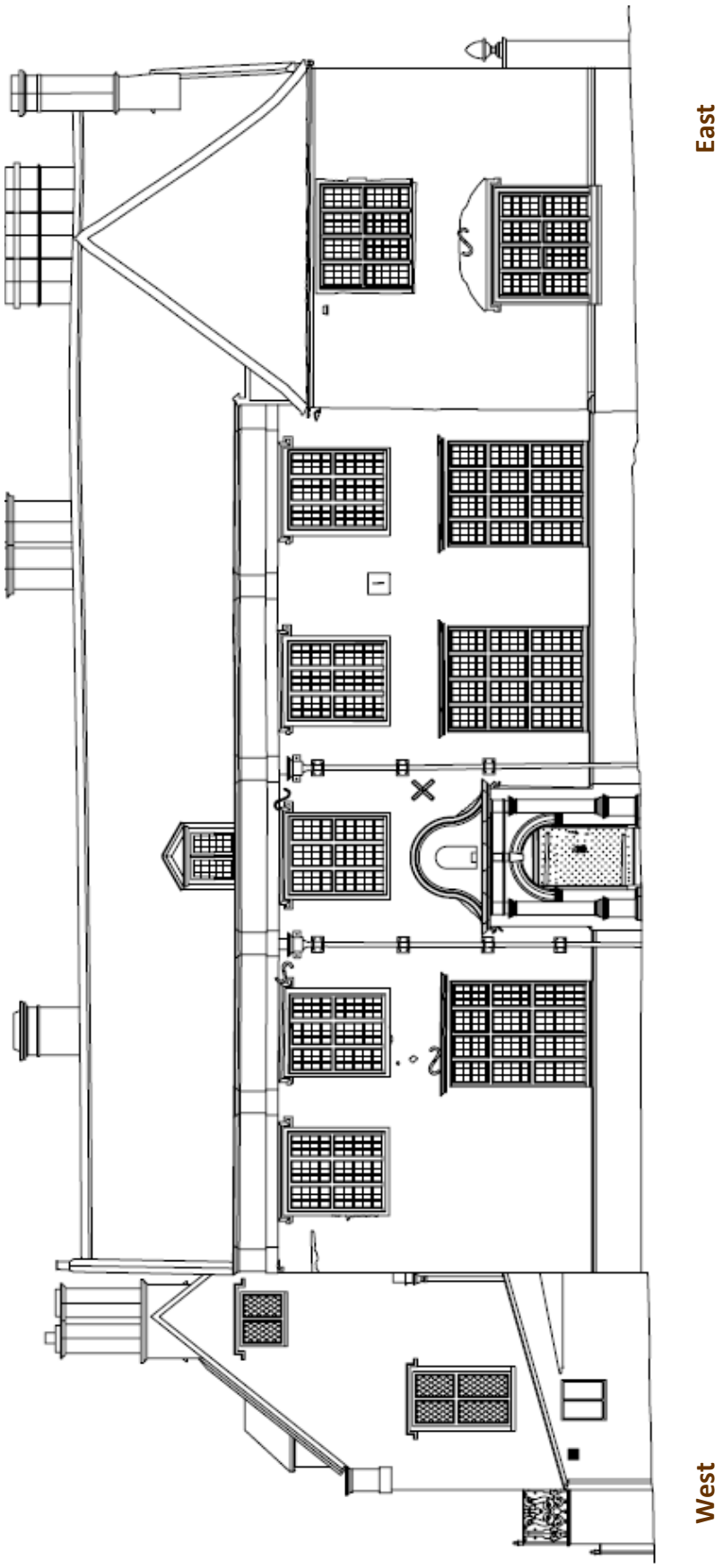

Figure 4b: South elevation of Avebury Manor (after Wessex Archaeology)

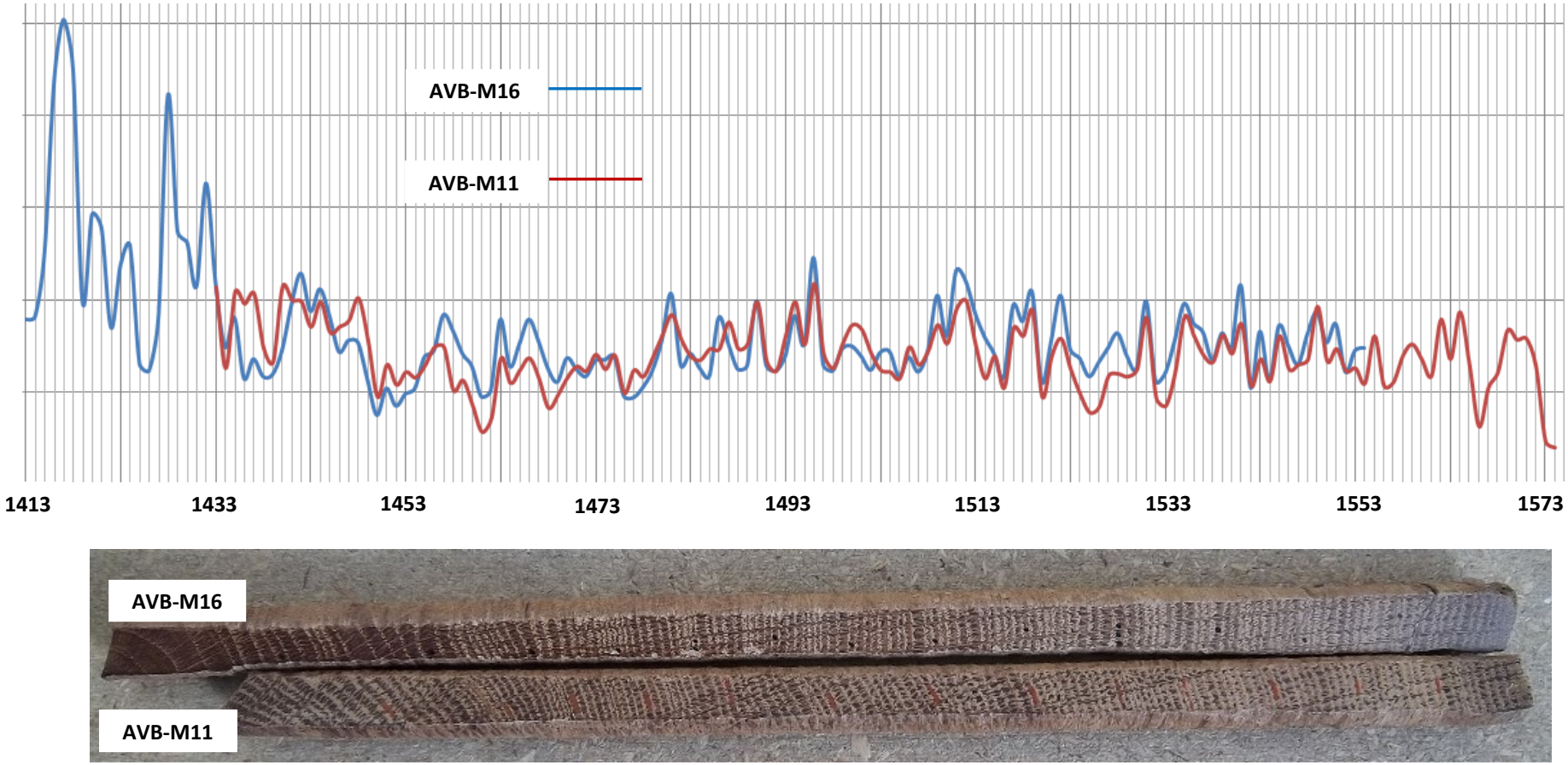

Figure 5: Graphic representation of the cross-matching of two samples, AVB-M11 (red) and M16 (blue). It can be seen that when cross-matched at the correct off-set positions, as here, the variations in width of the annual growth rings of these two samples correspond with a high degree of similarity. As 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 second 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 at any position.

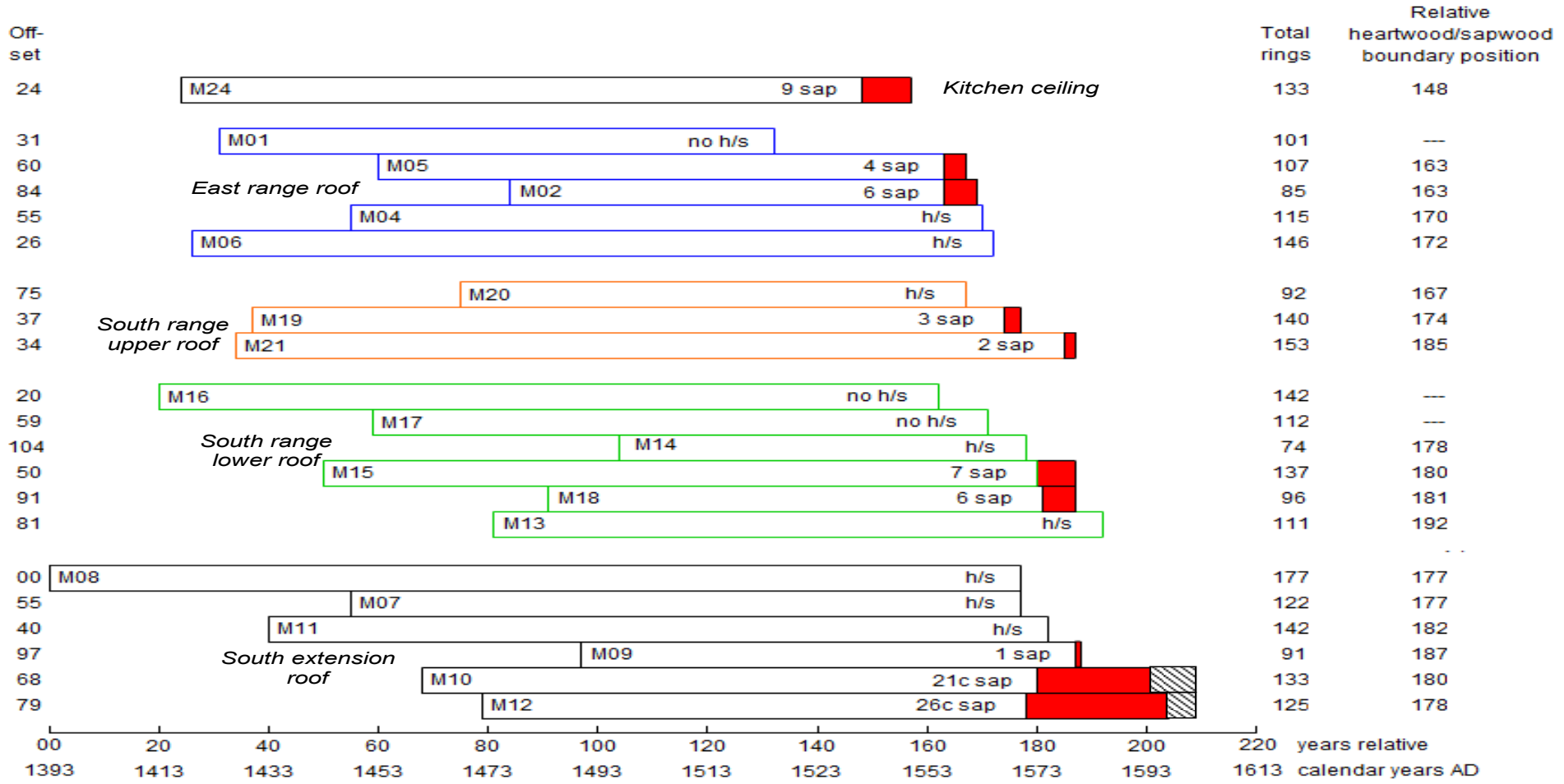

Figure 6: Bar diagram of the samples in site chronology AVBMSQ01 sorted by sample location. The samples are shown in the form of 'bars' at the positions where the variations in the rings cross-match with each other – this similarity being produced by the trees from which the sampled beams were derived all growing in the same place, *at the same time.*

White bars = heartwood rings. Shaded bars = sapwood rings. Hatcehd bars = lost sapwood rings. h/s = the last ring on the sample is at the heartwood/sapwood boundary. c = complete sapwood on the timber, but a portion has been lost in coring

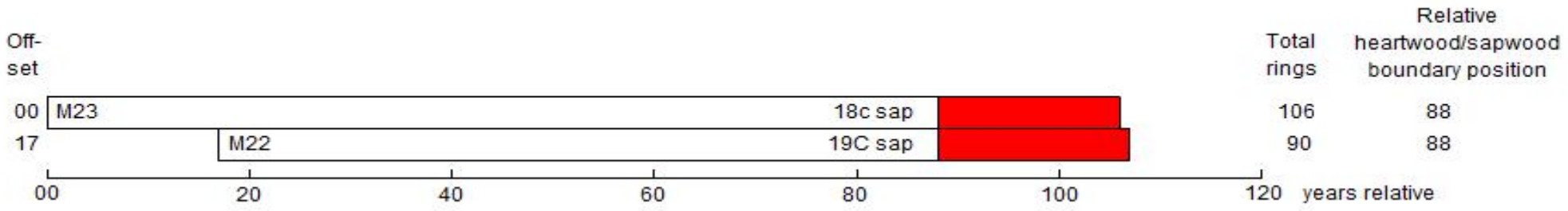

Figure 7: Bar diagram of the samples in site chronology AVBMSQ02

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

C = complete sapwood is retained on the sample
c = complete sapwood is found on the timber, but all or part of the sapwood has been lost from the sample in coring