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TREE-RING ANALYSIS OF SAMPLES FROM
THE SPIRELET TO THE SOUTH-EAST TRANSEPT,
THE ROOF OF THE NORTH-WEST TRANSEPT,
AND THE ROOF OF THE 'BAKEHOUSE', ST ANSELM'S TOWER
CANTERBURY CATHEDRAL,
KENT

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SUMMARY

Tree-ring analysis was undertaken on 46 of the 54 samples obtained from oak timbers within the spirelet to the south-east transept, the roof of the north-west transept, and the roof of the 'Bakehouse' within St Anselm's Tower at Canterbury Cathedral. The remaining eight samples had too few rings for reliable analysis.

Interpretation of the sapwood on the dated samples indicates that four of the timbers from the spire have an estimated felling date in the range 1097–1122, whilst two others here have an estimated felling date in the range 1257–82. The timbers of the Bakehouse roof appear to represent a single phase of felling dated to 1383. None of the samples from the roof of the north-west transept can be dated.

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INTRODUCTION

It is traditionally believed that St Augustine established a church in Canterbury, Christ Church, in the early seventh century, possibly using, or at least on the site of, an earlier, Roman, Christian chapel. In the mid-eighth century, Cuthbert built a second church adjacent to this, dedicated to St John, which was then enlarged and heightened by Archbishop Odo c 950. It was to this church that Abbot Lanfranc was appointed as Archbishop in 1070 by William I, and which he at once set about rapidly re-building, the new church being dedicated in 1077. At the end of the eleventh century, Archbishop Anselm set about an enlargement of Lanfranc's Cathedral, vastly extending the choir and providing a large crypt. This work appears to have been completed c 1130.

In 1174 the choir was damaged by an extensive fire and it fell to William of Sens to rebuild it in the new gothic style. This work was completed by his successor, William the Englishman, who also added the Trinity Chapel, a shrine for the relics of St. Thomas the Martyr, and the Corona ('crown') at the eastern end of the church. In the early-fifteenth century Prior Thomas Chillenden rebuilt the nave in the Perpendicular style, but left the Norman and Early English east end in place. The cathedral ceased to be an abbey during the Dissolution of the Monasteries, surrendering to the Crown in March 1539: it then reverted to its previous status of 'a college of secular canons'. The original Norman north-west tower was demolished in the late 1700s due to structural concerns. It was replaced during the 1830s with a Perpendicular style twin of the south-west tower, currently known as the 'Arundel Tower'. This was the last major structural alteration to the cathedral to be made.

THE ROOFS

Sampling and analysis by tree-ring dating of timbers within three specific areas of Canterbury Cathedral were commissioned by Rupert Austin of The Canterbury Archaeological Trust on behalf of the Dean and Chapter, this being undertaken during works to the roof of the south-east transept and the single spirelet here. Taking advantage of the ease of access and the placement of the necessary equipment at this time, sampling was extended to include the timbers of the north-west transept and the roof of the 'Bakehouse' within St Anselm's Tower.

Spirelet to the south-east transept

It has been thought for some time that the spirelet to the south-east transept is one of the cathedral's oldest roofs, most of those elsewhere having been rebuilt during the eighteenth, nineteenth, and twentieth centuries. The timberwork here comprises a conical frame of 15 rafters set on an octagonal ring beam or wall plate. The wall plates are held by two tiebeams set at right-angles to each other, and four further horizontal beams set into the plate at their outer ends and a horizontal rectangular frame near the middle (see Fig 3a–c). From the tiebeams and horizontal plates vertical posts, set in from the ends of the beams, rise to meet the rafters midway along their length as they come together at the apex of the spirelet, having passed braces which spring from lower down the rafters.

North-west transept

The roof of the north-west transept (Fig 4a/b) comprises four scissor-braced principal rafter trusses, the trusses having collars supported from the principals by almost straight braces. Struts, slightly curved, rise from the collar of each truss to meet the principals. There are two purlins to each pitch of the roof, there being wind braces from the principal rafters to the lower purlins only. The common rafter frames, five to each bay, are set onto a wall plate and given soulaces and ashlars, as are the trusses.

Roof to 'Bakehouse'

Although known as the 'Bakehouse' because of the presence of a large fireplace here, it is very unlikely that this was ever the function of this first-floor room to the south-east of the nave. The roof here comprises 14 close-set, low-pitched pairs of heavy rafters, set into a longitudinal ridge beam (Fig 5a/b).

SAMPLING

Thus, from the timbers available in these three areas, a total of 54 core samples was obtained. Each sample was given the code KCA-C (for Kent, Canterbury, site "C") and numbered 11–73, following on from samples KCA-C01–08 obtained from the 'Bell Harry Tower' during a small programme of analysis in 1988 (Howard *et al* 1988). Gaps have been left in the number sequence to further help differentiate sample locations. Thus, 11 samples, KCA-C11–21, were obtained from the spirelet to the south-east transept with, in an attempt to obtain a date from this denrdrochronologically difficult roof, a further 32 samples, KCA-C31–62, from the roof of the north-west transept. Finally, 11 samples, KCA-C63–73, were obtained from the roof of the 'Bakehouse'. The positions of these samples have been marked on plans and other drawings produced here as Figures 6–8, with further details of the samples being given in Table 1.

The Nottingham Tree-ring Dating Laboratory would like to take this opportunity to thank The Dean and Chapter of Canterbury Cathedral, not only for generously funding this programme of tree-ring analysis, but also for the help of their staff whose considerable assistance, ingenuity, and skill in manipulating equipment such as ladders and lights into awkward locations proved invaluable. Finally, we would also like to thank Rupert Austin of The Canterbury Archaeological Trust for providing drawings and much background information.

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 most frequently used building timber in England) 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 these annual growth-rings 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. Trees growing at the same time and in the same place thus have a very similar ring pattern.

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.

The third principle of tree-ring dating is that, until the early- to mid-eighteenth century, builders of timber-framed houses usually obtained all the wood needed for a given structure by felling the necessary trees in a single operation from one patch of woodland, or from closely adjacent woods. Furthermore, and contrary to popular belief, the timber was used 'green' and without seasoning, and there was very little long-term storage as in timber-yards of today. This fact has been well established from a number of studies where tree-ring dating has been undertaken in conjunction with documentary studies. Thus, establishing the felling date for a group of timbers gives a very precise indication of the date of their use in a building.

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 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, plus any allowance for partial cell growth of any following incomplete ring, is the felling date of the tree. In the Tables and bar diagrams of this report, the retention of complete sapwood on a sample is denoted by upper case 'C'.

Sometimes, complete sapwood is found on a timber, but, because of its soft condition, some, or all of it, crumbles as the sample is cored. It is possible to measure how much of the sapwood part of the core has been lost and from this it is sometimes possible to estimate the number of rings the lost portion might have represented. From this it is possible to make a reasonable estimate of the felling date of the timber. Such a state is represented by lower case 'c' in the Tables and bar diagrams.

Where the sapwood is not complete it is necessary to calculate a likely felling date range for 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, it is 95% probable 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)).

Given that in a timber-framed building the trees required for each phase have almost certainly been cut in a single felling operation especially for that building, it is usual to calculate the average date of the heartwood/sapwood boundary, not on the basis of each single individual sample, but from *all* the dated samples, where it exists, from each phase of a building and add 15 to 40 rings to this average to get the likely overall felling date range of all the timbers used.

In this calculation, wide variations in the position/date of the heartwood/sapwood boundary (possibly suggesting different felling dates) must be noted and taken into consideration.

ANALYSIS

In the case of the 54 samples obtained from the three locations at Canterbury Cathedral, each was prepared by sanding and polishing to clearly show the individual annual growth rings. It was seen at this time that eight samples had less than the minimum of 50 rings necessary for reliable dating, and they were rejected from this programme of analysis.

The annual growth-ring widths of the remaining 46 samples were, however, measured and these data were then compared with each other as described in the notes above. At a minimum value of t=4.5 11 different groups, accounting for 35 measured samples, could be formed, the individuals of each group cross-matching with each other at the positions shown in the bar diagram, Figures 9–19. The cross-matching samples of each group were combined at the indicated off-set positions to form site chronologies KCACSQ01–11. Each site chronology was then compared with a large corpus of reference chronologies for oak, this process indicating repeated and consistent matches with a high number of these references for three site chronologies. The evidence for this dating is given in the *t*-values of Tables 2–4.

Each site chronology thus created was compared with the remaining 11 measured but ungrouped samples. There was, however, no further cross-matching. Each of the ungrouped samples was then compared individually with the full corpus of reference material for oak, but again here was no further cross-matching and all these individuals must remain undated. This analysis may be summarised as below.

Site chronology	Number of samples	Number of rings	Date span AD (where dated)	Bar diagram Figure
KCACSQ01	4	162	932–1093	9
KCACSQ02	2	59	1184–1242	10
KCACSQ03	2	70	undated	11
KCACSQ04	10	156	1228–1383	12
KCACSQ05	3	105	undated	13
KCACSQ06	3	105	undated	14
KCACSQ07	2	99	undated	15
KCACSQ08	3	88	undated	16
KCACSQ09	2	81	undated	17
KCACSQ10	2	75	undated	18
KCACSQ11	2	68	undated	19
Ungrouped singles	11	---	undated	---
unmeasured	8	---	---	---

INTERPRETATION AND CONCLUSION

The spirelet

The earliest material is represented by the four dated samples from the spirelet in site chronology KCACSQ01 (Fig 9). None of these four samples retains complete sapwood (the last ring produced by the trees represented before they were cut down), and it is thus not possible to determine precisely when the timbers they represent were felled. All four samples, however, do retain some sapwood or at least the heartwood/sapwood boundary (h/s), and it is thus possible to calculate an estimated felling date range for the timbers. The average date of the heartwood/sapwood boundary on these four is 1082. Allowing for a 95% confidence limit of 15-40 for the number of sapwood rings the trees are likely to have would give the timbers an estimated felling date in the period 1097–1122.

Two other dated timbers used in the spirelet, and represented by samples KCA-C14 and C17 in site chronology KCACSQ02 (Fig 10), however, must have been felled later. The average date of the heartwood/sapwood boundary on these two is 1242. Again allowing for a 95% confidence limit of 15-40 for the number of sapwood rings the trees are likely to have would give the timbers an estimated felling date in the period 1257–1282.

'Bakehouse' roof

The latest material of all dated in this programme of analysis, are the timbers from the roof of the 'Bakehouse', represented by the 10 samples in site chronology KCACSQ04 (Fig 12). One of these samples, KCA-C69, retains complete sapwood. This means that it has the last ring produced by the tree represented before it was felled. In this case the last ring, and thus the felling of the tree, is dated to 1383. Given the relative position of the heartwood/sapwood boundary on all the samples from this roof, it is likely that they represent timbers cut as part of a single programme of felling, and that all the timbers used in this roof were felled in 1383.

Such an interpretation is supported by the cross-matching of the individual samples from this roof, with values in excess of t=7.0, t=8.0, and even t=9.0 being seen. Such high t-values would suggest that these timbers were all growing very close to each other in the same copse or stand of woodland. Were the timbers felled at different times there is a greater possibility that they would have come from different woodlands. Were this the case it would be expected that the samples would cross-match with each other less well than they do.

North-west transept roof

In respect of cross-matching it is interesting, though very disappointing, that there is so little between the samples from the north-west transept, nor any satisfactory, repeated and consistent, matching for any site chronology, or any individual sample from this roof, with any available reference chronology. This roof must, therefore, remain undated by tree-ring analysis for the moment, though it will of course be re-visited as further dated material from Kent and south-east England becomes available in the future.

This outcome is particularly unusual in respect of the number of samples obtained here, 32. The usual compliment for such a roof would normally be 10–12 samples from which it might be expected that at least 6–8 would cross-match with each other and date by comparison with the reference chronologies, in a similar fashion to the samples from the spirelet and the 'Bakehouse' roof.

There are various possibilities that might account for this. One possibility is that the material used in this roof has come from many different sources as individual trees, or as groups of two or three. The result is that the trees, although growing at the same time as each other, have been affected by different weather and thus have different ring patterns to each other. It is the differences in the growth patterns that precludes cross-matching between samples. However, even if this were the case, it might still be expected that some of the groups of samples which have formed, or some of the individual samples, would cross-match with some reference patterns from different areas of the country and thus be dated. As we have seen, this is not the case.

Indeed while the source woodland for the timbers in site chronologies KCACSQ01–SQ03, which are dated, cannot be identified precisely by dendrochronology (eg Bridge 2000), it is probable that these at least are of relatively local origin. As may be seen from Tables 2–4, which list short selections of the reference chronologies used to date each site sequence, the highest *t*-values, and thus the greatest degree of similarity, are almost always with the reference chronologies made up of material from other sites in Kent and south-east England. While the source woodlands for each of these sites is itself unknown it is unlikely that such timbers have come very far, and intimates that the timber used in the spirelet and the Bakehouse has come from Kent as well. It might thus be expected that the timbers of the north-west transept would come from Kent as well.

Another possibility is that the trees used here were all growing at the same time in the same place (or possibly also in different places), but have been affected on an individual basis at different times by some non-climatic effect such as coppicing, pollarding, or stripping. This might have the effect of masking or cancelling-out the climate pattern by which the samples are cross-matched with each other to form a site chronology and then cross-matched with the reference chronologies and dated. It should be pointed out, however, that there is no evidence in the ring patterns of any peculiarities, such as distortion or compression, which might indicate such activity. As far as can be seen, there is nothing unusual about the samples at all. Whatever the cause, the affect is that only some of these samples cross-match with each other to form a number of small site chronologies, and that none of them date by comparison to the reference chronologies.

A third possibility, and one which might require detailed archaeological examination of the timbers to confirm or reject, is that this roof is composed of timbers which have been felled at widely different dates and either stockpiled or reused from another roof. Such a case would account for the fact that the growth patterns do not cross-match with each other (because they were growing at different times and thus affected by different weather), and make it more likely that the timbers used here may also come from different sources. This has the effect of making the samples ‘singletons’, and while such samples can sometimes be dated, it is much more difficult than with well replicated groups, such as that seen in site chronology KCACSQ03 from the ‘Bakehouse’ roof. It should be stressed however, that, superficially at least, there is no evidence by way of redundant mortices and peg-holes, for reuse.

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Table 1: Details of tree-ring samples from Canterbury Cathedral, Kent

Sample number	Sample location	Total rings	Sapwood rings*	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
	Spirelet					
KCA-C11	Post, frame 2	nm	---	------	------	------
KCA-C12	Post, frame 15	71	11	1014	1073	1084
KCA-C13	Rafter, frame 15	55	21	------	------	------
KCA-C14	Brace, frame 13	58	6	1184	1235	1241
KCA-C15	Post, frame 11	nm	---	------	------	------
KCA-C16	Rafter, frame 10	143	h/s	932	1074	1074
KCA-C17	Brace, frame 9	53	9	1190	1233	1242
KCA-C18	Post, frame 8	121	h/s	973	1093	1093
KCA-C19	Brace, frame 8	70	26C	------	------	------
KCA-C20	Rafter, frame 7	75	h/s	1015	1089	1089
KCA-C21	Post, frame 4	75	11	------	------	------
	North-west transept					
KCA-C31	Truss 1, east archbrace	nm	---	------	------	------
KCA-C32	Truss 1, west archbrace	86	no h/s	------	------	------
KCA-C33	Bay 2, east ashlar 1	67	no h/s	------	------	------
KCA-C34	Bay 2, east ashlar 2	65	no h/s	------	------	------
KCA-C35	Bay 2 , east ashlar 5	nm	---	------	------	------
KCA-C36	Truss 2, west ashlar	84	no h/s	------	------	------
KCA-C37	Bay 3, west common rafter 2	61	h/s	------	------	------
KCA-C38	Bay 3, east common rafter 3	nm	---	------	------	------
KCA-C39	Bay 3, west common rafter 4	58	h/s	------	------	------
KCA-C40	Truss 3, east archbrace	77	h/s	------	------	------
KCA-C41	Bay 4, east common rafter 3	77	h/s	------	------	------
KCA-C42	Truss 4, west principal rafter	72	h/s	------	------	------

Table 1: continued

Sample number	Sample location	Total rings	Sapwood rings*	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
	North-west transept continued					
KCA-C43	Bay 4, east ashlar 1	60	h/s	------	------	------
KCA-C44	Truss 4, collar	nm	---	------	------	------
KCA-C45	Bay 4, west purlin	nm	---	------	------	------
KCA-C46	Bay 4, east ashlar 4	70	h/s	------	------	------
KCA-C47	Bay 4, east ashlar 5	66	h/s	------	------	------
KCA-C48	Truss 4, west archbrace	nm	---	------	------	------
KCA-C49	Truss 1, east queen strut	78	no h/s	------	------	------
KCA-C50	Truss 1, east scissor brace	66	h/s	------	------	------
KCA-C51	Truss 1, west queen strut	72	no h/s	------	------	------
KCA-C52	Truss 1, west scissor brace	81	h/s	------	------	------
KCA-C53	Truss 2, east archbrace	55	no h/s	------	------	------
KCA-C54	Truss 2, west scissor brace	75	no h/s	------	------	------
KCA-C55	Truss 3, east scissor brace	85	no h/s	------	------	------
KCA-C56	Truss 3, west queen strut	78	no h/s	------	------	------
KCA-C57	Bay 4, south windbrace, east side	78	no h/s	------	------	------
KCA-C58	Truss 4, east archbrace	75	no h/s	------	------	------
KCA-C59	Truss 4, east queen strut	75	h/s	------	------	------
KCA-C60	Truss 4, east scissor brace	73	no h/s	------	------	------
KCA-C61	Truss 4, west scissor brace	73	no h/s	------	------	------
KCA-C62	Truss 4, west queen strut	71	h/s	------	------	------
	Bakehouse roof					
KCA-C63	East rafter, frame 5	75	h/s	1279	1353	1353
KCA-C64	West rafter, frame 7	74	h/s	1285	1358	1358
KCA-C65	East rafter, frame 8	71	h/s	1294	1364	1364
KCA-C66	West rafter, frame 8	97	h/s	1255	1351	1351
KCA-C67	East rafter, frame 10	90	h/s	1275	1364	1364

Table 1: continued

Sample number	Sample location	Total rings	Sapwood rings*	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
	Bakehouse roof continued					
KCA-C68	West rafter, frame 10	115	22	1265	1357	1379
KCA-C69	East rafter, frame 11	141	37C	1243	1346	1383
KCA-C70	West rafter, frame 11	137	h/s	1228	1364	1364
KCA-C71	King post	73	h/s	------	------	------
KCA-C72	East rafter, frame 2	108	h/s	1243	1350	1350
KCA-C73	West rafter, frame 4	125	17	1245	1352	1369

*h/s = the last ring on the sample is at the heartwood/sapwood boundary

C = complete sapwood is retained sample not measured, where dated the last measured ring date is the felling date of the tree represented

nm = sample not measured

Table 2: *Results of the cross-matching of site chronology KCACSQ01 and relevant reference chronologies when first ring date is 932 and last ring date is 1093*

Reference chronology	*Span of reference*	*t*-value	
England, London	413–1728	9.8	(Tyers and Groves 1999 unpubl)
Newbury Farmhouse, Tonge, Kent	938–1172	9.5	(Arnold *et al* 2001)
London Billingsgate	611–1243	9.3	(Hillam 1992)
London Fennings Wharf	743–1241	9.1	(Tyers 1997)
LON-S01M	950–1193	7.7	(Morgan 1977)
Hampshire county chronology	443–1972	6.8	(Miles 2003)

Table 3: *Results of the cross-matching of site chronology KCACSQ02 and relevant reference chronologies when first ring date is 1184 and last ring date is 1242*

Reference chronology	*Span of reference*	*t*-value	
Kent-88	1158–1540	7.0	(Laxton and Litton 1989)
Ightham Mote, Kent	1157–1327	6.6	(Howard 2002 unpubl)
Hildenborough Manor, Hildenborough, Kent	1094–1329	5.6	(Arnold and Howard 2006 unpubl)
England, London	413–1728	5.3	(Tyers and Groves 1999 unpubl)
Nurstead Court (wing), Meopham, Kent	1183–1298	5.0	(Howard *et al* 1988)

Table 4: *Results of the cross-matching of site chronology KCACSQ03 and relevant reference chronologies when first ring date is 1228 and last ring date is 1383*

Reference chronology	*Span of reference*	*t*-value	
Worcester Cathedral, composite chronology	1286–1424	7.3	(Arnold *et al* 2003)
8-9, The Parade, Canterbury, Kent	1247–1374	6.7	(Arnold and Howard 2007)
Archbishop's Palace, Charring, Kent	1280–1481	5.6	(Howard *et al* 1998)
St Mary Magdalene, Cowden, Kent	1257–1439	5.5	(Howard *et al* 1999)
Cobham Hall, Cobham, Kent	1317–1662	5.3	(Arnold *et al* 2003)
Manor Farm Barn, Frindsbury, Kent	1254–1403	5.2	(Arnold *et al* 2002)

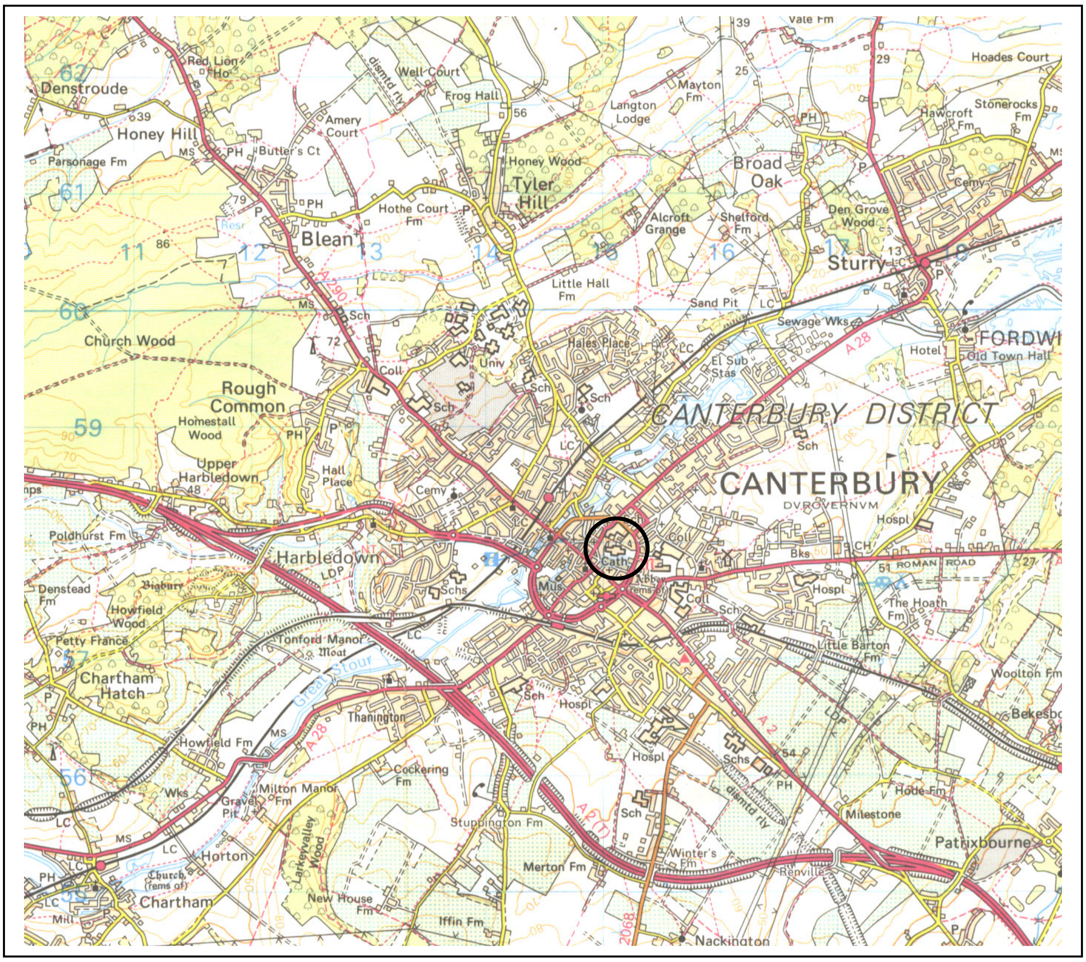

Figure 1: Map to show location of Canterbury Cathedral

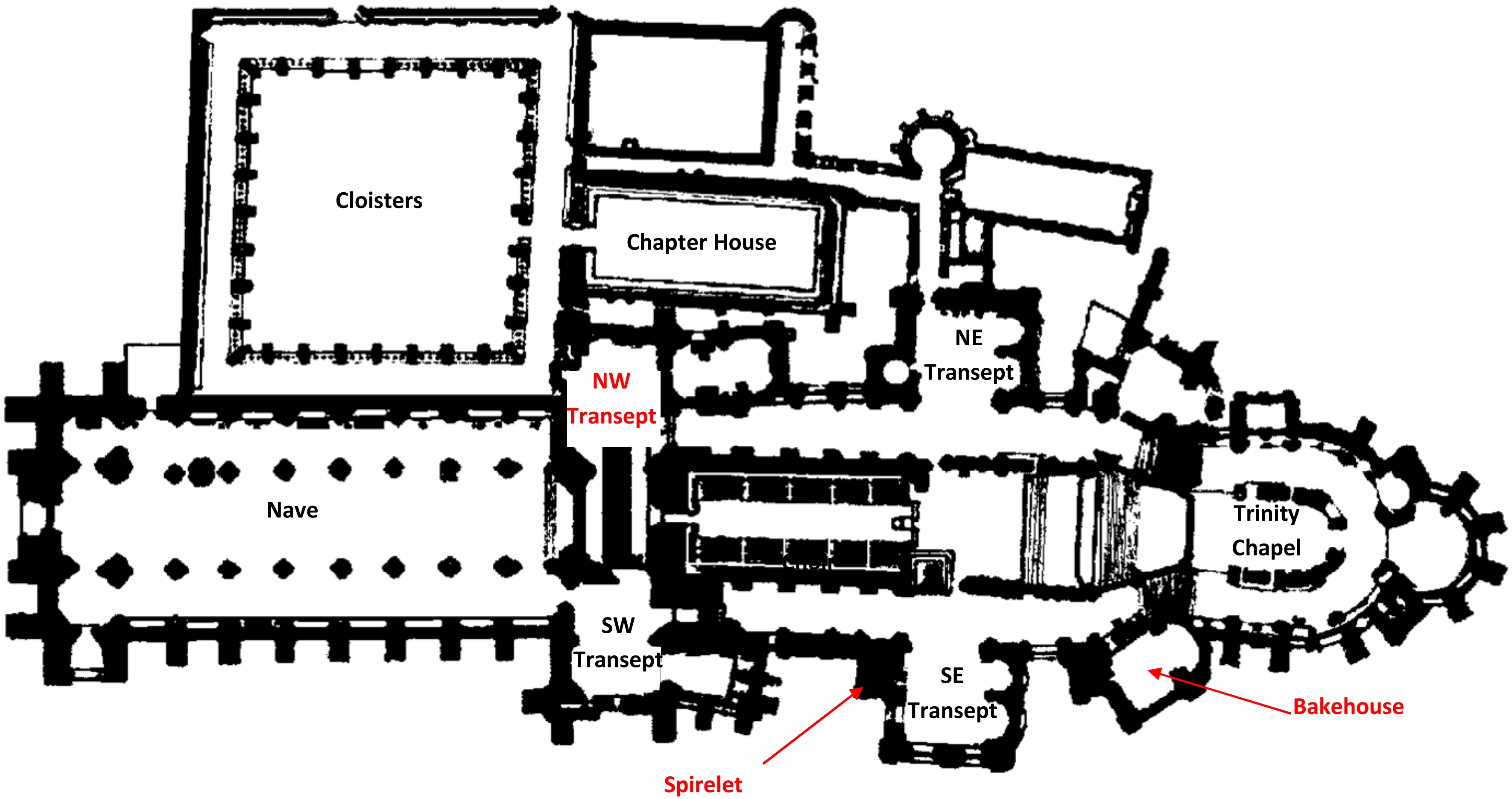

Figure 2: Plan of Canterbury Cathedral to show areas under examination

Figure 3a/b: Views of the spirelet showing the rafters, vertical posts, and passing braces

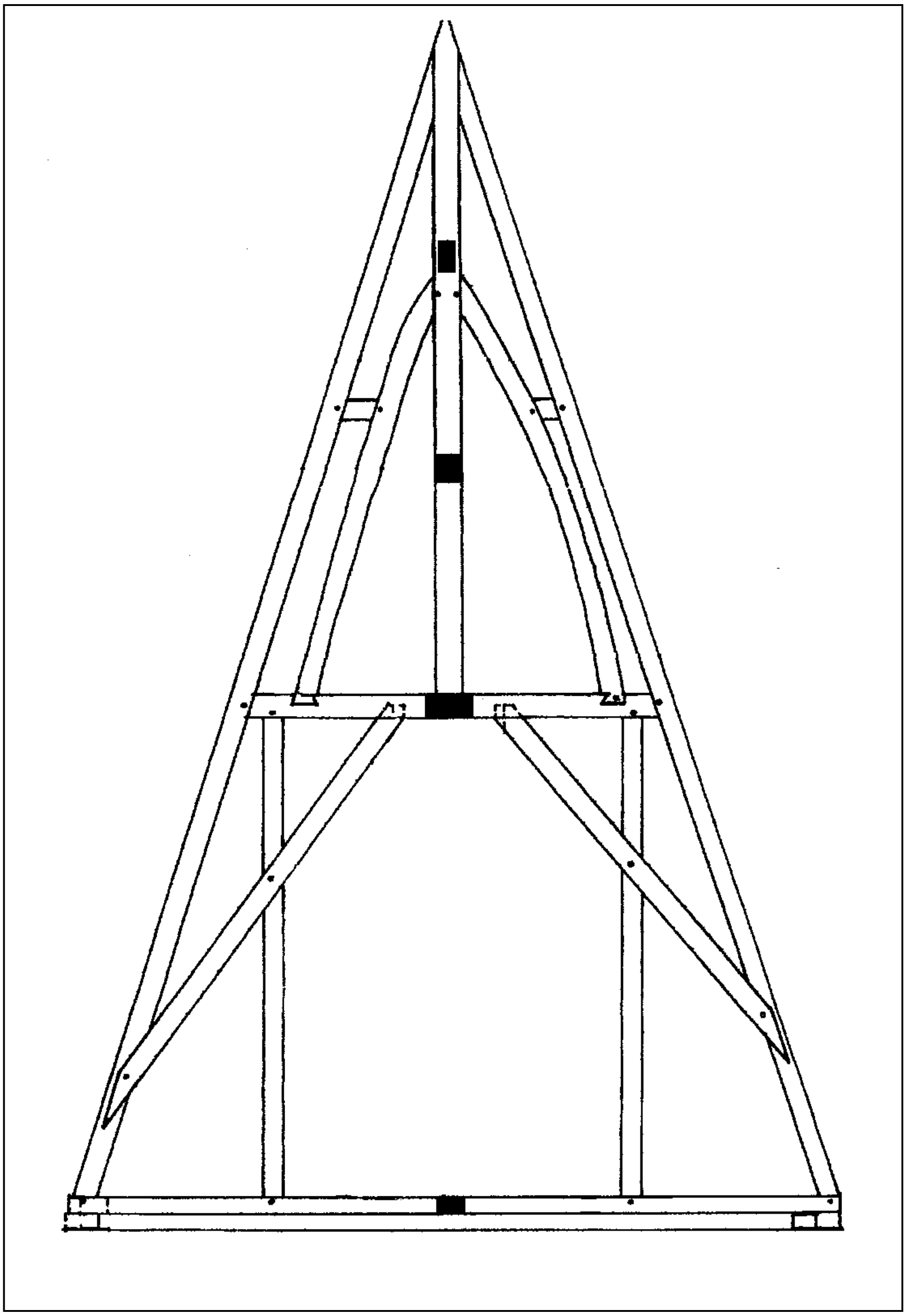

Figure 3c: Sectional drawing of the spirelet
(after T. E. Watkin, 1993)

Figure 4a/b: Views of the roof to the north-west transept

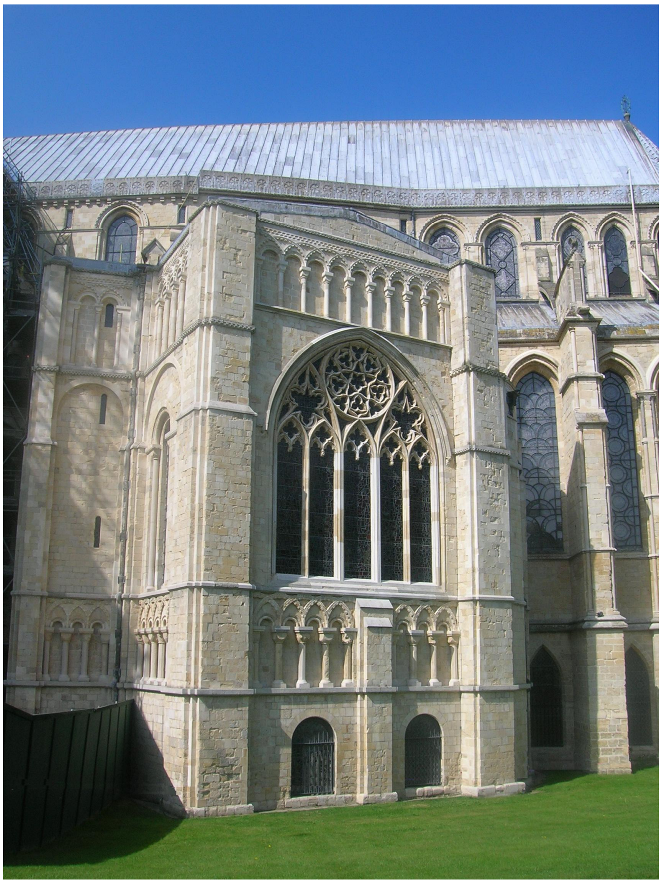

Figure 5a/b: View of St Anselm’s Tower, top, and the ‘Bakehouse’ roof, bottom

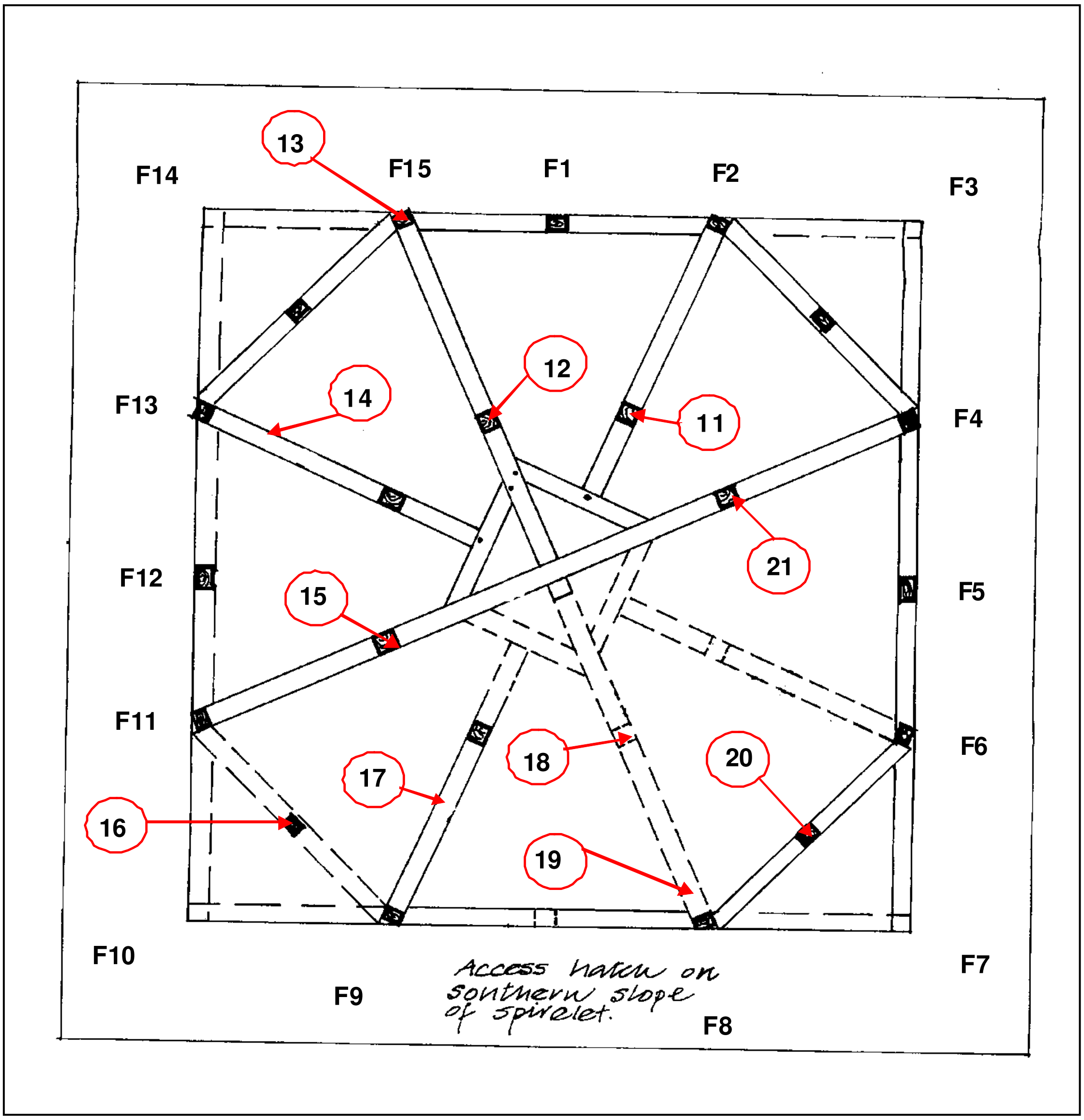

Figure 6: Plan of the spirelet to show position of sampled timbers
(after T.E.Watkin, 1993)

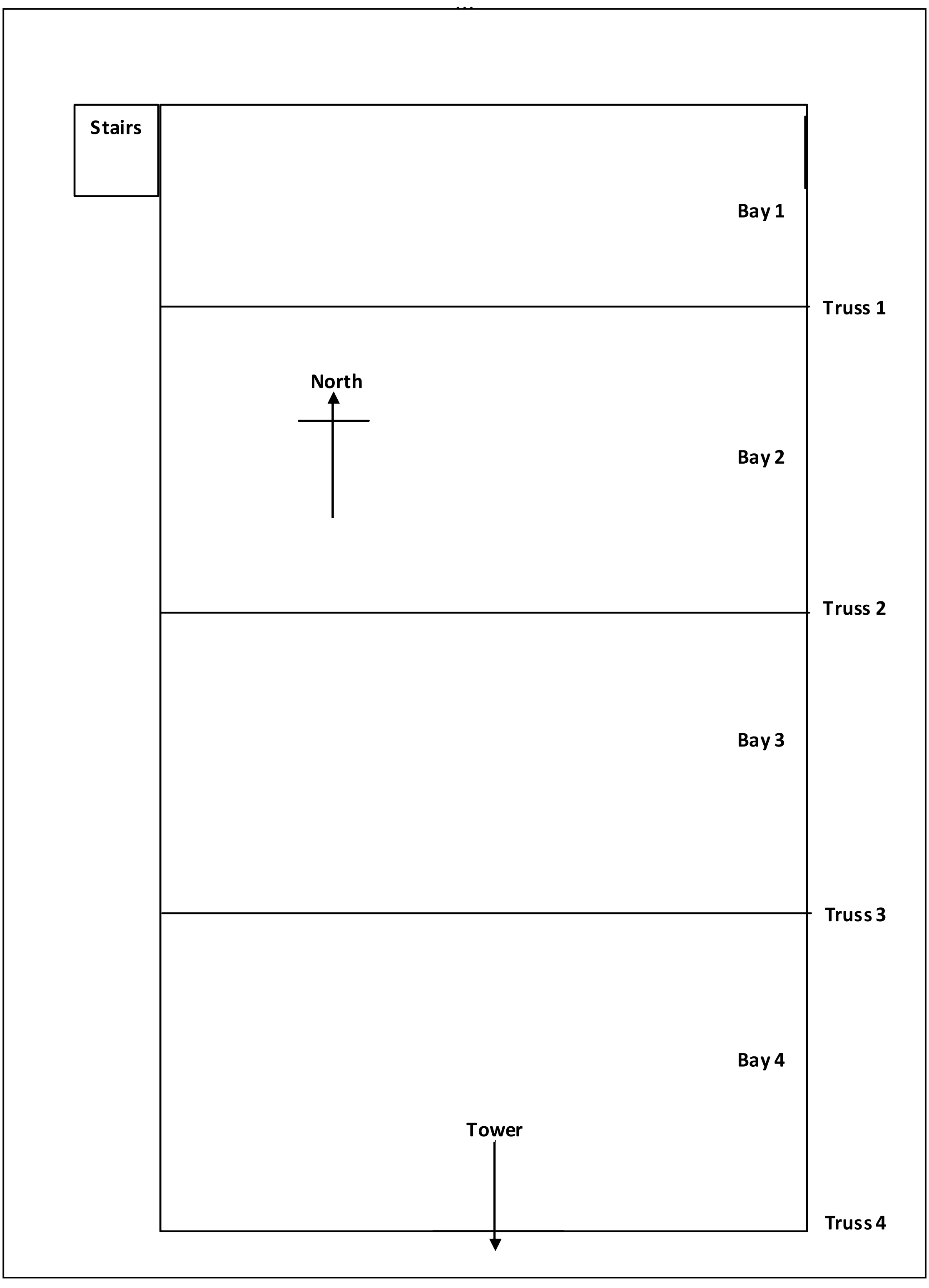

Figure 7a: Simple plan of north-west transept to show truss and bay positions

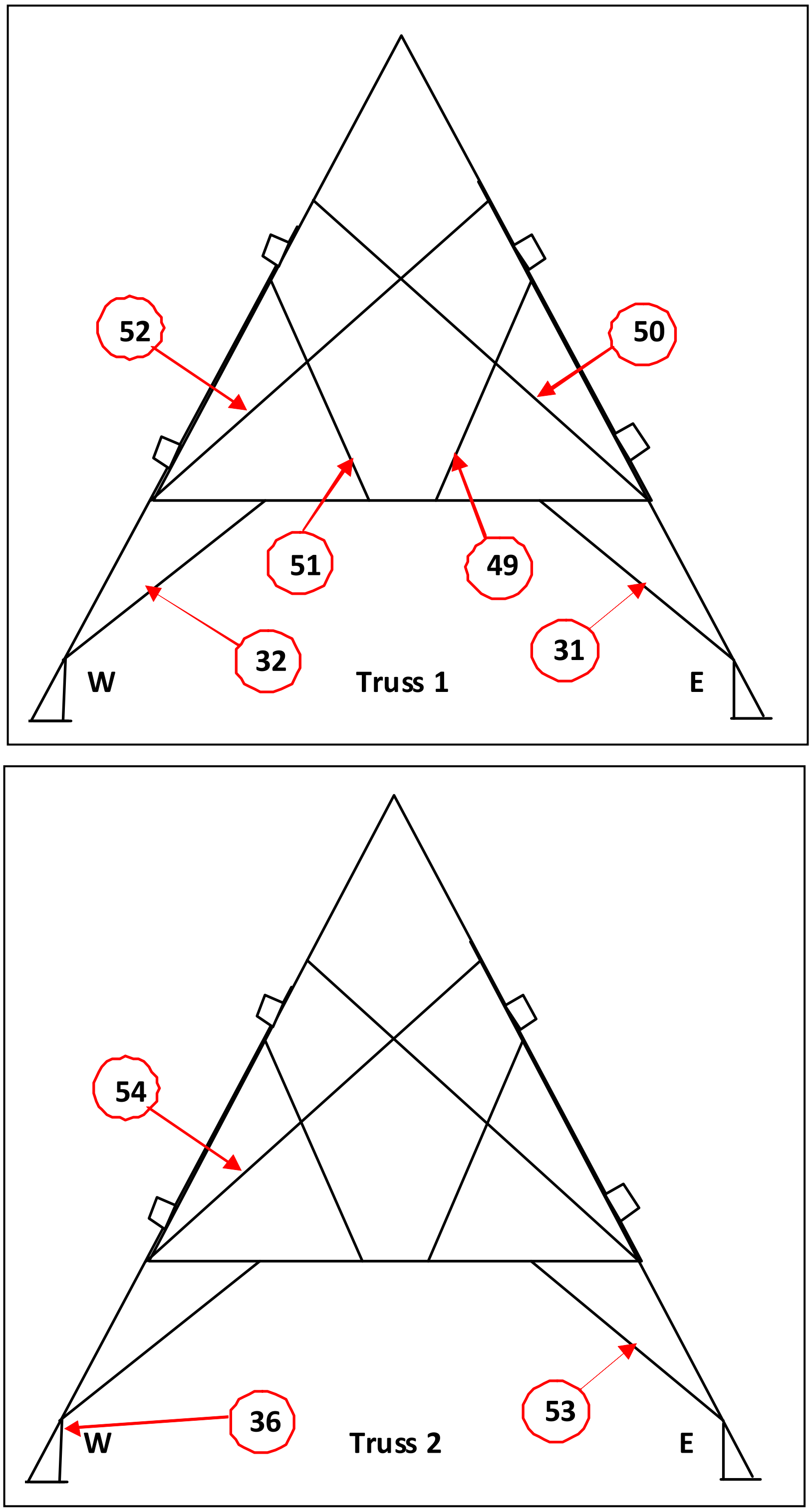

Figure 7b: North-west transept roof showing sampled timbers

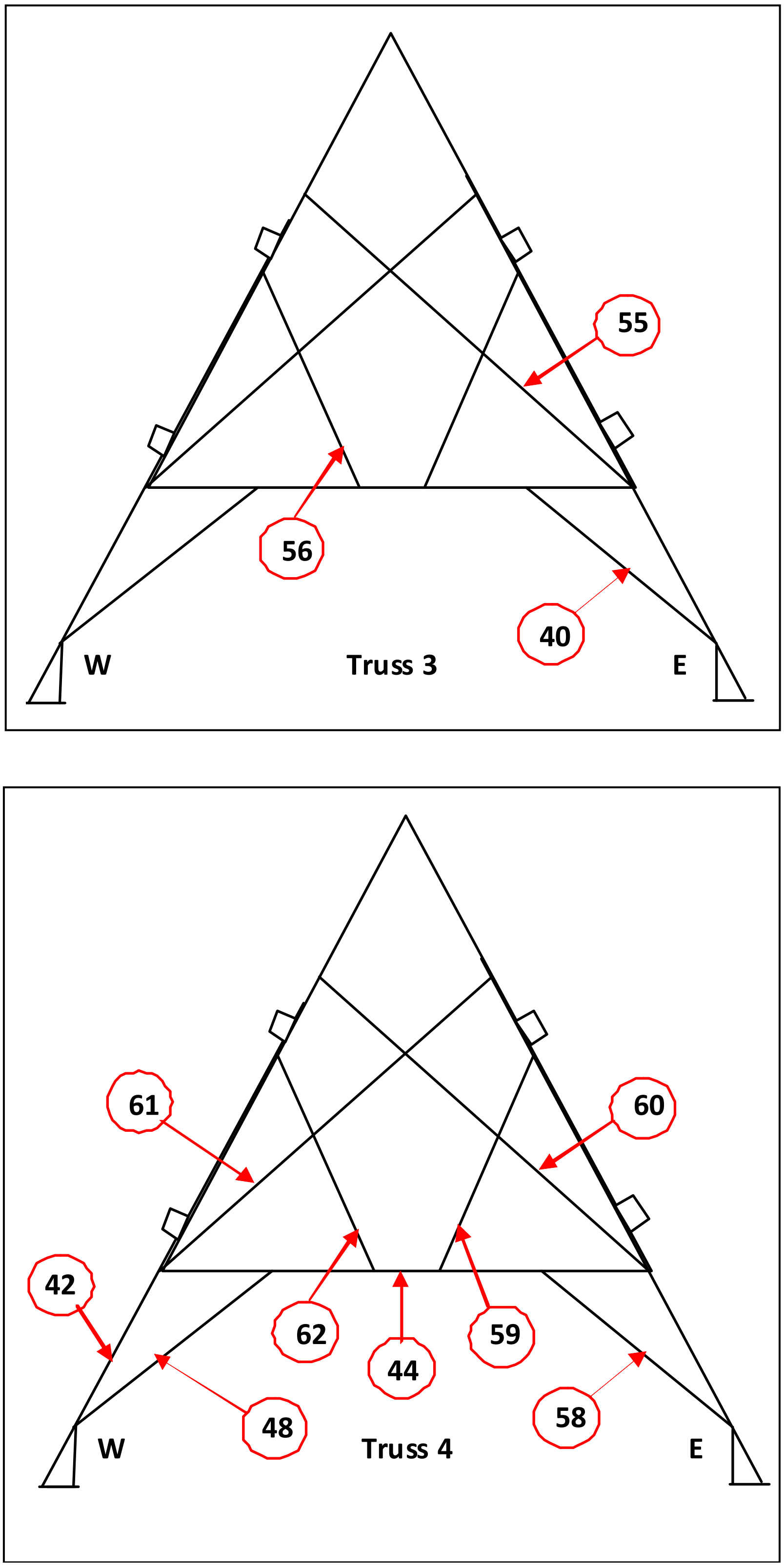

Figure 7c: North-west transept roof showing sampled timbers

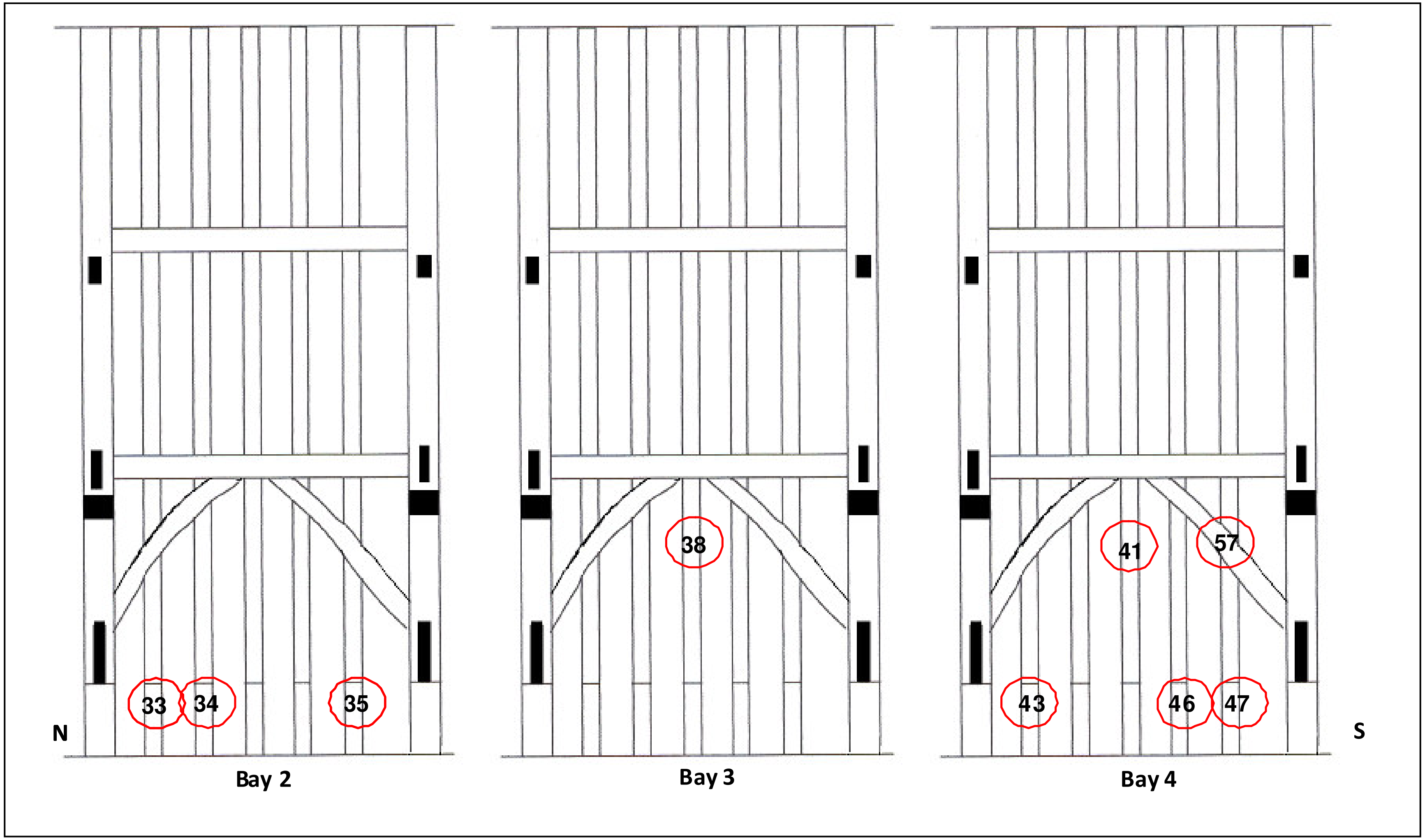

Figure 7d: Long-section through north-west transept roof to show sampled timbers (viewed from the west looking east)

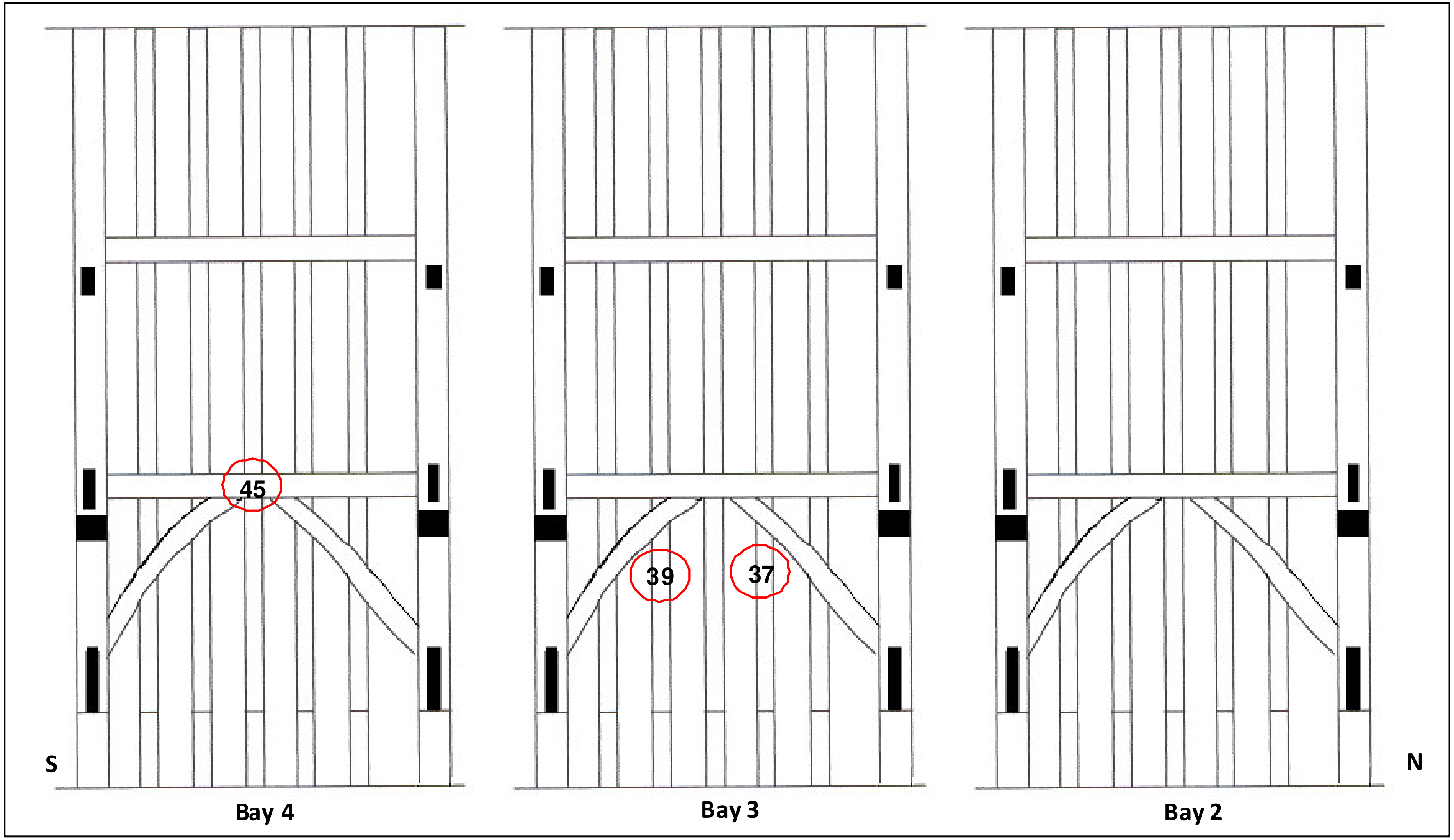

Figure 7e: Long-section through north-west transept roof to show sampled timbers (viewed from the east looking west)

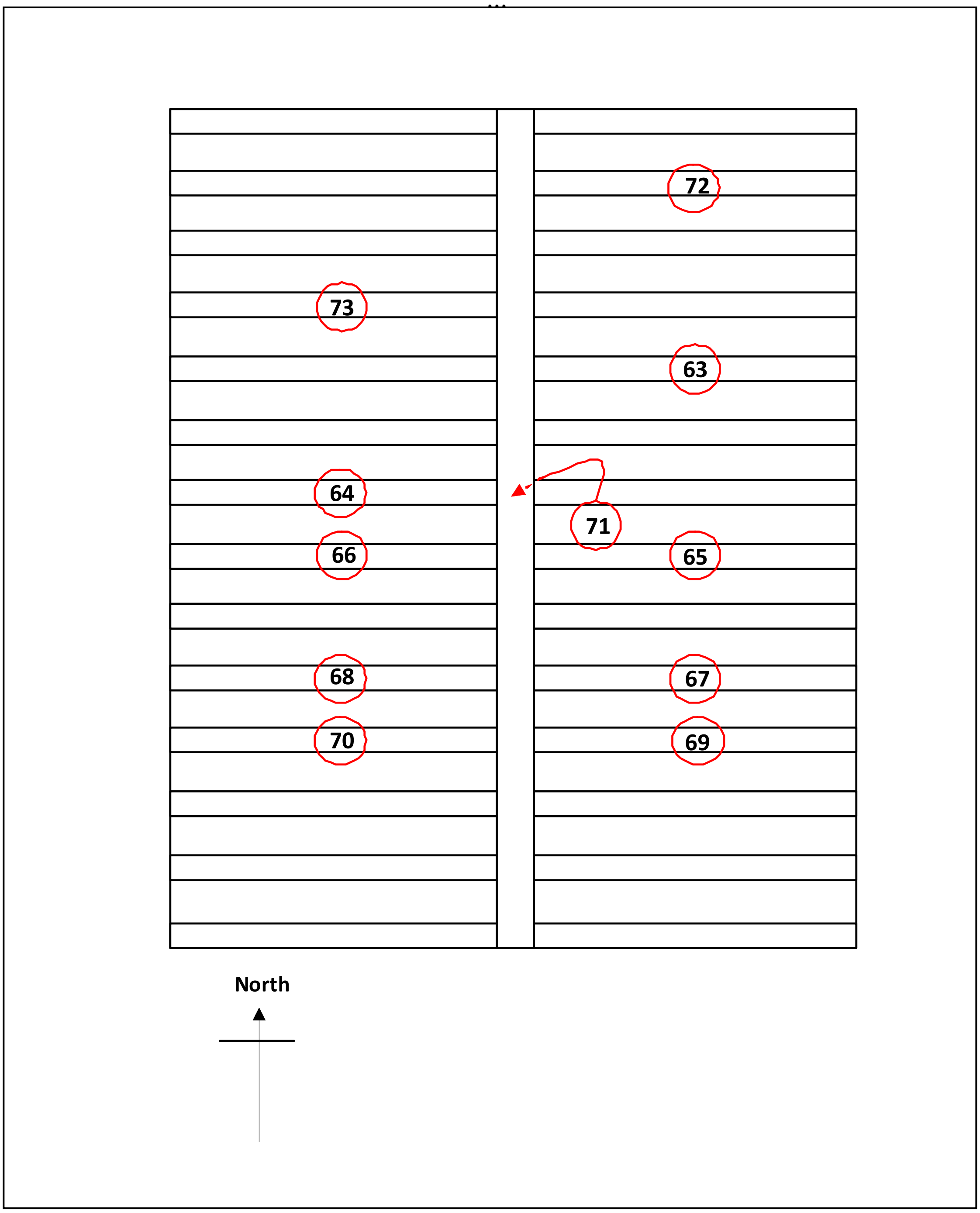

Figure 8: Plan of the 'Bakehouse' roof to show sampled timbers

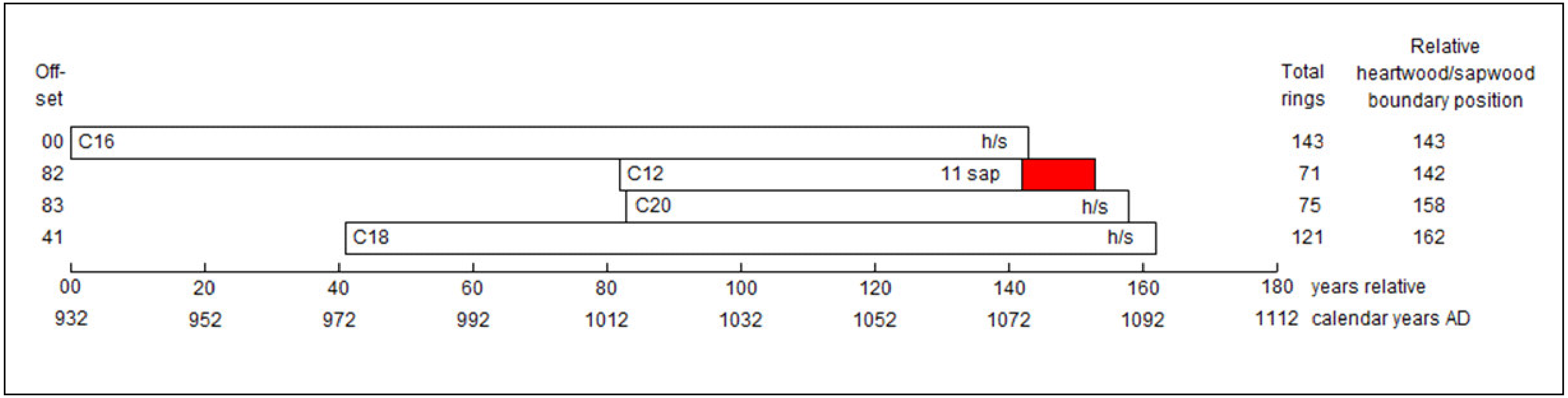

Figure 9: Bar diagram of the samples in site chronology KCACSQ01

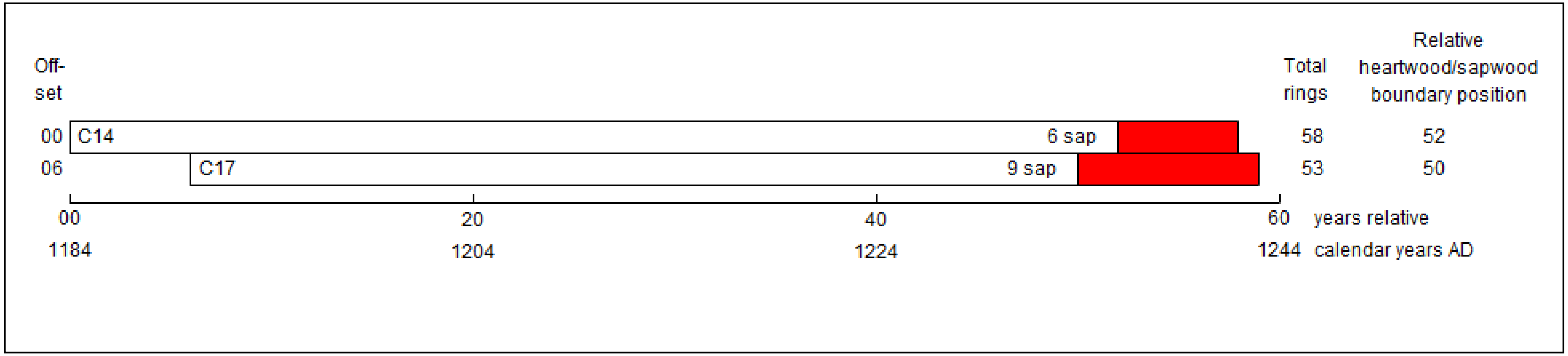

Figure 10: Bar diagram of the samples in site chronology KCACSQ02

White bars= heartwood rings, red shaded area = sapwood rings
h/s = where present, the last ring on the sample is at the heartwood sapwood boundary, ie, only the sapwood rings are missing

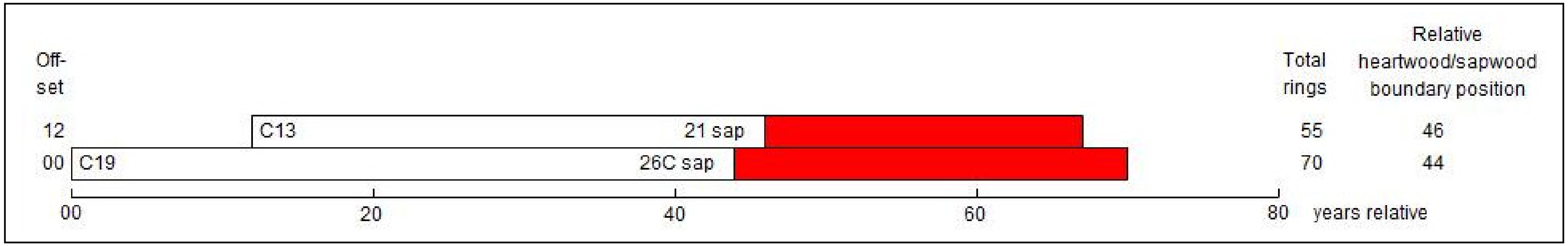

Figure 11: Bar diagram of the samples in site chronology KCACSQ03

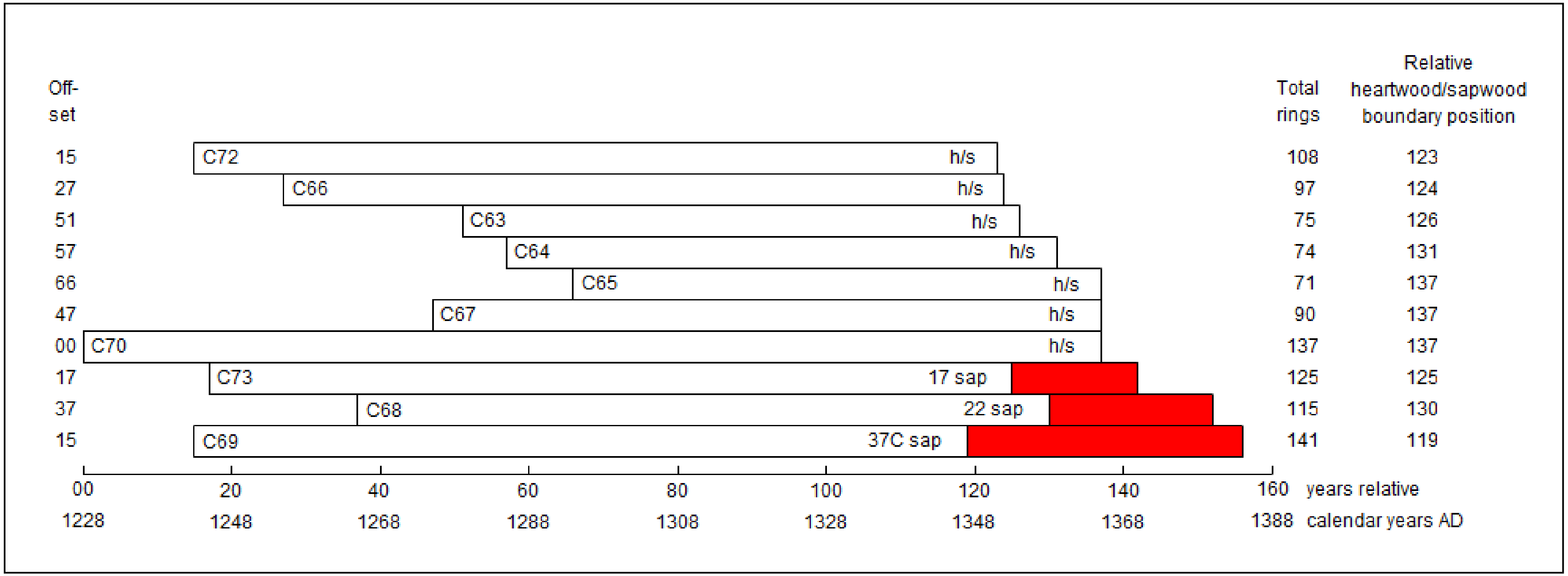

Figure 12: Bar diagram of the samples in site chronology KCACSQ04

White bars= heartwood rings, red shaded area = sapwood rings
h/s = where present, the last 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. Where dated the last measured ring is the felling date of the timber represented

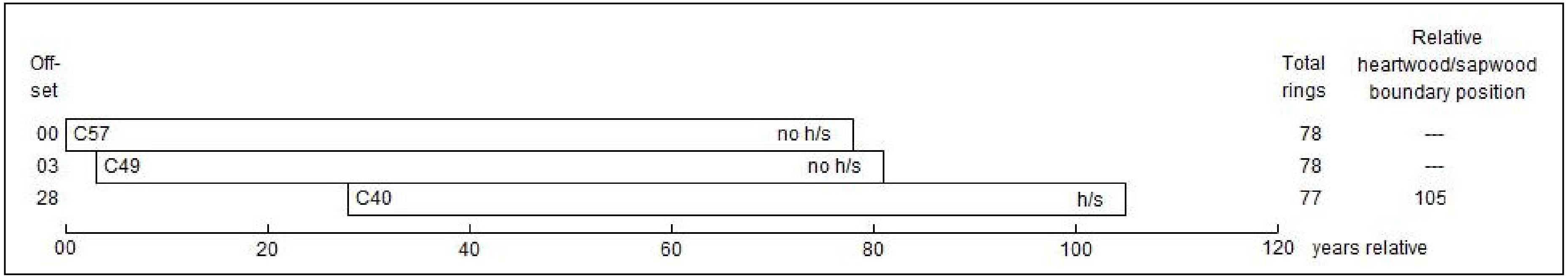

Figure 13: Bar diagram of the samples in site chronology KCACSQ05

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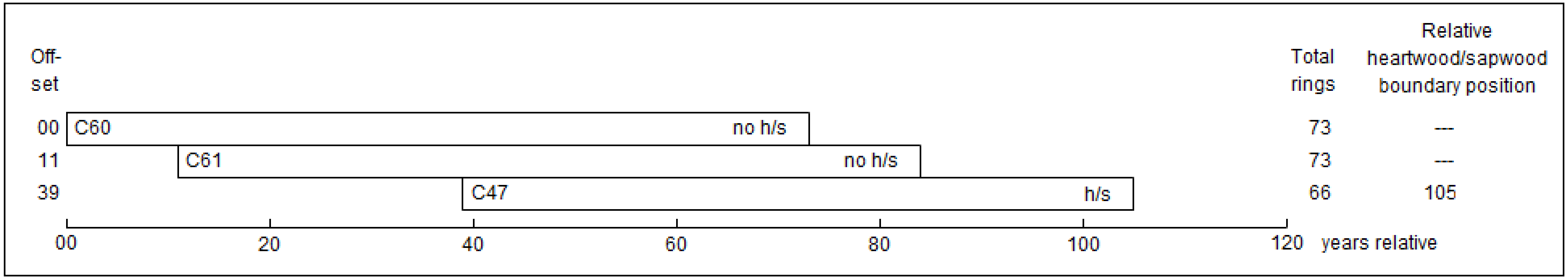

Figure 14: Bar diagram of the samples in site chronology KCACSQ06

White bars= heartwood rings, red shaded area = sapwood rings
h/s = where present, the last ring on the sample is at the heartwood sapwood boundary, ie, only the sapwood rings are missing

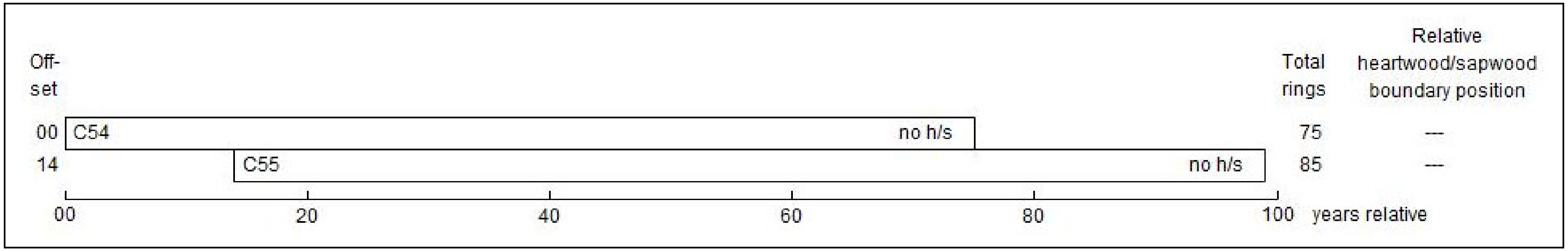

Figure 15: Bar diagram of the samples in site chronology KCACSQ07

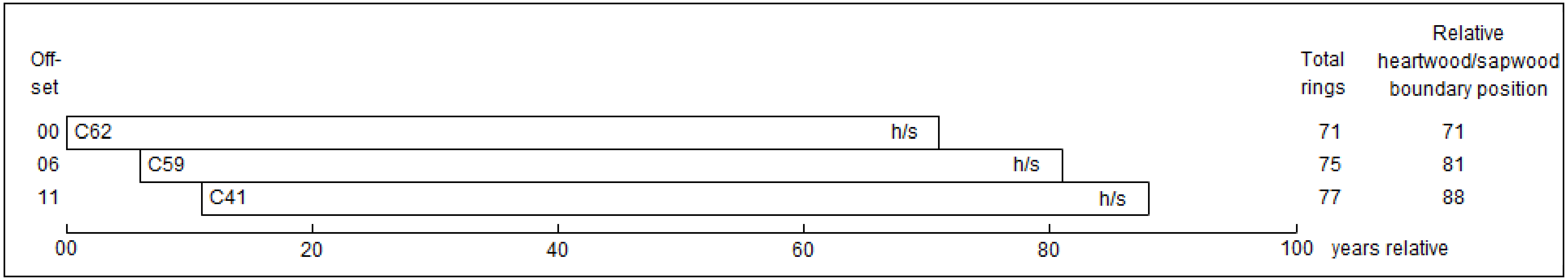

Figure 16: Bar diagram of the samples in site chronology KCACSQ08

White bars= heartwood rings
h/s = where present, the last ring on the sample is at the heartwood sapwood boundary, ie, only the sapwood rings are missing

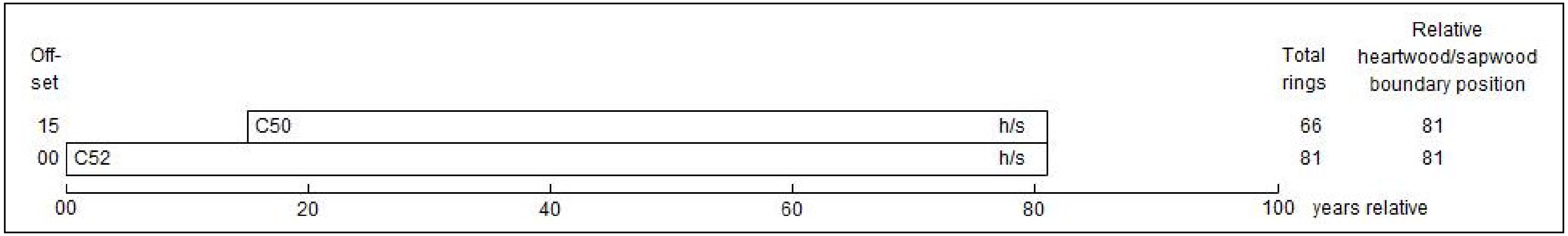

Figure 17: Bar diagram of the samples in site chronology KCACSQ09

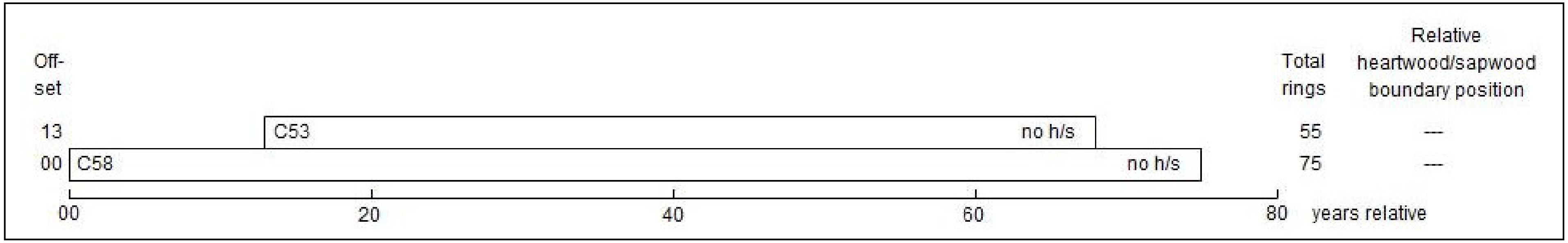

Figure 18: Bar diagram of the samples in site chronology KCACSQ10

White bars= heartwood rings
h/s = where present, the last ring on the sample is at the heartwood sapwood boundary, ie, only the sapwood rings are missing

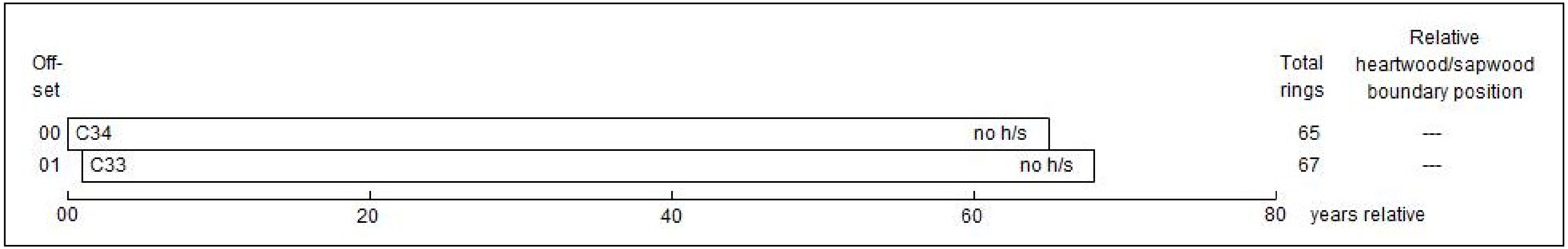

Figure 19: Bar diagram of the samples in site chronology KCACSQ11

White bars= heartwood rings
h/s = where present, the last ring on the sample is at the heartwood sapwood boundary, ie, only the sapwood rings are missing