Dendrochronology, timber analysis, and historic building consultants

KENARDINGTON MANOR, KENARDINGTON, KENT;

TREE-RING ANALYSIS OF TIMBERS

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SEPTEMBER 2012

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<u>SUMMARY</u>

Analysis by dendrochronology of samples taken from a series of different oak timbers to the roof of Kenardington Manor has resulted in the production of a single dated site chronology comprising 11 of the 13 samples obtained. This site chronology is 164 rings long, these rings dated as spanning the years 1307–1470. The interpretation of the sapwood on the samples would indicate that all the dated timbers were felled in 1475 specifically for the construction of this house.

Two samples remain ungrouped and undated.

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Introduction

Although a full archaeological building survey or drawn record of Kenardington Manor (TQ 969 323, Figs 1a/b) is not as part of this programme of tree-ring dating, it is clear that the house presents an impressive six-bay timber-framed building of tall, close-set, studs to both ground and first floor, with minimal lateral bracing, beneath a roof hipped at both ends. It is jettied to both its front elevation and to the west gable. The bay divisions of the house are formed by five crown-post roof trusses, with bay 4, between trusses 3 and 4, being very much narrower than all the other bays. The crown-post roof is a very common form of construction in Kent whereby each pair of common rafters is linked by a horizontal collar. Supporting the centre of the collars is a horizontal longitudinal beam, known as a collar purlin (or sometimes a crown plate), which runs the length of the building. In turn, the collar purlin is supported by crown posts which, at the trusses, rise from the centre of the tiebeam to the underside of the collar purlin.

The four east-most crown-post trusses at Kenardington Manor appear to be plain (ie, without any moulding or other decoration)(Fig 2a/b) while the fifth, west-most, truss has moulded decoration to the tiebeam, and the crown post has been given some embellishment as well (Fig 2c). The tiebeam of this truss, furthermore, is 'cranked', ie, it has a distinct angle, or bend, at its mid-point from whence rises the crown-post, whereas the tiebeams of the other four trusses appear to be straight. Truss five is also different from the others in that there are no down-braces from the crown-post to the tiebeam, such ogee braces being present on the first four trusses. All the trusses have up-braces from the crown-post to the collar purlin, with the fifth truss also having braces between its crown-post and collar.

Between the trusses, the paired frames of each bay have soulaces, or angled struts, between the common rafters and the collars. While it is not clear that the other bays have purlins, there is certainly one to each pitch of the roof in bay 5, these, like the truss to this bay, also being given a moulded decoration.

There is no evidence of smoke-blackening to any timbers of this roof, and it would appear that the first-floor frame is original and primary to the construction of the house and is not a later insertion. Indeed, it is remarkable how Kenardington Manor is little altered from its original form, and of how much of the house appears to represent a single phase of timber felling.

Sampling

Sampling and analysis by tree-ring dating of the timbers within Kenardington Manor were commissioned by the owner, Mr Thomas Baxendale. This was undertaken as part of a long-standing personal interest in the building and its history, and as part of a general programme of research into its origins and development. It was hoped that tree-ring dating would provide dates for the trusses of the roof, and thus the house, there being little doubt that these were primary and original to its construction; from the form of the roof trusses and by nature of the layout and arrangement of the building, the house has been dated stylistically to the later-fifteenth century. It was hoped that dendrochronology would either confirm this general interpretation or establish whether it was earlier or later, and also provide a more precise, or at least a much narrower, time frame for its construction.

With the aim of fulfilling this brief, core samples were obtained from a total of 13 different suitable oak timbers of the roof, all the timbers appearing to be primary and original to the roof structure, many of the frames and their constituent timbers showing consistent assembly, or carpenter's, marks (Fig 2d). Each oak sample was given the code KNR-A (for Kenardington – site 'A'), and numbered 01–13.

The positions of the sampled timbers were located and recorded at the time of coring, the details of these samples being given in Table 1. These details include the specific 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 front of the house taken to site-north. The positions of the samples have also been recorded on simple schematic plans or drawings of the trusses and on photographs. These are reproduced here as Figures 3 and 4a-d.

The Nottingham Tree-ring Dating Laboratory would like to take this opportunity to thank Mr Baxendale for commissioning and generously funding this programme of tree-ring analysis, and for the generous and entertaining hospitality shown at the time of sampling.

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.

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 of the Kenardington Manor samples

Each of the 13 samples obtained from the timbers within Kenardington Manor was prepared by sanding and polishing and the widths of their annual growth rings were measured. The data of these measurements then compared with each other as described in the notes above, by which process a single group comprising 11 cross-matching samples could be formed, the samples cross-matching with each other as shown in the bar diagram, Figure 5. The 11 cross-matching samples were combined at their indicated off-set positions to form KNRASQ01, a site chronology with an overall length of 164 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 1307 (the date of the earliest ring on any individual sample (KNR-A01)) to 1470 (the date of the latest ring on any individual sample (KNR-A03)). The evidence for this dating is given in the *t*-values of Table 2.

Site chronology KNRASQ01 was then compared with the two remaining ungrouped samples but there was no further satisfactory cross-matching. The two ungrouped samples were then compared individually with the full range of reference chronologies, but, again, there was no satisfactory cross-matching, and these two samples must, therefore, remain undated. There is no clear reason for this, the samples, KNR-A09 and A13, certainly having sufficient rings for reliable analysis, and neither of them showing any problems with their rings, such as stress or distortion, which might cause difficulties with dating. This, though, is not at all an unusual phenomenon in tree-ring analysis where one or two samples (and sometimes more) frequently remain undated.

Interpretation

Site chronology KNRASQ01 comprises 11 samples, all of them from the primary timbers of the roof. None of these 11 dated samples retains complete sapwood on its core (the last growth ring produced by a tree before it was cut down), and it is thus not possible to truly determine an absolutely precise felling date for any of the trees represented. One of the samples, KNR-A03, does, however, come from a timber which has complete sapwood on it but from which, due to the soft and fragile nature of this part of the wood, a small portion of the sapwood was lost from the sample in coring (this is denoted by lower case 'c' in Table 1 and the bar diagram). Given that the lost sapwood portion is only a few millilitres long, and probably represents only 3–5 rings, and that the last extant ring on this sample is dated to 1470, such a loss would suggest that the tree represented was felled no later than, say, 1475.

It is almost certain that the trees represented by all the other samples in site chronology KNRASQ01 were felled at this time as well. Such an interpretation is based on the fact that the relative position and date of the heartwood/sapwood boundary (denoted by h/s in Table 1 and the bar diagram) on the three other dated samples that retain it (KNR-A02, A05, and A06), is at an almost identical position/date to that on sample KNR-A03 (who's felling date *is* known with close approximation). Because of the fairly limited amount of sapwood found on oak trees (15-40 rings), a similar heartwood/sapwood boundary position/date on a group of samples is indicative of them representing trees felled at the same, or at least a similar, time.

The interpretation that all the trees were felled at one and the same time as each other is further supported by the degree of cross-matching between all 11 samples in site chronology KNRASQ01. This is generally sufficiently high to suggest that all the trees represented were growing close to each other in the same area of woodland. They were each affected in a similar way by the same growing conditions, this producing a very similar growth pattern in each tree. It would perhaps be unexpected to find trees which had originally been growing together, but felled at different times, being used together in the same part of the building. The inference is that all the trees were felled at the same time especially for the construction of this house.

Conclusion

It would appear, therefore, that the timbers used in the construction of Kenardington Manor are the same date as each other, all having been felled as part of a single overall programme of work in, it is closely estimated, 1475. As such, this date makes Kenardington Manor an early Kentish example of a house built with a first floor from the outset, an advance in style over the 'open hall' form which had been the norm till then.

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Table 1: Details of tree-ring samples from Kenardington Manor, Kenardington, Kent

Sample number	Sample location	Total rings	Sapwood rings*	First measured ring date (AD)	Heart/sap boundary (AD)	Last measured ring date (AD)
KNR-A01	South principal rafter, truss 5	132	no h/s	1307	------	1438
KNR-A02	Collar, frame 1, bay 2	77	4	1379	1451	1455
KNR-A03	North common rafter, frame 2, bay 2	92	20c	1379	1450	1470
KNR-A04	Collar, frame 5, bay 2	72	no h/s	1362	------	1433
KNR-A05	South common rafter 1, bay 2	65	h/s	1389	1453	1453
KNR-A06	North common rafter 5, bay 5	56	3	1401	1453	1456
KNR-A07	South soulace frame 6, bay 5	91	no h/s	1325	------	1415
KNR-A08	South soulace frame 8, bay 5	106	no h/s	1311	------	1416
KNR-A09	South common rafter 2, bay 6	81	no h/s	------	------	------
KNR-A10	South common rafter 3, bay 6	78	no h/s	1310	------	1387
KNR-A11	North common rafter 4, bay 6	68	no h/s	1379	------	1446
KNR-A12	North common rafter 7, bay 6	90	no h/s	1342	------	1432
KNR-A13	West common rafter 7, hip end	95	h/s	------	------	------

*h/s = the last ring on the sample is at the heartwood/sapwood boundary, i.e., only the sapwood rings are missing
c = complete sapwood is found on the timber sampled, but a portion of this has been lost from the sample in coring

Table 2: Results of the cross-matching of site chronology KNRASQ01 and the reference chronologies when the first ring date is 1307 and the last ring date is 1470

Reference chronology	***t*-value**	
The Commandery, Worcester	7.6	(Arnold and Howard 2006)
England, London	7.5	(Tyers and Groves 1999 unpubl)
Ashleworth Tithe Barn, Glos	7.3	(Bridge 2002)
Hampshire County Chronology	6.7	(Miles 2003)
Exeter composite chronology	6.7	(Arnold and Howard unpubl)
The Old Manor, West Lavington, Wilts	6.6	(Hurford *et al* forthcoming)
Blue House, East Sutton, Kent	6.2	(Howard *et al* 1998)
Chalgrove Manor, Chalgrove, Oxon	6.0	(Arnold *et al* 2008)

Site chronology KNRASQ01 is composite of the data of the 11 cross-matching samples as seen in the bar diagram Figure 5. This composite data produces an 'average' tree-ring pattern with a combined length of 164 rings, where the overall climatic signal of the 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 and cross-matches with a great number of these when the date of its first ring is 1307 and the date of its last ring is 1470. Table 2 gives only a small selection of the very best cross-matches as represented by '*t*-values' (ie, closeness, or degrees, of similarity).

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

Figure 2a (top): View of the west face of truss 1
Figure 2b (bottom): View of the west face of truss 2
Note the ogee down-braces from the crown-posts to the tiebeams as well as the up-braces from the crown-posts to the collar purlin

Figure 2c (top): View of the west face of truss 5. Note the cranked and moulded tiebeam and the decorated crown post of this truss, as well as the absence of down-braces. Note also the moulded purlin in this bay as well as the soulaces between rafters and collars
Figure 2d (bottom): View of assembly mark on a common rafter frame

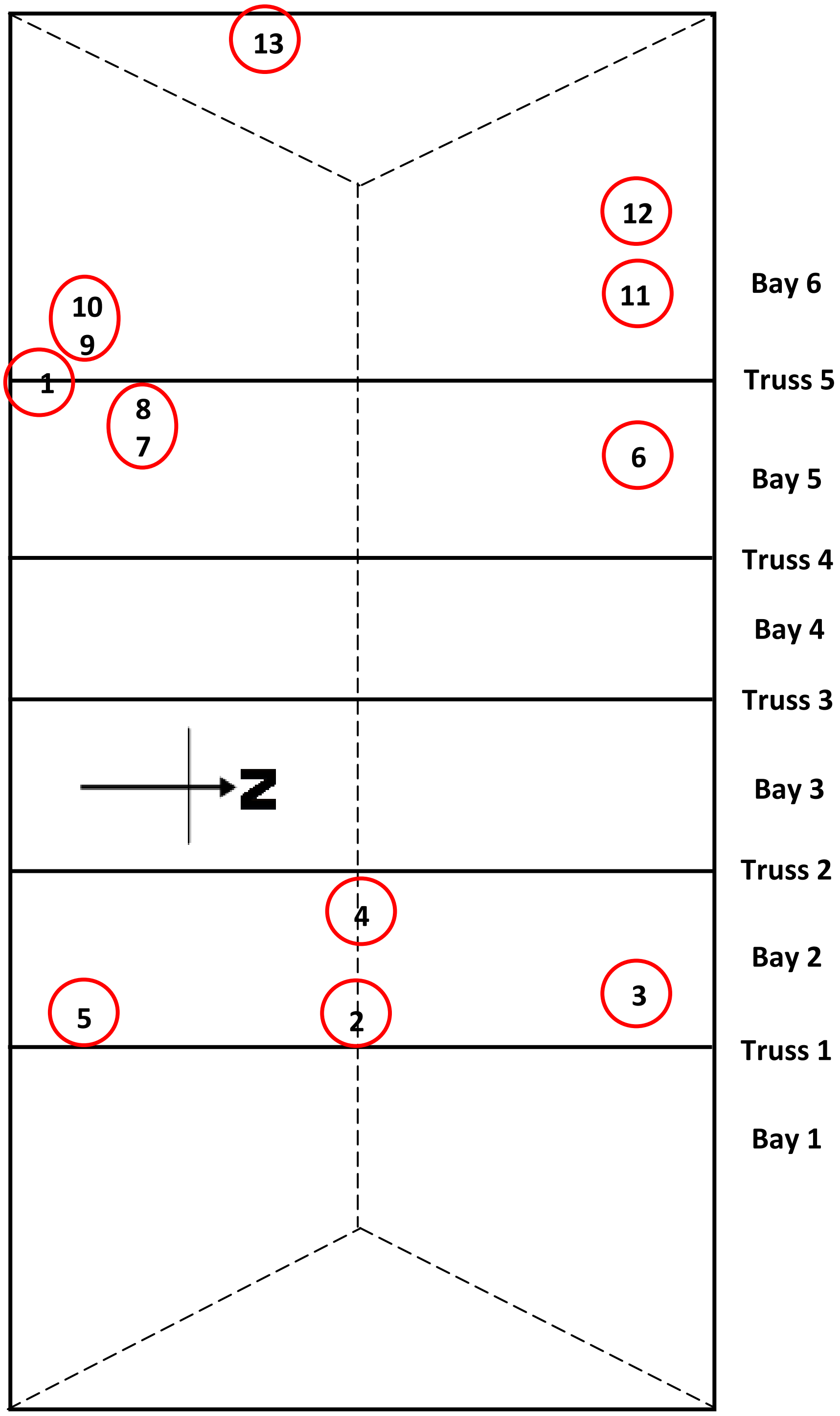


Figure 3: Simple schematic plan of the roof to show approximate positions of the sampled timbers

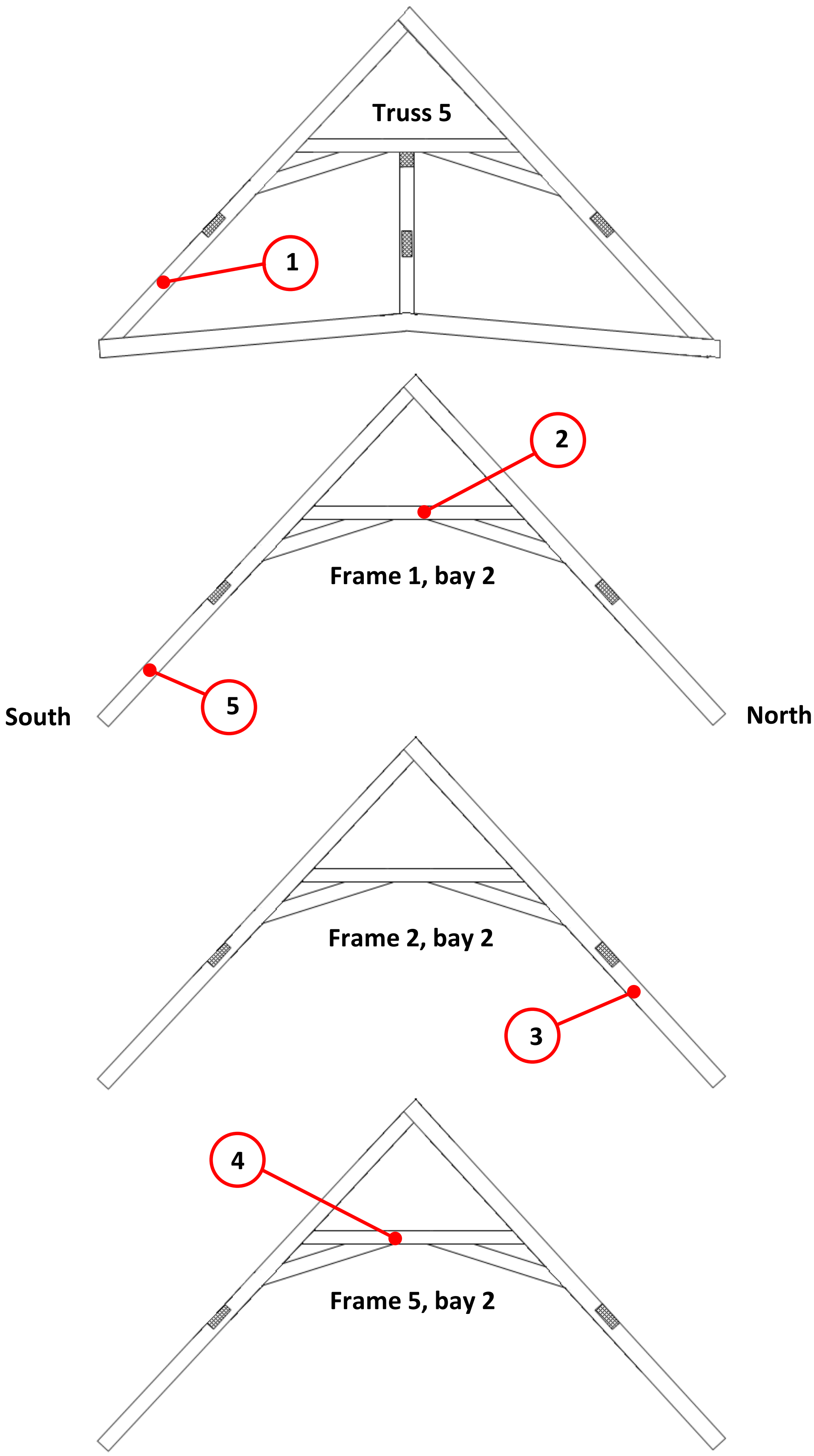


Figure 4a: Schematic representation of the common rafter frames and truss 5 to show sampled timbers

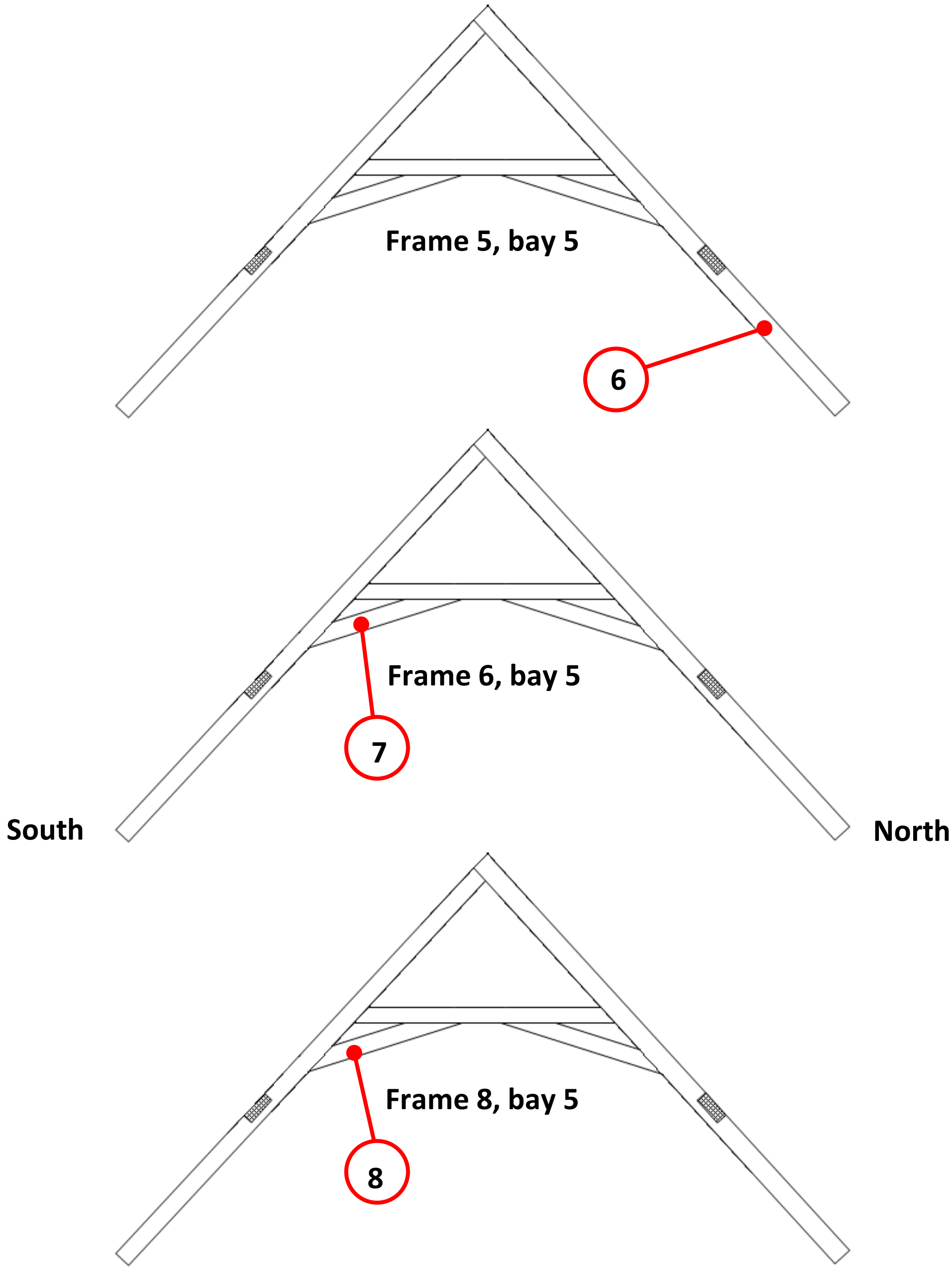


Figure 4b: Schematic representation of the trusses and frames to show sampled timbers

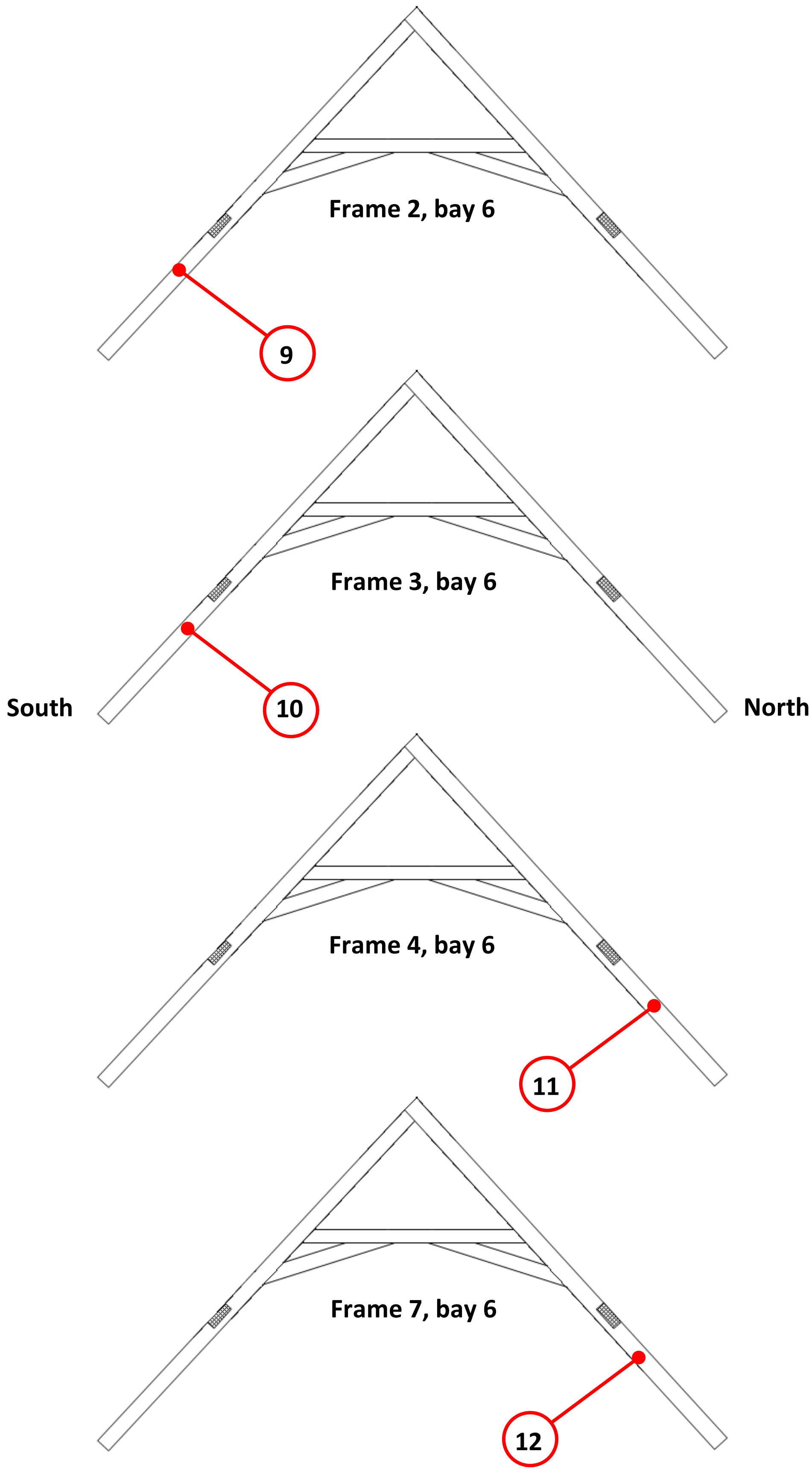
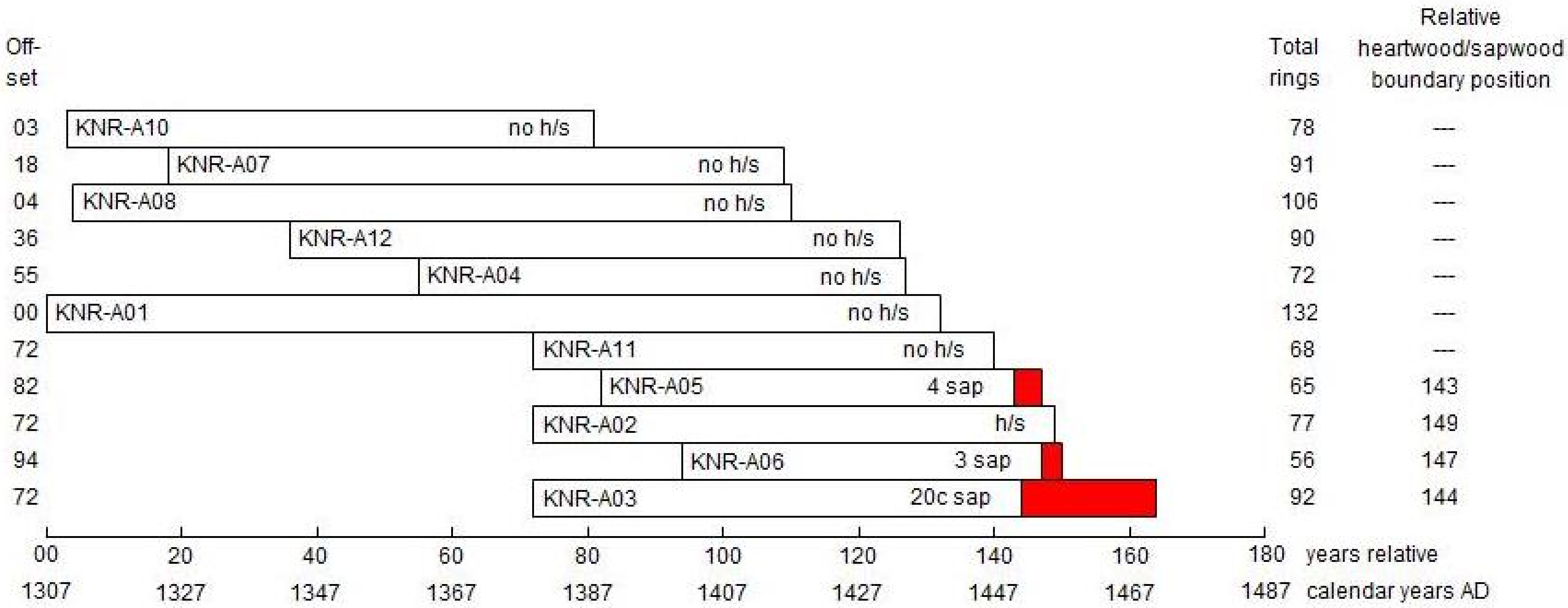


Figure 4c: Schematic representation of the trusses and frames to show sampled timbers

Figure 4d: Photograph of the west hip end to show sampled timber



Blank bars = heartwood rings, shaded bars = heartwood rings
h/s = the last ring on the sample is at the heartwood/sapwood boundary, i.e., only the sapwood rings are missing
c = complete sapwood is found on the timber, but all or part has been lost from the sample in coring.

Figure 5: Bar diagram of the samples in site chronology KNRASQ01

The 11 samples of site chronology KNRASQ01 are shown here in the form of a bar diagram at positions where the ring variations of each sample cross-match with each other. This similarity is produced by the trees represented sharing periods of growth in common (i.e., where the bars overlap). The samples are combined at these offsets to form a 'site chronology' which is compared with a large database of reference chronologies for all time periods for all parts of England. The site chronology cross-matches only with a date span of 1307–1470 (see Table 2).