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Summary

Of 252 samples from various high roofs of Ely Cathedral considered in this programme, 153 were selected for analysis, this producing 16 site chronologies. Of these chronologies, nine, comprising 108 samples, could be dated, with two further samples being dated individually. Seven chronologies, comprising 21 samples, did not date. There remain 22 individual samples ungrouped and undated.

The earliest material, felled in the mid-eleventh century, is found in the west tower turrets. Slightly later timbers, felled in the early-twelfth century, are found in the nave roof. Both probably represent reused Romanesque material.

Although two timbers of the nave roof were felled in AD 1223/24, the majority here was probably felled between AD 1290 and AD 1310. An individual nave timber has an estimated felling date in the range AD 1343-58. The latest nave material dates to the mid- to late-eighteenth century.

The Lady Chapel has material with an estimated felling AD 1297 to AD 1332, and 1318-53. A further timber has an estimated felling date in the range AD 1341-71, others being felled in AD 1726.

The south transept roof contains material estimated to have been felled *c* AD 1425/26.

Keywords

Dendrochronology
Standing Building

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Frontispiece: The Nave at Ely Cathedral. (© Crown copyright. NMR. AA98/00006)

Introduction

The site of Ely Cathedral (TL 541 803; Fig 1) has been a place of worship since at least AD 673, when Etheldreda, daughter of the king of East Anglia, founded a nunnery there. The site was sacked by the Danes in the AD 870s, but it was rebuilt, and by the tenth century had become a monastery of the Benedictine order. Nothing now, however, survives of the Anglo-Saxon church, which was entirely demolished when construction of the present building was commenced under the direction of Abbot Simeon in AD 1083. This work was largely complete by AD 1109 and Ely was elevated to the status of a cathedral as part of the Norman reforms of the English Church.

The cathedral was originally built with a central nave with aisles, crossed by the main north and south transepts which was topped by a low tower with a spire. At the west end of the cathedral was a further, smaller transept (with St. Catherine's Chapel), topped by a central tower between them. The west end of this original nave was terminated by a fine Romanesque facade to which was added the two-storey Galilee Porch, a later alteration in the Gothic style completed in AD 1215. The earliest surviving parts of the present cathedral, the north and south transepts, the south door and the nave, date from this time.

Slightly later in the thirteenth century, under Bishop Hugh Northwold, the short Romanesque asped choir of three bays to the east of the crossing was extended eastwards with a new six-bay addition. In addition work was undertaken to reconstruct the central tower at the west end. It is believed on documentary sources that the work on this retro-choir, or presbytery with its shrine of Saint Etheldreda, was complete by AD 1252.

In AD 1322 the central square Norman tower collapsed, destroying part of the choir and possibly part of the nave too. It was Alan of Walsingham who undertook repair of the damage taking the opportunity to widen the crossing, demolishing the first three western bays of the nave in the process, and topping the whole with the impressive octagonal lantern for which Ely Cathedral is famous. The fall of the tower and construction of the octagon interrupted work on the Lady Chapel, which had begun in AD 1321, and it was not completed until AD 1349.

At some time in the fifteenth century, the exact date is not recorded, an earthquake caused the collapse of the north-west transept. This was never rebuilt. However, further construction work was undertaken later with the Bishops' Chapels being completed in AD 1486 and AD 1530. The last great rebuilding and extension of the cathedral came during the early-sixteenth century, when two fine chantry chapels were built between the south transept and the Presbytery.

At the Dissolution of the Monasteries, the surrounding medieval buildings were either demolished or put to other uses and those that still survive are now used for many different purposes. The importance of the cathedral itself remained as the seat of the Bishop for a large portion of East Anglia. The painted decoration and carved statues all suffered under the fury of the iconoclasts of Henry VIII's time, but here and there faint traces remain.
In the mid-eighteenth century, the medieval rood screen was removed, thus providing

an open view which combines superbly with the spaciousness of the octagonal crossing (Frontispiece). The ceiling of the nave was boarded over and painted during the Victorian period and is a fine example of its time. A simple present-day plan of the cathedral is shown in Figure 2.

Sampling - AD 1987 - 90 and AD 1997 - 2002

Initially this programme of tree-ring dating considered an overall total of 252 samples from the various high roofs of the cathedral. Each sample has been given the code ELY-C (for Ely Cathedral) and is listed in Table 1. A large number of these samples, ELY-C01 - 167, were obtained during short periods of repair and restoration to small sections of the roofs between about AD 1987 and AD 1990.

These earlier samples, those obtained AD 1987 - 90, were generally taken as slices from rotted or decayed sections of timber. These decayed sections were often being removed to allow new pieces to be spliced in to the larger sound sections of timber remaining *in situ*. Samples were also obtained as slices from what appeared to be riven boards or planks set across rafters, or placed from collar to collar of the frames. In addition a few samples were obtained as graticule readings from some of the furniture, choir stalls, and backboards for example, on an occasional basis.

Because of the nature of the AD 1987 - 90 repair programme the early samples were generally obtained in a random, *ad hoc,* fashion determined more by the progress of this renovation work, rather than by a dedicated programme of dendrochronological research with the sampling of specific areas. Although the original location of all these sample timbers was recorded at the time, it was seen that many slices had fewer than 54 rings, less than the minimum for satisfactory tree-ring analysis, and such timbers were discarded. In some cases the sections of timber obtained were too decayed to be useable and these were discarded too. This is denoted by the term 'nk' (not kept) in Table 1. These samples thus do not form part of the present analysis. Furthermore, due to limited funding at that time, only a small number of the suitable samples that were initially obtained, those from about 40 timbers, were analysed as part of the earlier tree-ring dating programme.

It was only from the roof of the south transept, when scaffolding was in place in AD 1992, that satisfactory core samples, ELY-C168 - 176 and ELY-C185, could be obtained from suitable timbers with sufficient numbers of rings, and sapwood, or at least the heartwood/sapwood boundary. Additional core samples, ELY-C177 - 183 were obtained from timbers of the Lady Chapel roof, as part of a programme of research, when the lead covering was repaired in AD 1993.

Between AD 1993 and AD 2002 intermittent sampling has also been undertaken from some of the buildings of the cathedral complex, ie The Bishop's Palace. A much larger sampling programme from other buildings, such as the Cannonry, the Black Hostelry, and funded by English Heritage, has been undertaken since AD 2001. This is the subject of a separate report (Arnold *et al* 2004). The samples from these buildings have also been given the code ELY-C, and have been numbered consecutively from that last sample obtained from the cathedral.

A further small batch of samples, ELY-C305 - 313, was then obtained from the stair treads of the west tower turrets and analysed as part of a programme of research in AD 1994. One sample, ELY-C24, was obtained as a graticule reading from a choir stall backboard, one of the few pieces of cathedral furniture of fixings to be examined. These proved to be the last samples from the cathedral itself until the present programme of analysis began. Thus, given that samples have also come from other parts of the cathedral complex at different times, the samples from the cathedral roofs listed in Table 1 do not always run in consecutive order.

Sampling AD 2003

In AD 2003 English Heritage proposed a new programme of tree-ring analysis of timbers from the cathedral. As part of this new work it was decided that not only should a selection of the best samples obtained between AD 1987 and AD 1993, but never measured, now be analysed, but that further coring also be undertaken.

However, rather than dilute the number of samples taken by extending coring to wider ranging and additional areas within the cathedral, it was proposed that more intensive coring be undertaken only on those areas that had previously been sampled. It was hoped that this method of further intensive coring in specific areas would increase the number of samples cross-matching, and that the new samples would include more with complete sapwood. It was hoped that this approach would thus not only increase the number of timbers dated, but also increase the precision of the results obtained. It was believed that the dating of a larger amount of material more precisely might demonstrate possible phases of felling and potential stages of construction within the roofs.

With this sampling proposal in mind, therefore, some 56 further samples were obtained from the nave roofs. These new samples were designated ELY-C501 - 56. These newly obtained samples were to be analysed in conjunction with all those previously taken from the cathedral in earlier programmes of analysis.

Other areas, which had been sampled in the past, were also assessed in the hope of obtaining further samples, and samples with complete, or at least simply more sapwood. Such areas, the west tower / belfry for example, however, were found either to be lacking suitable accessible timbers, or had timbers that were now hidden by replacement lead work, as in the Lady Chapel roof for example. Additional samples could not be obtained from such areas.

Thus, taking both the previously obtained material (analysed and not), and the newly obtained cores, an overall total of 252 samples from the various high cathedral roofs were initially considered as part of this new programme of tree-ring dating. Of this initial overall total, 99 had to be rejected. Most of these rejects had too few rings for satisfactory analysis, though some were not analysed because, although they had sufficient rings, they may not have had sapwood or the heartwood/sapwood boundary. This programme of research therefore considers the data from 153 measured samples.

This sampling information given above is summarised overpage:

Sample area	Number of samples obtained / analysed	Sample numbers
Nave roof	226 / 132	ELY-C01 – 167 ELY-C302 – 304 ELY-C501 – 556
Lady Chapel roof	10 / 9	ELY-C168 – 178 ELY– C185
South transept roof	7 / 7	ELY-C177 – 183
West tower turrets	9 / 5	ELY-C305 – 313

Views of the nave roof are shown in Figures 3a – c. A view of the Lady Chapel roof is shown in Figure 4, with a drawing of a truss in this roof being given in Figure 5, and a plan in Figure 6.

The positions of the timbers cored were recorded at the time of sampling on drawings made by Elaine Guilding and Robert Howard at the time of the AD 1987 – 90 survey. These are reproduced here as Figures 31a to 33q. It should be pointed out that not all the timbers in the roof are illustrated in these drawings so that in some cases the position of some individual timbers is not shown. Details of the samples are given in Table 1. In this report the frames, bays, and individual timbers etc, have been numbered from east to west or from north to south as appropriate.

Further areas of possible sampling.

Given that in this new programme of work additional samples were to be obtained only from those areas which had been sampled before, a number of important areas of the high roofs would remain un-sampled. Such areas would include the Octagon lantern, and the Choir / east end. Other areas, although having benefited from some very small-scale sampling are poorly represented. However, although such areas were not sampled as part of this programme, they were to be assessed as to their suitability for dendrochronological dating as part of any possible future programme of tree-ring analysis.

Presbytery / choir / east end

From documentary sources, the Presbytery is believed to belong to Bishop Hugh Northwold's ambitious mid-thirteenth century expansion plans, when, to the original three Romanesque bays east of the crossing, a further six bays were added. Part of this roof was probably damaged by the fall of the central Romanesque tower in AD 1322, and parts may have been altered by the construction of the Octagon thereafter. This part of the cathedral roof has not been sampled before. Unfortunately it appears to have been replaced yet again and is now largely modern, ie, eighteenth-century. It does however contain a number of timbers re-used as purlins, raking shores, and struts. A modest amount of sampling from these timbers, and any other later oak material would certainly be worthwhile. Not only might this prove the date of the original construction but, knowing from documentary evidence the sources of the modern timber, it might also provide a reference chronology from a known location. A view of this roof is given in Figure 7.

The Octagon

The famous Octagon at Ely Cathedral has not been sampled either. This is in part because the date of its construction, *c* AD 1330, is well known from the documentary sources. The source of some of the timber is also known, documentary material indicating this as being Chicksands in Bedfordshire.

The Galilee Porch roof

Much of this roof, which has also not been sampled, has been replaced with relatively modern, probably eighteenth-century timbers, but this is not certain. It may be earlier, but it could also be later. It does however retain a small number of reused timbers which might be from the original early-twelfth century roof. With further tree-ring sampling it might be possible to more reliably demonstrate the stages of felling represented in this roof.

The west tower

Although this has been sampled before little satisfactory dating has resulted. It may, therefore, be worth obtaining additional samples. The great difficulty with this roof is one of access. Many of the oak timbers are at a great height and impossible to reach safely without a scaffolding tower, a boarded platform, and safety harness. Given the problems of access into the tower, it would be very difficult to get this equipment in to place.

If at any time in the future work is done in any of these roofs, if the lead covering and roof boards are ever removed for example, and a safety platform is put in place, sampling of the timbers in all these areas should be most strongly considered.

Analysis

Each sample to be analysed was prepared by sanding and polishing, and the growth-ring widths of all 153 were measured; the data of these measurements are given at the end of the report. The data of all these samples were compared with each other by the Litton/Zainodin grouping procedure (see appendix).

At a minimum *t*-value of 4.5 two larger groups, and 14 smaller groups of cross-matching samples could be formed. The largest of these groups contains a total of 43 samples, cross-matching with each other at relative positions as shown in the bar diagram, Figure 8. All 43 samples were combined at their indicated relative off-set positions to form site chronology ELYCSQ01, with a combined overall length of 300 rings. Site chronology ELYCSQ01 was compared with a large number of reference chronologies for oak indicating a series of satisfactory *t*-value cross-matches when the date of its first ring is AD 1029 and the date of its last ring is AD 1328. Evidence for this dating is given in the *t*-values of Table 2.

The next major group comprises a total of 33 samples, cross-matching with each other at relative positions as shown in the bar diagram, Figure 9. These 33 samples

were combined at their indicated relative off-set positions to form site chronology ELYCSQ02, with a combined overall length of 135 rings. Site chronology ELYCSQ02 was also compared to a large number of reference chronologies for oak indicating a series of satisfactory *t*-value cross-matches when the date of its first ring is AD 1206 and the date of its last ring is AD 1340. Evidence for this dating is given in the *t*-values of Table 3.

The next three groups comprise 7, 9, and 6 samples, cross-matching at relative positions as shown in the bar diagrams Figures 10, 11, and 12, with combined overall lengths of 112, 200, and 203, rings respectively. These respective groups were combined to make site chronologies ELYCSQ03, ELYCSQ04, and ELYCSQ05, which were then dated as spanning the years AD 1315 - AD 1426, AD 891 - AD 1090, and AD 1592 - AD 1794, respectively. Evidence for the dating of these three site chronologies is given in Tables 4 - 6.

A further 11 smaller groups, consisting of between two and five samples each, could also be formed, the relative positions of the cross-matching samples in all these groups being shown in the bar diagrams Figures 13 - 23. Only four of these site chronologies could be dated, three of them matching particularly well with European reference chronologies, specifically those from the Baltic regions. Evidence for the dating of this material is given in Tables 7 - 10.

Each site chronology was compared against all the others, and against the remaining single ungrouped samples. There was, however, no further satisfactory cross-matching. In some cases an attempt was made to date the samples of the smaller site chronologies, ie ELYCSQ08 and ELYCSQ11, by taking sub-groups of samples from them and comparing these with the reference chronologies. There was, however, no further satisfactory cross-matching.

Finally, each of the 24 remaining ungrouped single samples was then compared individually with a full range of reference chronologies, including those from the Baltic regions. This indicated satisfactory dating for two further samples, ELY-C53 and ELY-C159, both from the nave roof. ELY-C53 has 133 rings dated as spanning AD 1002 - AD 1134, while ELY-C159 has 156 rings dated as spanning AD 1133 - AD 1288. Evidence for this dating is given in the *t*-values of Tables 11 and 12.

Thus, of the 252 samples initially considered, 99 were rejected as unsuitable, and 153 were measured. Of these, 108 samples can be formed in to one of nine dated site chronologies, with two further samples being dated individually. A further 21 samples can be formed in to one of seven undated site chronologies. A total of 131 samples can thus be dated or grouped. Twenty-two samples remain ungrouped and undated.

These analytical results are summarized overpage.

Site chronology or sample	Number of samples	Number of rings	Date span (where dated)
ELYCSQ01 (see Fig 8)	43	300	AD 1029 - 1328
ELYCSQ02 (see Fig 9)	33	135	AD 1206 - 1340
ELYCSQ03 (see Fig 10)	7	112	AD 1315 - 1426
ELYCSQ04 (see Fig 11)	9	200	AD 891 - 1090
ELYCSQ05 (see Fig 12)	6	203	AD 1592 - 1794
ELYCSQ06 (see Fig 13)	3	181	AD 1109 - 1289
ELYCSQ07 (see Fig 14)	2	207	AD 1097 - 1303
ELYCSQ08 (see Fig 15)	5	161	Undated
ELYCSQ09 (see Fig 16)	3	177	Undated
ELYCSQ10 (see Fig 17)	2	161	AD 1019 - 1179
ELYCSQ11 (see Fig 18)	4	154	Undated
ELYCSQ12 (see Fig 19)	2	153	Undated
ELYCSQ13 (see Fig 20)	2	150	Undated
ELYCSQ14 (see Fig 21)	3	122	Undated
ELYCSQ15 (see Fig 22)	2	93	Undated
ELYCSQ16 (see Fig 23)	3	96	AD 933 - 1028
ELY-C53	1	133	AD 1002 - 1134
ELY-C159	1	156	AD 1133 - 1288

Interpretation

The nave roof (site chronologies ELYCSQ01, SQ02, SQ04, SQ05, SQ06, and SQ07)

A number of dated samples from the nave roof retain complete sapwood. This means that they retain the last sapwood ring that the tree produced before it was felled, and the date of this last ring is the date at which the timber represented was cut. Other samples retain the heartwood/sapwood boundary which, while not providing a precise felling date, does allow for the reliable estimation of a likely felling date range. Unsurprisingly, given the number of samples analysed and the range of places from

which samples have been taken, there appears to be a spread of felling dates for timber used in the nave roof.

The earliest material from the nave roof detected in this programme of analysis appears to be represented by the nine samples of site chronology ELYCSQ04. The majority of these samples do not retain the heartwood/sapwood boundary and it is thus not possible to determine a reliable felling date range for the timbers represented. The samples do, however, all cross-match together with high *t*-values, suggesting that they are from a similar source, and all the samples have very early last measured ring dates. These range from AD 982 on sample ELY-C533 to AD 1066 on sample ELY-C109.

Only one sample, ELY-C133, in site chronology ELYCSQ04, retains the heartwood/sapwood boundary, this being dated to AD 1090. Using a 95% confidence limit of 15 to 40 sapwood rings on mature oaks from this part of England would give the timber represented by this sample an estimated felling date in the range AD 1105 to AD 1130. Given that the sampled timbers do show evidence for reuse, by way of redundant mortices and peg holes, it is likely that all these timbers are indeed early timbers that have been reclaimed and reused.

It would appear, however, that the majority of timbers from the nave roof, almost all those represented in site chronologies ELYCSQ01 and ELYCSQ02, have felling dates clustering in a relatively short time period. This appears to range from the late-thirteenth century to the early-fourteenth century.

The latest certain felling date for any of these timbers is that represented by sample ELY-C33, in site chronology ELYCSQ02. This sample retains complete sapwood with a last measured ring date of AD 1304. Other samples in this chronology which retain complete sapwood have very similar dates; AD 1303 for samples ELY-C65 and C77, AD 1302 for samples ELY-C34, C51, and C91, AD 1301 for sample ELY-C108 and AD 1299 for sample ELY-C552.

Other samples in site chronology ELYCSQ02 are from timbers which may possibly have been felled a few years earlier than this. The earliest heartwood/sapwood boundary of any sample in site chronology ELYCSQ02 is found at relative position 62, AD 1267, on sample ELY-C551, with the next earliest being at relative position 68, AD 1273, on sample ELY-C528. However, it is certainly not impossible for these timbers to have been felled in the early-fourteenth century as well.

It is also possible that some timbers were felled a few years later than the bulk of those represented by site chronology ELYCSQ02. The latest heartwood/sapwood boundary is found at relative position 87, AD 1292, on sample ELY-C543. Were this timber to have been felled in, say, AD 1304 too, it would have had only 12 sapwood rings. Such a low number is below the usual 95% confidence limit of 15 sapwood rings. However, given the number of samples obtained it is not unexpected to find a small number of samples with less than this minimum.

The relative position of the heartwood/sapwood boundaries on the majority of other dated samples in site chronology ELYCSQ02 are generally very similar, ranging by only 14 years from relative position 71, AD 1276, on samples ELY-C522 and C523, to

relative position 85, AD 1290, on sample ELY-C36. Such a spread, while not necessarily representative of timbers with an identical felling date, is certainly indicative of a narrow range of felling dates, such as that indicated by those samples in site chronology ELYCSQ02 with complete sapwood.

Unlike a number of samples in site chronology ELYCSQ02, only one of those from the nave roof in site chronology ELYCSQ01, sample ELY-C524, retains complete sapwood. This sample has a last, complete sapwood, ring date of AD 1223, this being the felling date of the timber represented. Most of the other samples retain only the heartwood/sapwood boundary and it is thus not possible to determine with complete certainty the exact felling date of any of those timbers represented, though it is possible to estimate a likely felling date range.

The bar diagram of site chronology ELYCSQ01, Figure 8, shows that the heartwood/sapwood boundary on the bulk of samples moves gradually forward in time, from relative position 227, AD 1255, on sample ELY-C503, to relative position 264, AD 1292, on sample ELY-C537, a spread of 37 years. Again, the dates of the heartwood/sapwood boundaries indicate felling dates ranges in the late-thirteenth to early-fourteenth centuries. Using a 95% confidence limit of 15 to 40 sapwood rings on mature oaks from this part of England would give the two timbers represented by sample ELY-C503 and C537 estimated felling date ranges of AD 1270 to AD 1295, and AD 1307 to AD 1332, respectively. The estimated felling date ranges for the other samples with only the heartwood/sapwood boundaries lie between these two extremes.

Indeed, in looking at the bar diagram for site chronology ELYCSQ01 in Figure 8, it is just possible that groups of samples may represent stages of felling. One might consider samples ELY-C01, C04, C14, C501, C503, and C504 as representing one phase of felling, with samples ELY-C05, C45, C54, C58, C502, C516, and C554, representing another phase of felling perhaps some ten to 15 years later. A subsequent phase of felling, perhaps some ten years after this, might be seen in a larger series of samples whose heartwood/sapwood boundary varies from relative position 250, AD 1278, to relative position 255, AD 1283. The dates of the heartwood/sapwood boundaries are again indicative of timbers being felled between the late-thirteenth and the early-fourteenth centuries. There is no indication, however, of a date-trend paralleling the probable direction of construction, from east to west. Rather, we find timber with a mixture of felling dates at each end of the nave roof, and indeed in the middle of the roof as well.

Sample ELY-C149 in site chronology ELYCSQ01, certainly represents a timber felled later. This sample has a last measured ring date of AD 1328, this also being the heartwood/sapwood boundary date. Using a 95% confidence limit of 15 to 40 sapwood rings on mature oaks from this part of England would give the timber represented by this sample an estimated felling date range of AD 1343 - 68. The sample may represent a reclaimed timber from elsewhere in the cathedral that has been spliced in to the scissor brace that has been sampled.

Site chronology ELYCSQ05 (bar diagram Fig 12) contains six dated samples, four of which, ELY-C104, C110, C151, and C153, are also from the nave roof. Two of the samples, ELY-C104 and C110, retain complete sapwood, with last measured ring

dates of AD 1794 and AD 1791, respectively. These are thus the felling dates of the timbers represented. It is possible that the timber represented by sample ELY-C153, which has eight sapwood rings and a last measured ring date of AD 1783 was felled at about this time also.

The timber represented by sample ELY-C151 is likely to have been felled earlier. This sample has 15 sapwood rings, which is not complete, with a last measured ring date of AD 1750. It is likely that the timber was felled sometime between AD 1751 and AD 1775.

Three further samples from the nave roof, ELY-C157, C160 and C162, are to be seen in dated site chronology ELYCSQ06. It can be seen from Table 6 that this site chronology cross-matches best with a series of reference chronologies from the Baltic region, suggesting that these samples are from that area. The average last heartwood ring date on these three samples is AD 1283. Using a sapwood estimate of 9 to 35 rings would give the timbers represented, riven boards covering common rafters, an estimated felling date in the range AD 1292 to AD 1318.

Site chronology ELYCSQ07 contains one sample, ELY-C161 from a timber of the nave roof which is of probable Baltic origin, as again shown by its cross-matching with a series of reference chronologies from that area. Sample ELY-C161, in site chronology ELYCSQ07, has a heartwood/sapwood boundary date of AD 1189. Using a sapwood estimate of 9 to 35 rings would give the timber represented, another riven board covering common rafters, an estimated felling date in the range AD 1204 - 24. The second sample in chronology ELYCSQ07, ELY-C24, is from a choir backboard. This sample has a last measured heartwood ring date of AD 1303, but does not have the heartwood/sapwood boundary. It is thus not possible to estimate its felling date except to say that it is unlikely to be before AD 1312, based on a minimum of nine sapwood rings.

Two samples from the nave roof have been individually dated. ELY-C53 has a last measured ring date of AD 1134 but does not have the heartwood/sapwood boundary and it is thus not possible to reliably estimate its likely felling date range. It is, however, unlikely to have been felled before AD 1149, based on a minimum number of 15 sapwood rings.

Sample ELY-C159 has a last measured, heartwood/sapwood boundary, date of AD 1288. This timber, a riven board, is probably of Baltic origin. It is estimated that this timber has a felling date in the range AD 1297 to AD 1328, this figure based on a sapwood estimate of 9 - 35 sapwood rings for this region.

A number of other samples from the nave roofs are to be found in the remaining undated site chronologies. These are on occasion, however, to be found mixed with samples from other parts of the cathedral, as in site chronologies ELYCSQ08, or ELYCSQ09.

South transept roof. (bar diagram Fig 10, ELYCSQ03)

Two of the seven dated samples, ELY-C178 and C181, from the south transept roof

in site chronology ELYCSQ03, retain complete sapwood, with last measured ring dates, and thus felling dates, of AD 1425 and AD 1426, respectively. The relative positions of the heartwood/sapwood boundaries on the other dated samples in this site chronology ELYCSQ03 are consistent with a group of timbers having a generally similar felling date.

Lady Chapel roof (ELYCSQ01, SQ02 and SQ05, bar diagram Fig 8, Fig 9, and Fig 12)

Five of the ten samples from the Lady Chapel roof, ELY-C168, C169, C171, C173, and C175, have been dated as part of three different site chronologies. The earliest material from the roof detected in this analysis appears to be represented by samples ELY-C168 and C175, which have heartwood/sapwood boundary dates of AD 1303 and AD 1282 respectively. Using the usual allowance of 15 - 40 sapwood rings for these samples would give the respective timbers represented estimated felling dates in the range AD 1318 to AD 1343, and AD 1297 to AD 1322. It is possible that both timbers were felled at the same time between AD 1318 and AD 1322, where the felling date ranges of each sample overlaps.

A further sample from the Lady Chapel, ELY-C171, in site chronology ELYCSQ02, has 19 sapwood rings, with a last measured ring date of AD 1340. Using the same sapwood estimate as above, 15 - 40 rings, and allowing for the last measured ring date, would give the timber represented by this sample an estimated felling date in the range AD 1341 to AD 1361. It is again possible that this timber was felled at the same, or at least a similar time, to those others from the Lady Chapel discussed above.

Two timbers from the Lady Chapel that were certainly felled later are represented by samples ELY-C169 and C173, both in site chronology ELYCSQ05. These two samples both have complete sapwood, and the same last measured ring date of AD 1736. This is thus the felling date for both timbers.

West tower turrets (ELYCSQ10, SQ16, bar diagram Fig17 and Fig 23)

Site chronologies ELYCSQ10 and ELYCSQ16 comprise samples from timbers in the west tower turrets, four stair beams, ELY-C309, C310, C312, and C313, and a small board, ELY-C26. Two of the samples, ELY-C310 and C313, have an average last heartwood ring date of AD 1028. This gives the timbers represented an estimated felling date in the range AD 1043 - 68. This figure is based on a sapwood range of 15 to 40 rings. Two other timbers, represented by samples ELY-C26 and C312, are probably of Baltic origin, with one certainly, and possibly both, having a felling date of AD 1179.

An attempt to summarise these interpretations, and indicate the felling date, or the estimated felling date range of samples, or groups of samples within the roofs, is given overpage.

Sampling area	Sample numbers	Felling date or felling date range
West tower turrets	C309/310, C313 C26, C312	AD 1043 - 68 AD 1179
Nave	C03, C47, C88, C109, C133, C135, C303, C304, C533	AD 1105 - 30
Nave	C524, C525	Probably both samples AD 1223
Nave	C161	AD 1298 - AD 1324
Nave	C01, C04/5, C14, C16, C32-4, C36-8, C40, C42, C45, C49, C51/2, C54, C58, C65, C71, C74, C81, C87/8, C91-94, C96, C102, 104/5, C108, C110/11, C118, C140, C501-07, C509-14, C516/7, C522-25, C528, C530-32, C537/8, C540-43, C548/9, C551-56	*c* AD 1290 - AD 1310
Nave	C157, C160, C162	AD 1292 - AD 1318.
Nave	C159	AD 1297 - AD 1323
Nave	C149	AD 1343 - 68
Nave	C151 C110, C104 C153	AD 1751 - 75 AD 1791, AD 1794 AD 1790 - AD 1815
Lady Chapel roof	C175 C168 C171 C169, C173	AD 1288 - AD 1313 AD 1318 - 43 AD 1341 - 61 AD 1736
South transept roof	C177 – 183	AD 1425, AD 1426
Nave	C53	Not before AD 1149

A bar diagram showing the relative positions of the dated site chronologies and the two samples dated individually is given in the bar diagram, Figure 24.

Conclusion

Analysis by tree-ring dating has produced 16 site chronologies, ELYCSQ01 - 16. These comprise 108 samples in nine dated site chronologies, with two further samples being dated individually. Seven site chronologies, comprising 21 samples, are undated. There are a further 22 samples that are both ungrouped and undated.

This analysis has provided felling dates, or estimated felling date ranges, for timbers from a number of different locations in the high roofs. As suspected on carpentry and structural ground, tree-ring analysis has shown that these timbers have a wide spread of felling dates, showing the reuse of Romanesque material, early-fourteenth century material, fifteenth-century material, and eighteenth-century repairs.

The earliest material detected in this programme of analysis appears to be that represented by three samples, ELY-C309, C310 and C313, from the turrets of the west tower, with an estimated felling date in the mid- to later-eleventh century, between AD 1043 - 68. It is possible that these timbers were original to the Romanesque cathedral, which was commenced under Abbot Simeon, and believed to be complete by AD 1109, and that they have been reused in their present location. The west tower turrets contain another early timber, represented by sample ELY-C312. This has a last complete sapwood ring date, and thus a felling date of AD 1179.

It is possible that the next latest felling is represented by a group of nine samples from the nave roof, in site chronology ELYCSQ04 (bar diagram Fig 11). It is possible to determine a felling date range for only one of the timbers represented, this being between AD 1105 and AD 1130. Given the degree of cross-matching between the samples, however, it is likely that they represent a near single phase of felling in the early-twelfth century. If this is correct the timbers possibly represent further material from the original Romanesque cathedral, reused in the construction of the later roof.

The next latest material is also found in the nave roof and is represented by samples ELY-C524 and C525 in site chronology ELYCSQ01 (bar diagram Fig 8). Both have almost identical heartwood/sapwood boundaries, suggesting very similar felling dates, with sample ELY-C524 having a complete sapwood ring date, and thus a felling date, of AD 1223. It is possible that these timbers represent material felled for work on the Presbytery, or choir, which was commenced under Bishop Hugh Northwold at about this time and continued into the AD 1250s.

There then follows the felling of the majority of timbers, mainly from the nave roof, as represented by most of those samples in site chronologies ELYCSQ01 and ELYCSQ02 (bar diagram Figs 8 and 9). The felling of these timbers takes place in a fairly narrow time span between about AD 1290 and AD 1310.

Three further samples from the nave roof, represented by ELY-C157, C160 and C162 in site chronology ELYCSQ06 (bar diagram Fig 13), are probably felled at about the same time as the majority of timbers discussed immediately above, and may be

representative of the same phase of work. These timbers, riven boards across the rafter frames have an estimated felling date in the range AD 1292 to AD 1318. It is probable that the timber used for these boards originates in the Baltic region of Europe.
While there is documentary evidence for the mid-thirteenth century work of Bishop Northwold on the Presbytery and west tower, it would appear there is no direct historical context or previous documentary record for this late-thirteenth or early-fourteenth century work to the nave roof. It is possible that work on the nave was simply a project to replace the old Romanesque nave roof with the more up to date form used in the Presbytery.

An individual sample from the nave roof, ELY-C149, represents an outlier from the many body of felled timber. It is estimated that the timber has a felling date in the range AD 1343 to AD 1358.

The latest material from the nave roof is represented by samples ELY-C104, C110, C151, and C153. The timber represented by sample ELY-C151 has an estimated felling date in the range AD 1751 to AD 1785. Samples, ELY-C110 and C104 represent timbers felled in AD 1791 and AD 1794, respectively. It is likely that the timber represented by sample ELY-C153 was felled at about this time too. The felling of these timbers presumably relates to late-eighteenth century repairs as well.

Elsewhere in the cathedral, the earliest material from the Lady Chapel roof detected in this programme is represented by samples ELY-C168 and C175, which have estimated felling dates in the range AD 1318 to AD 1353, and AD 1297 to AD 1332. It is possible that both timbers were felled at the same time between AD 1318 and AD 1332, where the felling date ranges of each sample overlap. A further timber from the Lady Chapel, represented by ELY-C171, has an estimated felling date in the range AD 1341 - 71. It is again possible that this timber was felled at the same or similar time. It is probable that the felling of these timbers is directly related to the construction of the Lady Chapel in the early- to mid-fourteenth century.

Two other timbers from the Lady Chapel, represented by samples ELY-C169 and C173, both with complete sapwood, were felled in AD 1726. These probably represent eighteenth-century repair work.

From the south transept roof come a group of seven dated samples, two of which, ELY-C178 and C181, have complete sapwood. These two samples indicate felling dates of AD 1425 and AD 1426, respectively for the timbers represented. The relative positions of the heartwood/sapwood boundaries on the other dated samples in this site chronology, ELYCSQ03, are consistent with a group of timbers having a very similar, if not identical, felling date. It is possible that these represent repairs or complete renewal of the south transept roof after the undated collapse in this part of the cathedral following an earthquake.

These conclusions may be sumarised as overpage.

Sampling area	Felling date or estimated felling date range	Historical context
West tower turrets	AD 1043 - 68	Original Romanesque work
Nave roof	AD 1105 - 30	Original Romanesque work
Nave roof	AD 1223	Material destined for mid-thirteenth century Presbytery?
Nave roof	*c* AD 1290 - AD 1310	Replacement of original Romanesque roof
Nave roof	AD 1343 - 58	Repair timber
Nave roof	AD 1751 - 85 AD 1791, AD 1794	Late-eighteenth century repairs
Lady Chapel roof	Early- to mid-fourteenth century	Original early- to mid-fourteenth century building
	AD 1726, AD 1726	Late-eighteenth century repairs
South transept roof	AD 1425 / AD 1426	Repairs after undated fifteenth century collapse

Two major site chronologies, consisting of 43 and 33 samples respectively have been formed. Although these site chronologies overlap in time, AD 1029 - AD 1328, and AD 1206 – AD 1340, they do not cross-match with each other. This would suggest that the respective timbers of each site chronology come from different localities, some distance apart. From documentary evidence the source of some timber felled in the mid-thirteenth century, and supposedly destined for the west tower and probably the Presbytery also, is known. Two sources are known to be near Alconbury in Huntingdonshire, and Kingswood in Essex. It is possible that some of the late-thirteenth and early-fourteenth century timber used in the nave is from the same sources. Judging by the other different groups of samples created, it is possible that other sources of timber are also used.

Certainly one other source that is identified seems to be indicated by the cross-

matching is the Baltic. It is again possible that some of the undated material, both undated site chronologies and single sample are from different sources in Europe. Thus, using this tree-ring analysis it may be possible to further refine the dates obtained if they can be linked with documentary information for repair or modification. This may aid in the identification of the source roof, or roofs, of the reused material. The documentary sources may also provide information about the woodland sources of this timber.

Of the 22 ungrouped and undated samples almost half have less than 60 rings which, whilst sufficient for satisfactory for analysis, is relatively low. The longest ungrouped and undated sample, ELY-C11, has 123 rings. Some of these longer samples do show some slight distortion, perhaps due to stressed growing conditions, and this might account for them not dating. Many of the other such samples show no problems.

It is possible that the lack of dating for some samples is due to their being of a date and or from an area for which there are no relevant reference chronologies available. Further sampling from Ely Cathedral might help date some of these samples. Given the nature of the material used in the roof and the extent of reused old timbers it is also possible that some of the undated samples represent singletons of diverse date. Such timbers are often difficult to date, particularly when they have lower numbers of growth-rings.

An assessment of fixtures and fittings

Whilst the new programme of tree-ring analysis of the high roofs was in progress the opportunity was taken to examine items within the cathedral under the general heading 'fixtures and fittings', a term that is taken to cover three categories: furniture, panels, and doors, although there are some other timber items. Overall there is nothing that appears at first inspection to be particularly ancient or unusual. There are, however, two interesting features that might repay some dendrochronological investigation, if only to verify their dates with greater certainty, and possibly determine the provenance of the wood used. These are the misericords in the choir, and a muniments chest, currently placed in the south transept.

Misericords and other seats of the choir Figs 25 and 26

The misericords are placed on both sides of the choir in three tiers, or ranks, of seats, with only the rear rank to each side being classic examples. These are of the typical tilting type seat with a slightly dished shelf upon which to rest when stood up. Some of these are believed to be of thirteenth century date, others are believed to be fourteenth century (Fearn, 1997). The undersides of the tilting pieces are decorated with carved figures, leafs, scrolls, and other motifs. It is believed that a study of these has been made, but whether published, or indeed even how available this study is, is not certain.

The misericords, and indeed the stalls in which they are housed, that is the sides and backs of the seats, and the divisions between each seat, all appear to have good ring

counts. They are not exceptionally tight, as might be expected of Baltic timber, but have sufficient rings and should provide good samples. This might suggest they are made from English oak, but again this is unknown.
Sampling could probably be undertaken by taking the seats off their hinges, preparing an edge, and reading *in situ* with a graticule. It would also be possible to photograph a prepared edge. Similar methods have been successfully applied to misericords in the past, such as those at Southwell Minster in Nottinghamshire, with satisfactory result being obtained. This might be a little more difficult at Ely, however, because of the unusual hinge type. Because small wooded plugs cover the screws, it is difficult to see how the hinges attached to the seat. This is an area that the Clerk of Works may be able to help with. An alternate, and possibly additional, source of samples might be other parts of the stalls. The divisions between them could be cored, with a micro-borer, near the floor in which case it would not be possible to see the core sites afterwards.

The forward ranks of seating here appear quite different and are probably much more recent. They might be eighteenth century, but it is more likely that they are of nineteenth-century date. It would again probably be possible to get samples by graticule reading. If they are relatively late, it might also be possible to find out from documentary sources where the timber used came from.

The misericords and other seats at Ely Cathedral contain large quantities of oak paneling with posts, rails, and carved decorative pieces. Some portions of it, base or cross rails for example, could be cored and might provide worthwhile samples. Most of the other pieces, however, could not be cored because they are too thin, and edges could only be read with a graticule if the entire structure were taken apart. None of this paneling looks earlier than the nineteenth century, but this would certainly be worth checking if, and when, any work on them is ever undertaken.

Muniments chest, Fig 27

There is also the muniments chest, or 'strong box', currently held in the south transept of the cathedral. This chest is about 2.5 metres long, by about 1 metre wide, and about 0.70 metres deep. It is made up of a number of boards held together by extensive, and impressive, ironwork. It is known as the 'Reformation Chest', because of some believed connection to its possible date, though no authority is certain of its provenance. It appears as if there has been quite a certain amount of patching and splicing in of pieces to it, and many of the timbers have different grain patterns to each other. The lid, and parts of the front in particular, appear to be slightly wide ringed. The side or end pieces on the other hand do appear to have very narrow rings; it is possible that these pieces are of Baltic origin. At the time of assessment the back of the chest was difficult to see, this being against the wall.

Most of the ends of the boards of the muniments chest are covered by metal straps, or are hidden in joints. Fortunately the end, or side, pieces have good areas of exposed rings. These could be prepared fairly easily and read with a graticule. However a potential problem with these pieces is that the exposed edges might not prepare very well and it would be difficult to get a clean, readable surface.

Apart from these larger items there are a number of other candidates for possible tree-ring dating, though possibly no less interesting. There are, for example, a small number of kneelers in the cathedral, possibly eight in total. It is probably unlikely that any of these is any earlier than the nineteenth century, though it is possible that they might be of eighteenth-century date, though again, there is no authoritative view on these items. The majority of these kneelers are oak where the shelf portions of them (where prayer books would be rested) do have exposed ends with quite good ring counts. It would be very easy to take readings of these.

Benches, pews, and other items

There are also a few benches, pews, stands, and small tables or desks that show some areas of end-grain. Each item usually presents only one available edge for sampling, and from the standpoint of tree-ring dating, they generally tend to have low, though probably sufficient, numbers of rings for analysis. Most items show quite clean end-grain surfaces and would need little preparation. These could be quite easily read with a graticule. Most of these items again appear to be nineteenth century, but once again this is not certain.

Graticule readings could also be made quite easily from a very modern looking set of oak benches, steps, and stands currently placed at the crossing. These must have been obtained in the last 10 years or so, and the source of the timber might be known. This source could be English, but it would not be surprising if was foreign. Several very clean edges are available with little preparation being required, with the ring counts certainly looking suitable.

Paneling

Another, rather more remote, possibility for tree-ring analysis is the paneling within the cathedral. This is naturally to be found in great quantities not only in the choir above the misericord stalls, but also in several chapels at Ely. On the whole this again all appears to be of either eighteenth or nineteenth-century date. Apart from a few decorative mouldings there is nothing that looks particularly ancient. Unfortunately, this paneling could not be cored because of its thinness, and it would probably be impossible to get a graticule reading without taking sections of it apart. There might be some elements of various sections that could be core sampled, some posts or rails for example, but they might produce short cores and have too few rings.

Doors

The final items assessed are the doors; there are naturally quite a number of these. All of them appear to be made of rather clean, squarely cut, and well-planed planks, suggesting that they may be of relatively late date. None of the doors appeared stylistically to be of exceptional antiquity. Judging by the grain, the door planks do have quite good ring counts, and they would probably produce suitable tree-ring samples. The problem with these is again that of sampling. A couple of the doors,

particularly the large west door in the Galilee Porch, are in theory thick enough to be cored with a micro-borer. The problem would be in reaching the outer planks through the surrounding architrave, and in coring the inner planks. The planks are all set so closely together that it would be almost impossible to find an edge from which to start drilling. It is unlikely that a graticule reader could be used either, firstly because this would require taking this huge door off its hinges, and secondly there is an architrave strip hiding the bottom and top edges of the door planks.

All the other doors have similar problems. The 'Prior's Door' off the south nave aisle, for example, is again made up of a series of close-set, clean-planned planks that look relatively late. They too appear to have good ring counts. However, it would again be very difficult to core them, and probably impossible to read rings with a graticule because of architrave strips at top and bottom.

Lintels

In connection with the doors it was noted that one or two of them had wooden lintels. The door to the south-west tower stair, the one which leads to the Glass Museum, has what appear to be five, probably reused, timbers in it. These timbers appear to have sufficient rings for satisfactory analysis and consideration might be given to sampling these as well.

Passageway roof

Other wooden objects seen include the new oak beamed roof between the choir aisle and the Lady Chapel. The source of the timber is probably well documented, as of course is its date, the roof being 'unveiled' in AD 2000. Depending on where the wood has come from it might provide some useful modern reference material. This roof could be cored quite easily in the same way as any other.

Shuttering boards, Fig 28

The ceilings vaults of the passageways leading up through the south-west tower have the remains, here and there, of shuttering boards. These are small strips of wood, 3 - 4 cms wide by about 8 - 10 cms long, by perhaps 1 cm thick. They are set into the mortar of the vault. Such pieces are seen elsewhere, Lincoln Cathedral for example, but have not been sampled. Usually, and this is the case at Ely Cathedral, they are too small, with low ring counts, or too fragile, to produce useable samples. About six such pieces were seen at Ely Cathedral.

Wall beams, Fig 29

Another area of possible sampling is a series of long oak timbers set horizontally within the walls of the south-west tower, roughly just below bell-chamber level. It is difficult to understand what these timbers do (though them may be some sort of bracing), or how they were put in place. This is in large measure because only parts

of each timber are visible. In some cases timbers cross in front of window openings, and pass through voids cut in the walls. The timbers are fixed at their ends by being tennoned into short cross pieces, which are themselves set in to small voids in the walls of the tower. The tennon of the long pieces pass right through the mortices of the end cross pieces, the tennon being held by a wedge or small chock. The majority of these timbers would probably provide satisfactory tree-ring samples.

Window and door frame

Within the cathedral there is on display an oak window-frame. This is believed to have come from Prior Crauden's Study in the Prior's House, one of the precinct buildings. The frame consists of two upright posts and a lintel, with various carved pieces as decoration. The grain on the uprights suggests quite good ring counts, and it would be easy to core these. The lintel on the other hand looks like it is derived from fast-grown timber and thus likely to have a low number of rings. The decorative pieces could not be cored and could not be read with a graticule unless the frame is partially dismantled. On the basis of stylistic evidence it is believed that this piece dates from *c* AD 1325.

Also on display is an oak door-frame consisting of two uprights and a lintel, Fig 30. The uprights again look as if they would provide suitable samples for tree-ring analysis, and could be sampled by coring. The lintel appears to have very wide rings and this timber would probably not be worth sampling. No indication of the possible date of this door is given.

Recommendations

If consideration is given to the possibility of sampling any of these items it is recommended that some order or priority might be suggested. This order is based on a combination of factors such as the likely age and interest in the item, the likelihood of obtaining a reliable date, and the difficulty of, or disruption caused by, sampling.

Priority should perhaps be given to the misericords, with sampling to include not only the seats themselves, but also the stalls that house them. Both elements ought to produce useable samples, it is likely that they are the same date, but it is possible that the timber could be from different sources. Analysis will hopefully establish the date of these items more reliably.

Secondly, consideration should be given to sampling the muniments chest. This ought to provide up to six samples with little detrimental impact on the piece. The date of this object appears to be unclear. It is possible that the sampled elements of the chest are of Baltic, or at least European, origin.

Thirdly it is suggested that the sampling of the kneelers set at various points round the cathedral be considered. The dates of items of this nature seem to be at best rather indeterminate, often thought of as being eighteenth or nineteenth century, though usually completely unknown. It is possible that many such items from many other sites are simply discarded as being of no interest. Analysis of some of these

items might establish a more accurate date for this type furniture in general. These would be easy to sample, by reading with a graticule, and would cause little disruption.

Finally, it is suggested that the horizontal beams of the south-west tower might be sampled. It is known that the cathedral suffered earthquake damage in the past and these may have been inserted as a result to 'clamp' and strengthen the stonework.

If further sampling were considered the modern oak stands and steps at the crossing might be the next best candidates, followed by the door and window frames on display. It is not certain where these items have come from, and they would provide only 2 - 3 samples each.

The sampling of the doors is not recommended unless they are thought to be particularly old, or their dates are in dispute. They would in any case be difficult to sample. Nor is the sampling any paneling recommended. It would be pleasing to establish dates for various pieces, but unless they are taken apart it would be difficult to obtain readings. This applies to many of the smaller items of furniture too, assuming of course that they were of interest. The shuttering boards in the ceilings are probably original, but are unlikely to provide satisfactory samples and the sampling of these is not recommend.

In conclusion it is possible to state that the sampling and analysis of additional material from Ely Cathedral, both from the roof and from the fixtures and fittings could have significant benefits. Not only would it help inform the future management of the site but it would provide data on the historic context of the building too. The overall dates, and the possible phases and sequential development of several areas of roofing which are unknown or uncertain at the moment might be more reliably determined. The extent of reuse of earlier material, or the insertion of later repair and alteration material, is also unclear, and this too might be established.

The dating and phasing of several elements of the furniture, fixtures, and fittings is likewise uncertain. There is little scientific evidence for the dating of this class of item, some of them potentially important pieces. It is possible that smaller items, kneelers and pews for example, which are sometimes considered less important, may not receive the conservation and management that they deserve.

The sampling and analysis of these additional roofs, and some elements of furniture and fittings, might go some way to resolving these potential problems.

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Table 1: Details of samples from the high roofs of Ely Cathedral

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
	Nave roof					
ELY-C01	North lower rafter, frame 7	101	h/s	AD 1156	AD 1256	AD 1256
ELY-C02	North rafter, frame 4	nm	---	------	------	------
ELY-C03	North upper rafter, frame 15	100	no h/s	AD 966	------	AD 1065
ELY-C04	South rafter, frame 14	230	h/s	AD 1029	AD 1258	AD 1258
ELY-C05	South rafter, frame 5	82	h/s	AD 1190	AD 1271	AD 1271
ELY-C06	South rafter, frame 4	nm	---	------	------	------
ELY-C07	South rafter, frame 6	98	no h/s	------	------	------
ELY-C08	North rafter, frame 5	nm	---	------	------	------
ELY-C09	South ashlar, frame 18	nm	---	------	------	------
ELY-C10	North rafter, frame 6	nm	---	------	------	------
ELY-C11	South sole piece, frame 3	123	23C	------	------	------
ELY-C12	North sole piece, frame 6	82	2	------	------	------
ELY-C13	North sole piece, frame 11	81	h/s	------	------	------
ELY-C14	North sole piece, frame 13	133	h/s	AD 1124	AD 1256	AD 1256
ELY-C15	South ashlar, frame 20	nm	---	------	------	------
ELY-C16	South ashlar, frame 28	70	14	AD 1220	AD 1275	AD 1289
ELY-C17	North rafter, frame 28	nm	---	------	------	------
ELY-C18	South rafter, frame 31	nm	---	------	------	------
ELY-C19	North sole piece, frame 30	nm	---	------	------	------
ELY-C20	South sole piece, frame 31	nm	---	------	------	------
ELY-C21	North rafter, frame 34	nm	---	------	------	------

Table 1: continued

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
	Nave roof					
ELY-C22	Block, frame 18 - 19, south side	136	no h/s	------	------	------
ELY-C23	North sole piece, frame 18	nm	---	------	------	------
ELY-C24	Choir stall back-board	207	no h/s	AD 1097	------	AD 1303
ELY-C25	North sole piece, frame 37	nm	---	------	------	------
ELY-C26	Small board, west tower turret	63	h/s	AD 1088	AD 1150	AD 1150
ELY-C27	North lower rafter, frame 31	nm	---	------	------	------
ELY-C28	North rafter, frame 18	nm	---	------	------	------
ELY-C29	North scissor brace, frame 18	nm	---	------	------	------
ELY-C30	North scissor brace, frame 19	nm	---	------	------	------
ELY-C31	Lower collar, frame 15	nm	---	------	------	------
ELY-C32	South scissor brace, frame 28	67	8	AD 1220	AD 1278	AD 1286
ELY-C33	Lower collar, frame 28	83	22C	AD 1222	AD 1282	AD 1304
ELY-C34	Lower collar, frame 30	83	23C	AD 1220	AD 1279	AD 1302
ELY-C35	South scissor brace, frame 30	nm	---	------	------	------
ELY-C36	Upper collar, frame 30	84	2	AD 1209	AD 1290	AD 1292
ELY-C37	Upper collar, frame 34	81	29C	AD 1223	AD 1274	AD 1303
ELY-C38	South scissor brace, frame 34	83	4	AD 1207	AD 1285	AD 1289
ELY-C39	Upper collar frame 34	nm	---	------	------	------
ELY-C40	Lower collar, frame 34	70	2	AD 1222	AD 1289	AD 1291
ELY-C41	North rafter, frame 35	nm	---	------	------	------
ELY-C42	North sole piece, frame 35	62	15C	AD 1223	AD 1269	AD 1284

Table 1: continued

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
	Nave roof					
ELY-C43	South rafter, frame 36	nm	---	------	------	------
ELY-C44	South sole piece, frame 36	74	h/s	------	------	------
ELY-C45	South sole piece, frame 37	83	8	AD 1191	AD 1265	AD 1273
ELY-C46	North sole piece, frame 37	nm	---	------	------	------
ELY-C47	Support, frame 37	98	no h/s	AD 904	------	AD 1001
ELY-C48	South rafter, frame 37	nm	---	------	------	------
ELY-C49	North sole piece, frame 38	65	h/s	AD 1217	AD 1281	AD 1281
ELY-C50	South sole piece, frame 39	105	21C	------	------	------
ELY-C51	South ashlar, frame 39	68	16C	AD 1235	AD 1286	AD 1302
ELY-C52	South rafter, frame 39	85	h/s	AD 1201	AD 1285	AD 1285
ELY-C53	North sole piece, frame 39	133	no h/s	AD 1002	------	AD 1134
ELY-C54	North rafter, frame 39	78	h/s	AD 1196	AD 1273	AD 1273
ELY-C55	North sole piece, frame 40	66	h/s	------	------	------
ELY-C56	South sole piece, frame 40	nk	---	------	------	------
ELY-C57	South ashlar, frame 40	nk	---	------	------	------
ELY-C58	North rafter, frame 40	82	h/s	AD 1194	AD 1275	AD 1275
ELY-C59	North scissor brace, frame 40	nk	---	------	------	------
ELY-C60	South scissor brace, frame 40	nk	---	------	------	------
ELY-C61	North sole piece, frame 40	nk	---	------	------	------
ELY-C62	North rafter, frame 41	nk	---	------	------	------
ELY-C63	North sole piece, frame 41	nk	---	------	------	------

Table 1: continued

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
	Nave roof					
ELY-C64	North rafter, frame 42	nk	---	------	------	------
ELY-C65	North ashlar piece, frame 43	81	15C	AD 1223	AD 1288	AD 1303
ELY-C66	North rafter plate, frame 42	nk	---	------	------	------
ELY-C67	North sole piece, frame 43	67	h/s	------	------	------
ELY-C68	North sole piece, frame 44	nk	---	------	------	------
ELY-C69	North plank frame 45 – 50	nm	---	------	------	------
ELY-C70	Plank, location uncertain	55	9	------	------	------
ELY-C71	South rafter, frame 41	87	h/s	AD 1203	AD 1289	AD 1289
ELY-C72	South sole piece, frame 41	153	h/s	------	------	------
ELY-C73	South rafter, frame 42	nk	---	------	------	------
ELY-C74	North scissor brace, frame 42	70	5	AD 1219	AD 1283	AD 1288
ELY-C75	South sole piece, frame 43	nk	---	------	------	------
ELY-C76	South rafter, frame 44	nk	---	------	------	------
ELY-C77	South sole piece, frame 45	nk	---	------	------	------
ELY-C78	South sole piece, frame 46	nk	---	------	------	------
ELY-C79	North sole piece, frame 46	nk	---	------	------	------
ELY-C80	North scissor brace, frame 47	69	2	------	------	------
ELY-C81	North sole piece, frame 47	62	h/s	AD 1217	AD 1278	AD 1278
ELY-C82	South rafter, frame 47	nm	---	------	------	------
ELY-C83	Lower collar, frame 50	nm	---	------	------	------
ELY-C84	North sole piece, frame 52	76	23	------	------	------

Table 1: continued

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
	Nave roof					
ELY-C85	North aisle rafter	63	8	------	------	------
ELY-C86	North sole piece, frame 45	nm	---	------	------	------
ELY-C87	South rafter, frame 51	95	h/s	AD 1195	AD 1289	AD 1289
ELY-C88	North lower rafter, frame 52	126	no h/s	AD 908	------	AD 1033
ELY-C89	South scissor brace, frame 53	nm	---	------	------	------
ELY-C90	North scissor brace, frame 53	nm	---	------	------	------
ELY-C91	North rafter, frame 53	89	21C	AD 1214	AD 1281	AD 1302
ELY-C92	South rafter, frame 53	68	h/s	AD 1218	AD 1285	AD 1285
ELY-C93	North rafter, frame 54	80	h/s	AD 1204	AD 1283	AD 1283
ELY-C94	North rafter, frame 55	84	2	AD 1202	AD 1283	AD 1285
ELY-C95	North sole piece, frame 56	85	no h/s	------	------	------
ELY-C96	North rafter, frame 56	62	no h/s	AD 1208	------	AD 1269
ELY-C97	Lower collar, frame 56	nm	---	------	------	------
ELY-C98	South rafter, frame 57	nm	---	------	------	------
ELY-C99	North sole piece, frame 57	nm	---	------	------	------
ELY-C100	North sole piece, frame 58	nm	---	------	------	------
ELY-C101	North rafter, frame 58	nm	---	------	------	------
ELY-C102	South rafter, frame 58	75	h/s	AD 1205	AD 1279	AD 1279
ELY-C103	South rafter, frame 58	nm	---	------	------	------
ELY-C104	South firring piece 59	105	22C	AD 1690	AD 1772	AD 1794
ELY-C105	South rafter, frame 59	86	2	AD 1200	AD 1283	AD 1285

Table 1: continued

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
	Nave roof					
ELY-C106	South sole piece, frame 59	91	no h/s	------	------	------
ELY-C107	North rafter, frame 60	nm	---	------	------	------
ELY-C108	South sole piece, frame 61	86	17C	AD 1216	AD 1284	AD 1301
ELY-C109	North rafter, frame 62	156	no h/s	AD 911	------	AD 1066
ELY-C110	Plank to south aisle frame 62	102	15C	AD 1690	AD 1776	AD 1791
ELY-C111	North sole plate, frame 62	113	h/s	AD 1166	AD 1278	AD 1278
ELY-C112	South sole piece, frame 62	nm	---	------	------	------
ELY-C113	North rafter, frame 63	nm	---	------	------	------
ELY-C114	North rafter, frame 64	nm	---	------	------	------
ELY-C115	South ashlar, frame 64	165	h/s	------	------	------
ELY-C116	North rafter, frame 64	nm	---	------	------	------
ELY-C117	North rafter, frame 65	nm	---	------	------	------
ELY-C118	North rafter, frame 65	77	h/s	AD 1204	AD 1280	AD 1280
ELY-C119	South scissor brace, frame 62	nm	---	------	------	------
ELY-C120	South rafter, frame 63	nm	---	------	------	------
ELY-C121	South scissor brace, frame 63	63	no h/s	------	------	------
ELY-C122	South sole piece, frame 65	nm	---	------	------	------
ELY-C123	Lower collar, frame 65	nm	---	------	------	------
ELY-C124	South scissor brace, frame 65	nm	---	------	------	------
ELY-C125	South rafter, frame 65	nm	---	------	------	------
ELY-C126	South sole piece, frame 66	nm	---	------	------	------

Table 1: continued

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
	Nave roof					
ELY-C127	South sole piece, frame 57	nm	---	------	------	------
ELY-C128	North sole piece, frame 67	nm	---	------	------	------
ELY-C129	North scissor brace, frame 67	61	11	------	------	------
ELY-C130	South sole piece, frame 68	nm	---	------	------	------
ELY-C131	Upper collar, frame 68	nm	---	------	------	------
ELY-C132	North sole piece, frame 68	nm	---	------	------	------
ELY-C133	North rafter, frame 68	185	h/s	AD 906	AD 1090	AD 1090
ELY-C134	North scissor brace, frame 69	nm	---	------	------	------
ELY-C135	North sole piece, frame 69	116	no h/s	AD 894	------	AD 1009
ELY-C136	Board support north, frame 69	nm	---	------	------	------
ELY-C137	North scissor brace, frame 71	nm	---	------	------	------
ELY-C138	South sole piece, frame 71	nm	---	------	------	------
ELY-C139	South scissor brace, frame 71	nm	---	------	------	------
ELY-C140	North sole plate, frame 72	81	h/s	AD 1206	AD 1286	AD 1286
ELY-C141	South scissor brace, frame 72	nm	---	------	------	------
ELY-C142	North sole piece, frame 74	83	no h/s	------	------	------
ELY-C143	Strut to north rafter, frame 74	nm	---	------	------	------
ELY-C144	South scissor brace, frame 75	nm	---	------	------	------
ELY-C145	North scissor brace, frame 75	nm	---	------	------	------
ELY-C146	North sole piece, frame 76	nm	---	------	------	------
ELY-C147	North rafter, frame 76	nm	---	------	------	------

Table 1: continued

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
	Nave roof					
ELY-C148	North strut, frame 77	nm	---	------	------	------
ELY-C149	South scissor brace, frame 77	100	h/s	AD 1229	AD 1328	AD 1328
ELY-C150	North sole piece, frame 77	nm	---	------	------	------
ELY-C151	North sole piece, frame 78	73	15	AD 1678	AD 1735	AD 1750
ELY-C152	North scissor brace, frame 78	nm	---	------	------	------
ELY-C153	Riven plank, location uncertain	80	8	AD 1704	AD 1775	AD 1783
ELY-C154	Riven plank, location uncertain	54	22C	------	------	------
ELY-C155	Riven plank, location uncertain	60	4	------	------	------
ELY-C156	Riven plank, frame 17	104	no h/s	------	------	------
ELY-C157	Riven plank, frame 31	181	3	AD 1109	AD 1286	AD 1289
ELY-C158	Riven plank, frame 22	120	h/s	------	------	------
ELY-C159	Riven plank, frame 23	156	h/s	AD 1133	AD 1288	AD 1288
ELY-C160	Riven plank, frame 17	146	7	AD 1137	AD 1275	AD 1282
ELY-C161	Riven plank, frame 16	136	4	AD 1158	AD 1189	AD 1293
ELY-C162	Riven plank, frame 15	134	h/s	AD 1156	AD 1289	AD 1289
ELY-C163	Riven plank, location uncertain	nm	---	------	------	------
ELY-C164	Riven plank, frame 3	nm	---	------	------	------
ELY-C165	Riven plank, frame 36	nm	---	------	------	------
ELY-C166	Riven plank, frame 7	nm	---	------	------	------
ELY-C167	Riven plank, frame 2	nm	---	------	------	------

Table 1: continued

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
	Lady Chapel roof					
ELY-C168	North wall plate at west end	106	h/s	AD 1198	AD 1303	AD 1303
ELY-C169	Tiebeam at west end	145	23C	AD 1592	AD 1713	AD 1736
ELY-C170	Upper wall plate, north side	68	18	------	------	------
ELY-C171	Lower wall plate north side	99	19	AD 1242	AD 1321	AD 1340
ELY-C172	Lower collar truss 1	94	23	------	------	------
ELY-C173	Ridge, truss1 - 3	75	22C	AD 1662	AD 1714	AD 1736
ELY-C174	Lower wall plate, south side	54	h/s	------	------	------
ELY-C175	Upper wall plate, south side	60	9	AD 1223	AD 1273	AD 1282
ELY-C176	Parapet tie, south side	nm	---	------	------	------
ELY-C185	Upper purlin east side bay 3	121	38C	------	------	------
	South transept roof					
ELY-C177	East rafter 1, bay 5	67	h/s	AD 1338	AD 1404	AD 1404
ELY-C178	West rafter 2, bay 4	99	33C	AD 1327	AD 1392	AD 1425
ELY-C179	West rafter 3, bay 5	61	h/s	AD 1341	AD 1401	AD 1401
ELY-C180	West rafter 1, bay 5	69	h/s	AD 1338	AD 1406	AD 1406
ELY-C181	East rafter 2, bay 5	112	18C	AD 1315	AD 1408	AD 1426
ELY-C182	East rafter 4, bay 5	76	h/s	AD 1334	AD 1409	AD 1409
ELY-C183	East principal brace truss 5	72	no h/s	AD 1317	------	AD 1388

Table 1: continued

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
ELY-C302	North lower rafter, frame 76	150	h/s	------	------	------
ELY-C303	North upper rafter, frame 52	90	no h/s	AD 924	------	AD 1013
ELY-C304	South lower rafter, frame 15	155	no h/s	AD 891	------	AD 1045
	West tower turrets					
ELY-C305	North east turret, stair beam 103	nm	---	------	------	------
ELY-C306	North west turret, stair beam 107	nm	---	------	------	------
ELY-C307	North west turret, stair beam 110	nm	---	------	------	------
ELY-C308	North west turret, stair beam 109	nm	---	------	------	------
ELY-C309	North west turret, stair beam 108	64	no h/s	AD 933	------	AD 996
ELY-C310	North east turret, stair beam 91	72	h/s	AD 957	AD 1028	AD 1028
ELY-C311	South east turret, stair beam 95	96	no h/s	------	------	------
ELY-C312	North west turret, stair beam 56	161	29C	AD 1019	AD 1150	AD 1179
ELY-C313	North east turret, stair beam 78	92	h/s	AD 936	AD 1027	AD 1027

Table 1: continued

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
	Nave roof					
ELY-C501	North upper rafter, frame 7	80	h/s	AD 1182	AD 1261	AD 1261
ELY-C502	South rafter, frame 7	72	h/s	AD 1196	AD 1267	AD 1267
ELY-C503	South rafter, frame 9	95	h/s	AD 1161	AD 1255	AD 1255
ELY-C504	North rafter, frame 14	211	h/s	AD 1046	AD 1256	AD 1256
ELY-C505	North rafter, frame 16	70	2	AD 1212	AD 1279	AD 1281
ELY-C506	South rafter, frame 16	79	h/s	AD 1202	AD 1280	AD 1280
ELY-C507	North rafter, frame 29	54	h/s	AD 1228	AD 1281	AD 1281
ELY-C508	Upper collar, frame 29	78	h/s	------	------	------
ELY-C509	North rafter, frame 30	64	h/s	AD 1217	AD 1280	AD 1280
ELY-C510	North rafter, frame 31	68	h/s	AD 1211	AD 1278	AD 1278
ELY-C511	South rafter, frame 31	54	h/s	AD 1231	AD 1284	AD 1284
ELY-C512	Upper collar, frame 31	54	6	AD 1239	AD 1286	AD 1292
ELY-C513	Upper collar, frame 33	58	6	AD 1229	AD 1280	AD 1286
ELY-C514	South rafter, frame 33	65	h/s	AD 1223	AD 1287	AD 1287
ELY-C515	Upper collar, frame 36	58	1	------	------	------
ELY-C516	Upper collar, frame 64	95	h/s	AD 1179	AD 1273	AD 1273
ELY-C517	Upper collar, frame 66	89	13	AD 1208	AD 1283	AD 1296
ELY-C518	North rafter, frame 67	54	h/s	------	------	------
ELY-C519	Upper collar, frame 67	54	h/s	------	------	------
ELY-C520	South rafter, frame 67	56	h/s	------	------	------
ELY-C521	South rafter, frame 68	54	h/s	------	------	------

Table 1: continued

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
	Nave roof					
ELY-C522	Upper collar, frame 71	54	h/s	AD 1223	AD 1276	AD 1276
ELY-C523	Upper collar, frame 72	54	h/s	AD 1223	AD 1276	AD 1276
ELY-C524	Upper collar, frame 73	68	25C	AD 1156	AD 1198	AD 1223
ELY-C525	South rafter, frame 74	56	18	AD 1160	AD 1197	AD 1215
ELY-C526	North upper rafter, frame 76	77	45C	------	------	------
ELY-C527	Upper collar, frame 76	83	h/s	------	------	------
ELY-C528	North rafter, frame 77	67	11	AD 1218	AD 1273	AD 1284
ELY-C529	South rafter, frame 77	68	10	------	------	------
ELY-C530	North rafter, frame 79	67	h/s	AD 1217	AD 1283	AD 1283
ELY-C531	Upper collar, frame 79	112	8	AD 1169	AD 1272	AD 1280
ELY-C532	Upper collar, frame 80	86	6	AD 1206	AD 1295	AD 1291
ELY-C533	South upper rafter, frame 15	64	no h/s	AD 919	------	AD 982
ELY-C534	Upper collar, frame 15	nm	---	------	------	------
ELY-C535	North scissor brace, frame 15	nm	---	------	------	------
ELY-C536	North scissor brace, frame 16	54	h/s	------	------	------
ELY-C537	South rafter, frame 19	86	h/s	AD 1207	AD 1292	AD 1292
ELY-C538	North rafter, frame 19	97	h/s	AD 1195	AD 1291	AD 1291
ELY-C539	North rafter, frame 22	nm	---	------	------	------
ELY-C540	North rafter, frame 24	73	h/s	AD 1214	AD 1286	AD 1286
ELY-C541	North scissor brace, frame 29	68	5	AD 1221	AD 1283	AD 1288
ELY-C542	South scissor brace, frame 29	59	h/s	AD 1227	AD 1285	AD 1285

Table 1: continued

Sample number	Sample location	Total rings	*Sapwood rings	First measured ring date	Last heartwood ring date	Last measured ring date
	Nave roof					
ELY-C543	Lower collar, frame 29	63	h/s	AD 1230	AD 1292	AD 1292
ELY-C544	Lower collar, frame 31	54	11	------	------	------
ELY-C545	North rafter, frame 32	54	h/s	------	------	------
ELY-C546	Upper collar, frame 32	nm	---	------	------	------
ELY-C547	North rafter, frame 33	nm	---	------	------	------
ELY-C548	North rafter, frame 34	61	h/s	AD 1222	AD 1282	AD 1282
ELY-C549	North rafter, frame 35	56	h/s	AD 1230	AD 1285	AD 1285
ELY-C550	South rafter, frame 35	54	h/s	------	------	------
ELY-C551	Upper collar, frame 35	70	19	AD 1217	AD 1267	AD 1286
ELY-C552	Lower collar, frame 37	83	16	AD 1217	AD 1283	AD 1299
ELY-C553	South rafter, frame 38	65	h/s	AD 1219	AD 1283	AD 1283
ELY-C554	North rafter, frame 38	60	h/s	AD 1215	AD 1274	AD 1274
ELY-C555	Upper collar, frame 42	58	no h/s	AD 1217	------	AD 1274
ELY-C556	Upper collar, frame 43	60	no h/s	AD 1170	------	AD 1229

* h/s = the heartwood/sapwood boundary is the last ring on the sample
C = complete sapwood retained on sample, the last measured ring date is the felling date of the timber
nm = sample not measured
nk = sample not kept due to having less than 50 rings

Table 2: Results of the cross-matching of site chronology ELYCSQ01 and relevant reference chronologies when first ring date is AD 1029 and last ring date is AD 1328

Reference chronology	Span of chronology	*t*-value	
Chichester Cathedral, West Sussex	AD 1173 - 1295	10.3	(Howard *et al* 1992)
St Albans Cathedral, Herts	AD 1060 - 1262	9.3	(Howard *et al* 2000a)
England London	AD 413 - 1728	8.7	(Tyers and Groves 1999 unpubl)
Reading Waterfront, Berks	AD 1160 - 1407	8.0	(Groves *et al* 1997)
Butter Market, Thame, Oxon	*AD 1161 - 1289*	7.9	(Howard *et al* 1993a)
Southern England	AD 1083 - 1981	7.6	(Bridge 1988)
East Midlands	AD 882 - 1981	7.1	(Laxton and Litton 1988)
Chicksands Priory, Beds	AD 1200 - 1541	7.0	(Howard *et al* 1998)

Table 3: Results of the cross-matching of site chronology ELYCSQ02 and relevant reference chronologies when first ring date is AD 1206 and last ring date is AD 1340

Reference chronology	Span of chronology	*t*-value	
Reading Waterfront, Berks	AD 1160 - 1407	6.4	(Groves *et al* 1997)
Southern England	AD 1083 - 1981	5.8	(Bridge 1988)
East Midlands	AD 882 - 1981	5.5	(Laxton and Litton 1988)
Kent-88	AD 1158 - 1540	5.2	(Laxton and Litton 1989)
England London	AD 413 - 1728	5.2	(Tyers and Groves 1999 unpubl)
Donnington-le-Heath Manor, Leics	AD 1127 - 1269	5.2	(Esling *et al* 1989)
Cross Keys Inn, Leicester	AD 1104 - 1309	5.1	(Howard *et al* 1988)
England	AD 401 - 1981	4.6	(Baillie and Pilcher 1982 unpubl)

Table 4: Results of the cross-matching of site chronology ELYCSQ03 and relevant reference chronologies when first ring date is AD 1315 and last ring date is AD 1426

Reference chronology	Span of chronology	*t*-value	
Ware Priory, Ware, Herts	AD 1223 -1416	8.7	(Howard *et al* 1997b)
England London	AD 413 - 1728	7.1	(Tyers and Groves 1999 unpubl)
19, Henley Street Alcester, Warwicks	*AD 1322 - 1393*	6.4	(Alcock *et al* 1989)
Southern England	AD 1083 - 1981	6.4	(Bridge 1988)
East Midlands	AD 882 - 1981	6.1	(Laxton and Litton 1988)
Chicksands Priory, Beds	AD 1200 - 1541	6.1	(Howard *et al* 1998)
Sinai Park, Staffs	AD 1227 - 1750	5.7	(Tyers 1997a)
Reading Waterfront, Berks	AD 1160 - 1407	5.7	(Groves *et al* 1997)

Table 5: Results of the cross-matching of site chronology ELYCSQ04 and relevant reference chronologies when first ring date is AD 891 and last ring date is AD 1090

Reference chronology	Span of chronology	*t*-value	
London Fennings Wharf	AD 802 - 1354	10.9	(Tyers 1997b)
England London	AD 413 - 1728	10.5	(Tyers and Groves 1999 unpubl)
London Fleet Valley	AD 745 - 1226	9.6	(Tyers and Hibbard 1993)
London Billingsgate	*AD 611 - 1243*	9.5	(Hillam 1992)
London Bull Wharf	AD 620 - 1181	8.0	(Tyers and Boswijk1997)
Westwick Cottage, Hemel Hempstead, Herts	AD 940 - 1179	6.6	(Howard *et al* 1997a)
Hansacre Hall, Staffs	AD 965 - 1279	5.3	(Esling *et al* 1990)

Table 6: Results of the cross-matching of site chronology ELYCSQ05 and relevant reference chronologies when first ring date is AD 1592 and last ring date is AD 1794

Reference chronology	Span of chronology	*t*-value	
Old Barn, Stratford upon Avon, Warwicks	AD 1591 - 1735	9.8	(Howard *et al* 1996)
East Midlands	AD 882 - 1981	9.7	(Laxton and Litton 1988)
Main Street, Cosby, Leics	AD 1642 - 1734	9.5	(Alcock *et al* 1991 unpubl)
Quenby Hall, Leics	AD 1575 - 1724	9.2	(Howard *et al* 1993b)
Chicksands Priory, Beds	AD 1670 - 1814	8.4	(Howard *et al* 1998)
Stoneleigh Abbey, Stoneleigh, Warwicks	AD 1646 - 1813	8.2	(Howard *et al* 2000b)
Burleigh House, Burleigh, Cambs	AD 1686 - 1809	7.2	(Howard *et al* 1992)
England	AD 401 - 1981	5.6	(Baillie and Pilcher 1982 unpubl)

Table 7: Results of the cross-matching of site chronology ELYCSQ06 and relevant reference chronologies when first ring date is AD 1109 and last ring date is AD 1289

Reference chronology	Span of chronology	*t*-value	
GDANSK	AD 996 - 1985	5.1	(Eckstein 1989 unpubl)
FLE-4M2	AD 1131 - 1350	4.6	(Fletcher 1978 unpubl)
YOR-Z01M	AD 1113 - 1381	4.5	(Fletcher and Morgan 1981)
BALTIC	AD 1156 - 1697	4.3	(Tyers and Groves pers comm)
REF-7	AD 993 - 1267	4.1	(Fletcher 1977)

Table 8: Results of the cross-matching of site chronology ELYCSQ07 and relevant reference chronologies when first ring date is AD 1097 and last ring date is AD 1303

Reference chronology	Span of chronology	*t*-value	
GDANSK	AD 996 - 1985	8.1	(Eckstein 1989 unpubl)
FLE-4M2	AD 1131 - 1350	7.5	(Fletcher 1978)
BALTIC	AD 1156 - 1697	6.3	(Tyers and Groves pers comm)
Ewerby, Notts	AD 1174 - 1314	6.2	(Howard *et al* 1991)
Hadleigh, Suffolk	AD 1157 - 1431	4.7	(Howard *et al* 1990 unpubl)

Table 9: Results of the cross-matching of site chronology ELYCSQ10 and relevant reference chronologies when first ring date is AD 1019 and last ring date is AD 1179

Reference chronology	Span of chronology	*t*-value	
Angle Choir, Lincoln Cathedral	AD 912 - 1248	8.1	(Laxton and Litton 1988)
Peterborough Cathedral, Cambs	AD 887 - 1225	8.0	(Tyers 1999)
St Hugh's Choir, Lincoln Cathedral	AD 882 - 1191	7.8	(Laxton and Litton 1988)
East Midlands	AD 882 - 1981	7.5	(Laxton and Litton 1988)
ENYO67	AD 440 - 1823	6.7	(Tyers and Groves pers com)
Forehill, Ely, Cambs	AD 963 - 1128	6.7	(Nayling 1999)
Enmw89	AD 860 - 1790	5.4	(Tyers and Groves pers com)
England	AD 401 - 1981	5.0	(Baillie and Pilcher 1982 unpubl)

Table 10: Results of the cross-matching of site chronology ELYCSQ16 and relevant reference chronologies when first ring date is AD 933 and last ring date is AD 1028

Reference chronology	Span of chronology	*t*-value	
East Midlands	AD 882 - 1981	8.3	(Laxton and Litton 1988)
St Hugh's Choir, Lincoln Cathedral	AD 882 - 1191	7.6	(Laxton and Litton 1988)
London Fleet Valley	AD 745 - 1226	6.4	(Tyers and Hibbard 1993)
Angle Choir, Lincoln Cathedral	AD 912 - 1248	5.8	(Laxton and Litton 1988)
England London	AD 413 - 1728	5.3	(Tyers and Groves 1999 unpubl)
London Fennings Wharf	AD 802 - 1354	5.1	(Tyers 1997b)
London Bull Wharf	AD 620 - 1181	5.0	(Tyers and Boswijk1997)

Table 11: Results of the cross-matching of sample ELY-C53 and relevant reference chronologies when first ring date is AD 1002 and last ring date is AD 1134

Reference chronology	Span of chronology	*t*-value	
St Hugh's Choir. Lincoln Cathedral	AD 882 - 1191	7.1	(Laxton and Litton 1988)
ENYO67	AD 440 - 1823	7.0	(Tyers and Groves pers com)
East Midlands	AD 882 - 1981	6.4	(Laxton and Litton 1988)
Peterborough Cathedral, Cambs	AD 887 - 1225	5.9	(Tyers 1999)
Angle Choir, Lincoln Cathedral	AD 912 - 1248	5.7	(Laxton and Litton 1988)
ENNW0245	AD 892 - 1618	5.7	(Tyers and Groves pers com)
Forehill, Ely, Cambs	AD 963 - 1128	4.8	(Nayling 1999)

Table 12: Results of the cross-matching of sample ELY-C159 and relevant reference chronologies when first ring date is AD 1133 and last ring date is AD 1288

Reference chronology	Span of chronology	*t*-value	
GDANSK	AD 996 - 1985	7.1	(Eckstein 1989 unpubl)
Hadleigh, Suffolk	AD 1157 - 1431	5.3	(Howard *et al* 1990 unpubl)
FLE-4M2	AD 1131 - 1350	5.2	(Fletcher 1978)
BALTIC	AD 1156 - 1697	4.7	(Tyers and Groves pers comm)
Ewerby, Notts	AD 1174 - 1314	4.1	(Howard *et al* 1991)

Figure 1: Map to show general location of Ely Cathedral

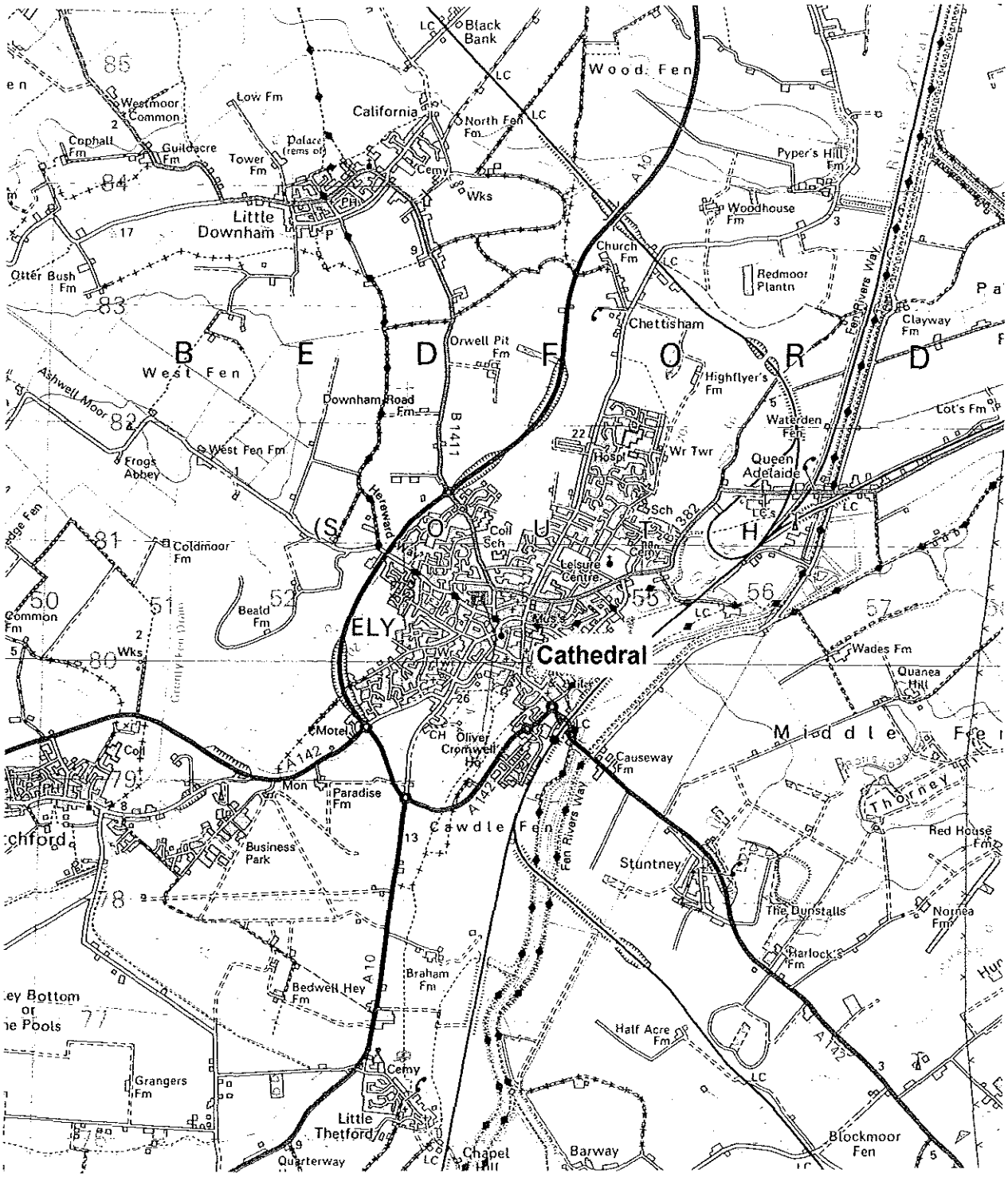


Figure 2: General plan of Ely Cathedral.

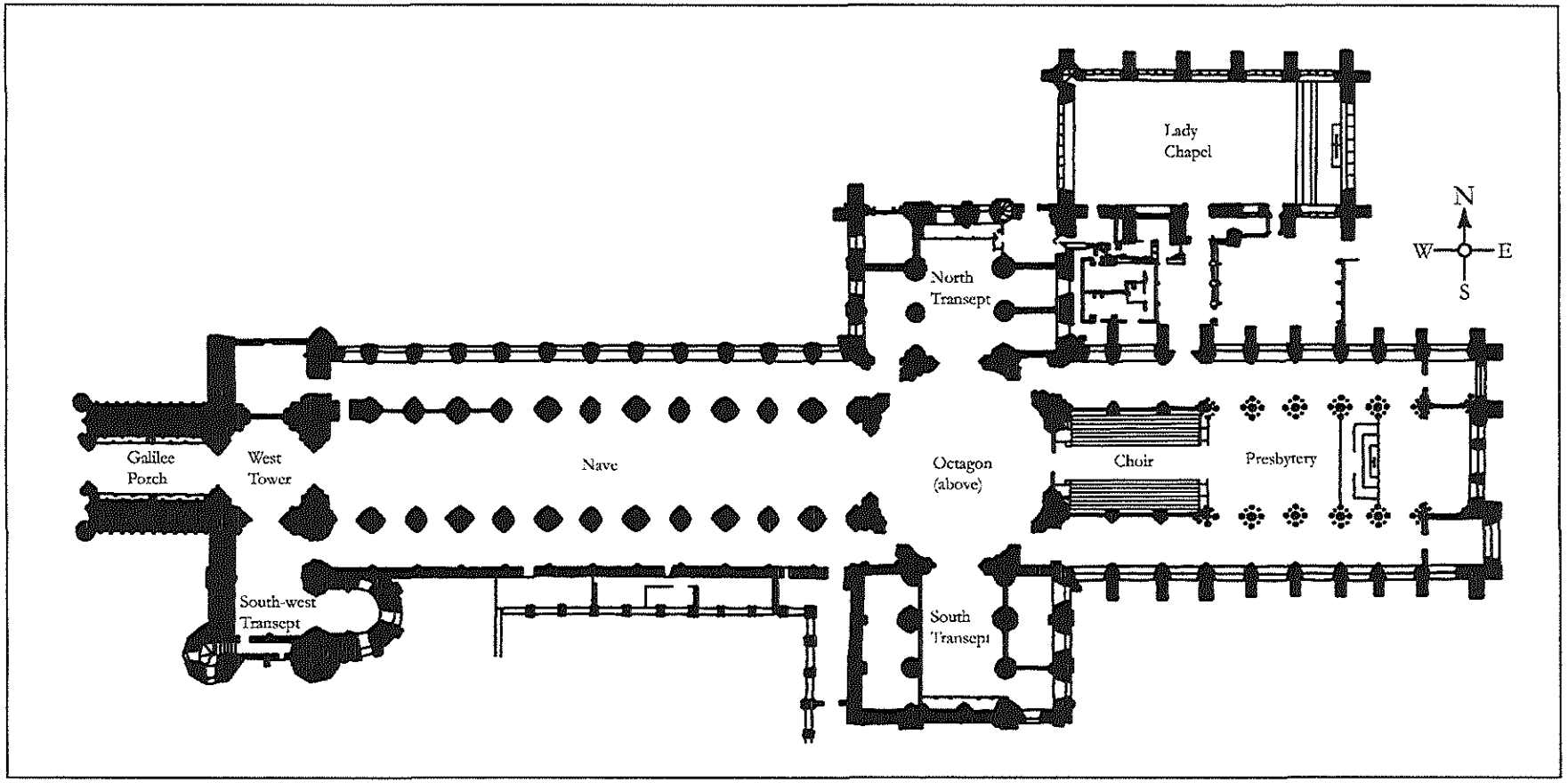


Figure 3a: View of the nave roof looking west to east at walk-way level. (© Crown copyright. NMR. BB87/7303)

Figure 3b: Photograph of the south side of the nave roof at wall plate level taken during repairs. (© Crown copyright. NMR. BB87/7319)

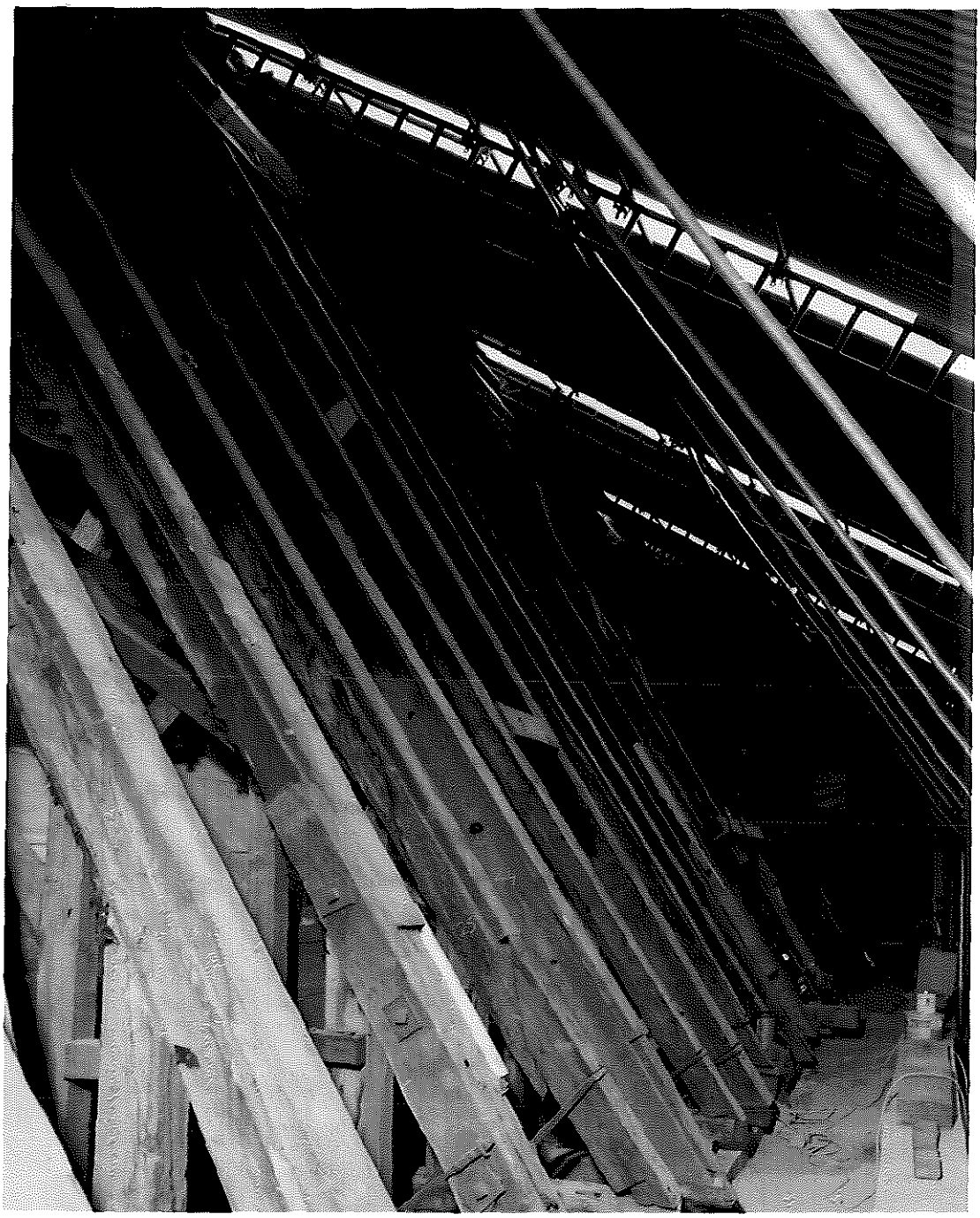


Figure 3c: Photograph of the nave roof showing the crossing of the scissor braces just above the level of the ceiling. (© Crown copyright. NMR. BB87/7325)

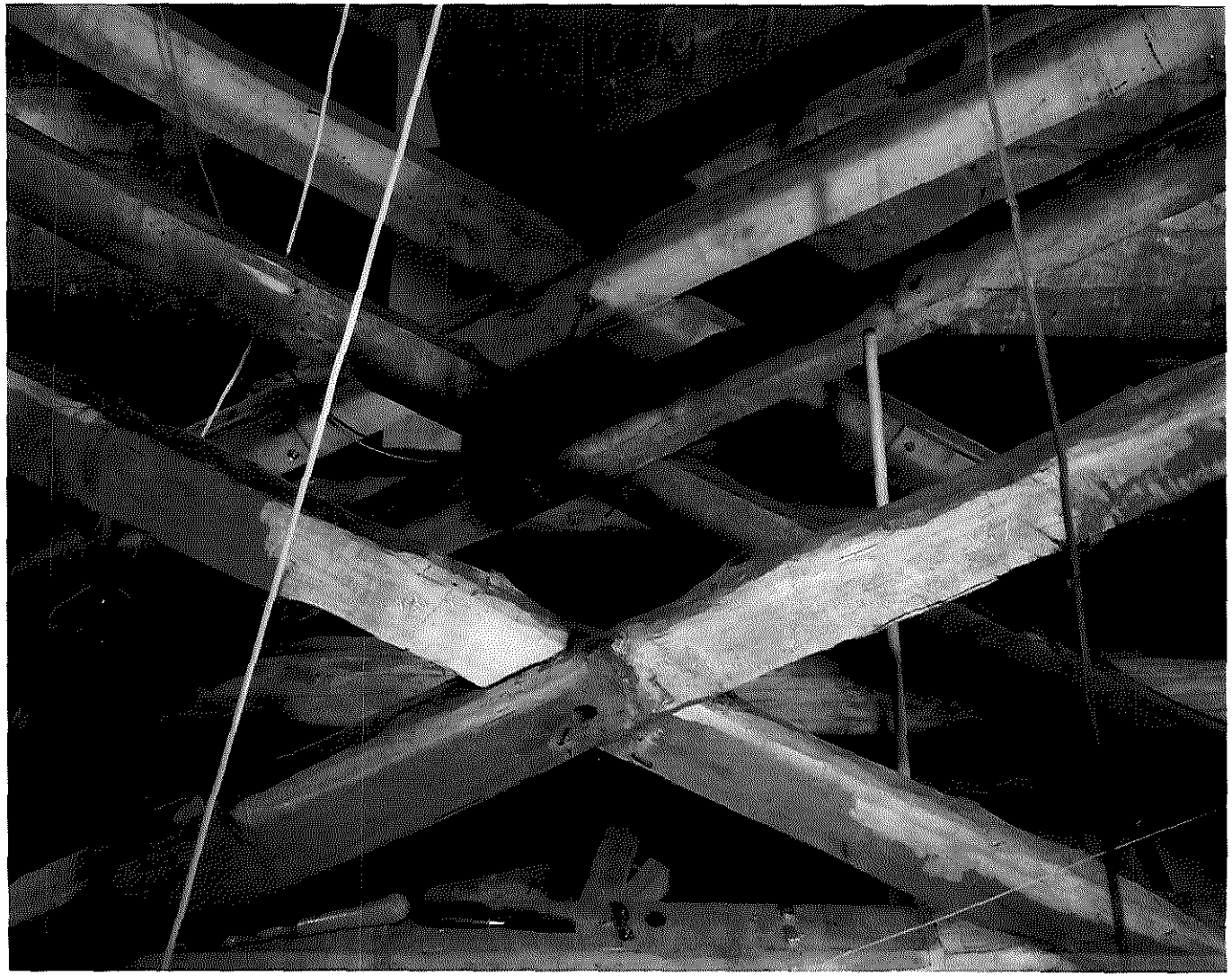


Figure 4: Photograph of the Lady Chapel roof showing the modern softwood trusses. (© Crown copyright. NMR. BB88/5843)

Figure 5: Drawing of a typical truss in the Lady Chapel roof (after Elaine Guilding)

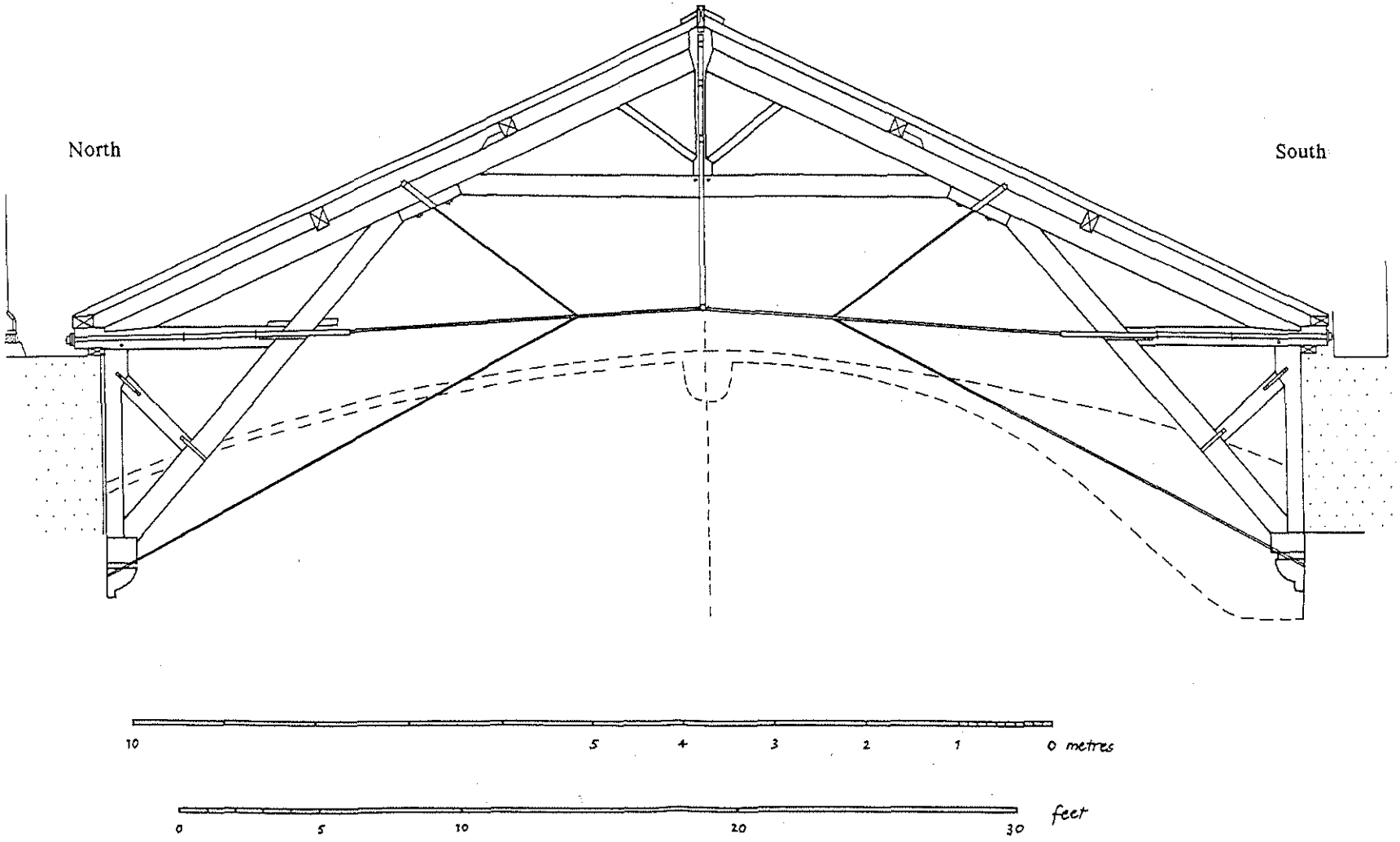


Figure 6: Plan of the Lady Chapel roof showing approximate location of sampled timbers (after Purcell, Miller, Tritton, and Partners)

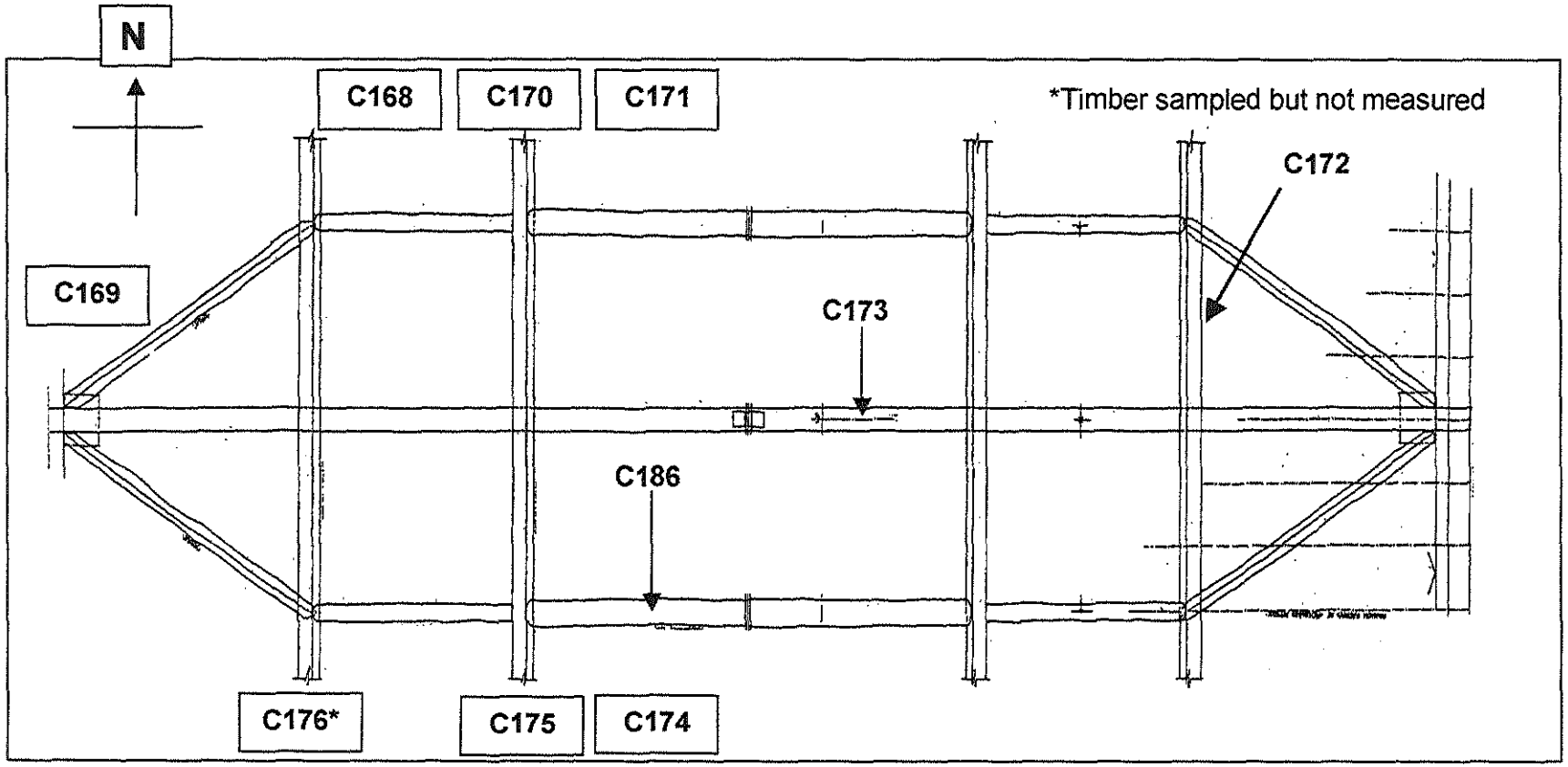
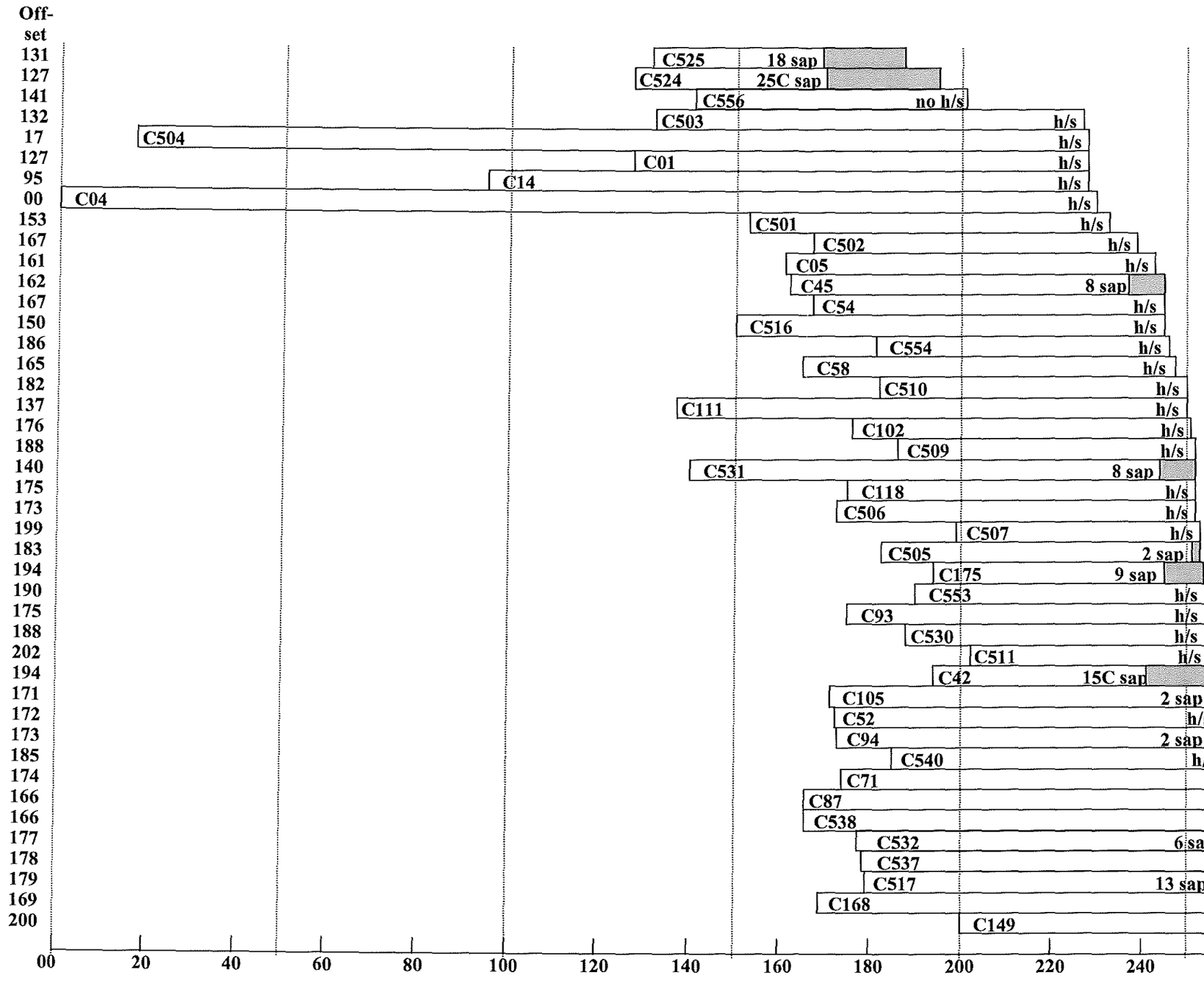


Figure 7: Photograph of the Presbytery Roof. (© Crown copyright. NMR. BB98/17656)

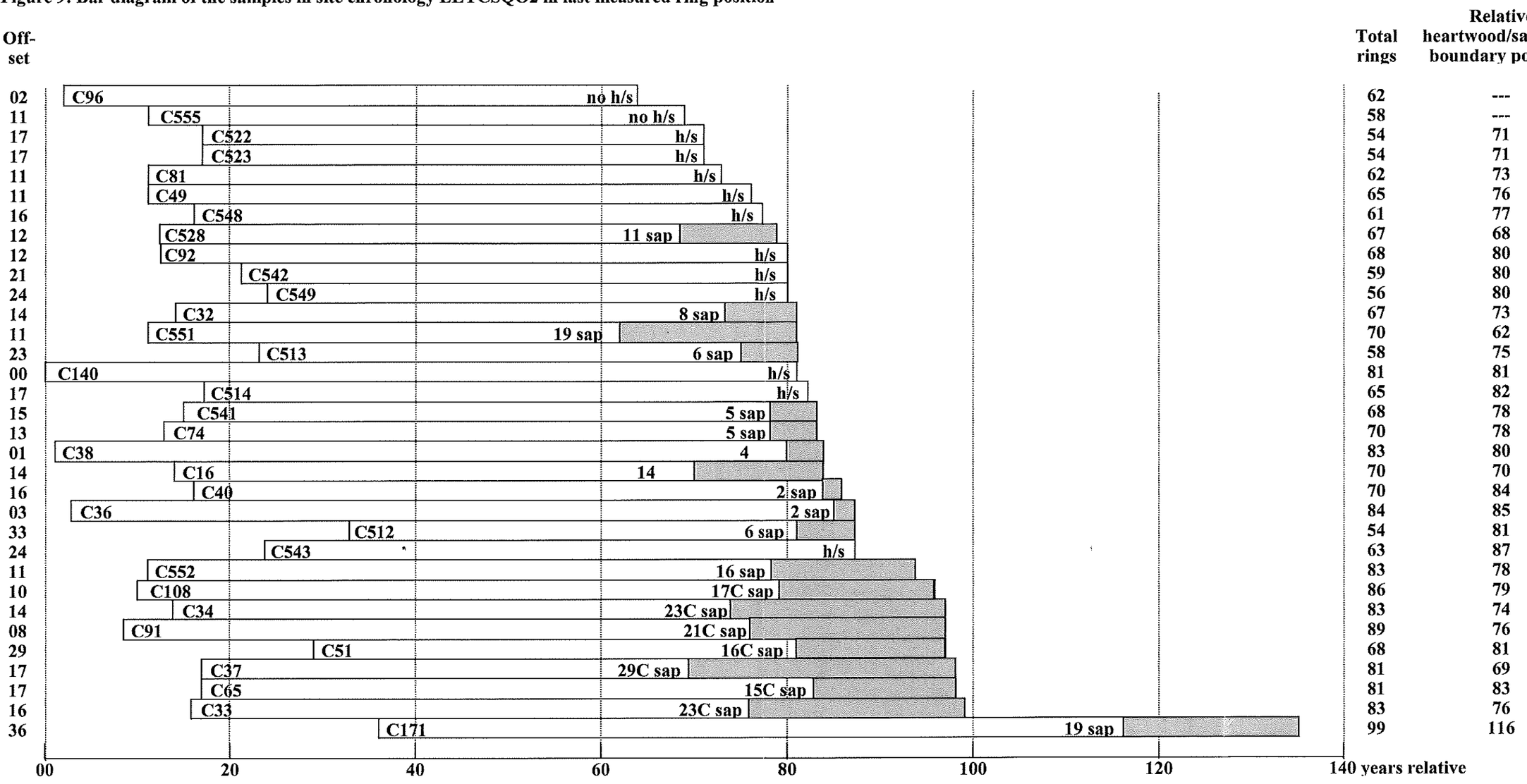
Figure 8: Bar diagram of the samples in site chronology ELYCSQO1 in last measured ring position



Off-set	Total rings	Relative heartwood/sapwood boundary position
131	56	169
127	68	170
141	60	---
132	95	227
17	211	228
127	101	228
95	133	228
00	230	230
153	80	233
167	72	239
161	82	243
162	83	237
167	78	245
150	95	245
186	60	246
165	82	247
182	68	250
137	113	250
176	75	251
188	64	252
140	112	244
175	77	252
173	79	252
199	54	253
183	70	251
194	60	245
190	65	255
175	80	255
188	67	255
202	54	256
194	62	241
171	86	255
172	85	257
173	84	255
185	73	258
174	87	261
166	95	261
166	97	263
177	86	257
178	86	264
179	89	255
169	106	275
200	100	300

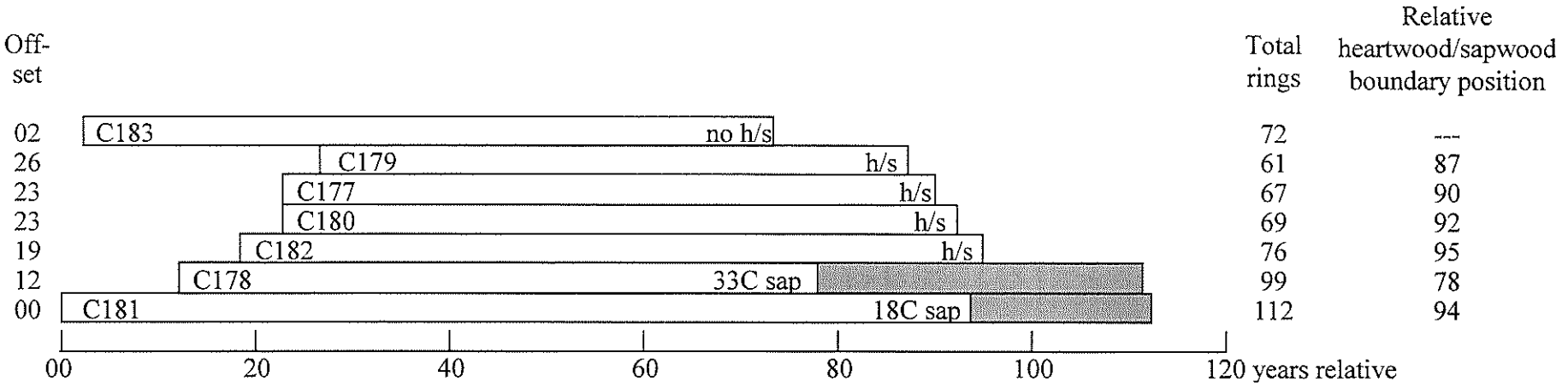
white bars = heartwood rings, shaded area = sapwood rings
h/s = heartwood/sapwood boundary is last ring on sample
C = complete sapwood retained on sample, the last measured ring date is the felling date of the timber

Figure 9: Bar diagram of the samples in site chronology ELYCSQO2 in last measured ring position



white bars = heartwood rings, shaded area = sapwood rings
h/s = heartwood/sapwood boundary is last ring on sample
C = complete sapwood retained on sample, the last measured ring date is the felling date of the timber

Figure 10: Bar diagram of the samples in site chronology ELYCSQ03

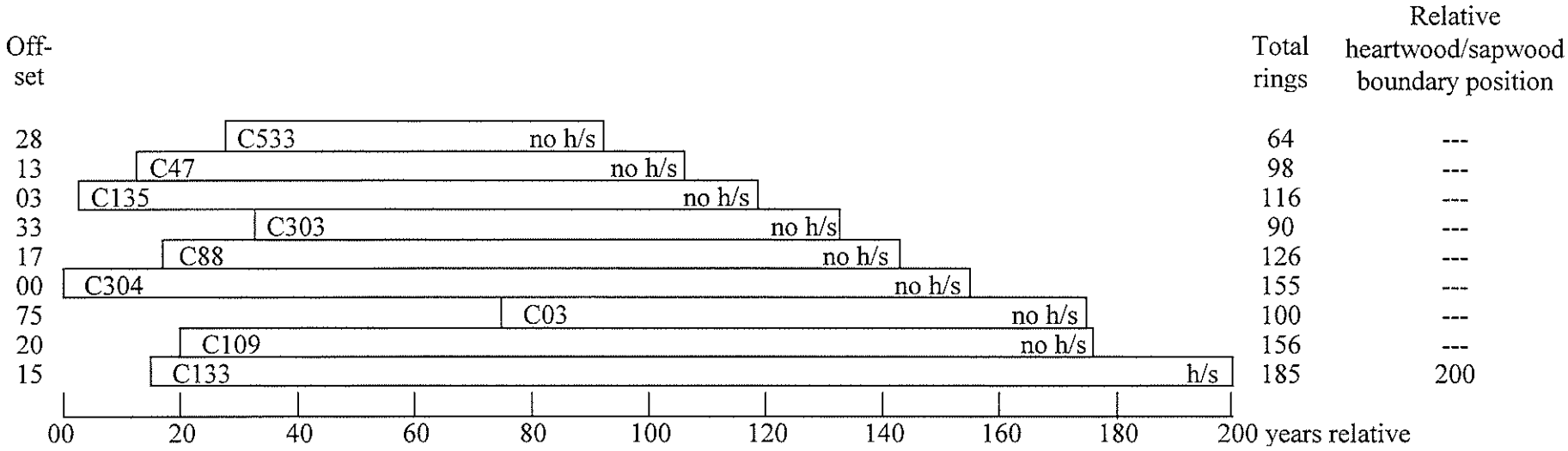


white bars = heartwood rings, shaded area = sapwood rings

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

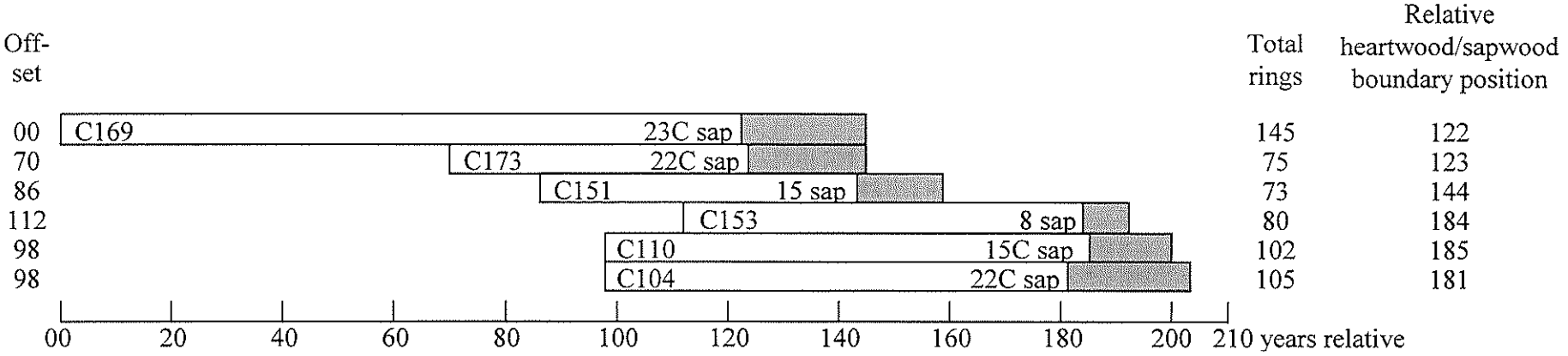
C = complete sapwood retained on sample, the last measured ring date is the felling date of the timber

Figure 11: Bar diagram of the samples in site chronology ELYCSQ04



white bars = heartwood rings, shaded area = sapwood rings
h/s = heartwood/sapwood boundary is last ring on sample

Figure 12: Bar diagram of the samples in site chronology ELYCSQ05



white bars = heartwood rings, shaded area = sapwood rings

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

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

Figure 13: Bar diagram of the samples in site chronology ELYCSQ06

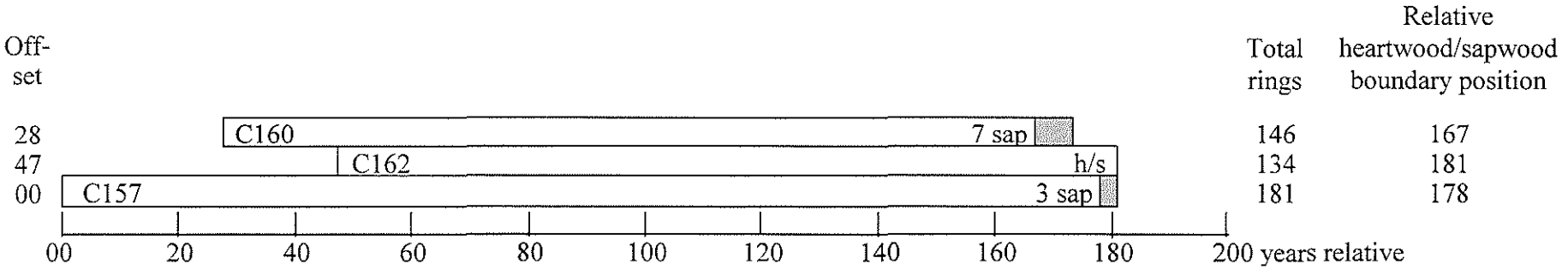
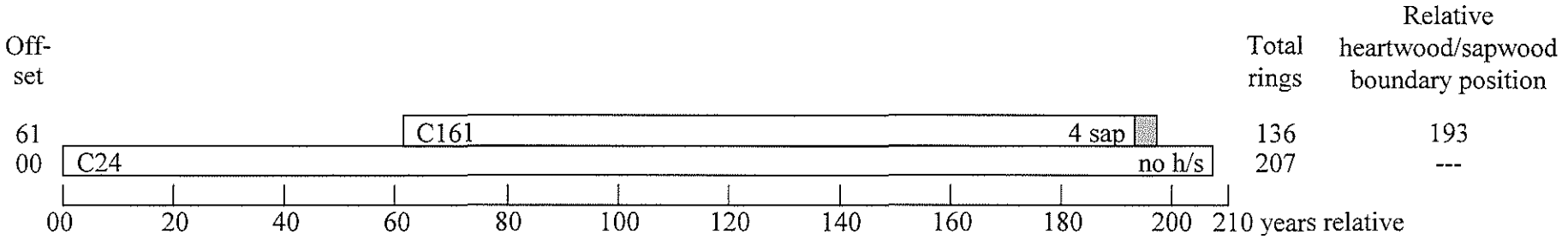


Figure 14: Bar diagram of the samples in site chronology ELYCSQ07



white bars = heartwood rings, shaded area = sapwood rings

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

Figure 15: Bar diagram of the samples in site chronology ELYCSQ08

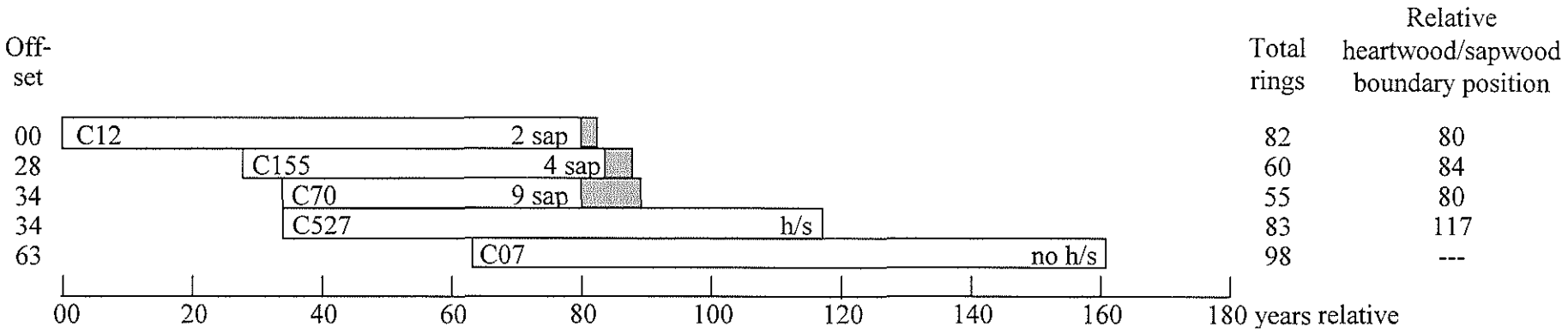
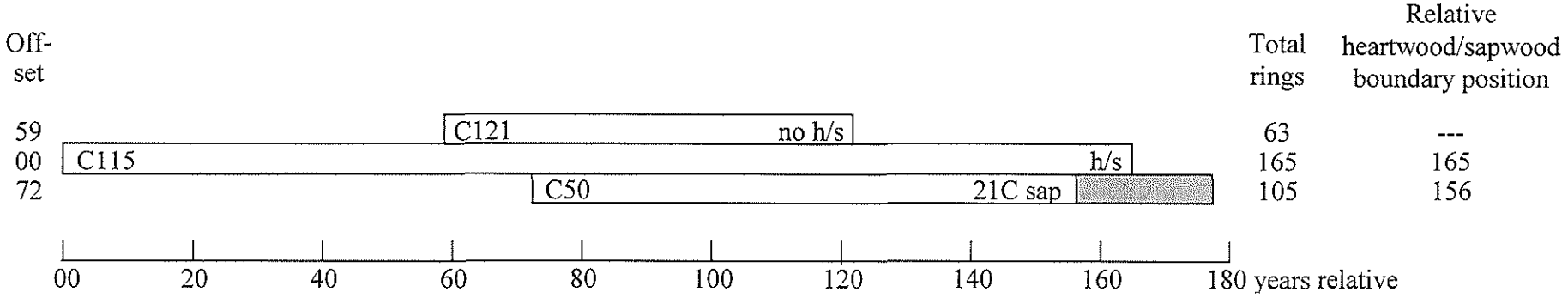


Figure 16: Bar diagram of the samples in site chronology ELYCSQ09



white bars = heartwood rings, shaded area = sapwood rings

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

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

Figure 17: Bar diagram of the samples in site chronology ELYCSQ10

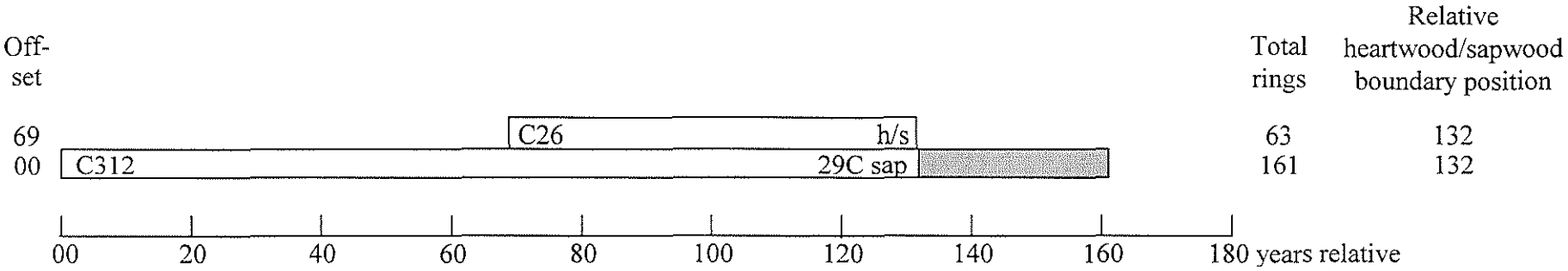
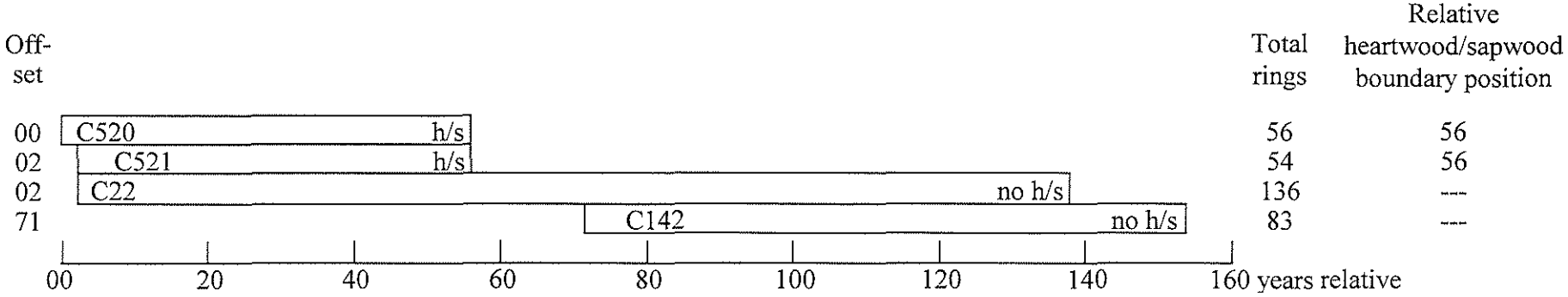


Figure 18: Bar diagram of the samples in site chronology ELYCSQ11



white bars = heartwood rings, shaded area = sapwood rings

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

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

Figure 19: Bar diagram of the samples in site chronology ELYCSQ12

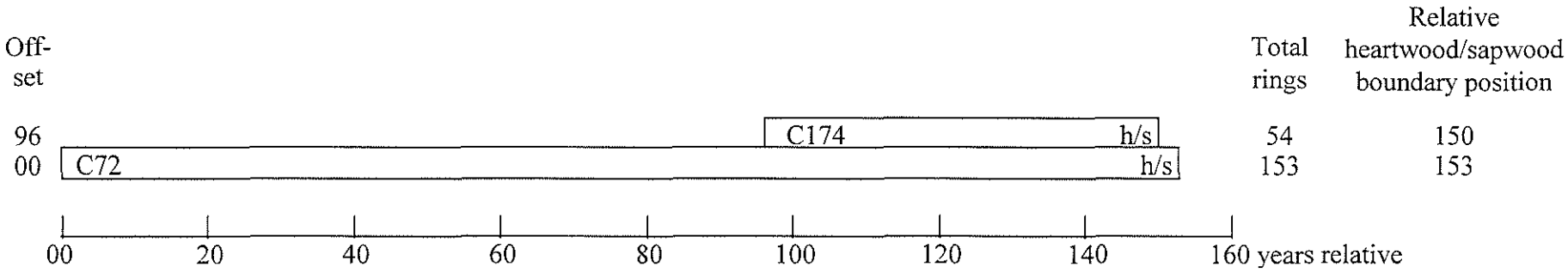
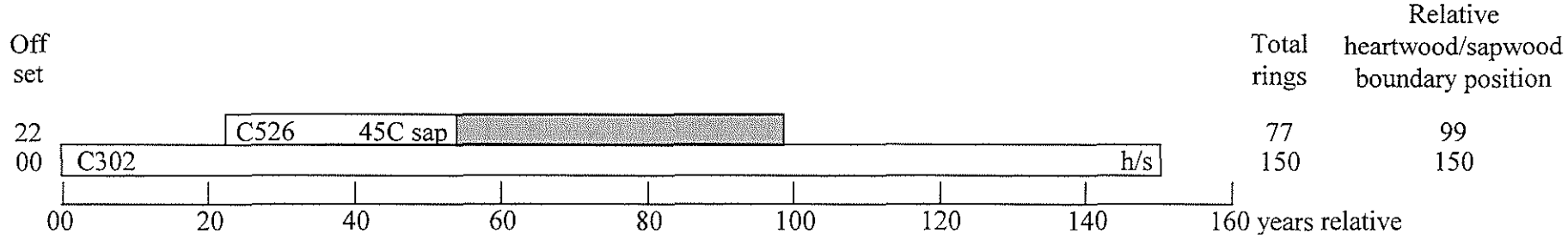


Figure 20: Bar diagram of the samples in site chronology ELYCSQ13



white bars = heartwood rings, shaded area = sapwood rings

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

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

Figure 21: Bar diagram of the samples in site chronology ELYCSQ14

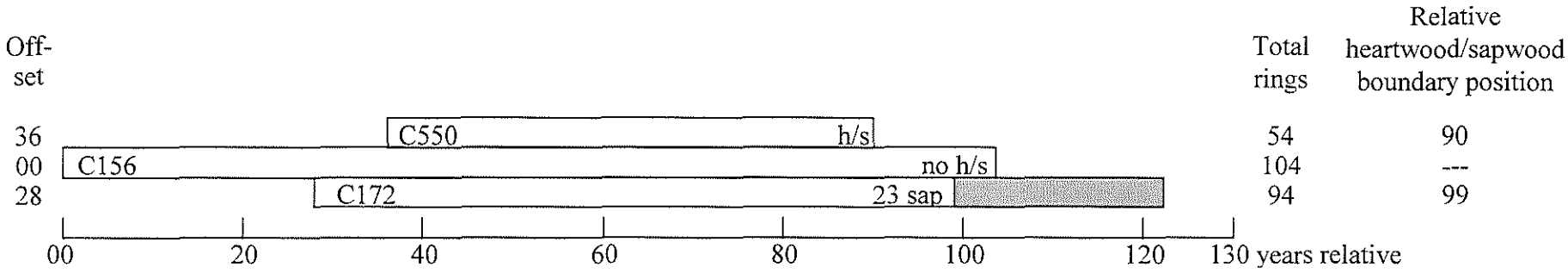
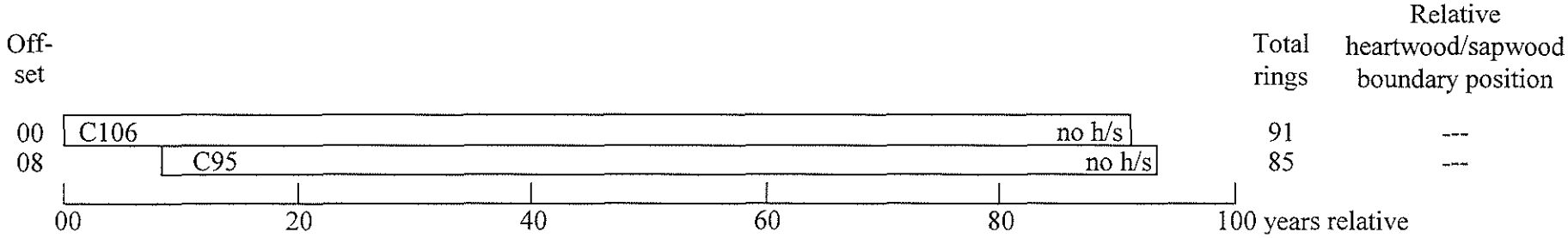


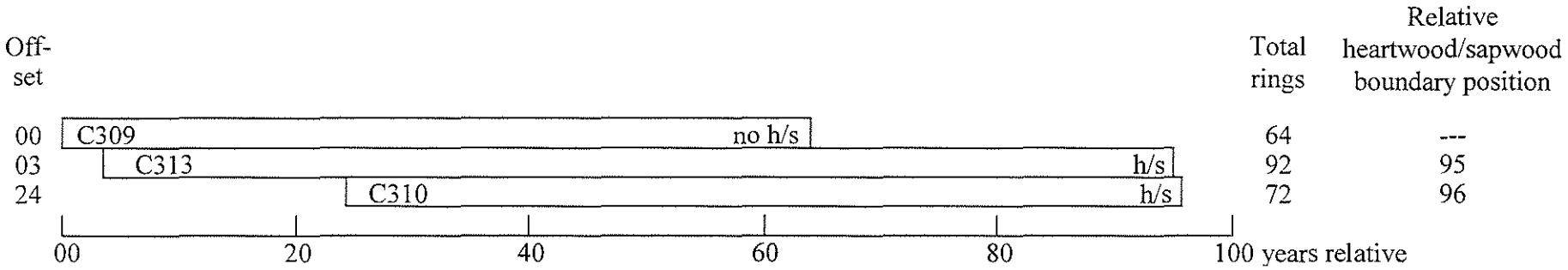
Figure 22: Bar diagram of the samples in site chronology ELYCSQ15



white bars = heartwood rings, shaded area = sapwood rings

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

Figure 23: Bar diagram of the samples in site chronology ELYCSQ16



white bars = heartwood rings, shaded area = sapwood rings

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

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

Figure 24: Bar diagram to show relative position of the nine dated site chronologies, and the two individually dated samples

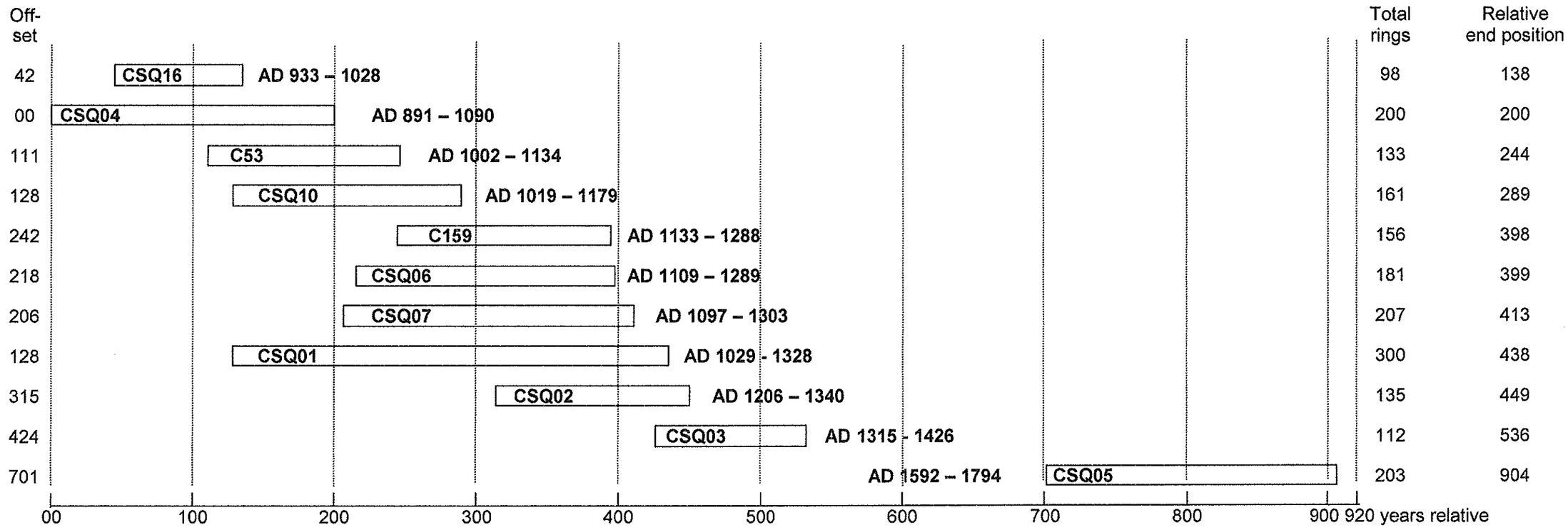


Figure 25: A view of the choir stalls. (© Crown copyright. NMR. BB94/2760)

Figure 26: Photograph of a typical misercord. (© Crown copyright. NMR. AA66/860)

Figure 27: The muniments chest
(photo Dr Peter Marshall)

Figure 28: Photograph showing the remains of two shuttering boards (photo Dr Peter Marshall)

Figure 29: Photograph of the horizontal beams in the south-west tower (photo Dr Peter Marshall)

Figure 30: Door frame
(photo Dr Peter Marshall)

Figure 31a: Nave roof, frame 2 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

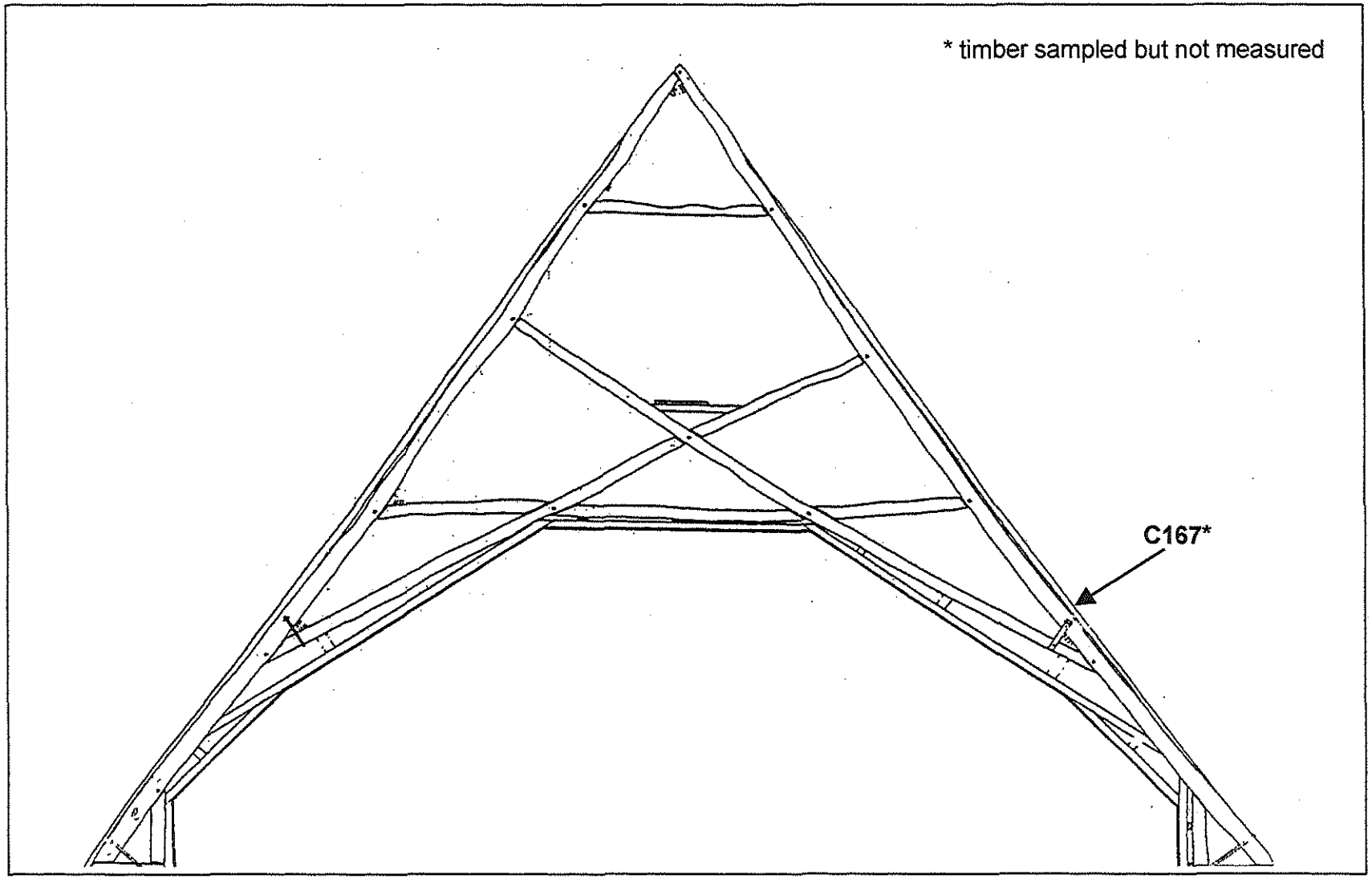


Figure 31b: Nave roof, frame 3 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

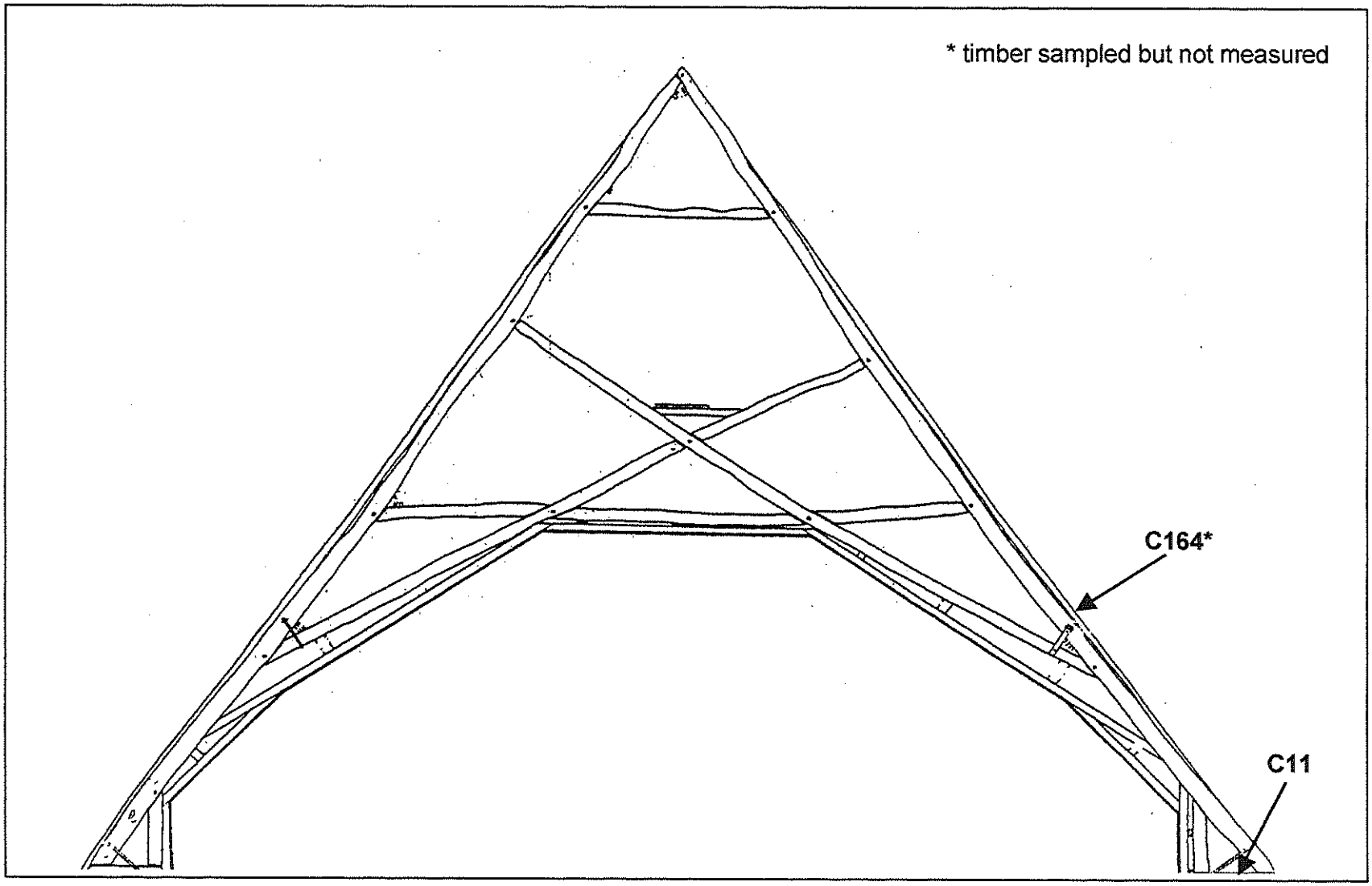


Figure 31c: Nave roof, frame 4 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

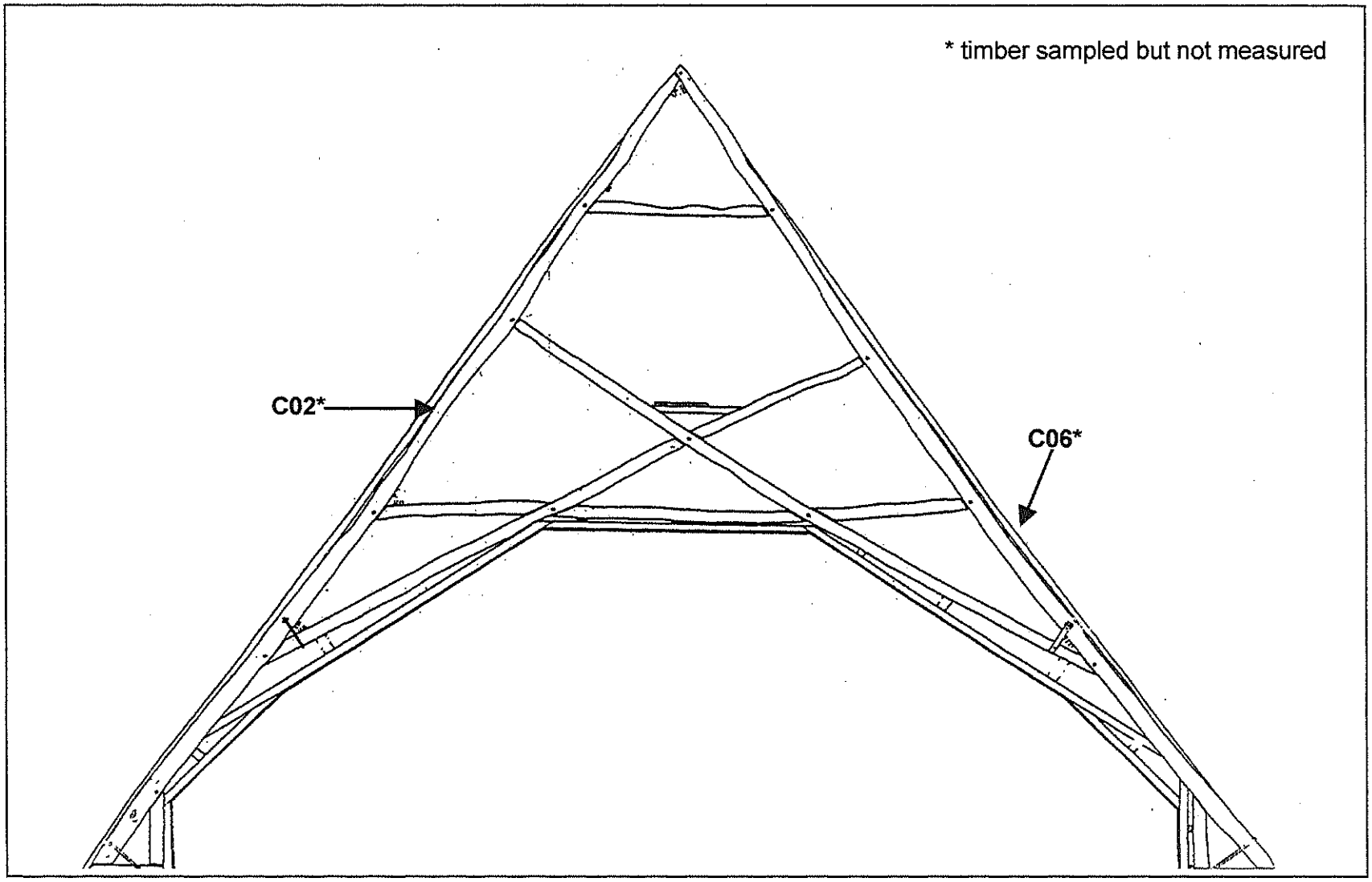


Figure 31d: Nave roof, frame 5 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

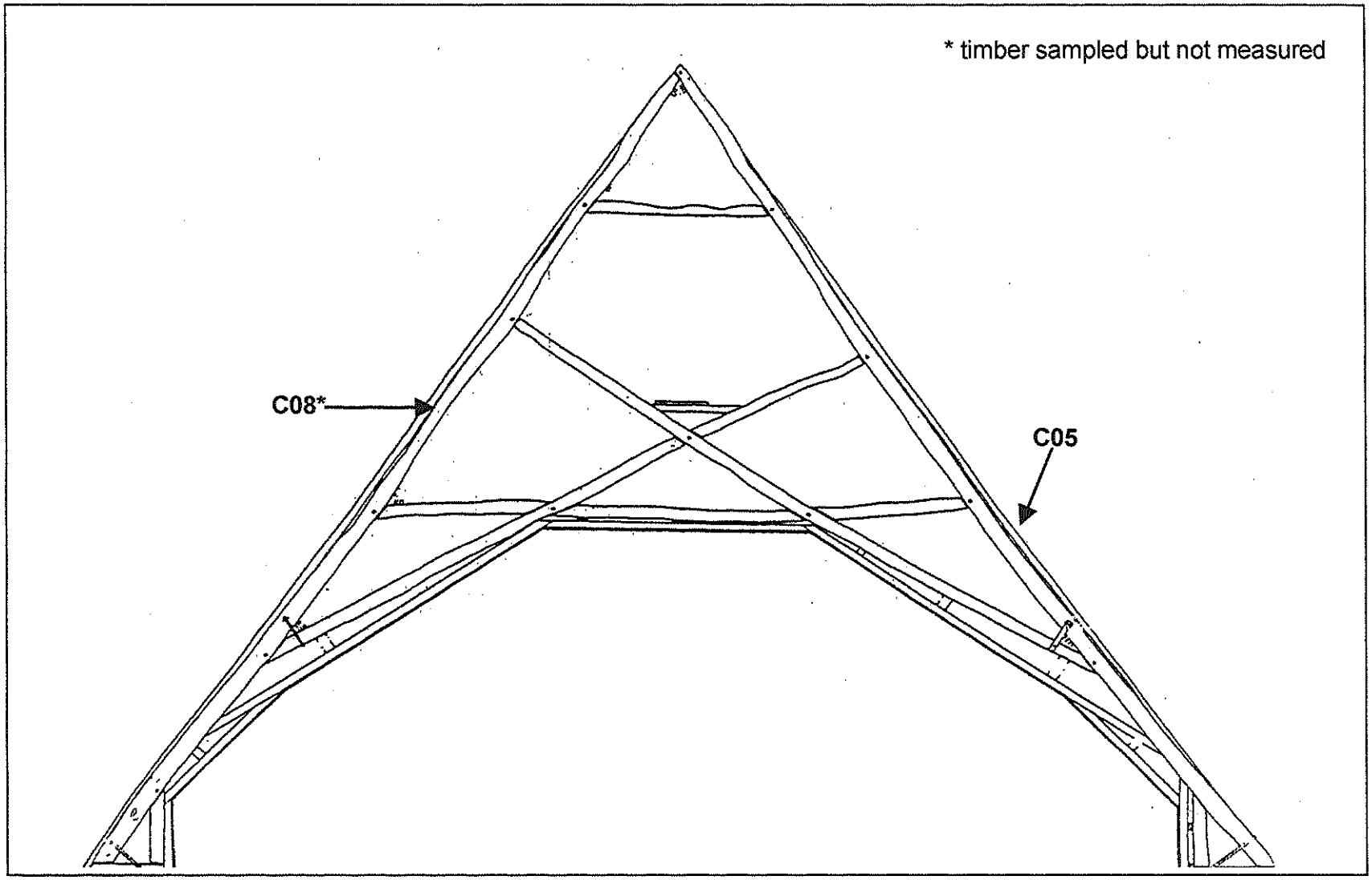


Figure 31e: Nave roof, frame 6 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

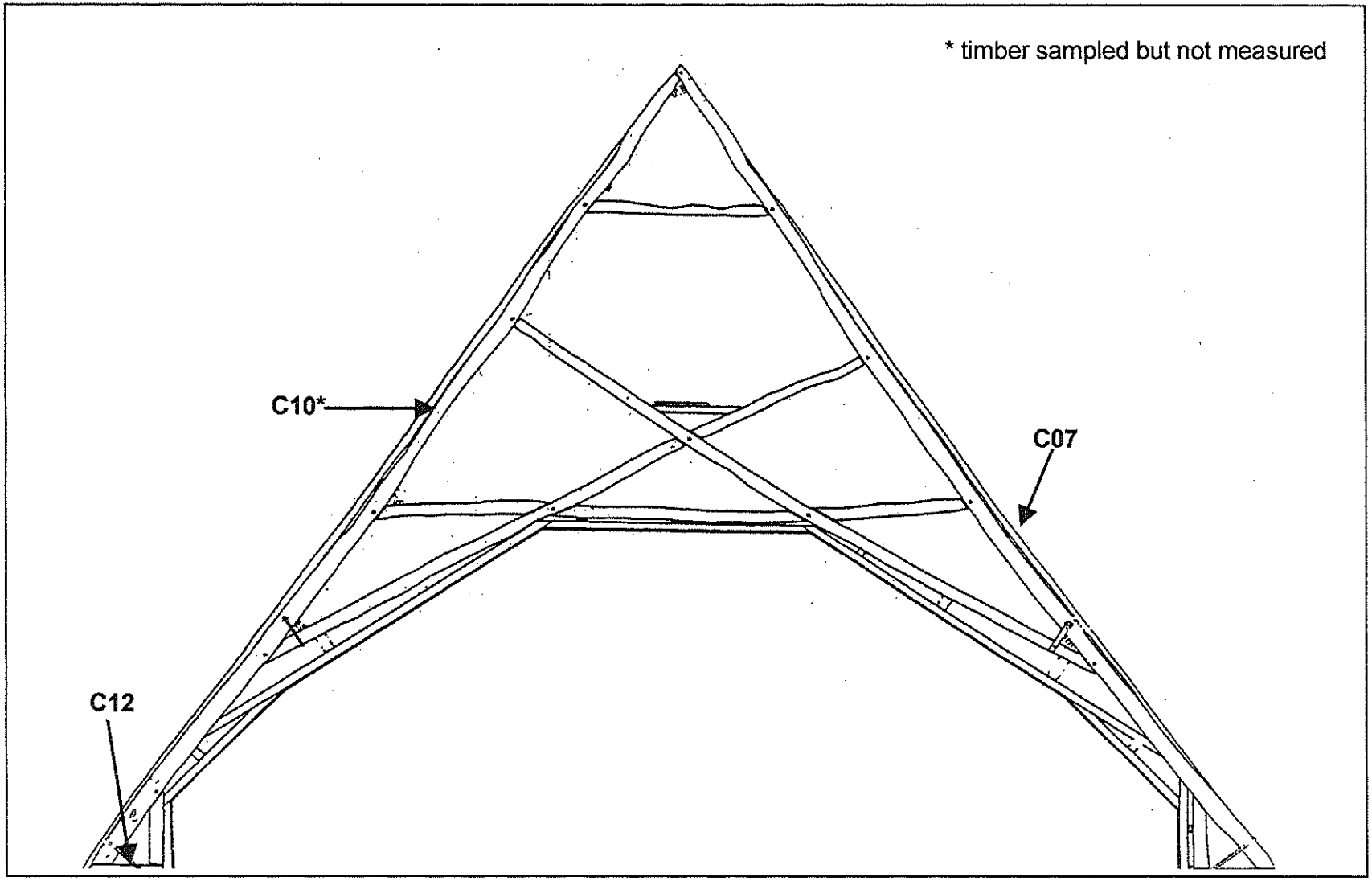


Figure 31f: Nave roof, frame 7 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

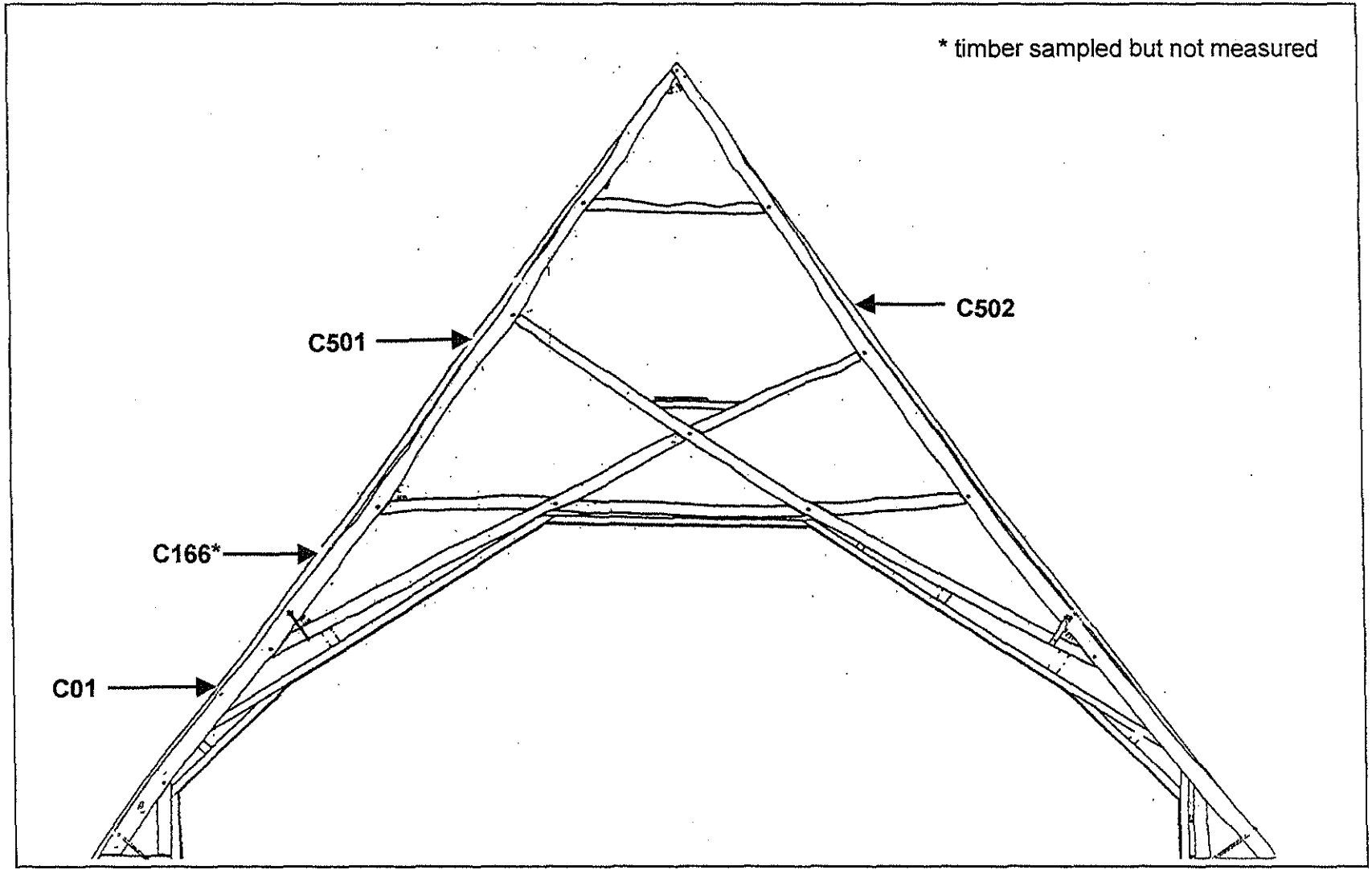


Figure 31g: Nave roof, frame 9 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

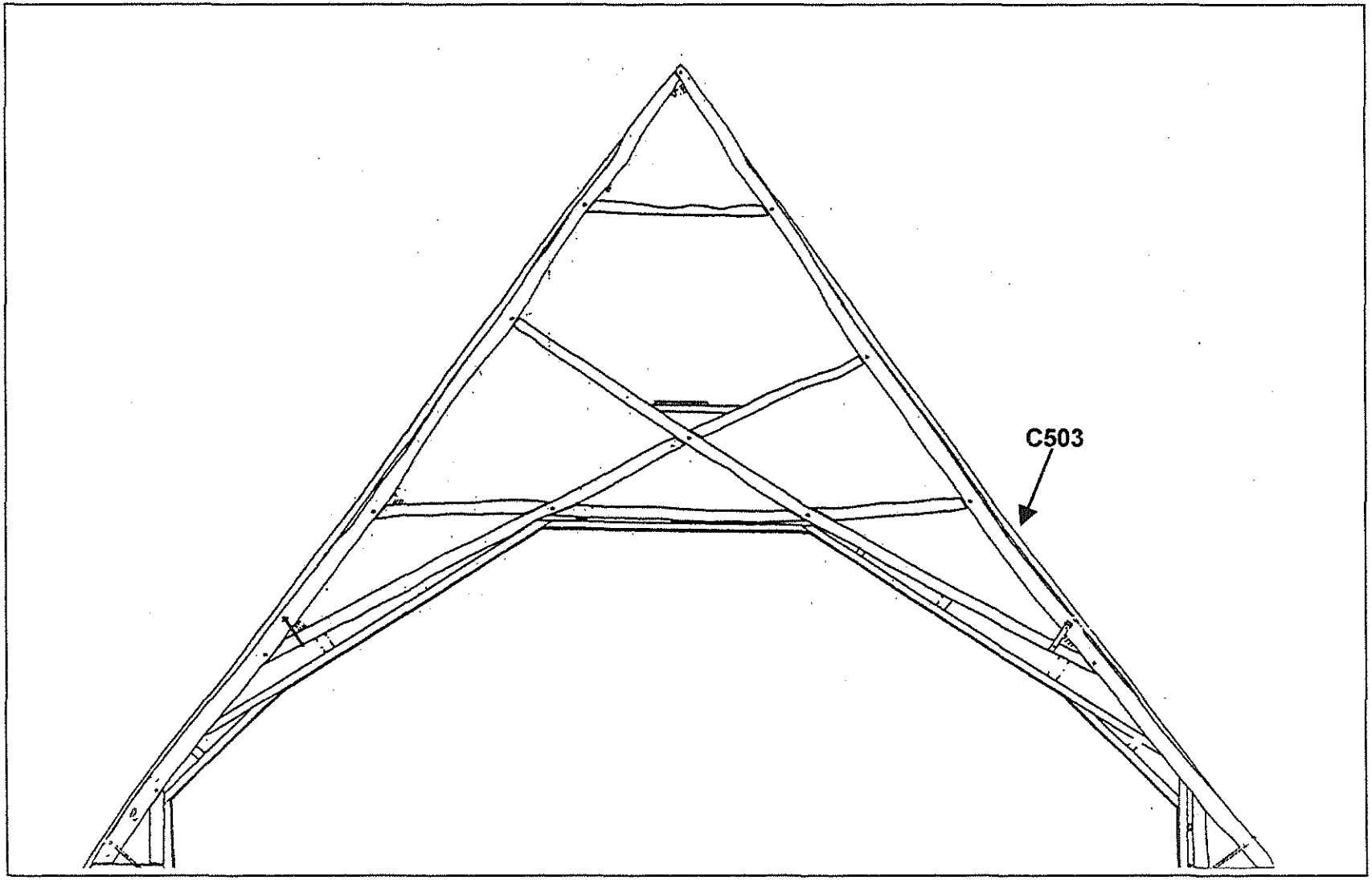


Figure 31h: Nave roof, frame 11 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

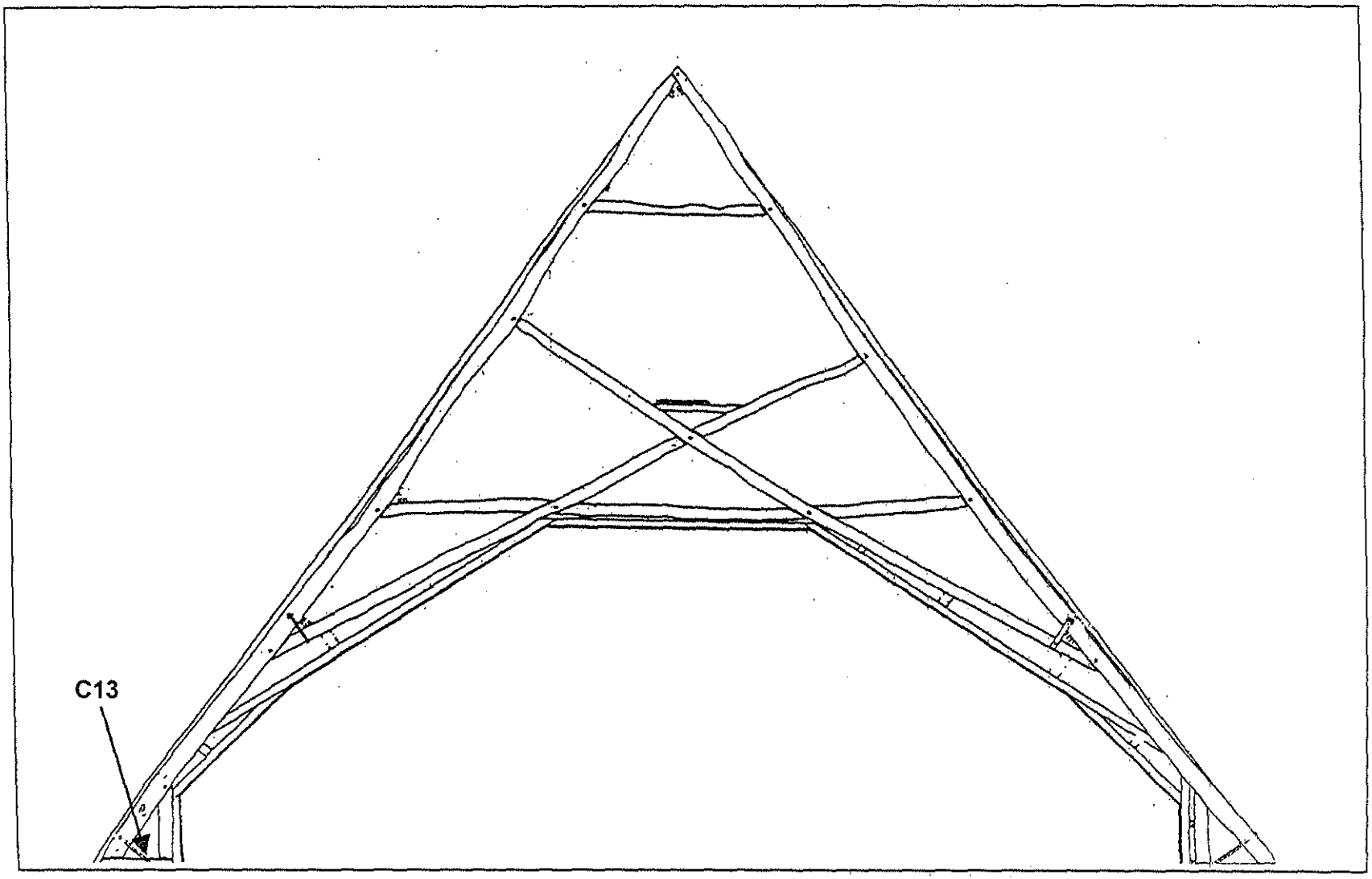


Figure 31i: Nave roof, frame 13 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

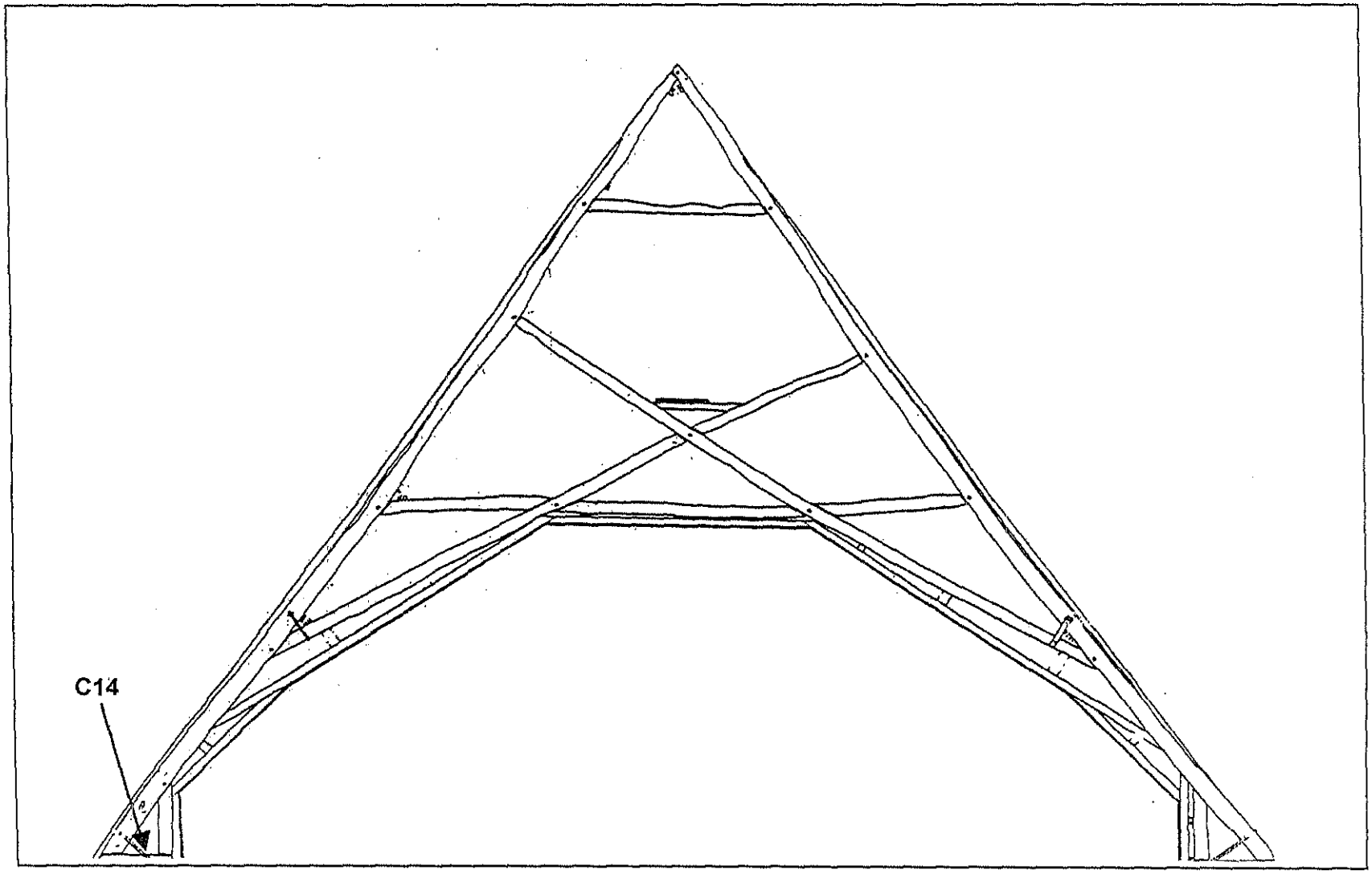


Figure 31j: Nave roof, frame 14 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

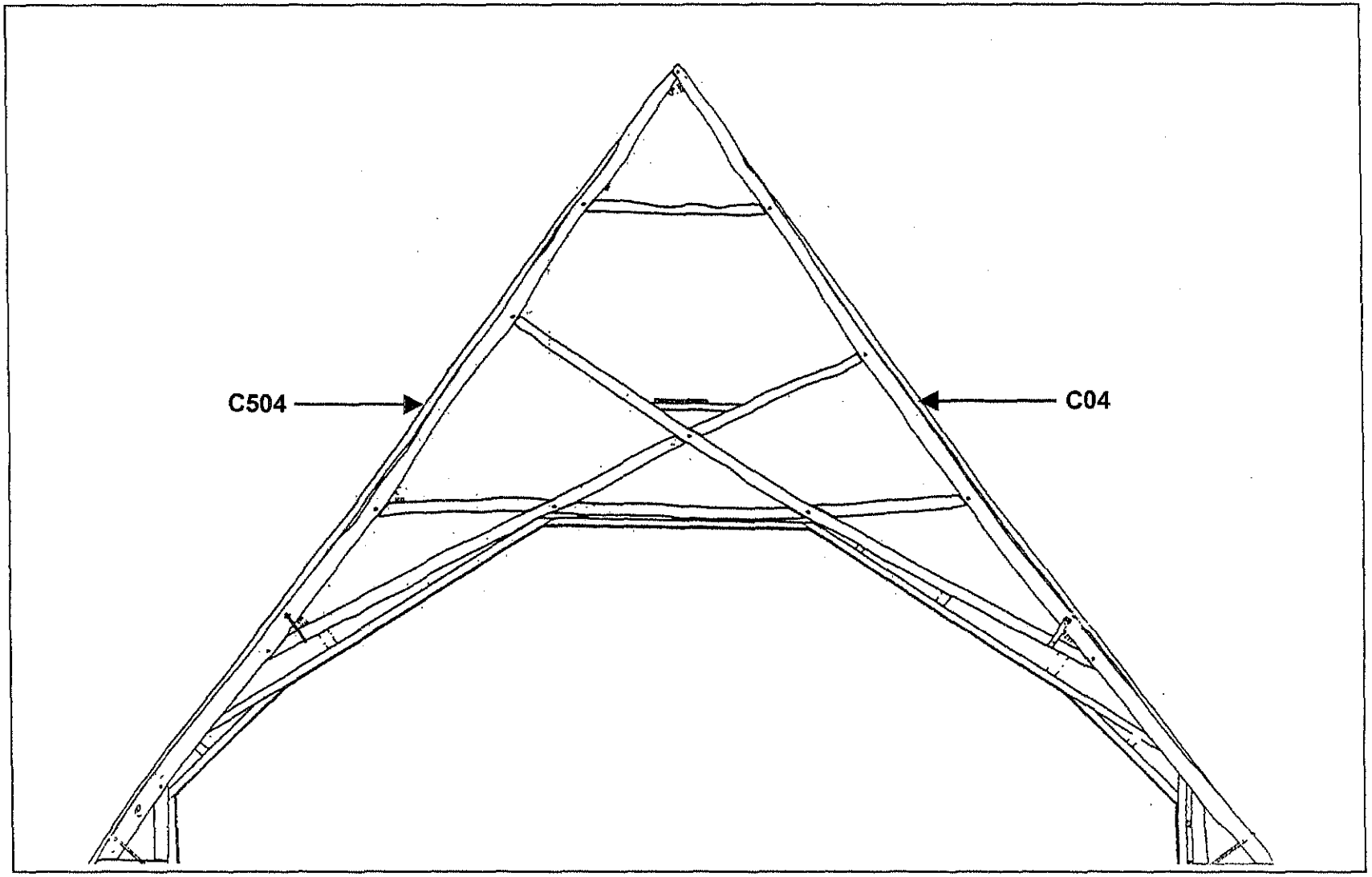


Figure 31k: Nave roof, frame 15 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

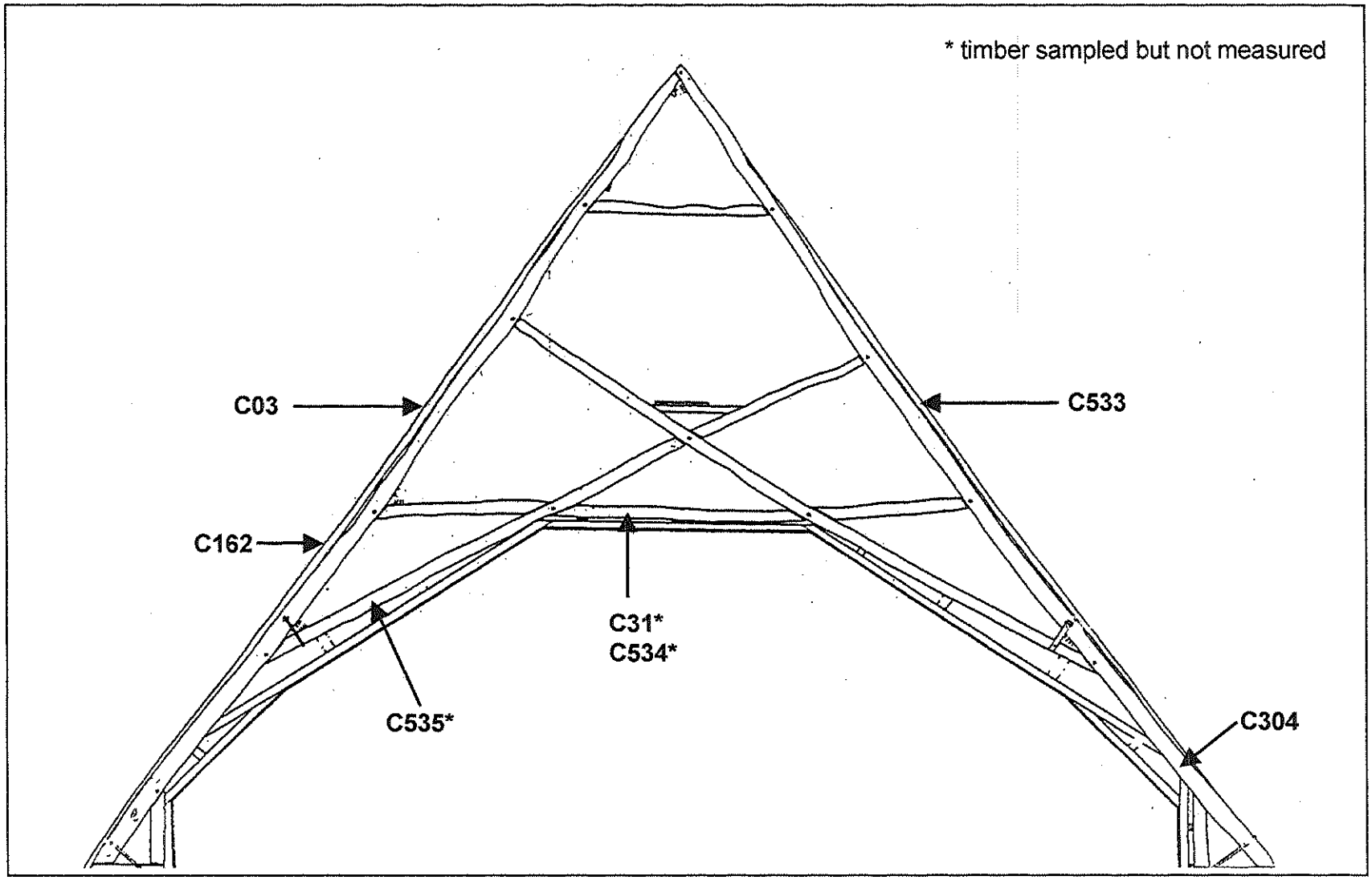


Figure 31l: Nave roof, frame 16 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

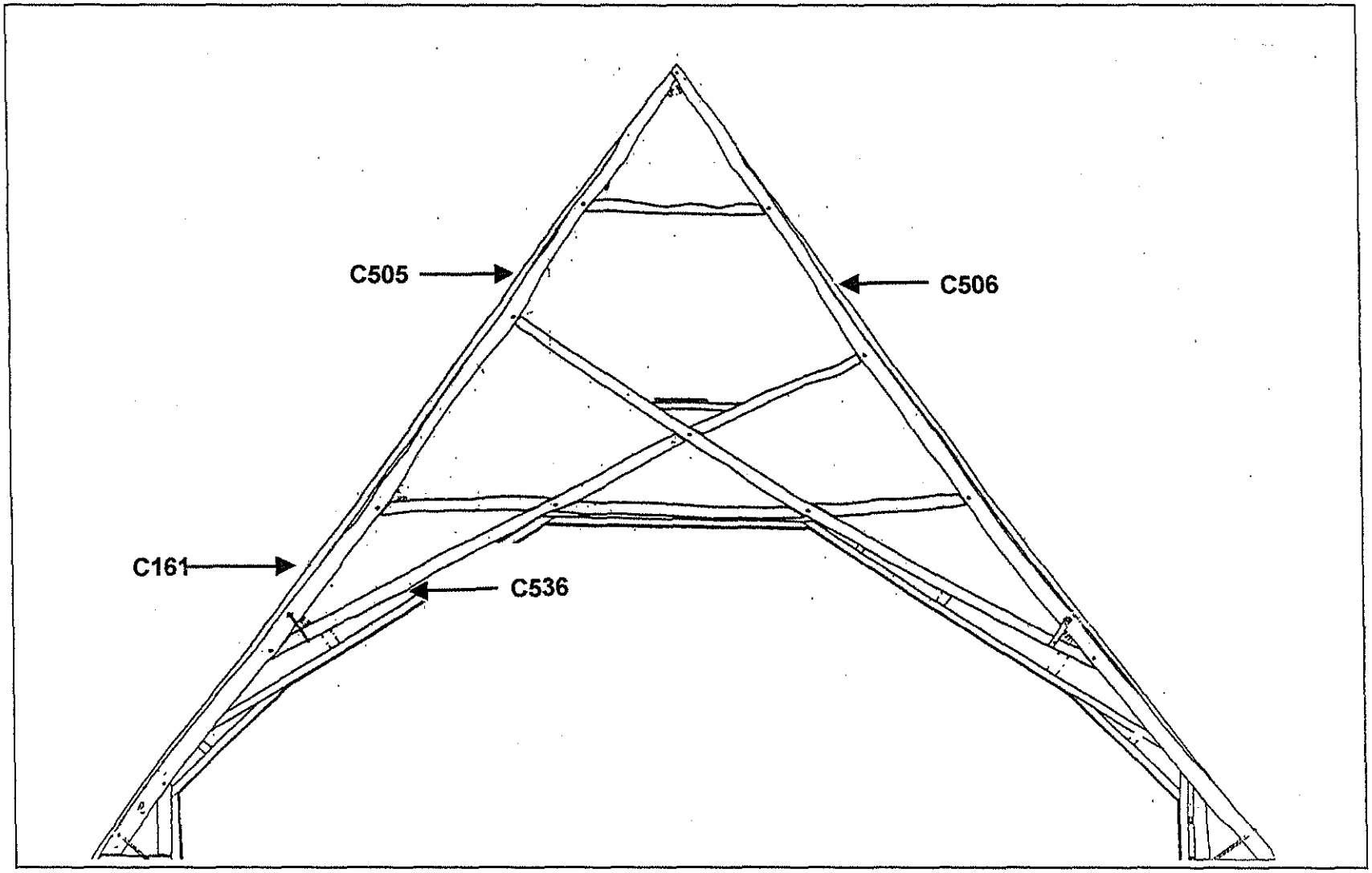


Figure 31m: Nave roof, frame 17 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

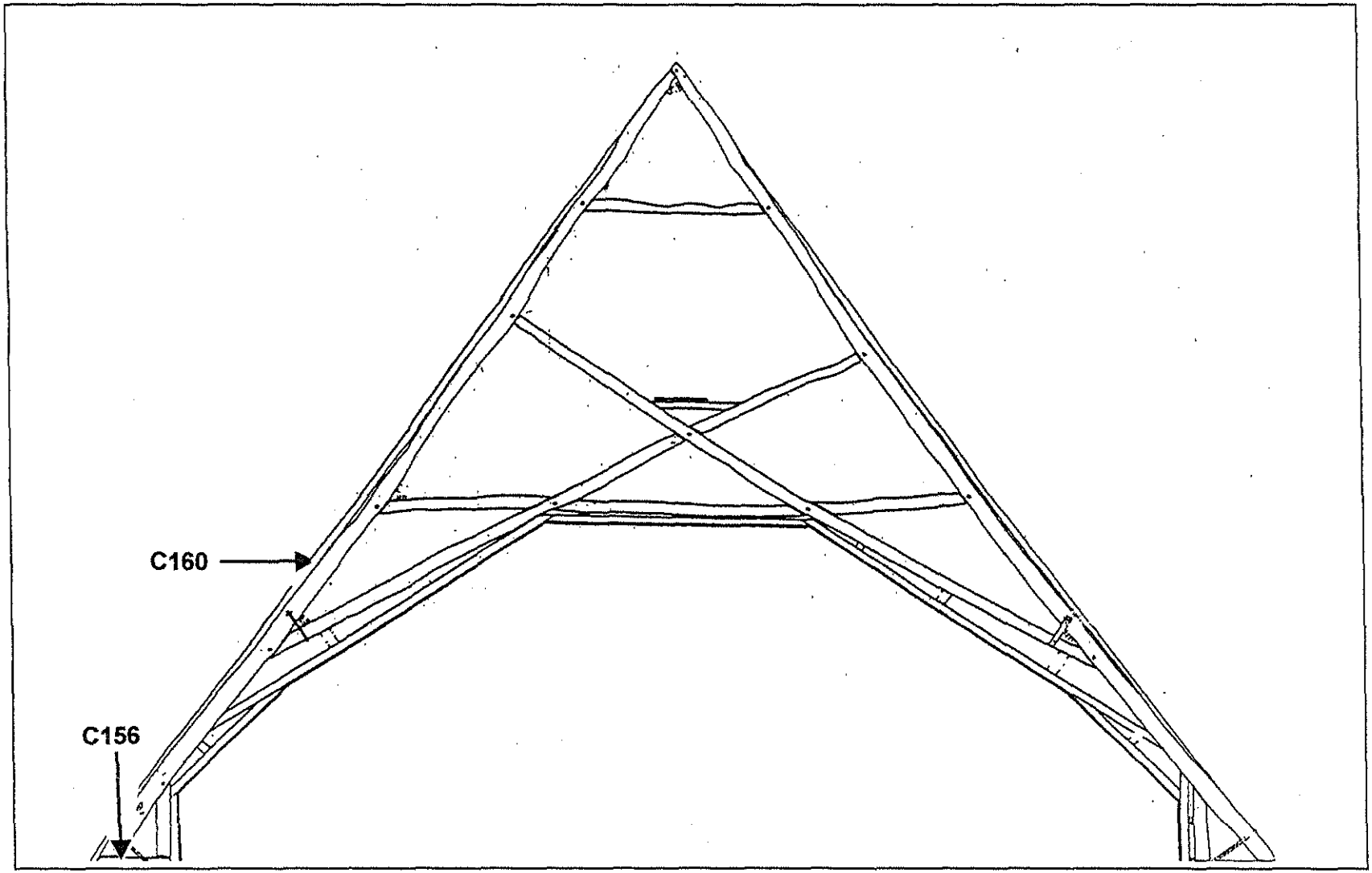


Figure 31n: Nave roof, frame 18 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

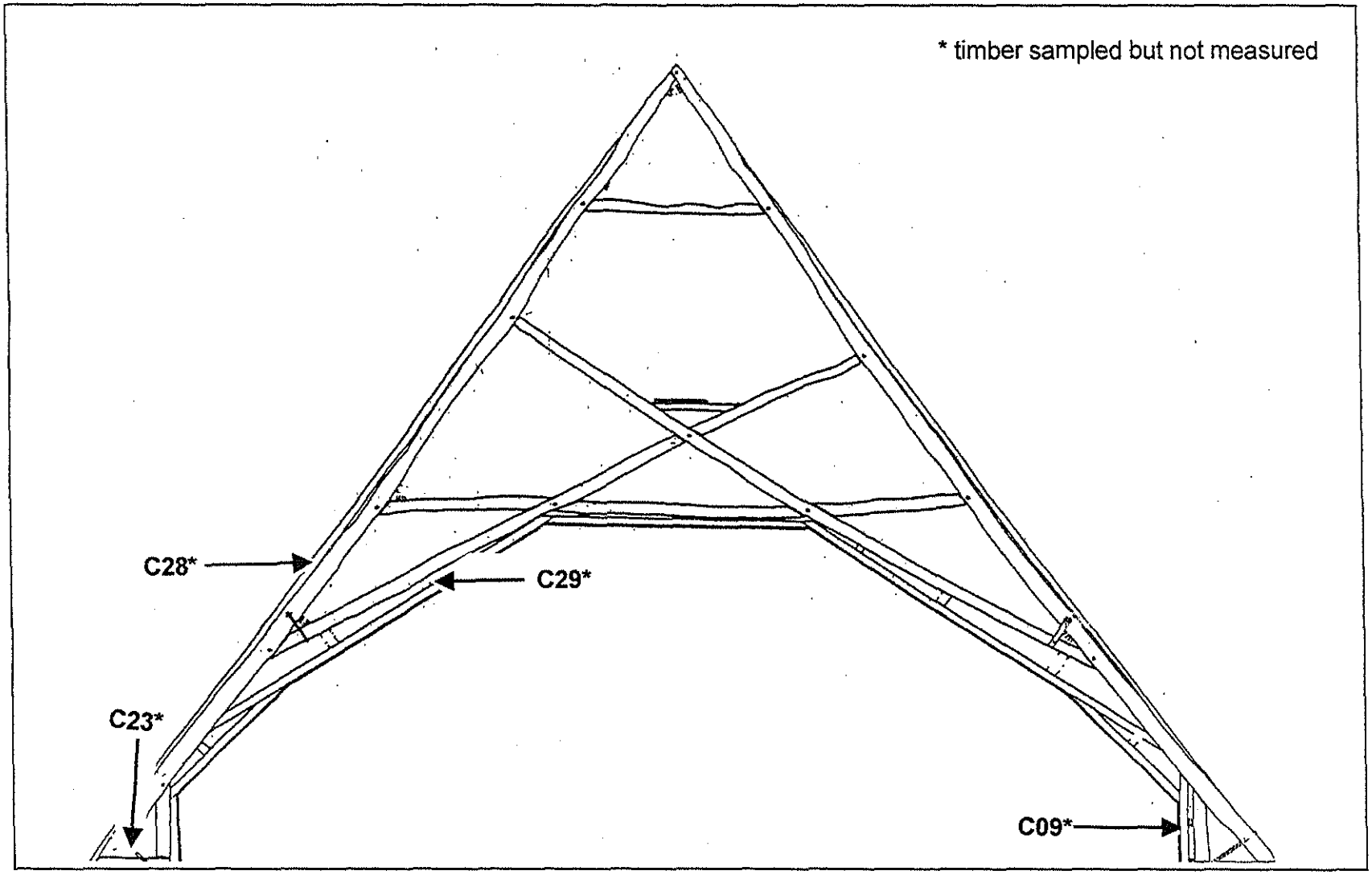


Figure 31o: Nave roof, frame 19 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

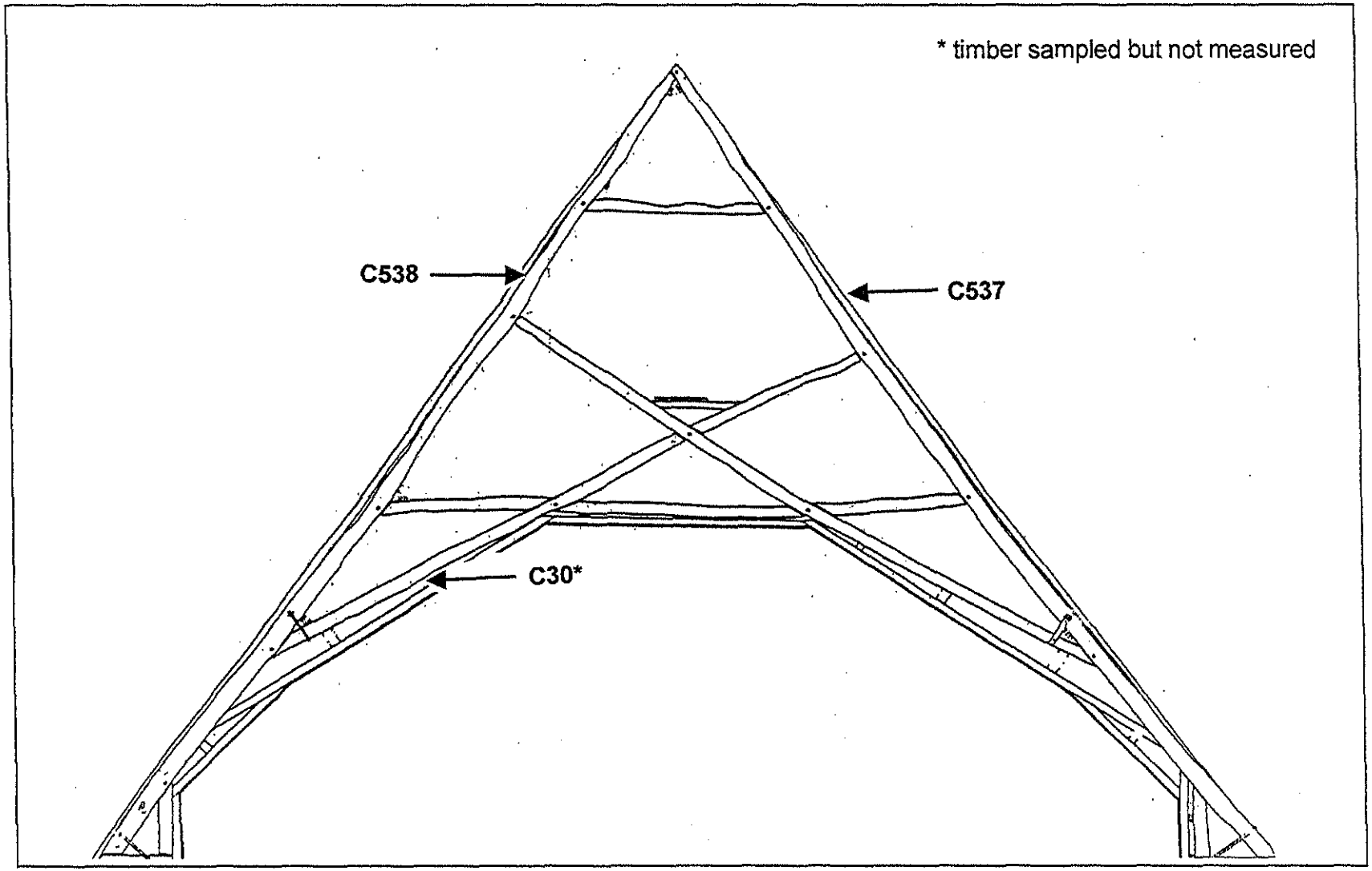


Figure 31p: Nave roof, frame 20 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

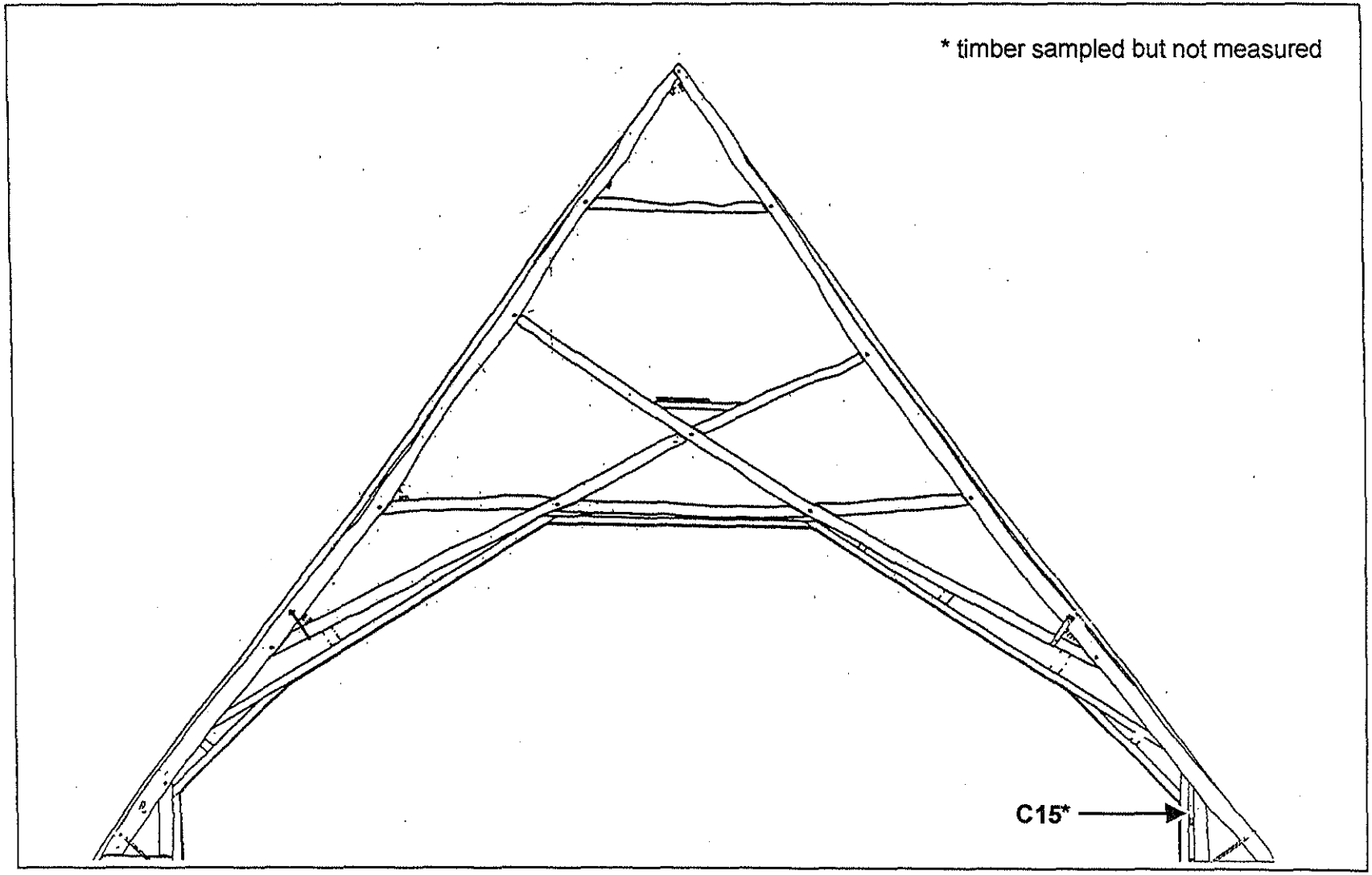


Figure 31q: Nave roof, frame 22 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

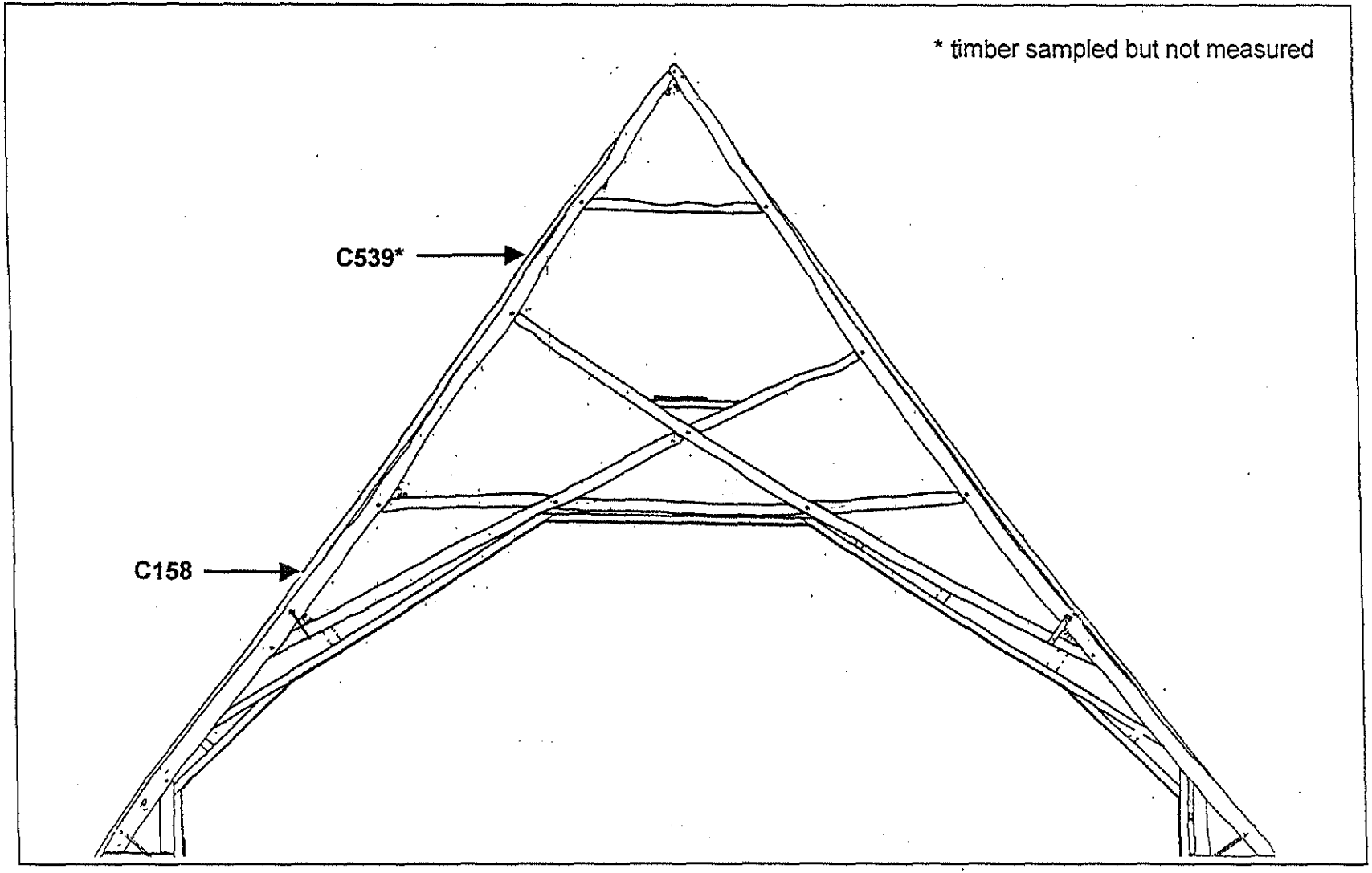


Figure 31r: Nave roof, frame 23 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

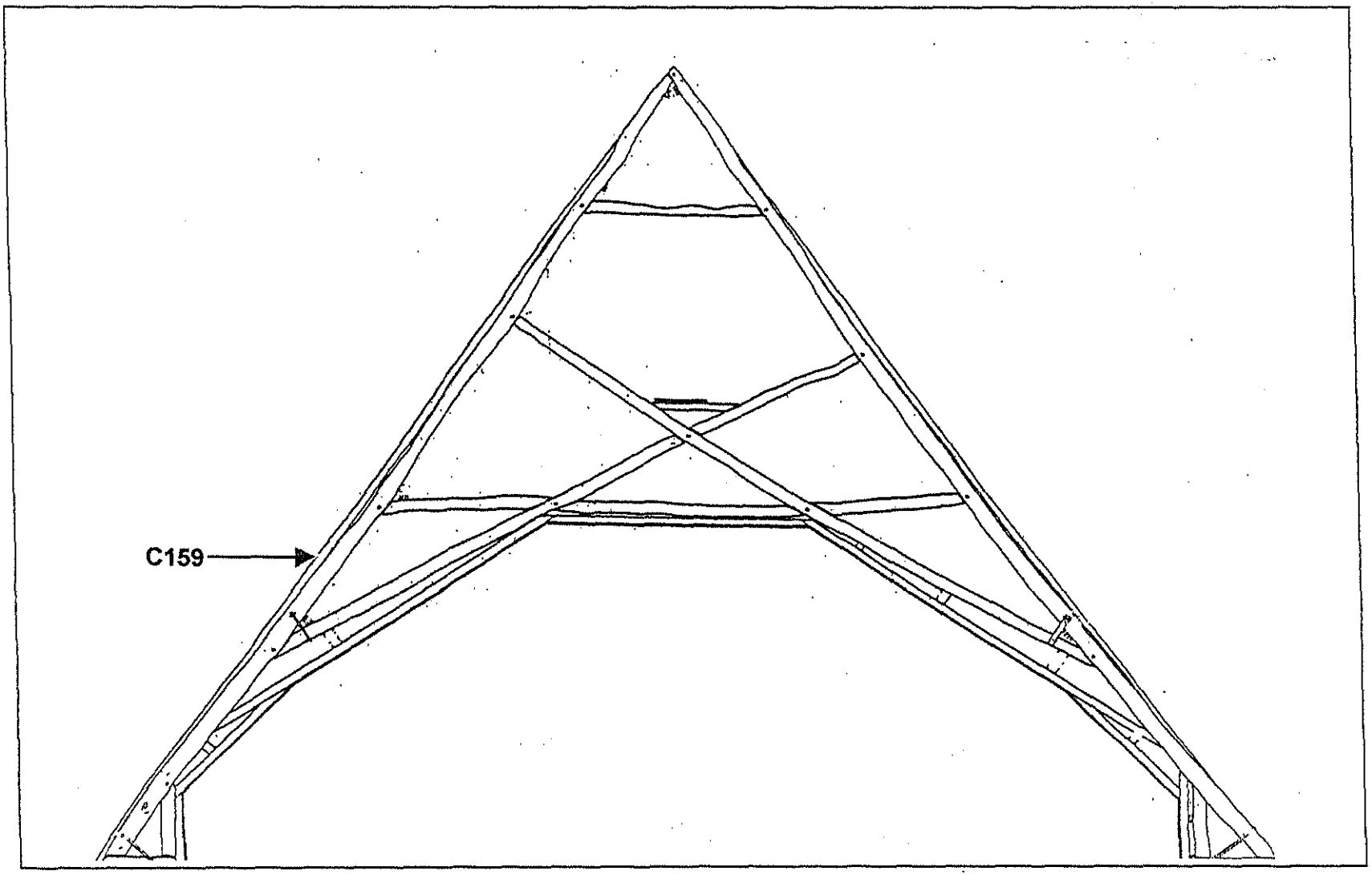


Figure 31s: Nave roof, frame 24 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

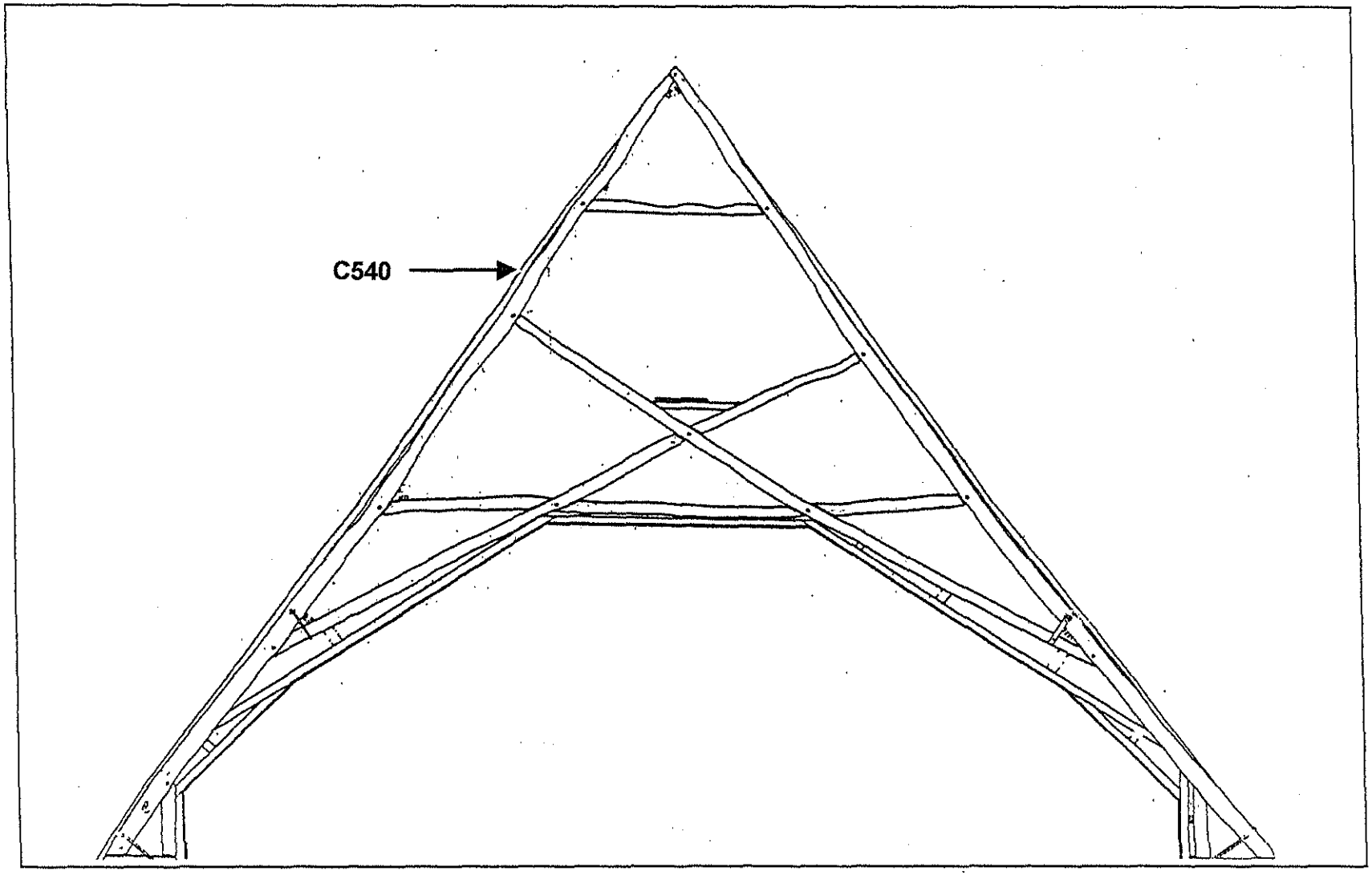


Figure 31t: Nave roof, frame 28 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

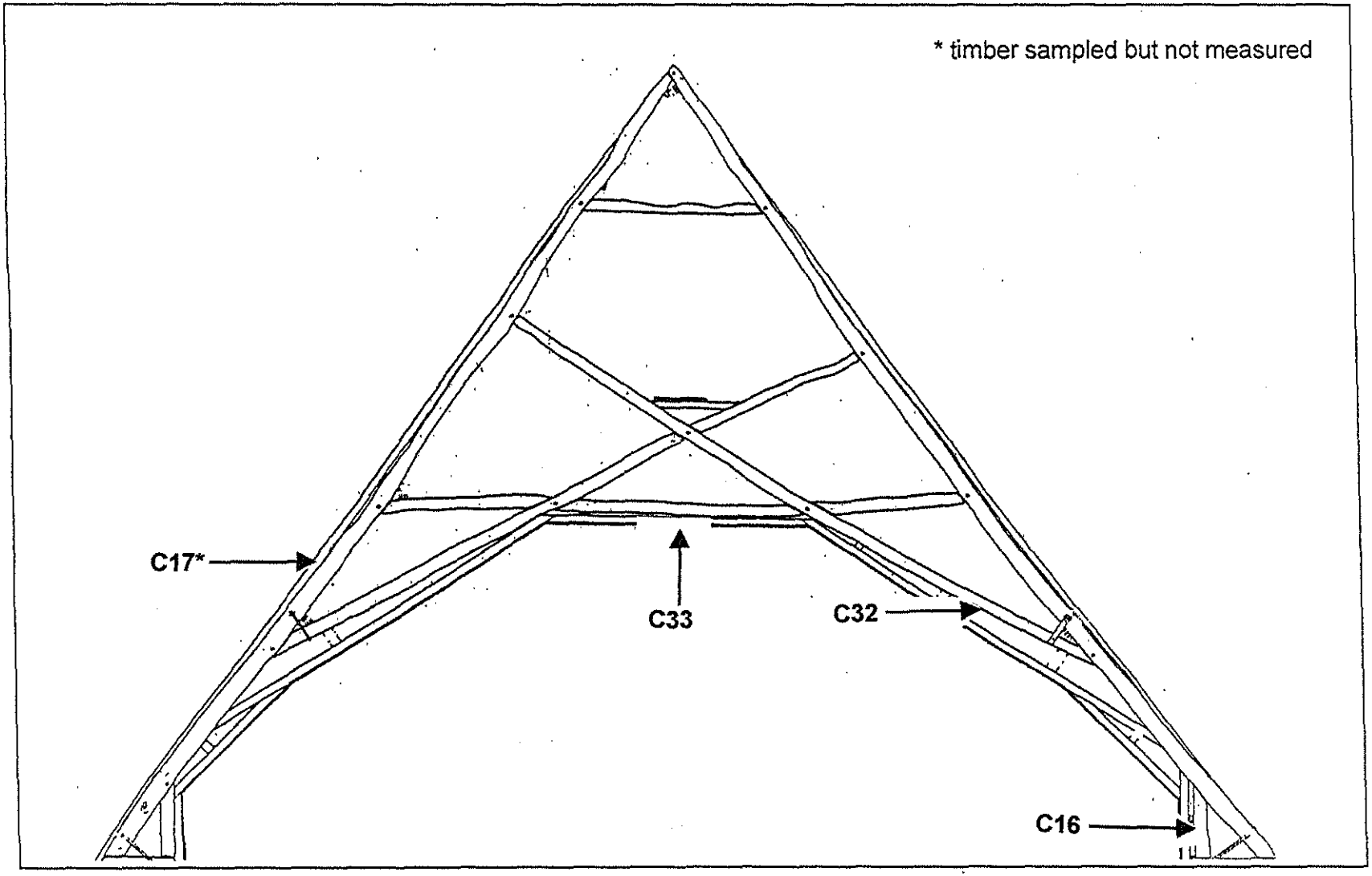


Figure 31u: Nave roof, frame 29 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

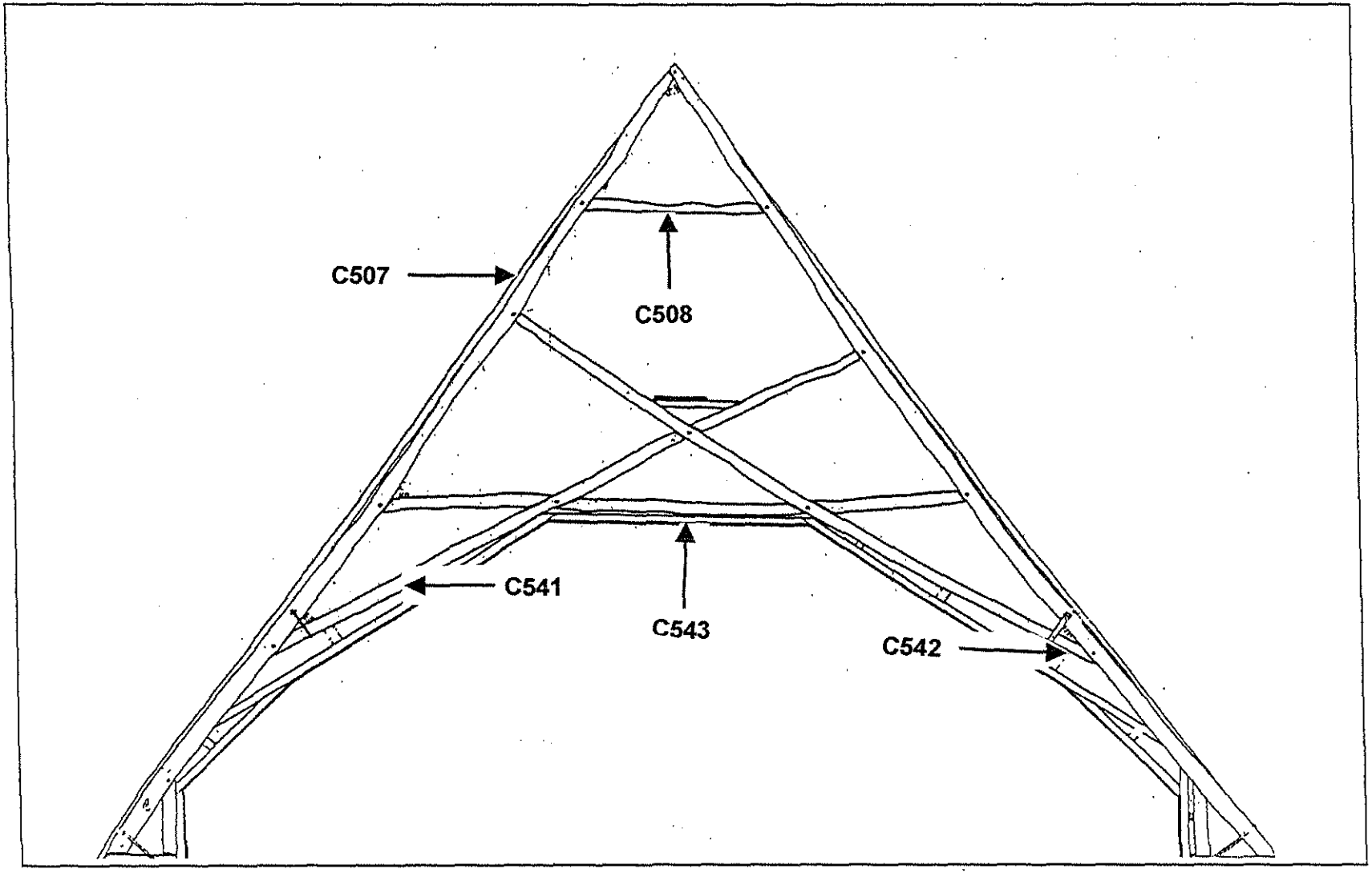


Figure 31v: Nave roof, frame 30 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

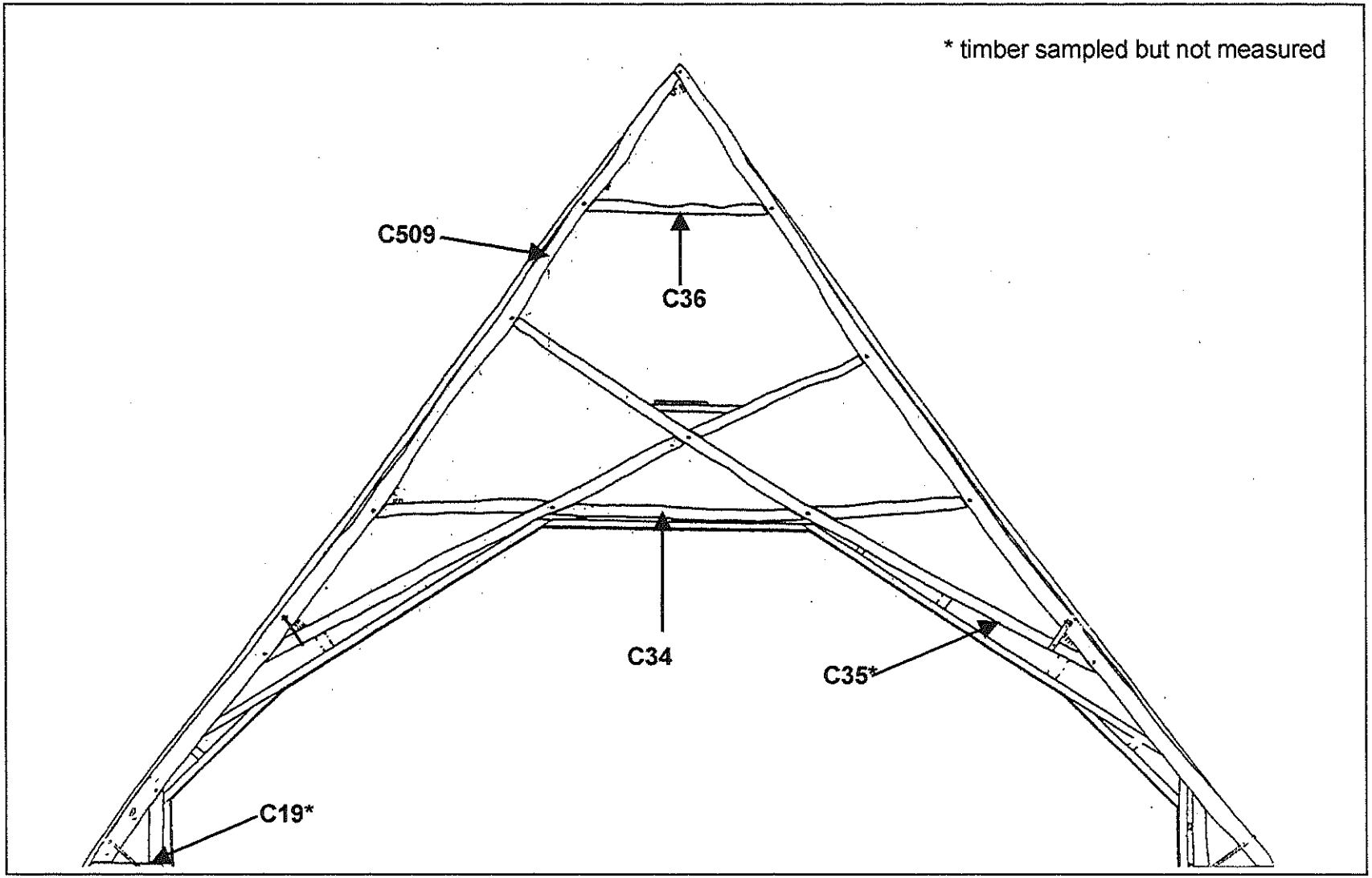


Figure 31w: Nave roof, frame 31 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

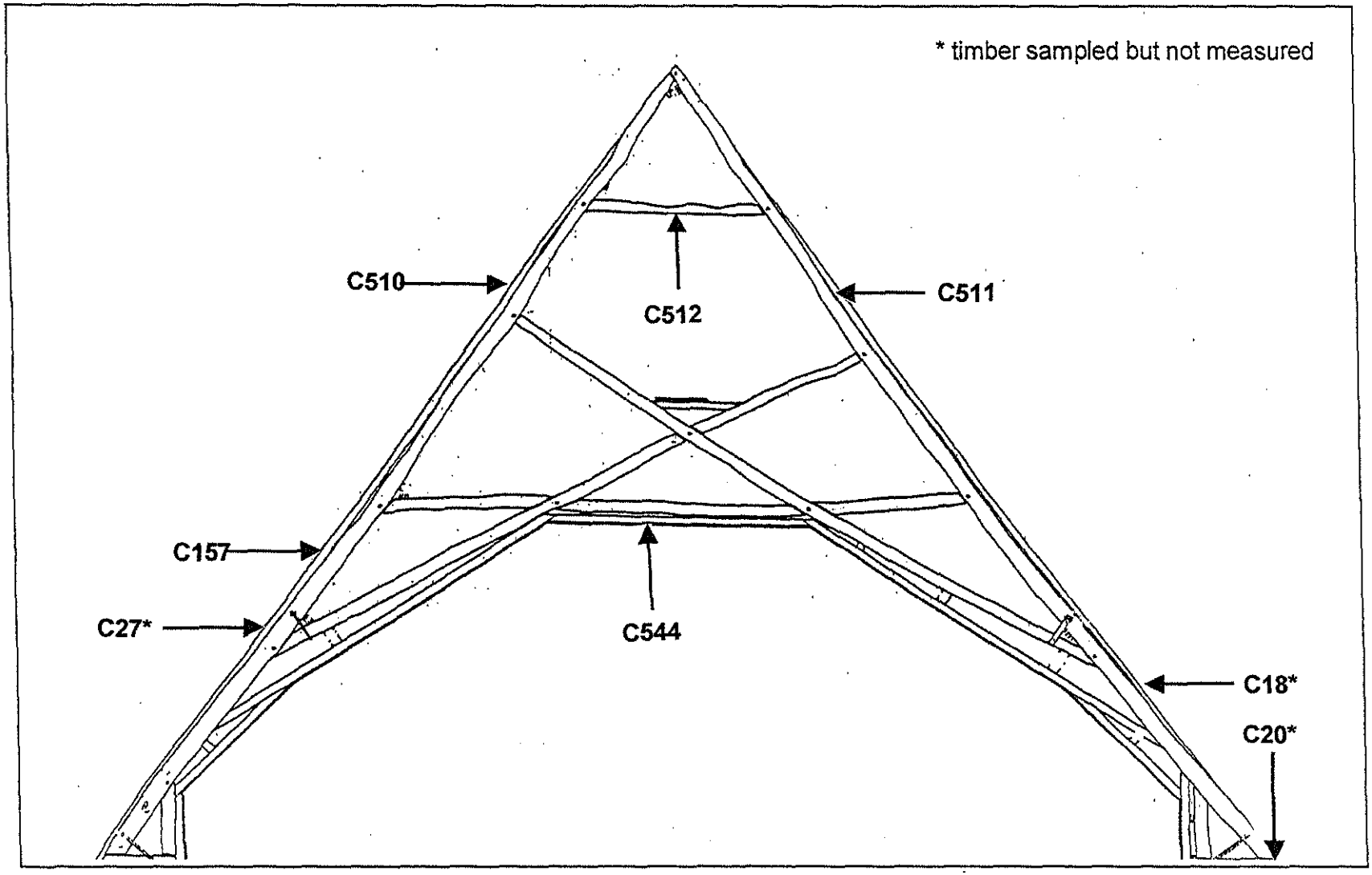


Figure 31x: Nave roof, frame 32 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

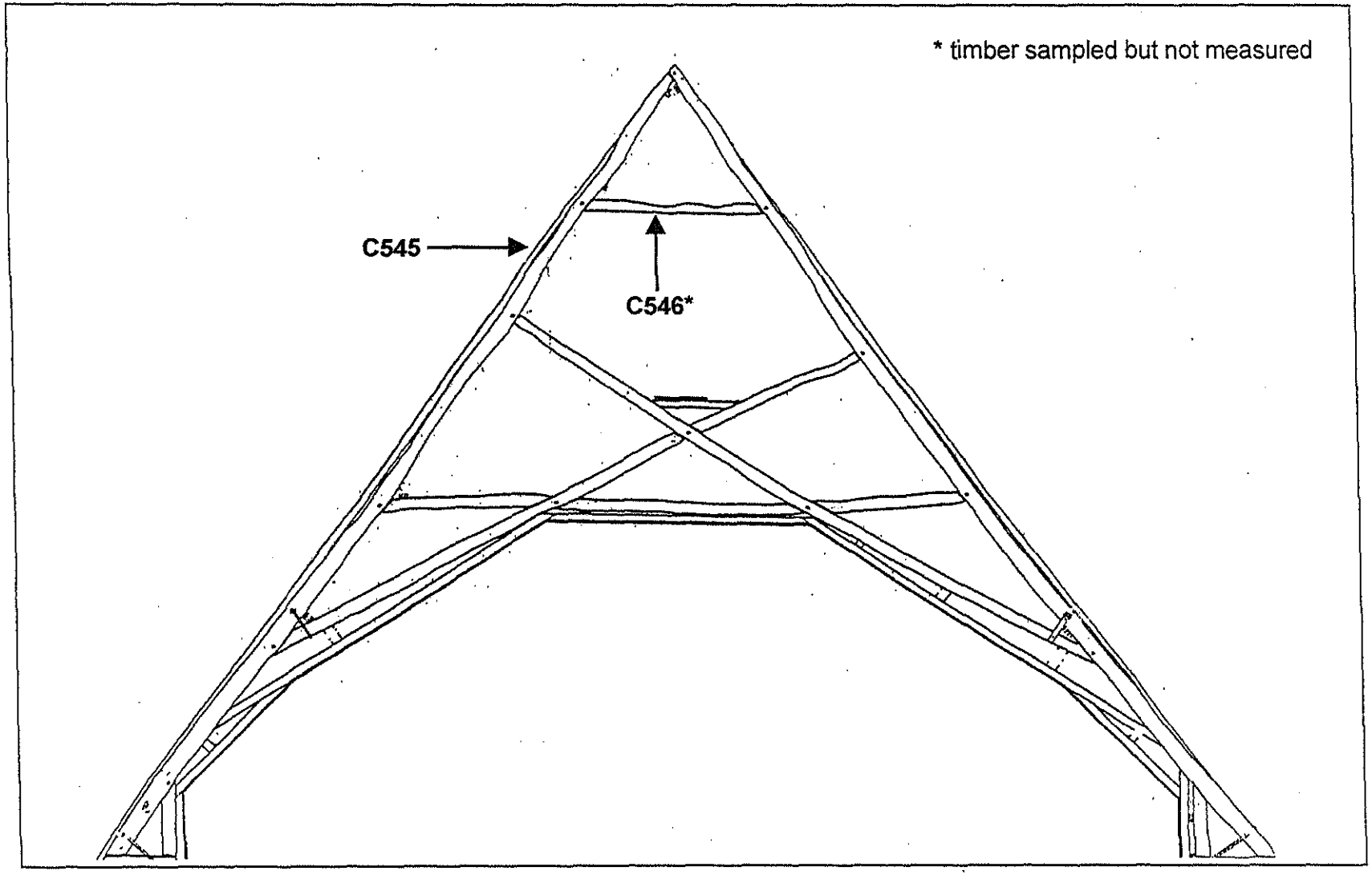


Figure 31y: Nave roof, frame 33 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

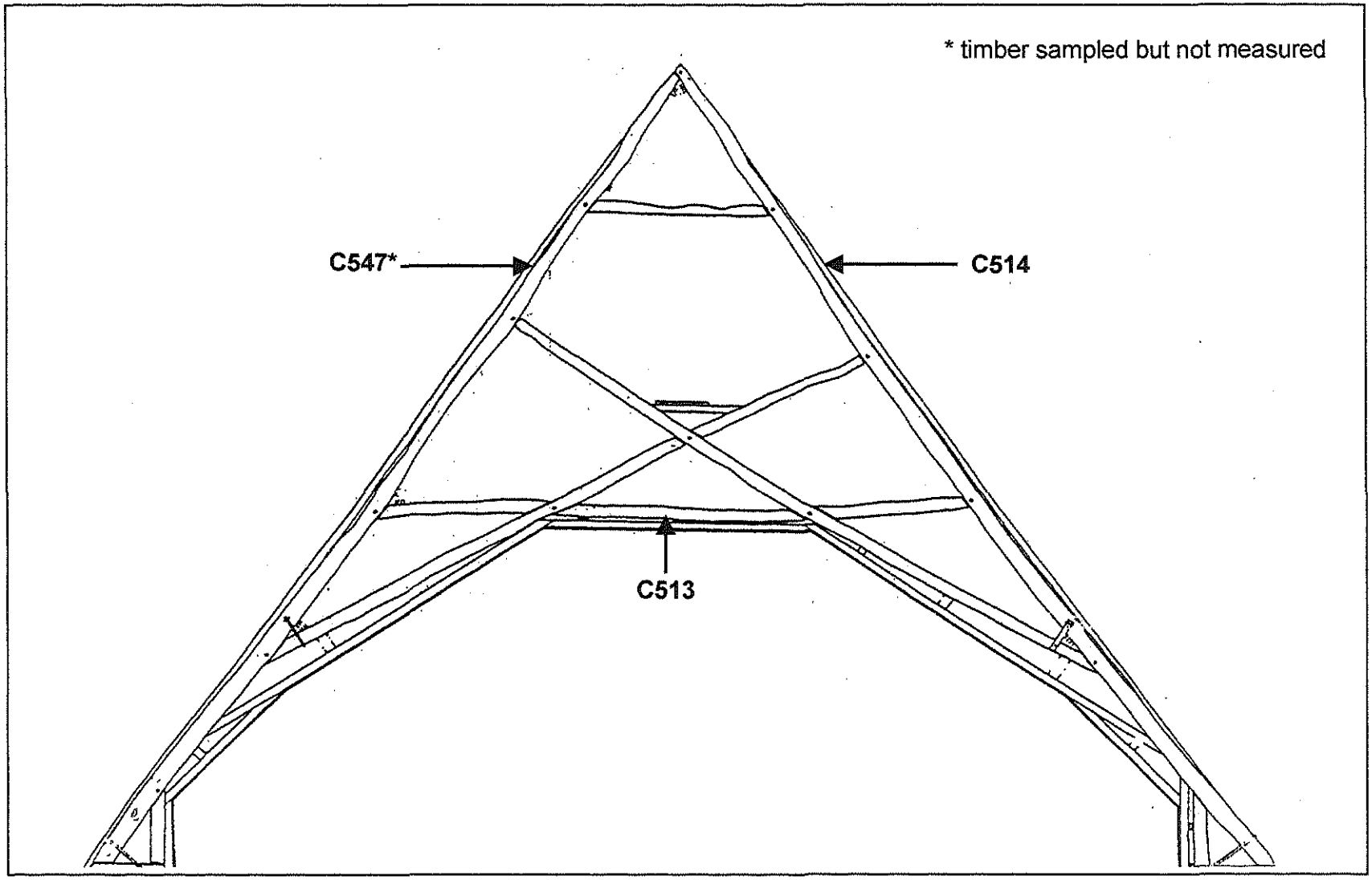


Figure 31z: Nave roof, frame 34 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

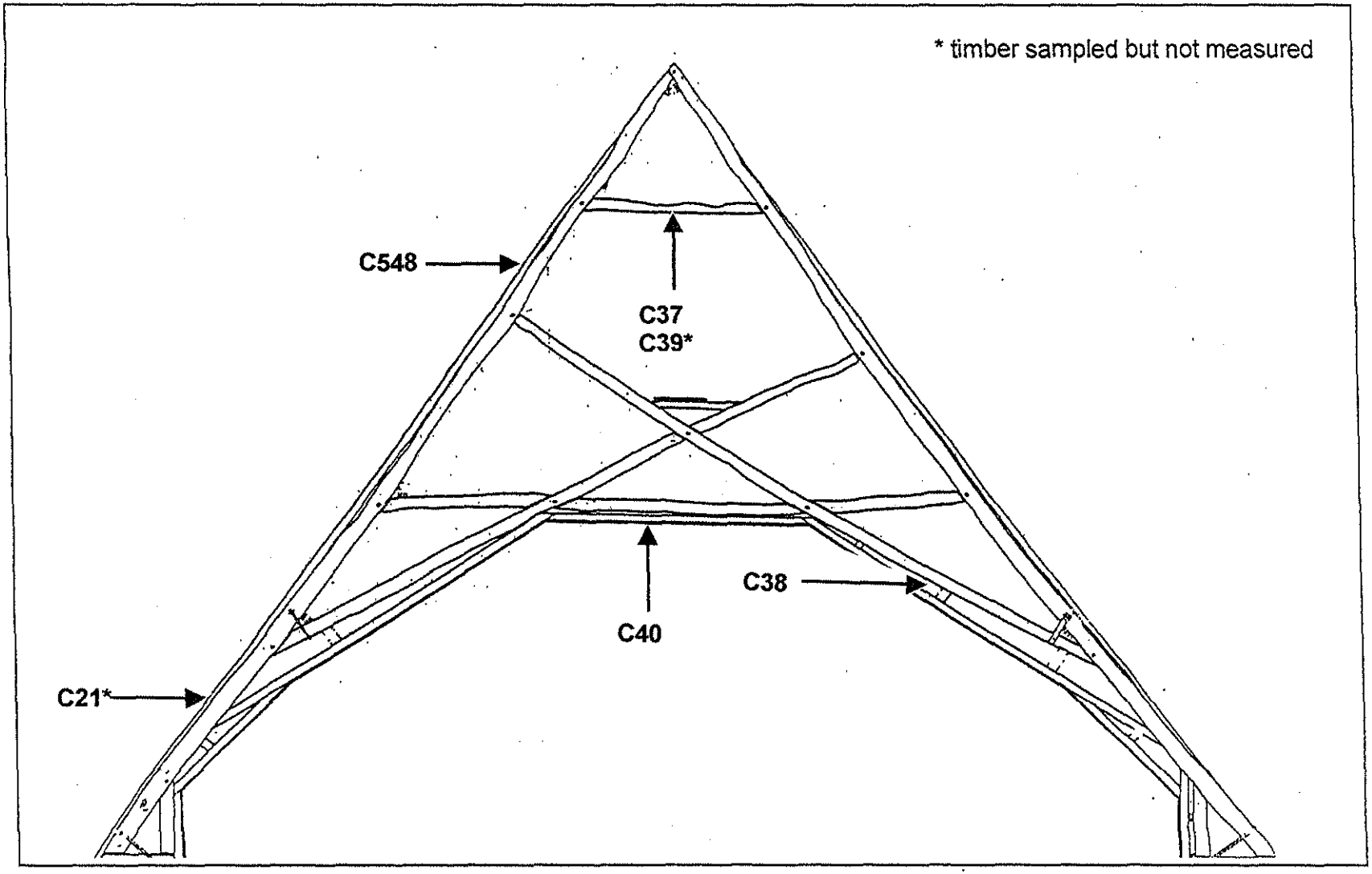


Figure 32a: Nave roof, frame 35 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

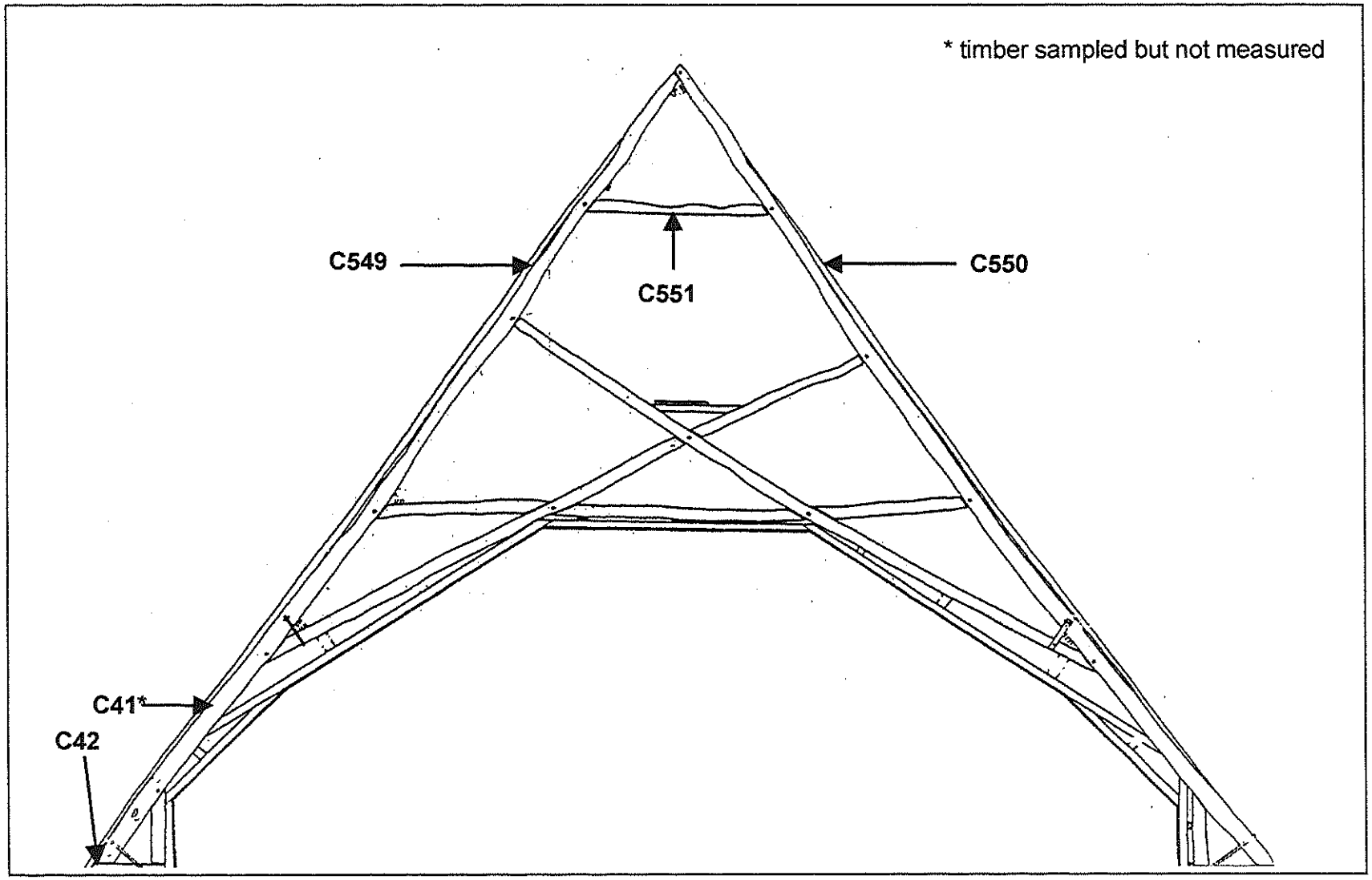


Figure 32b: Nave roof, frame 36 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

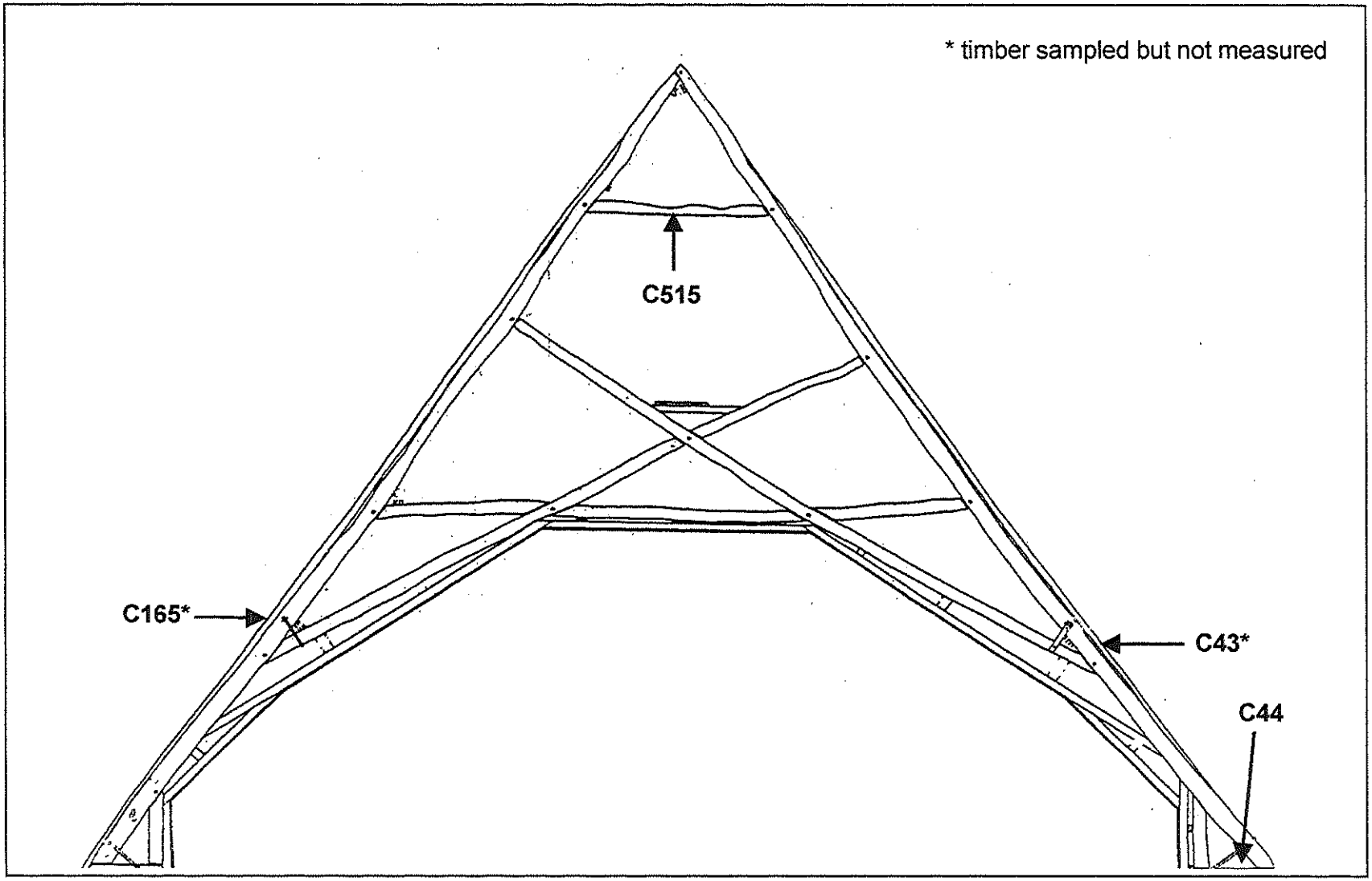


Figure 32c: Nave roof, frame 37 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

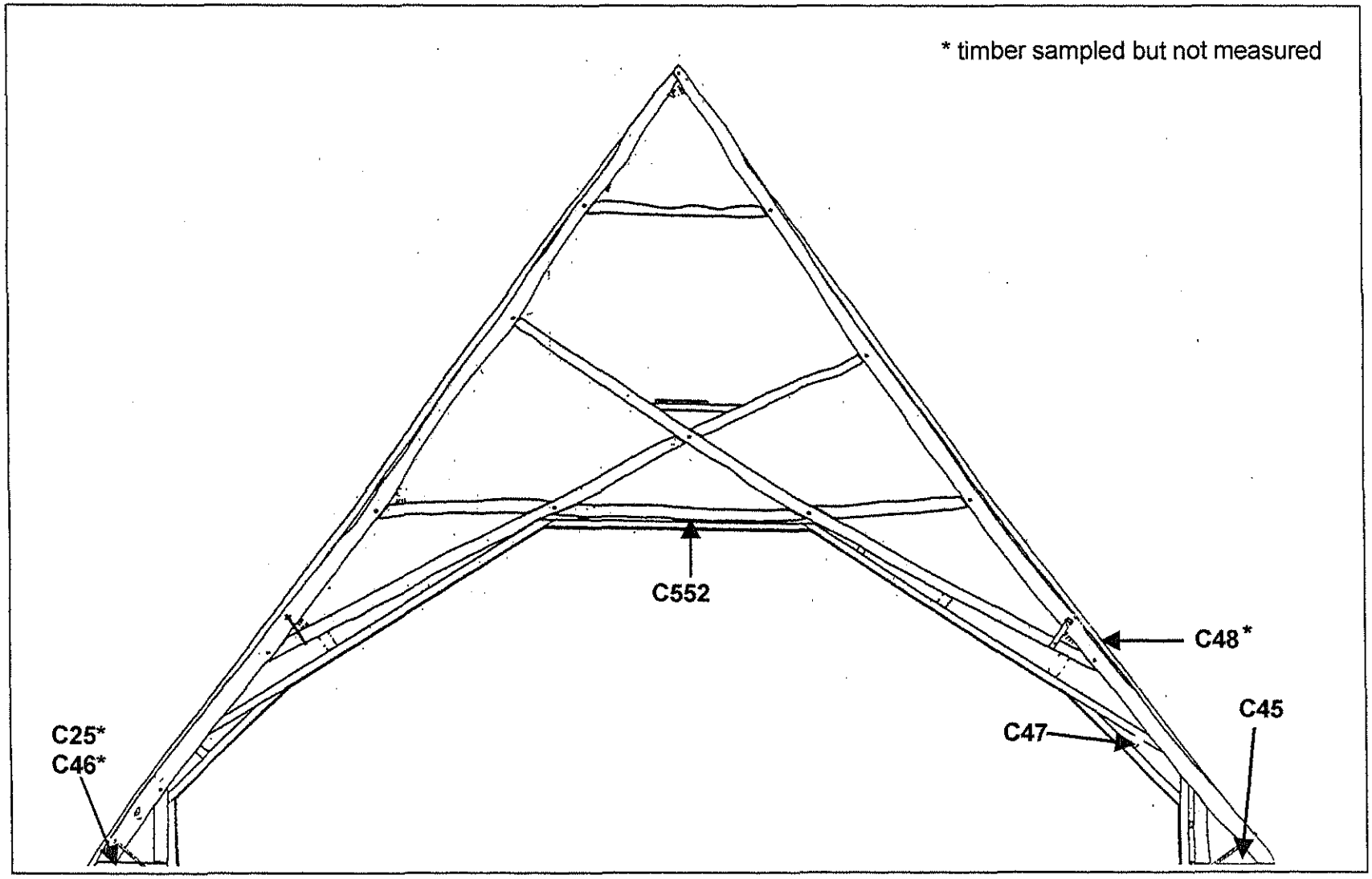


Figure 32d: Nave roof, frame 38 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

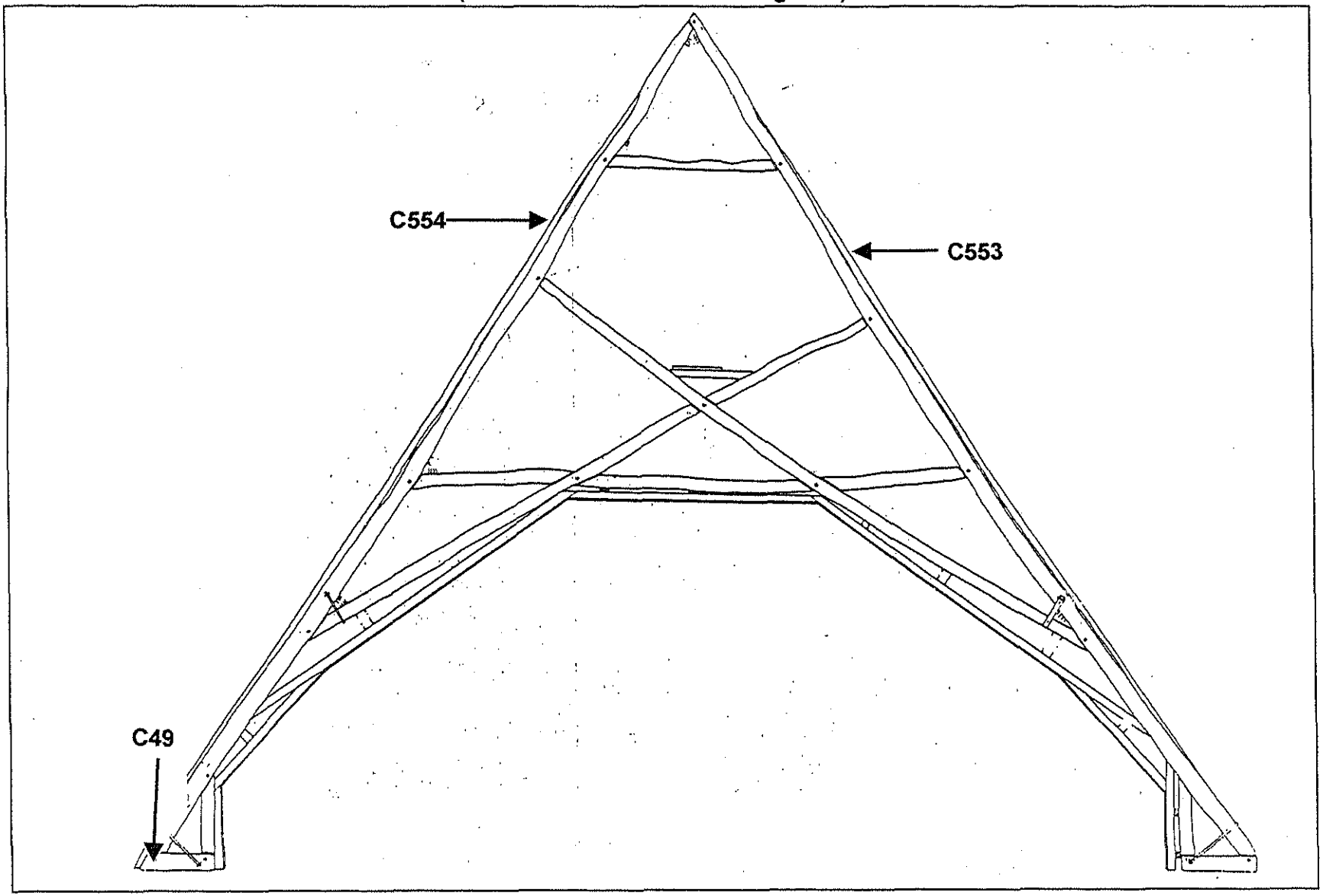


Figure 32e: Nave roof, frame 39 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

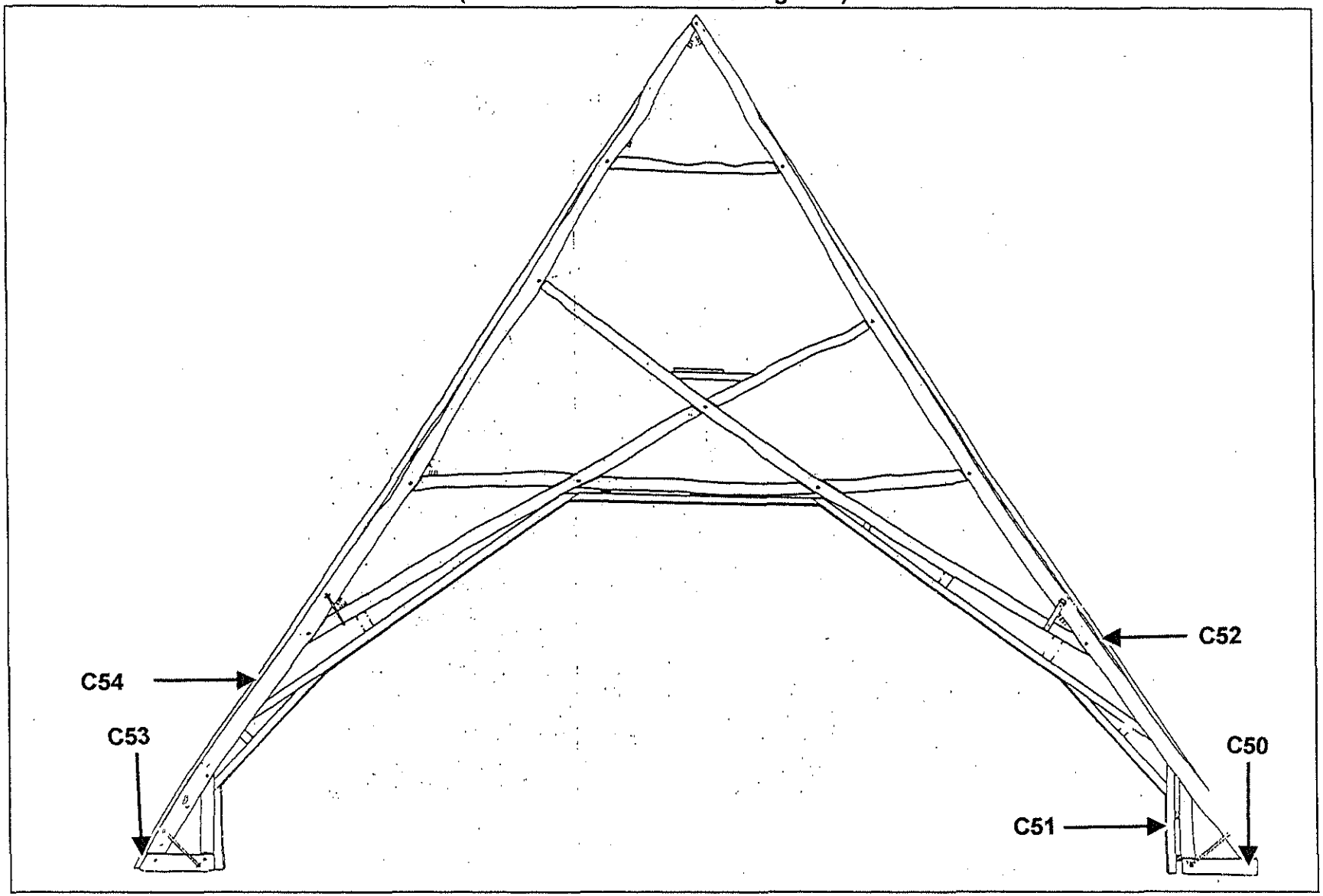


Figure 32f: Nave roof, frame 40 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

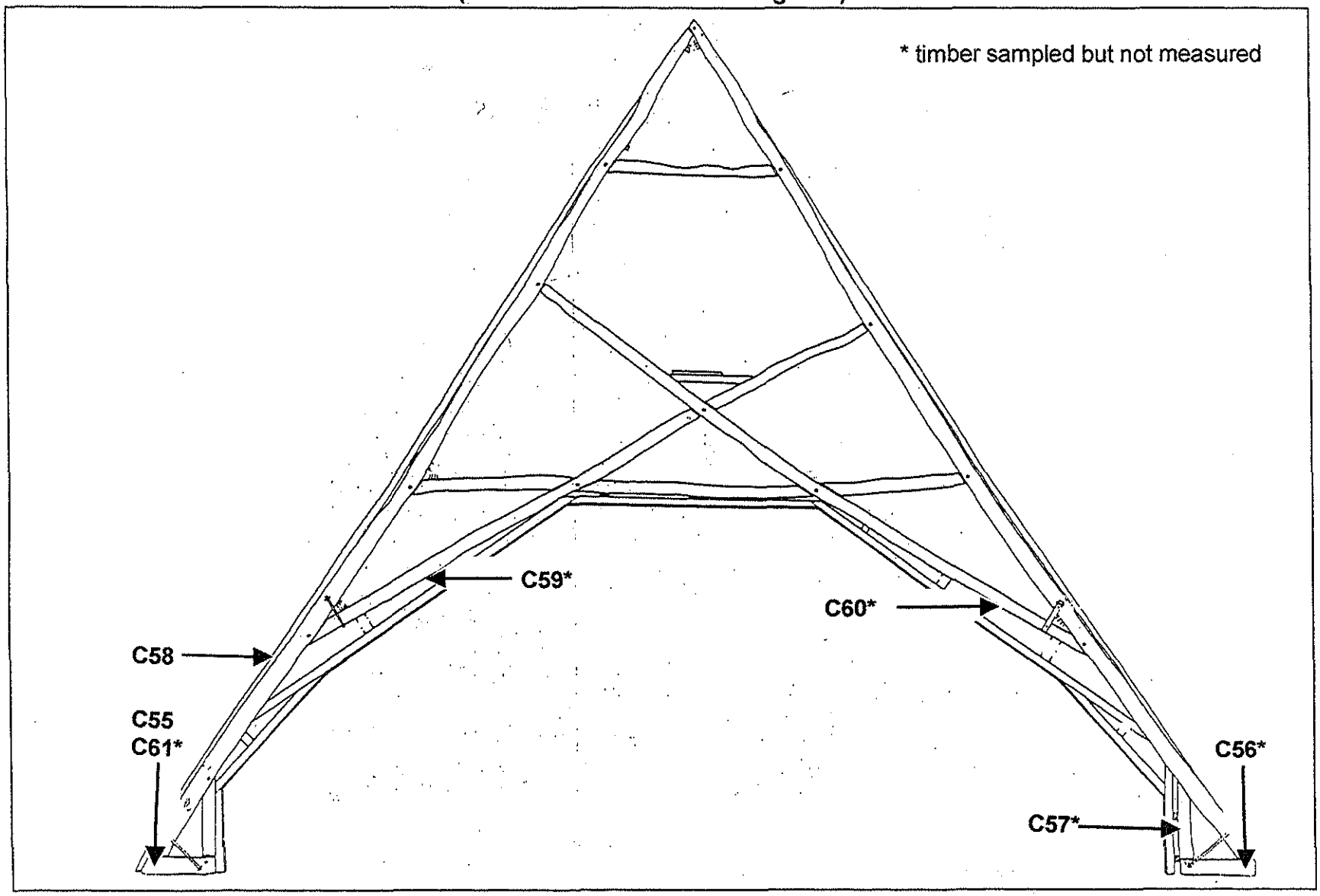


Figure 32g: Nave roof, frame 41 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

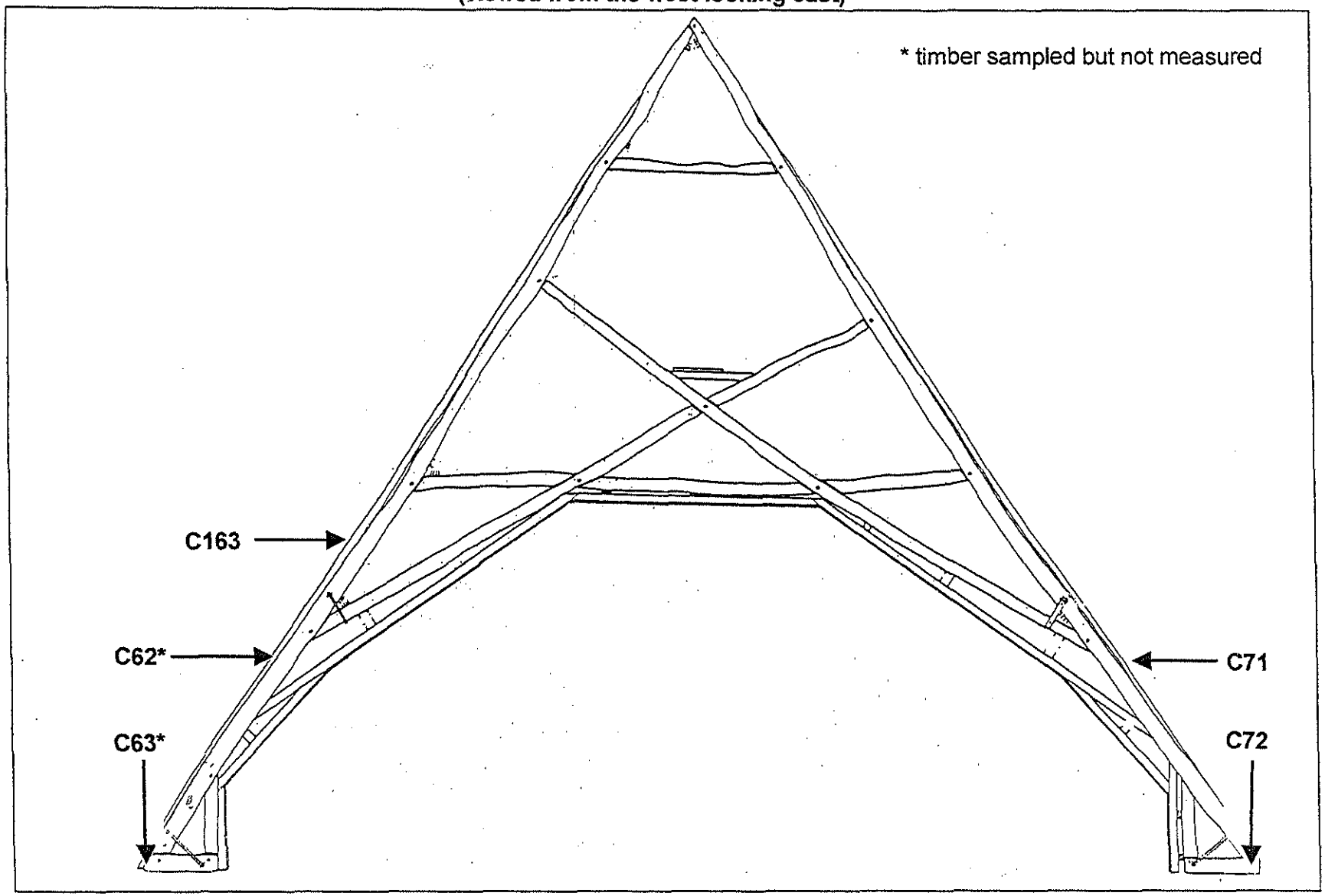


Figure 32h: Nave roof, frame 42 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

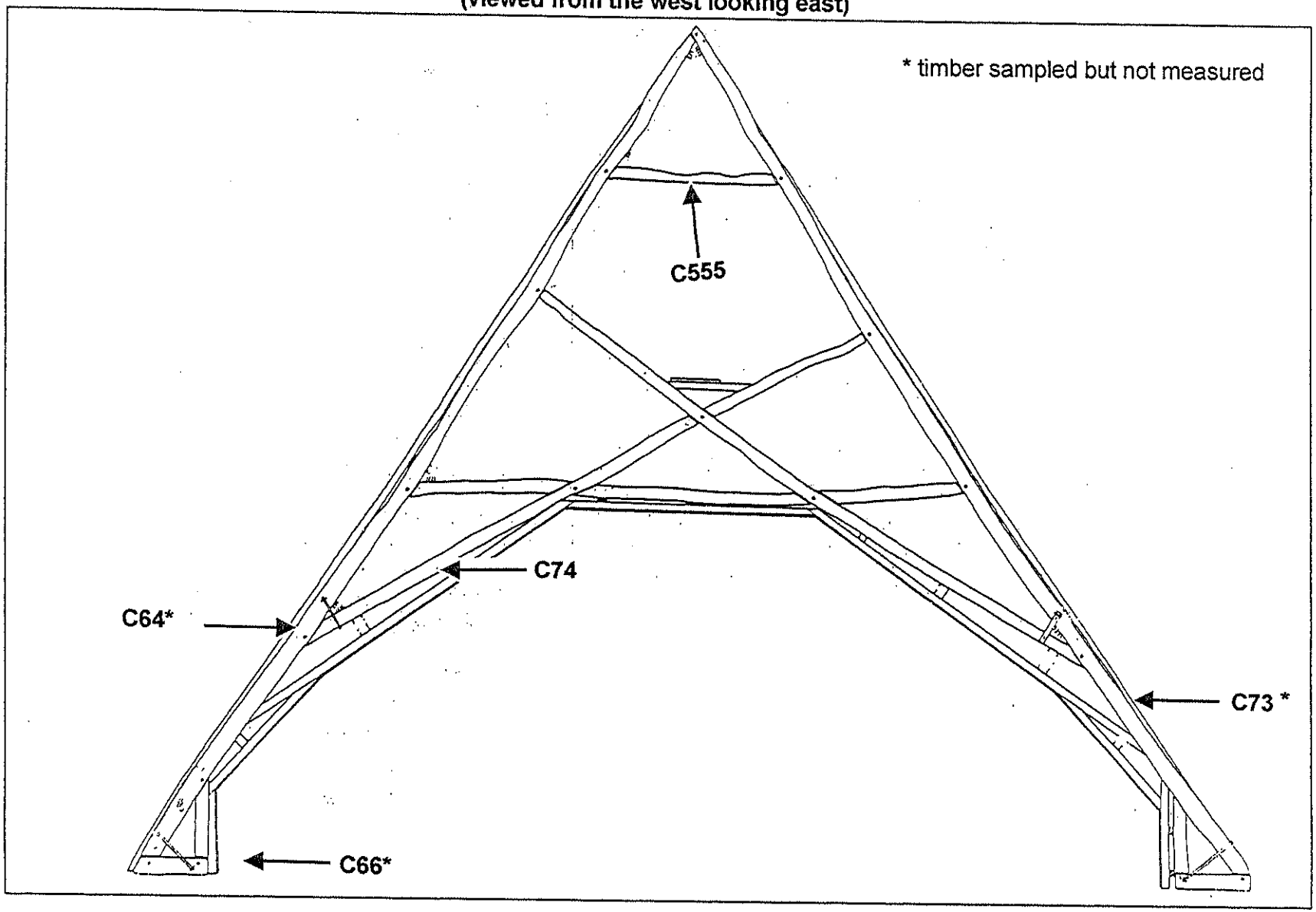


Figure 32i: Nave roof, frame 43 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

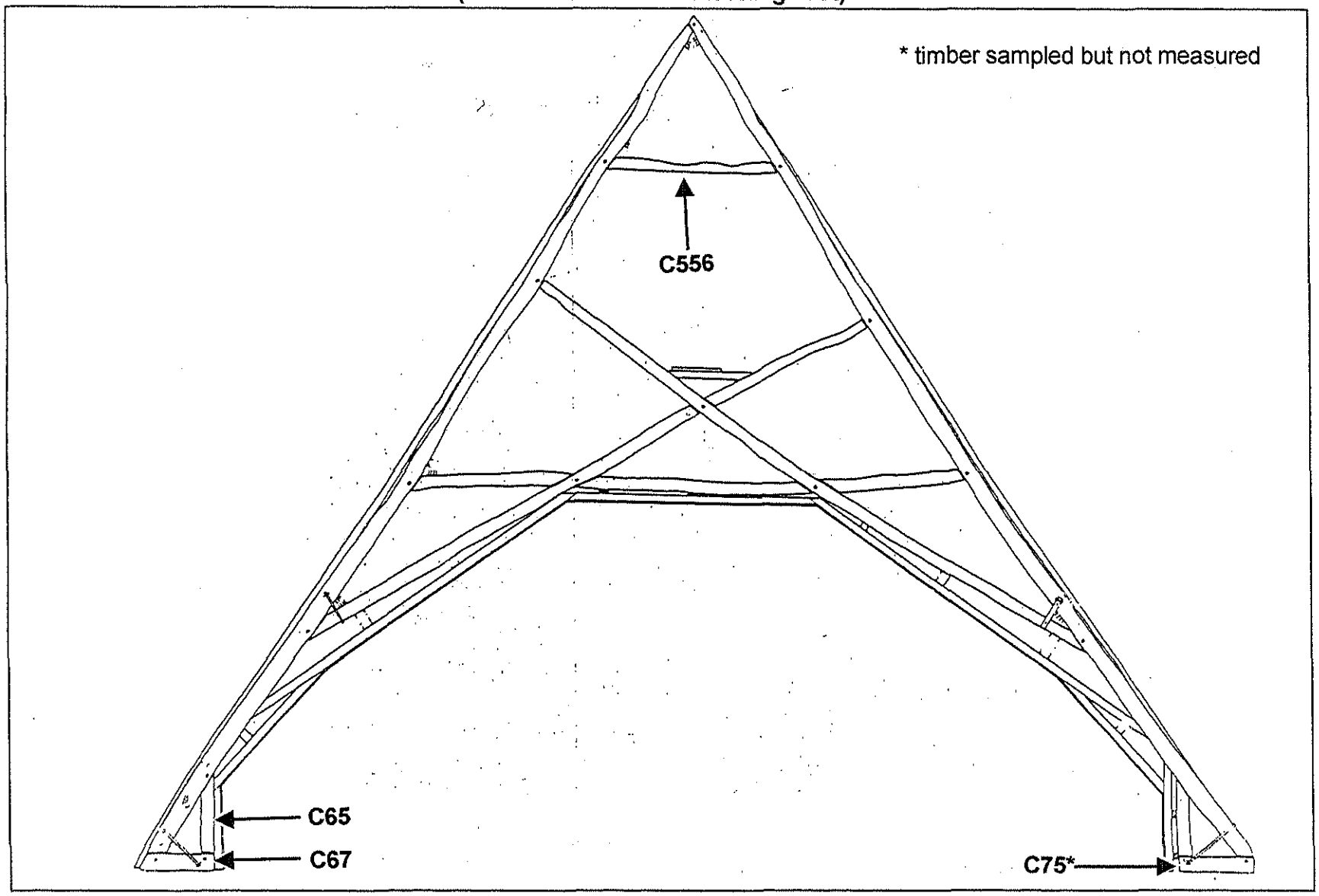


Figure 32j: Nave roof, frame 44 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

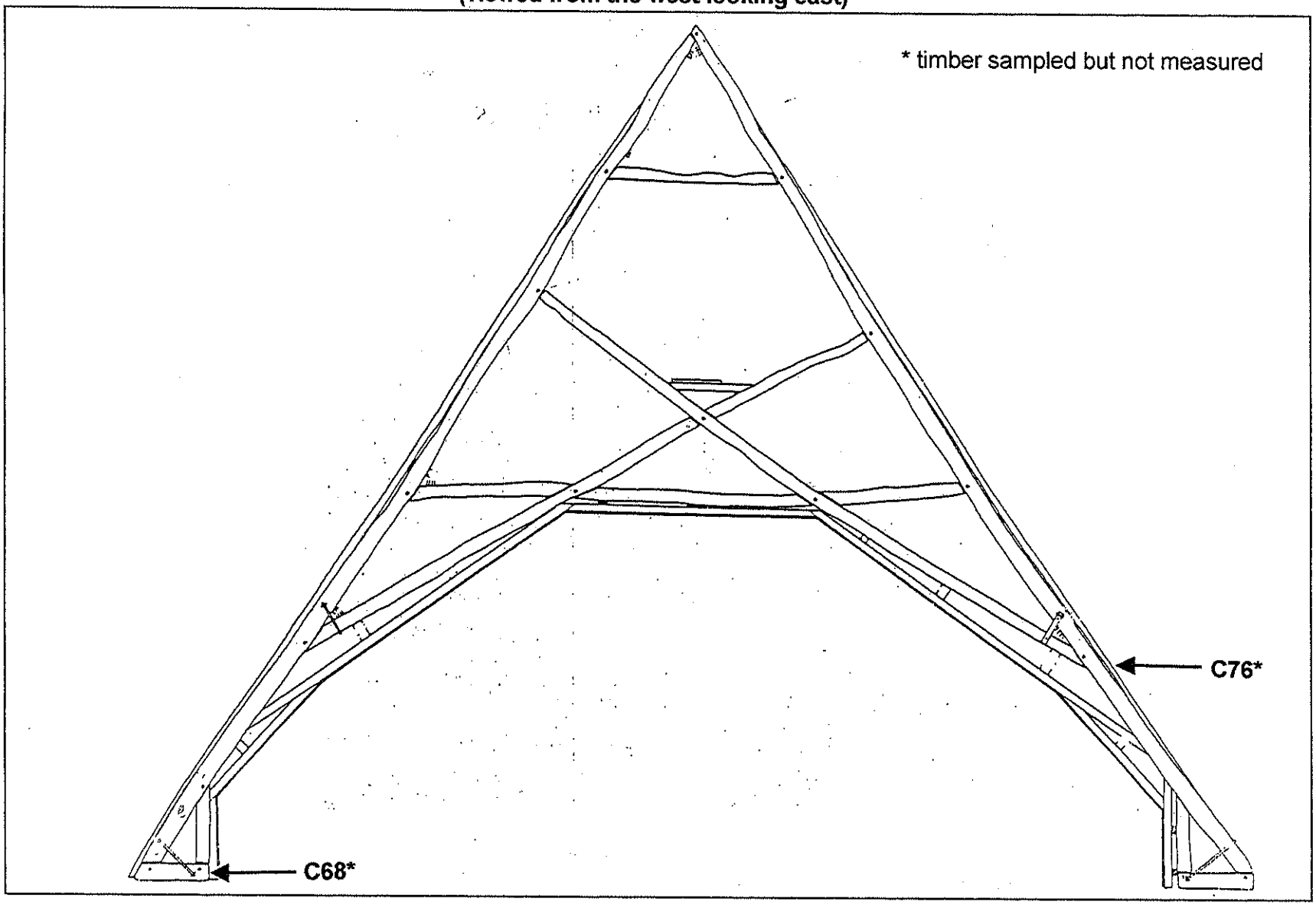


Figure 32k: Nave roof, frame 45 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

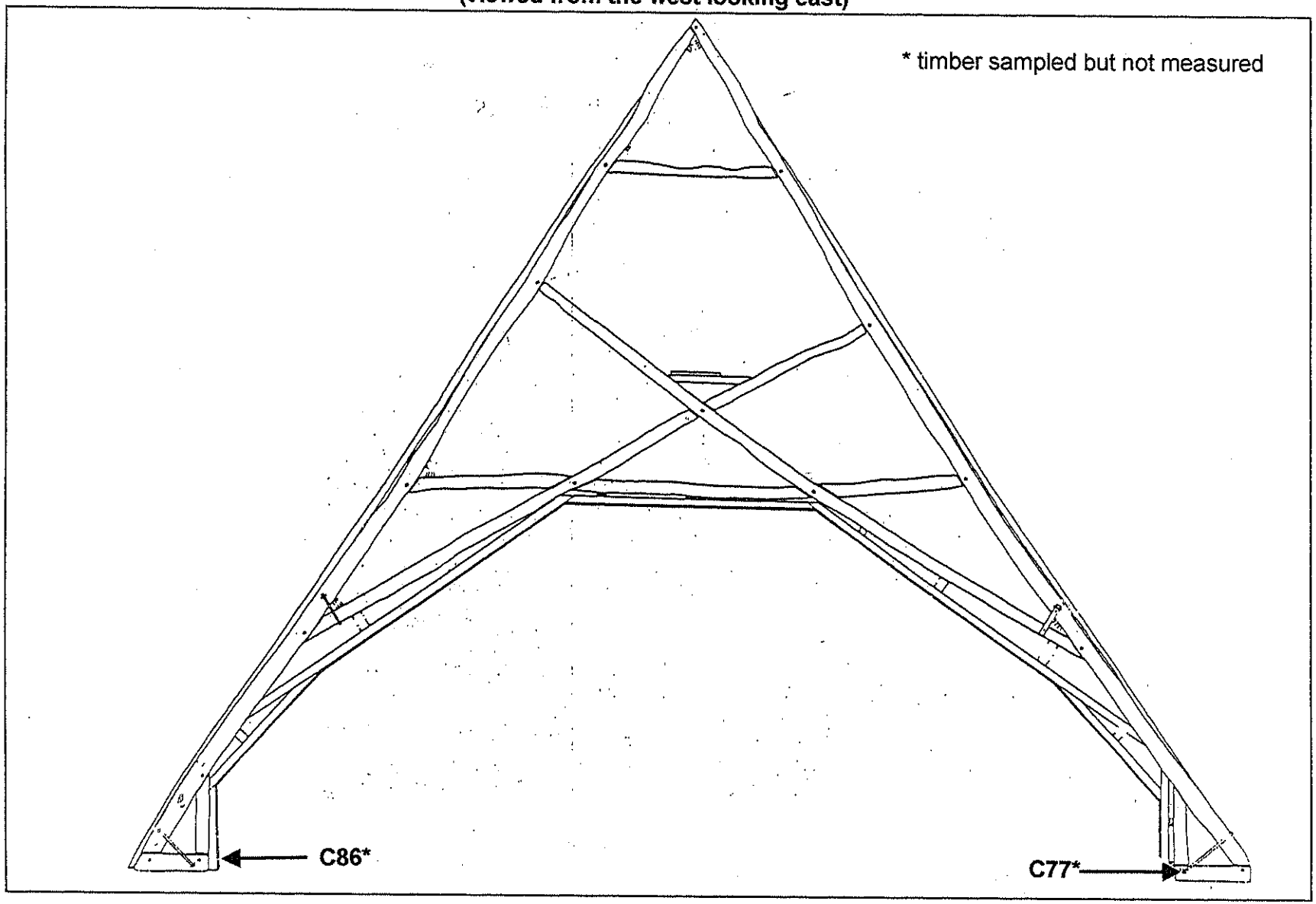


Figure 32l: Nave roof, frame 46 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

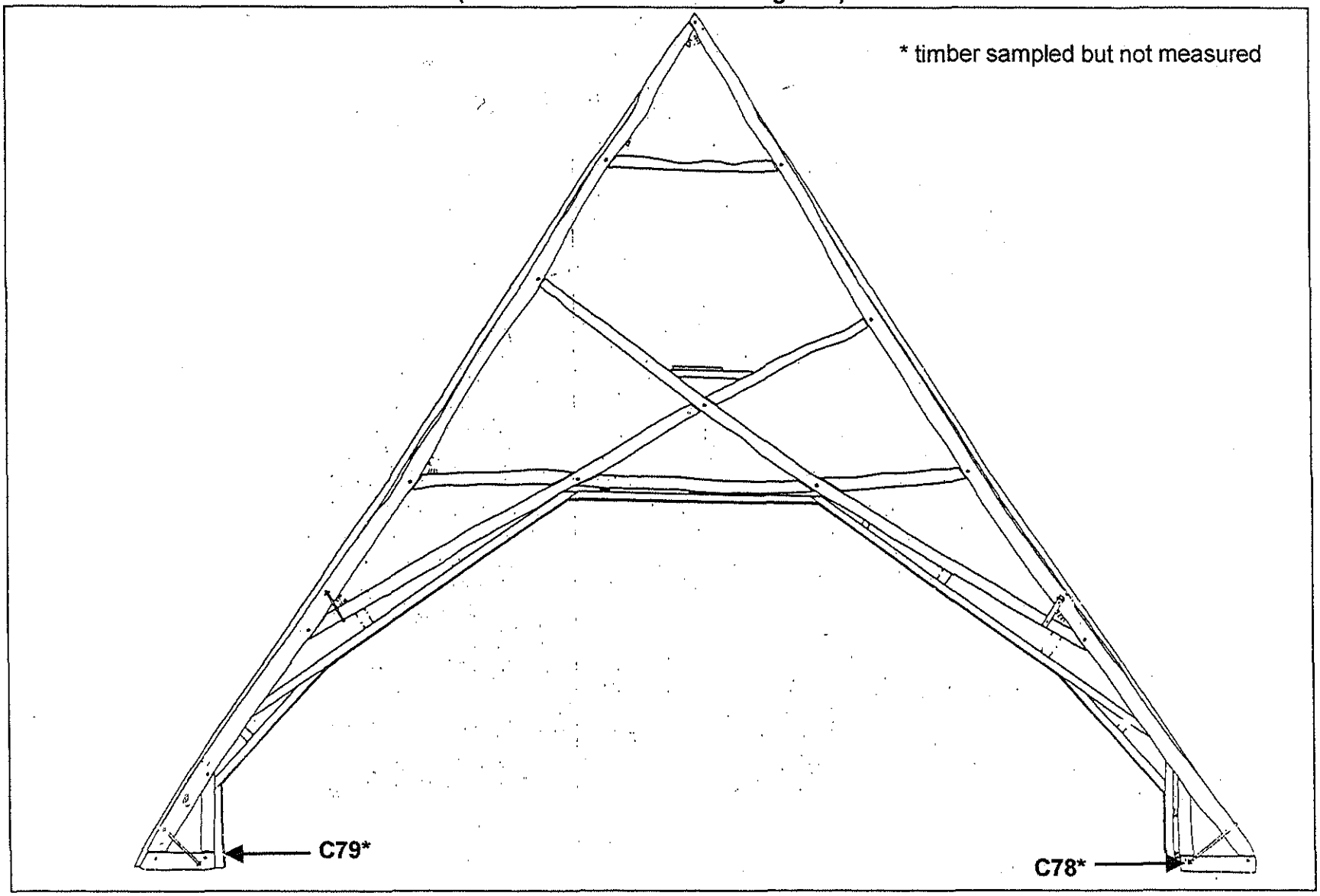


Figure 32m: Nave roof, frame 47showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

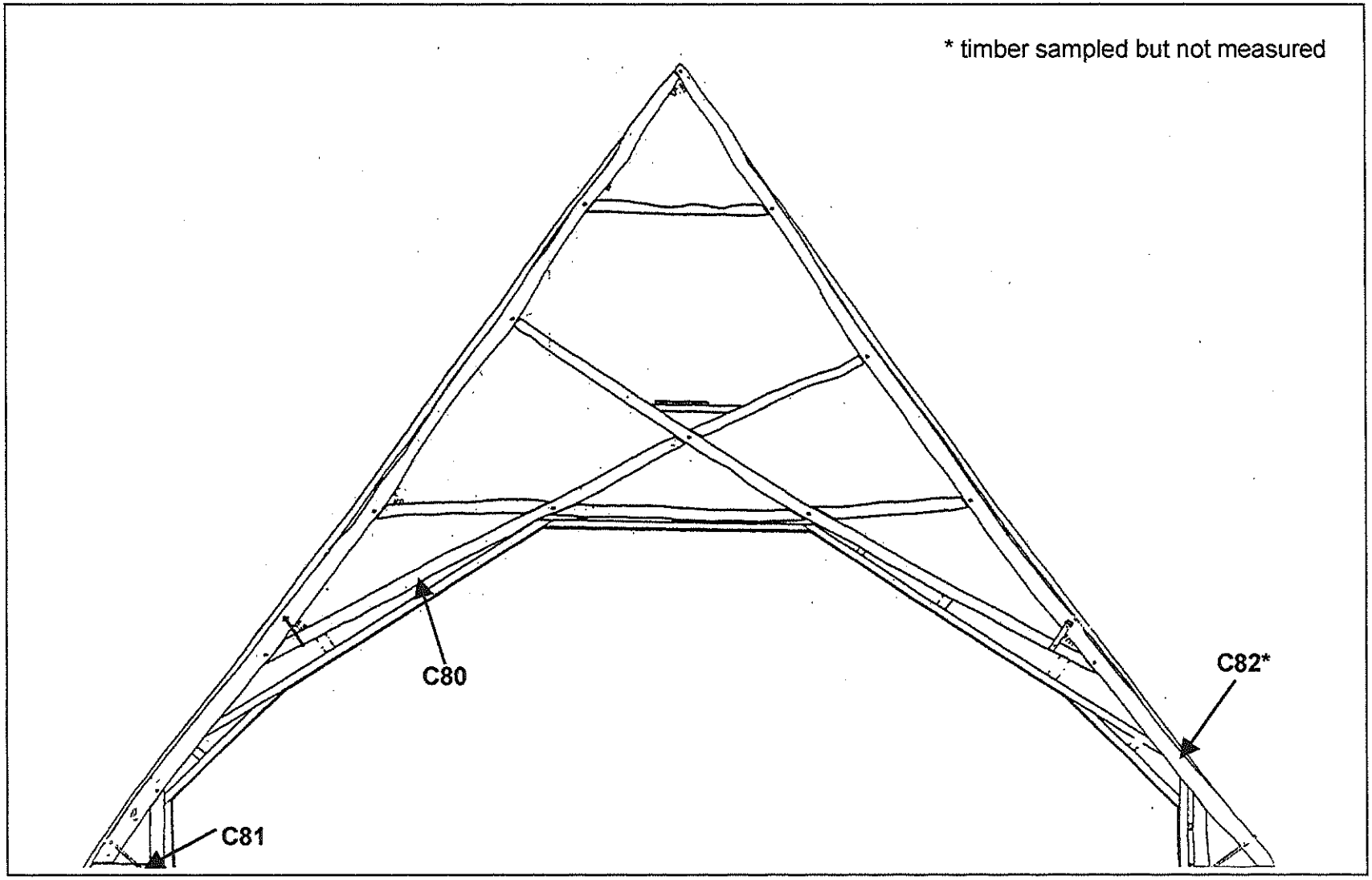


Figure 32n: Nave roof, frame 50 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

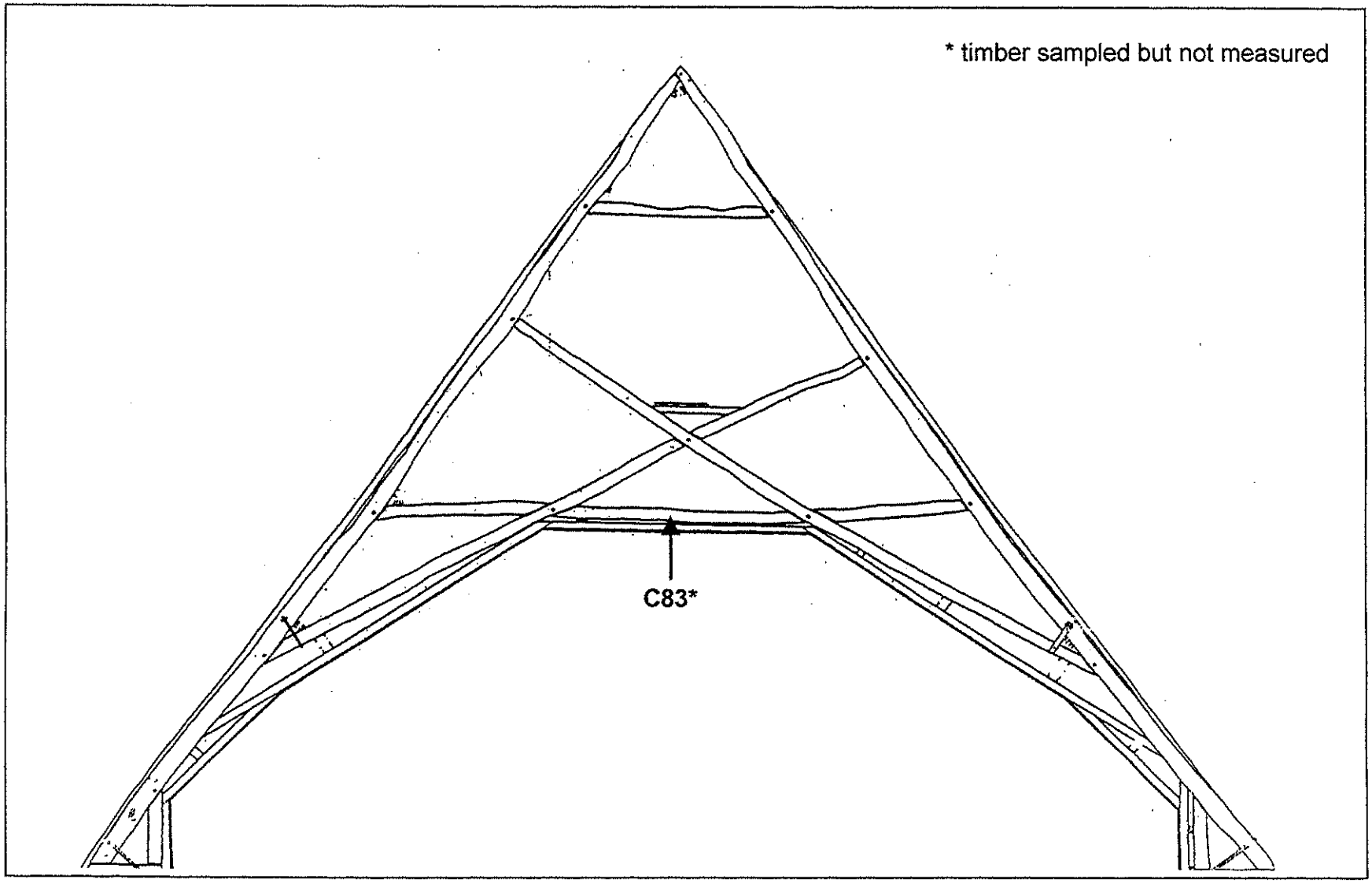


Figure 32o: Nave roof, frame 51 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

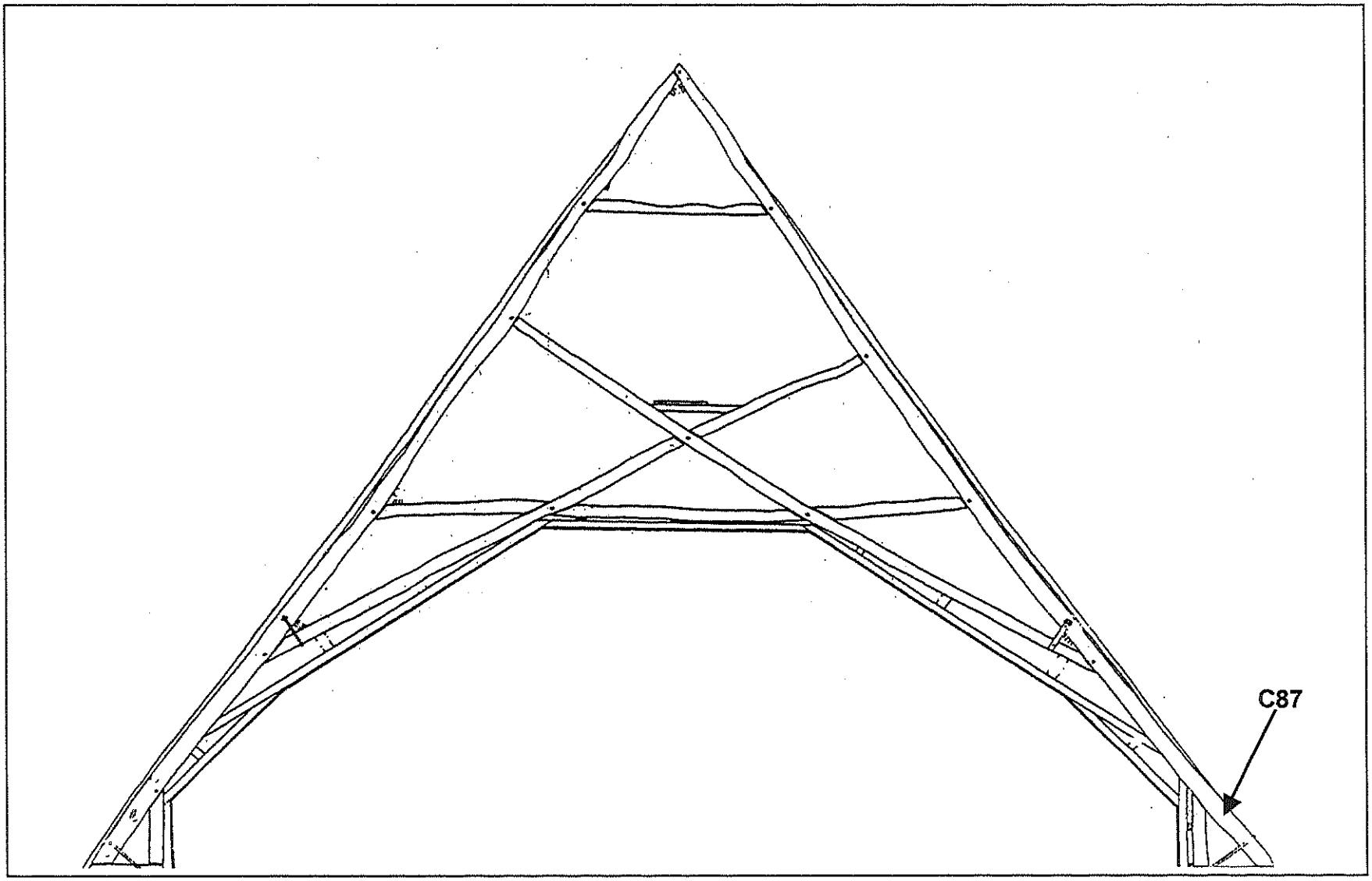


Figure 32p: Nave roof, frame 52 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

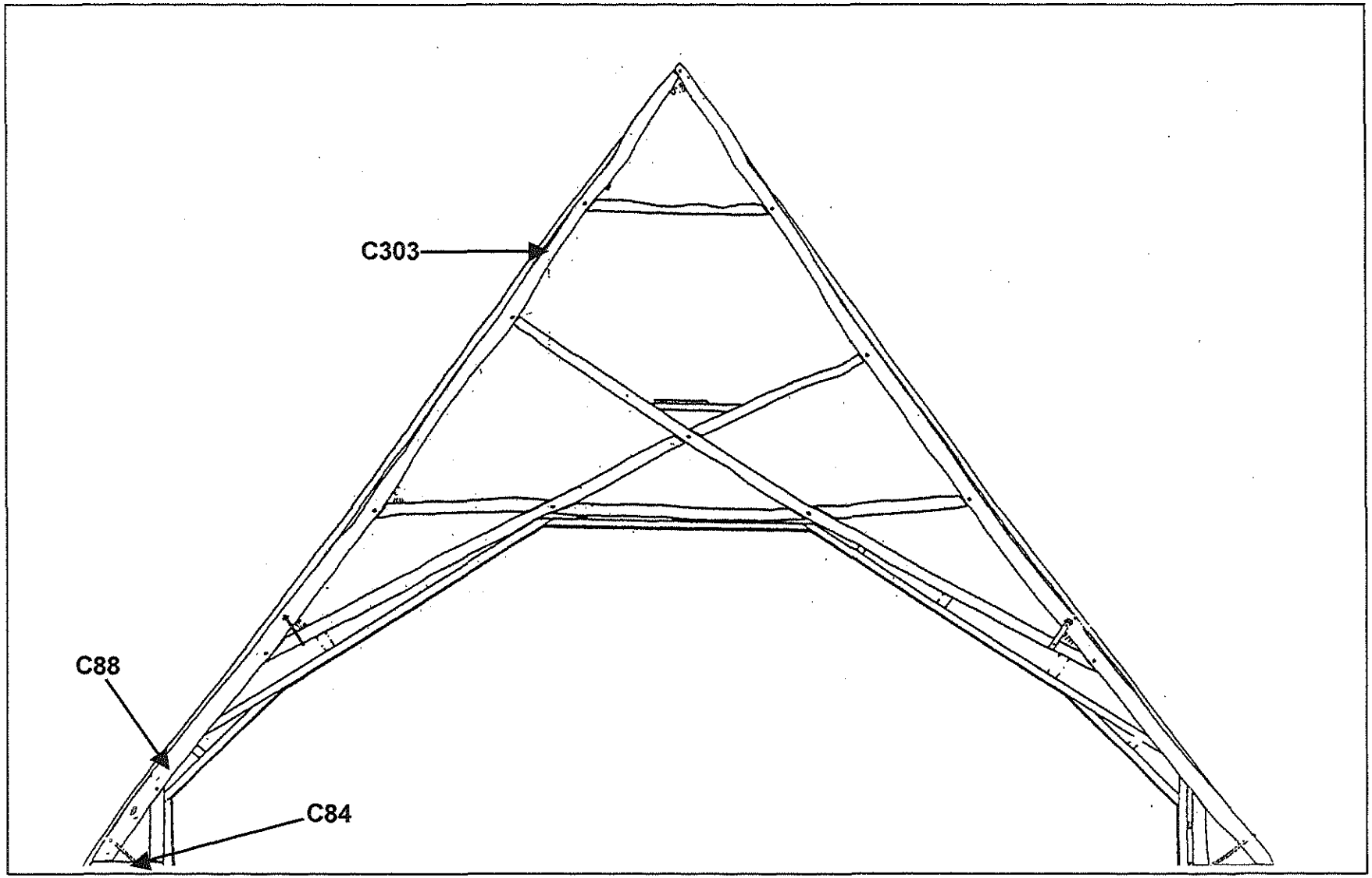


Figure 32q: Nave roof, frame 53 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

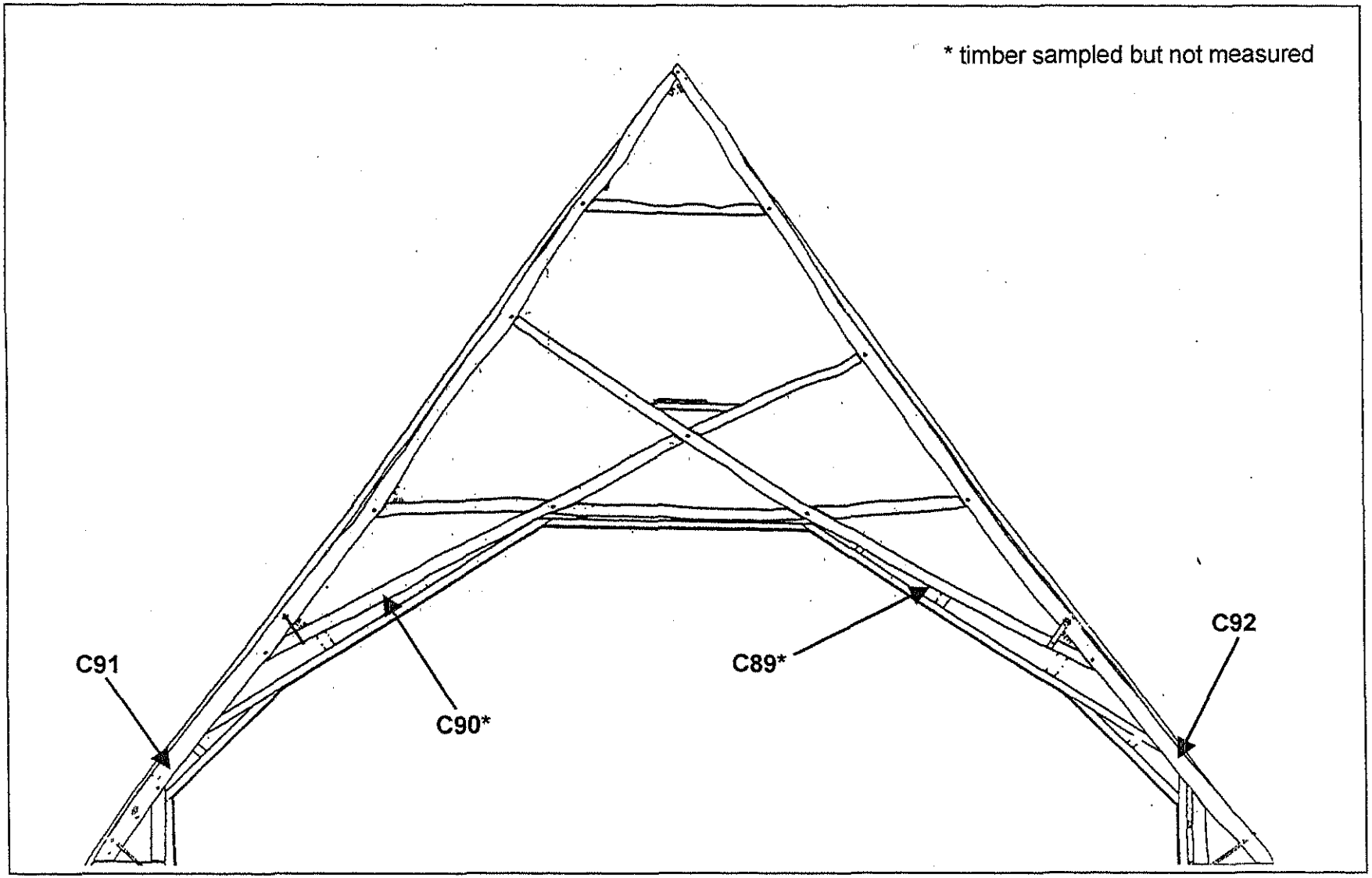


Figure 32r: Nave roof, frame 54 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

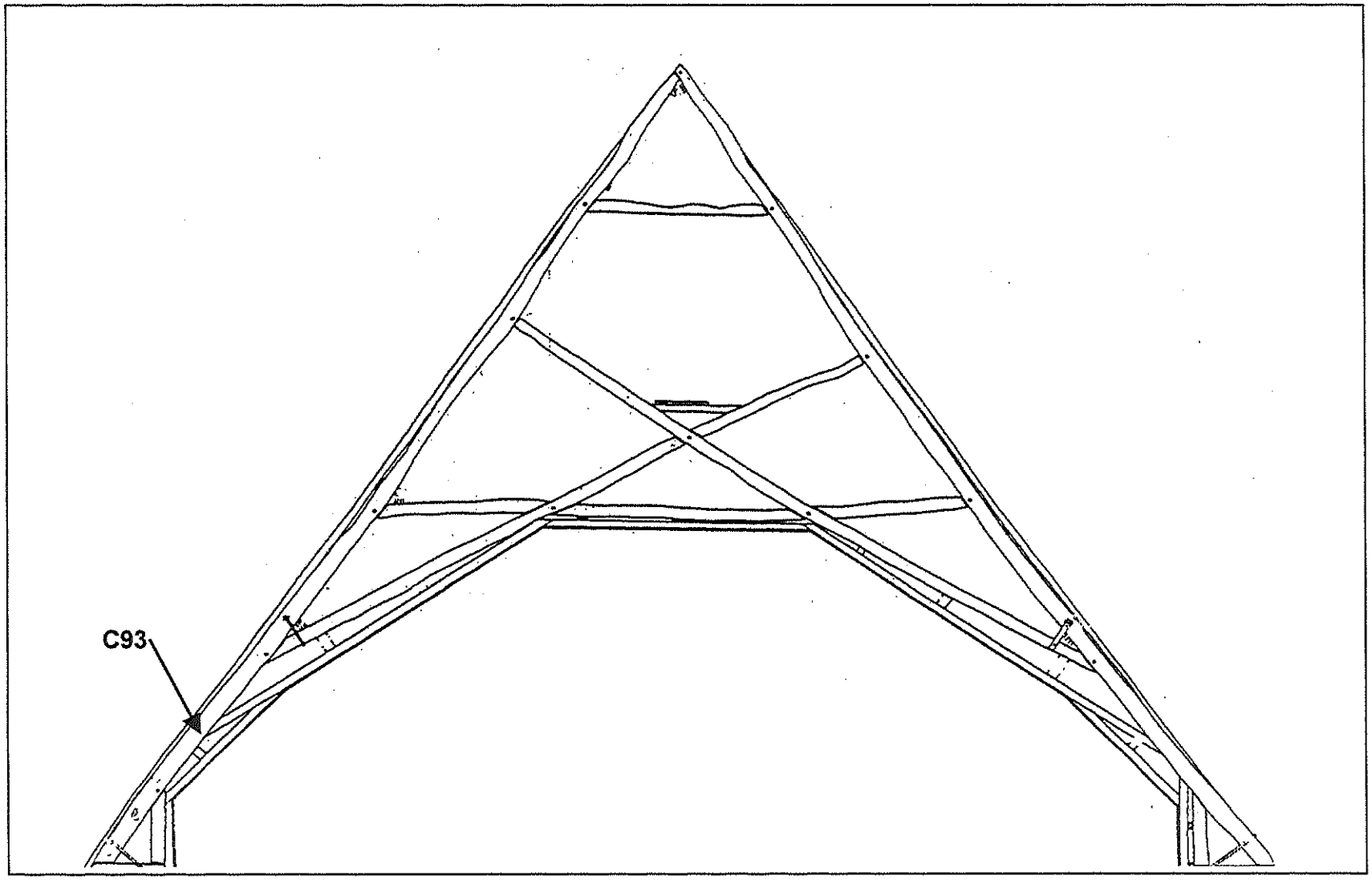


Figure 32s: Nave roof, frame 55 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

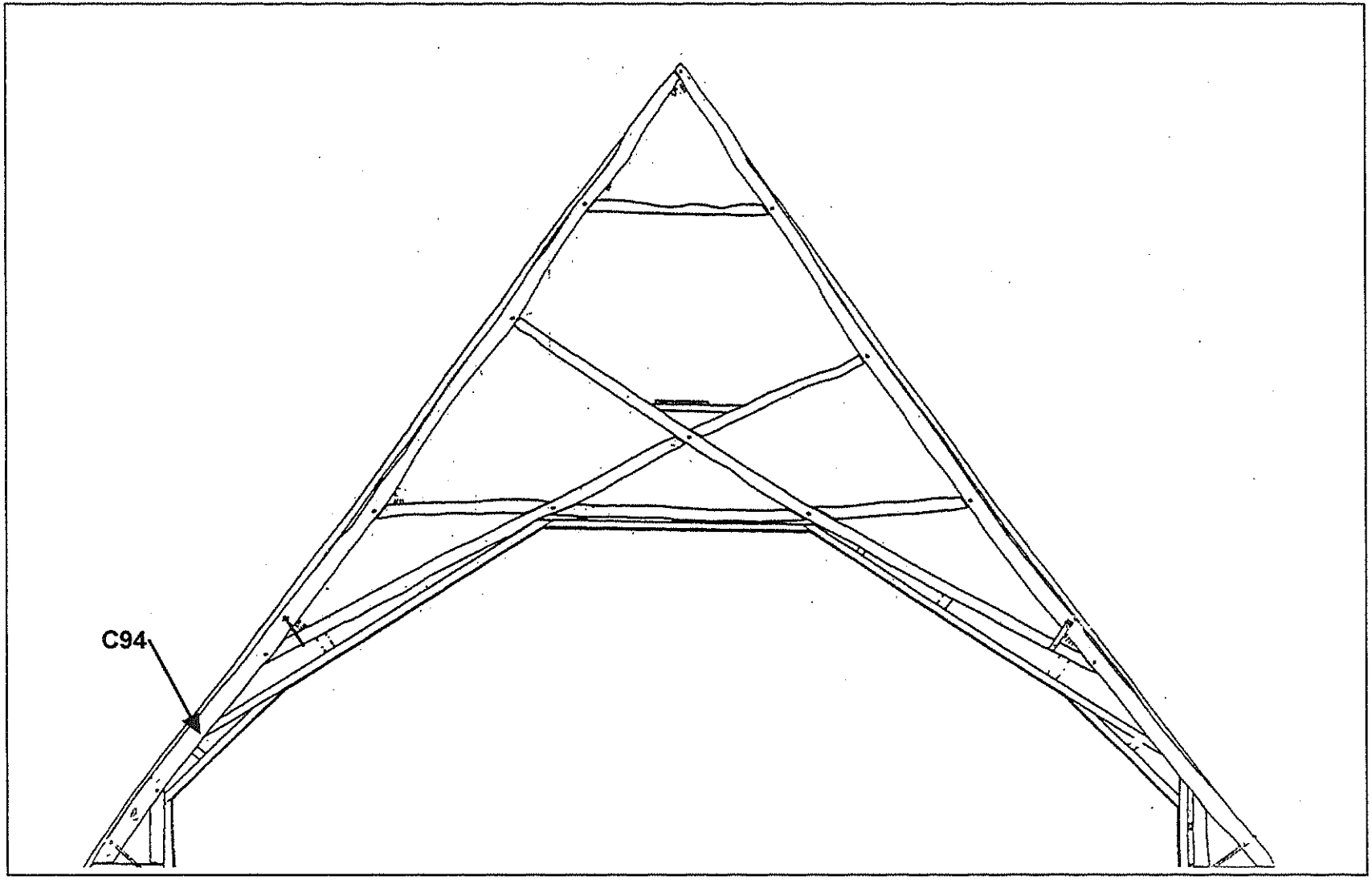


Figure 32t: Nave roof, frame 56 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

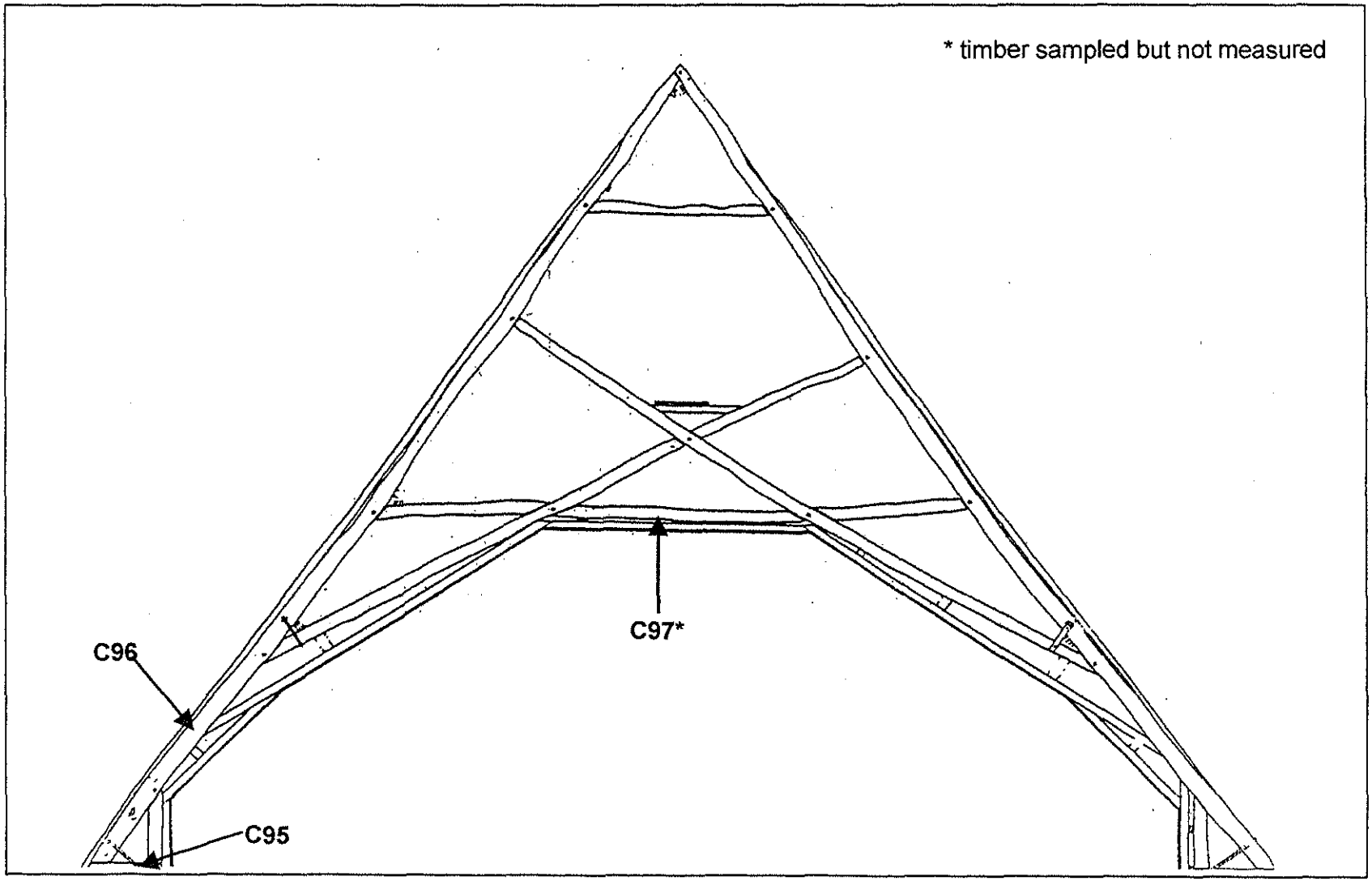


Figure 32u: Nave roof, frame 57 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

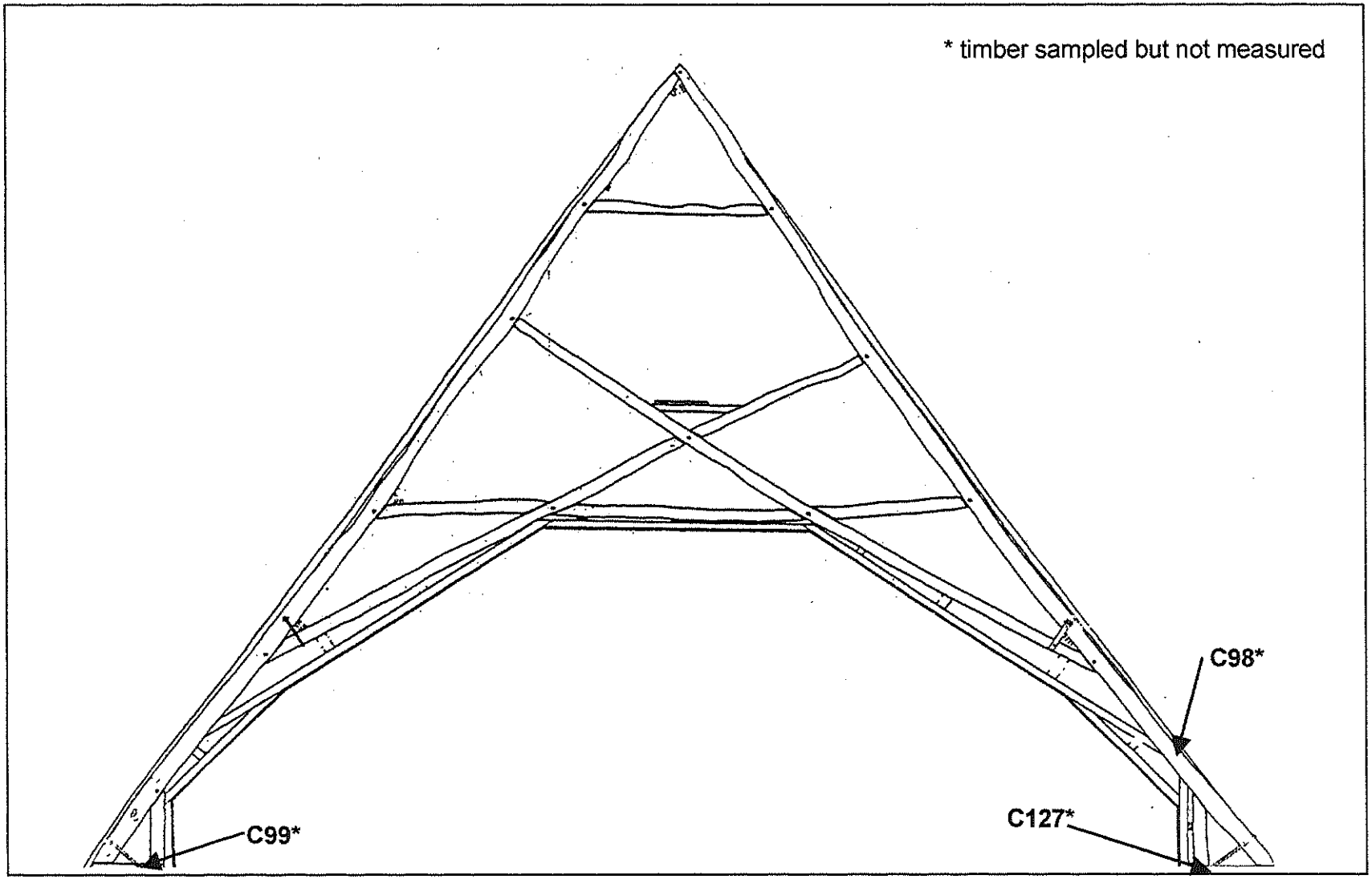


Figure 32v: Nave roof, frame 58 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

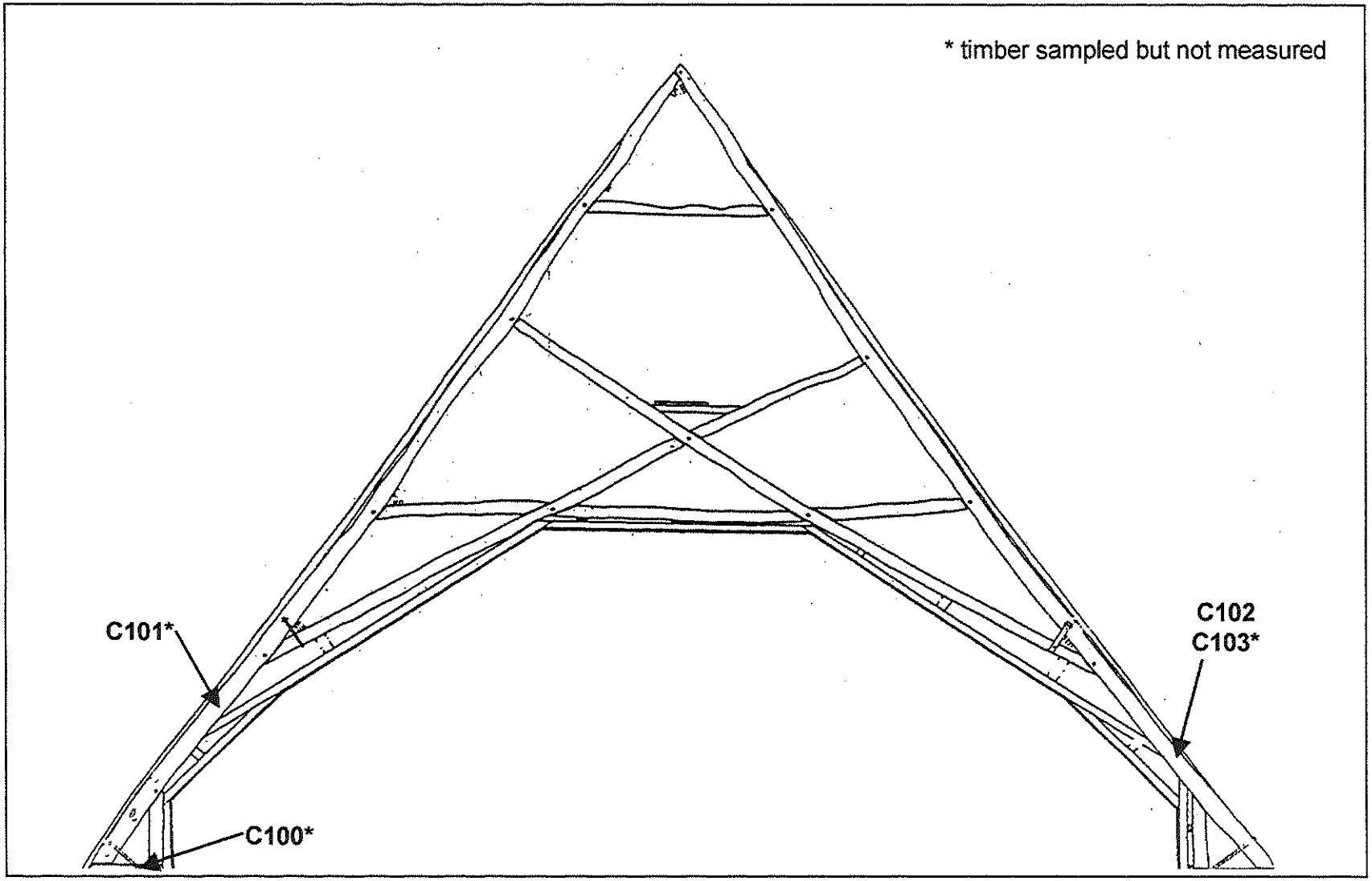


Figure 32w: Nave roof, frame 59 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

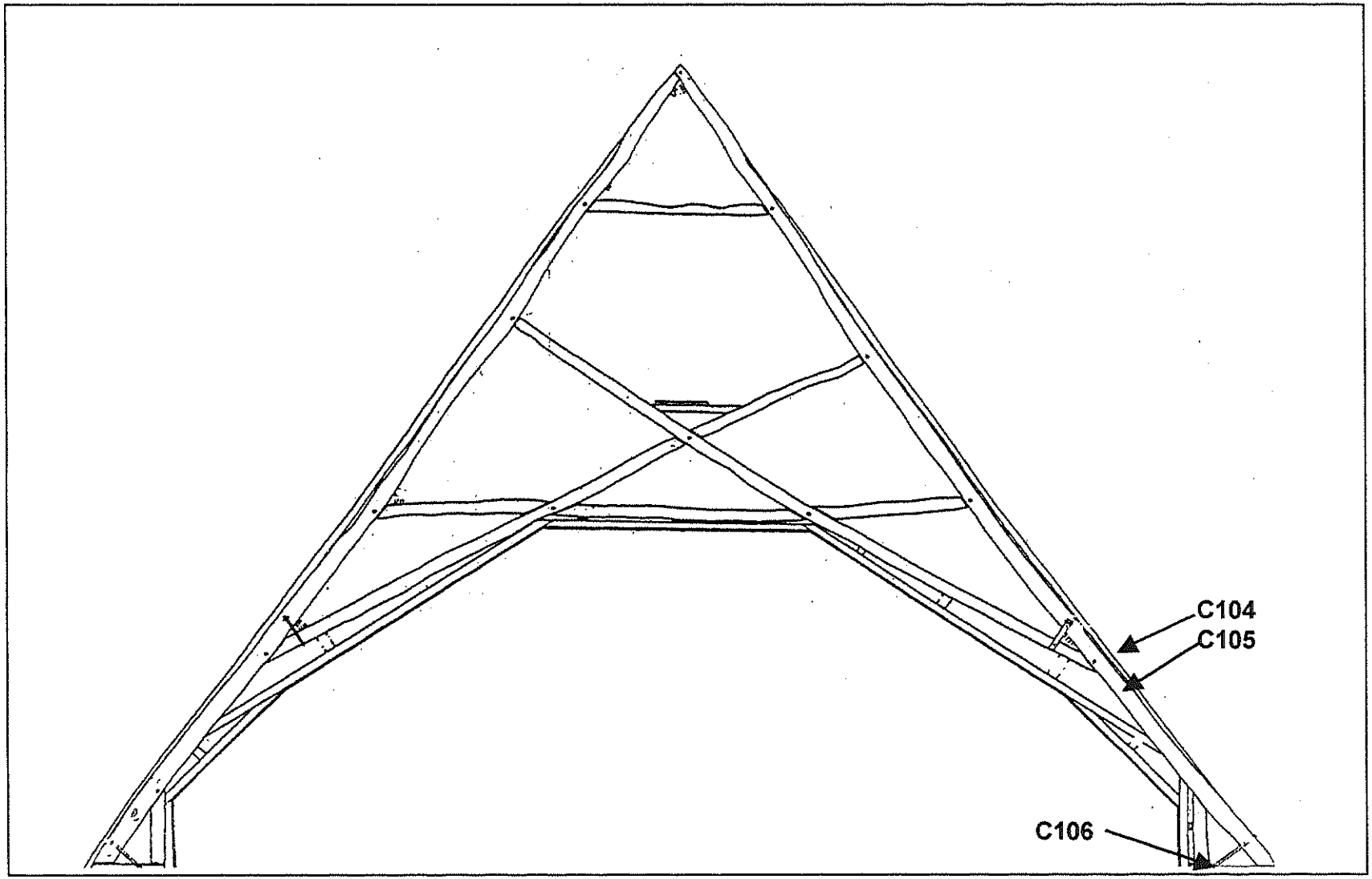


Figure 32x: Nave roof, frame 60 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

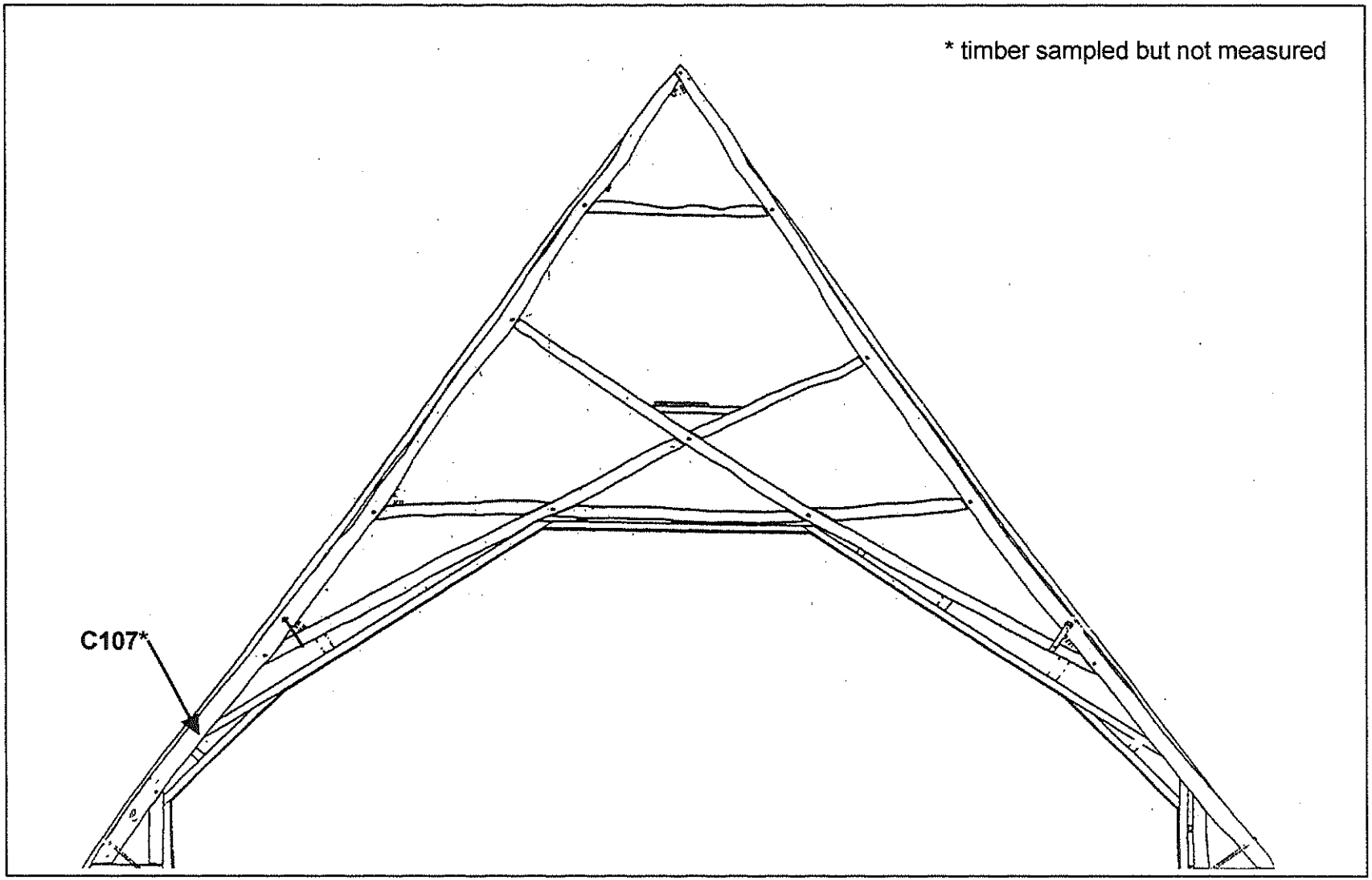


Figure 32y: Nave roof, frame 61 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

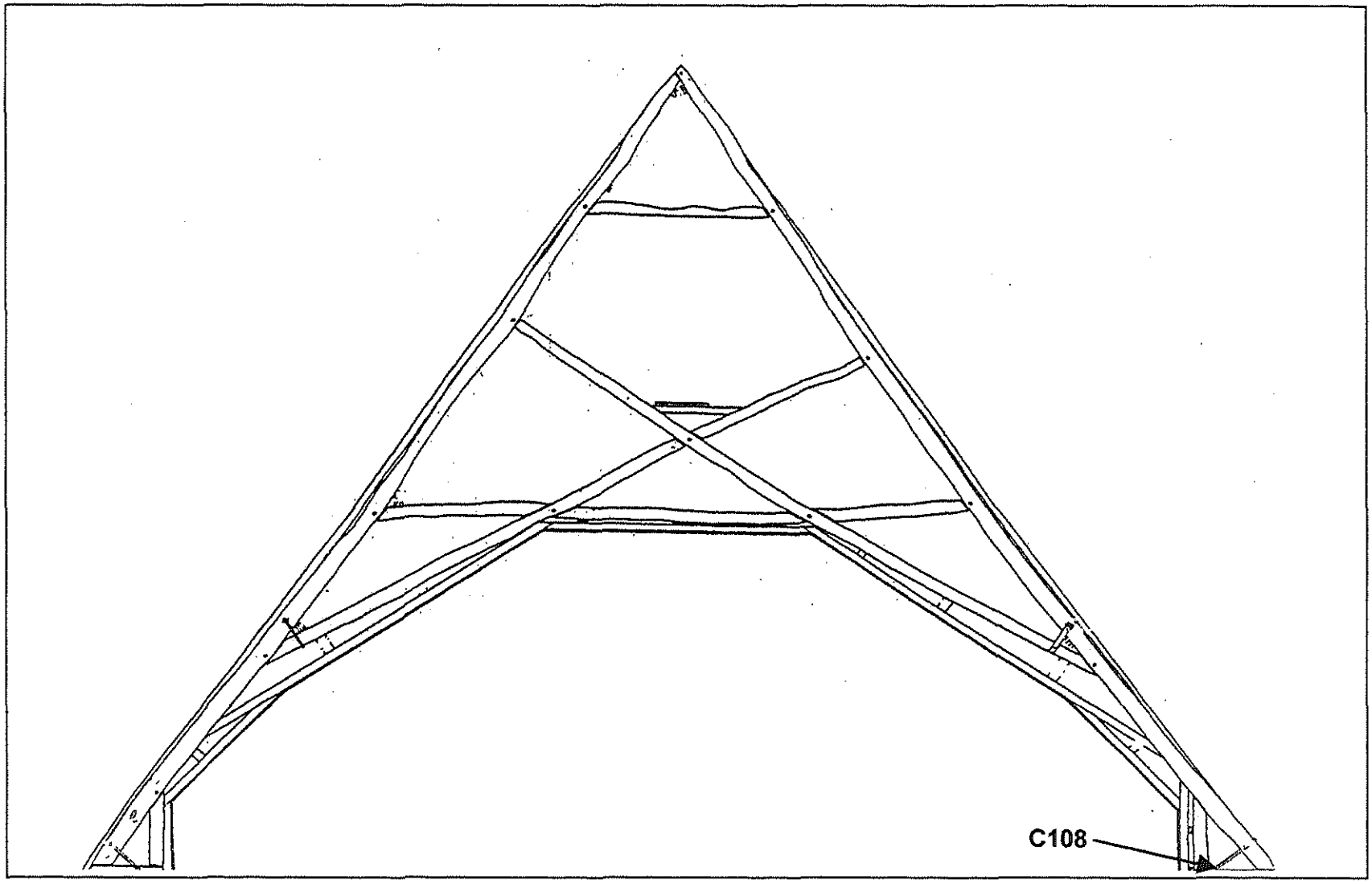


Figure 32z: Nave roof, frame 62 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

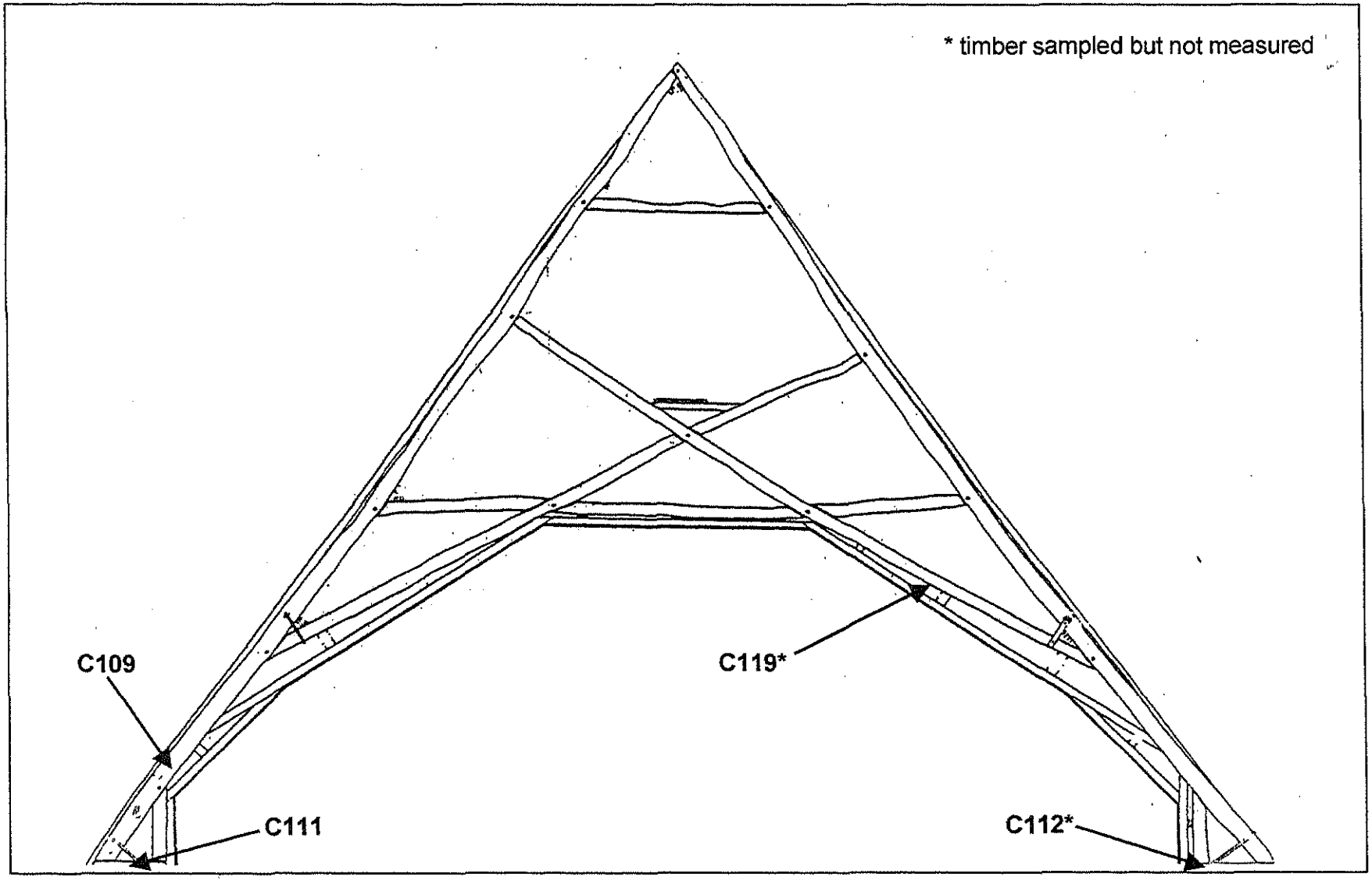


Figure 33a: Nave roof, frame 63 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

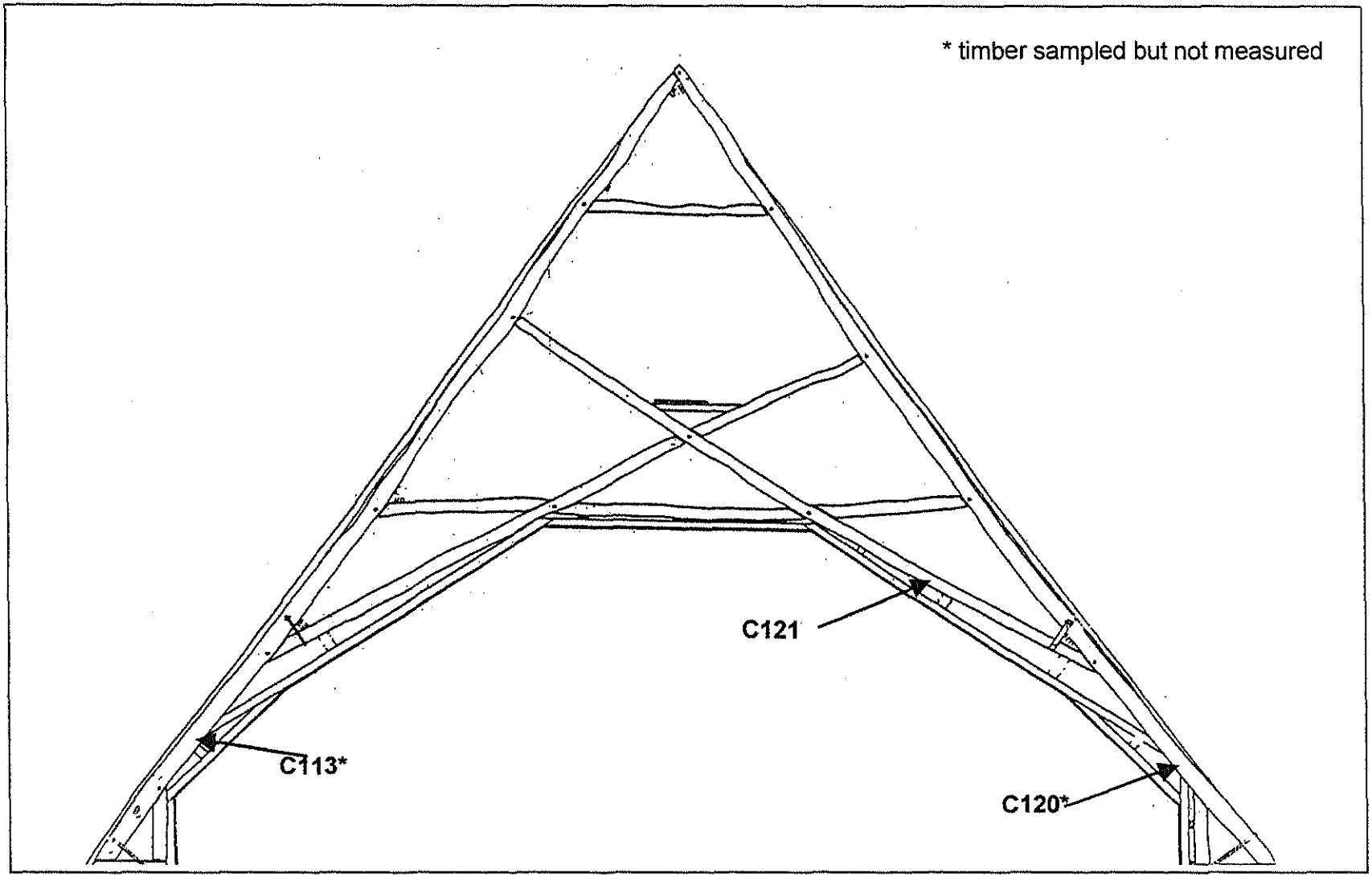


Figure 33b: Nave roof, frame 64 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

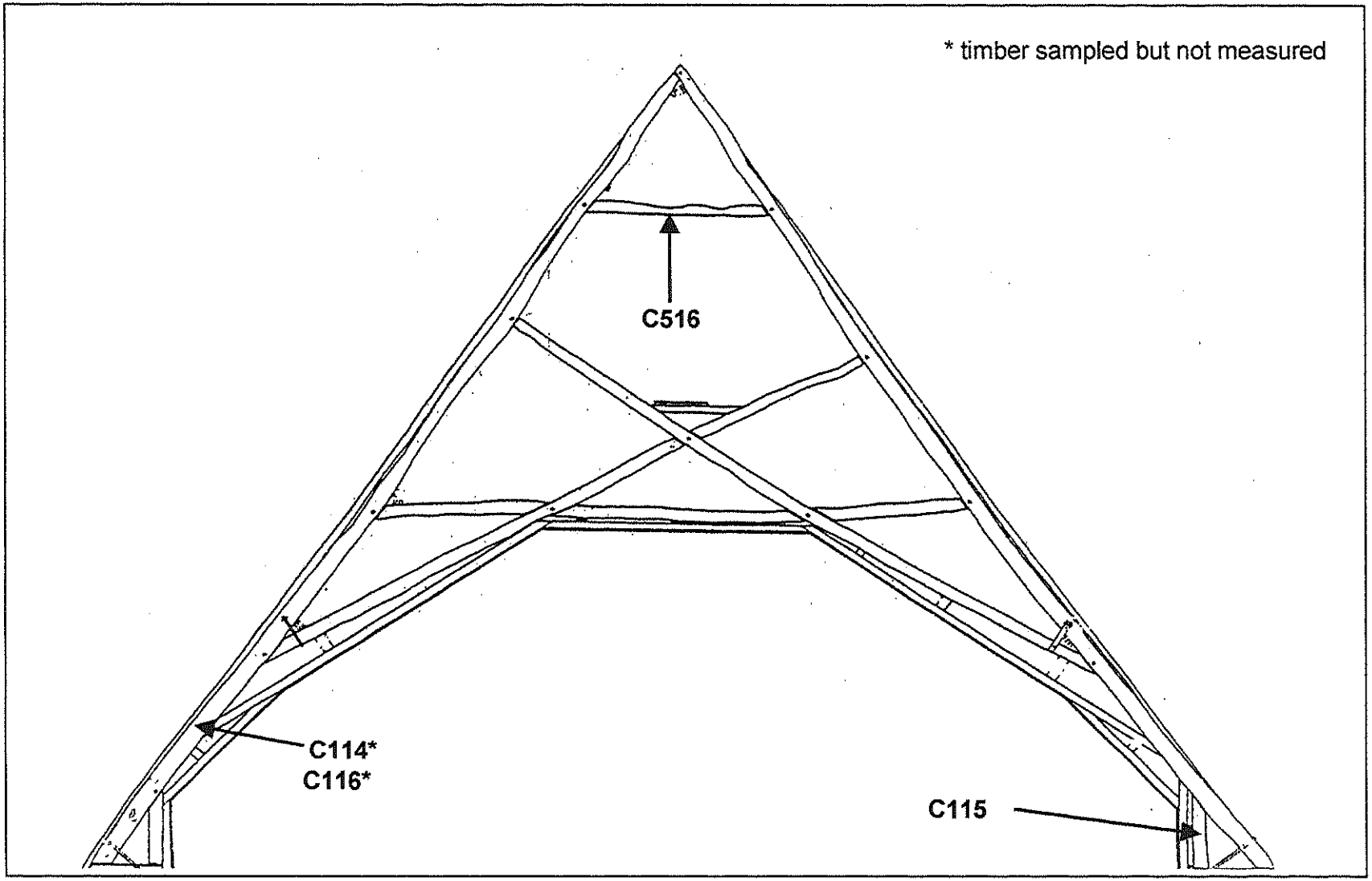


Figure 33c: Nave roof, frame 65 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

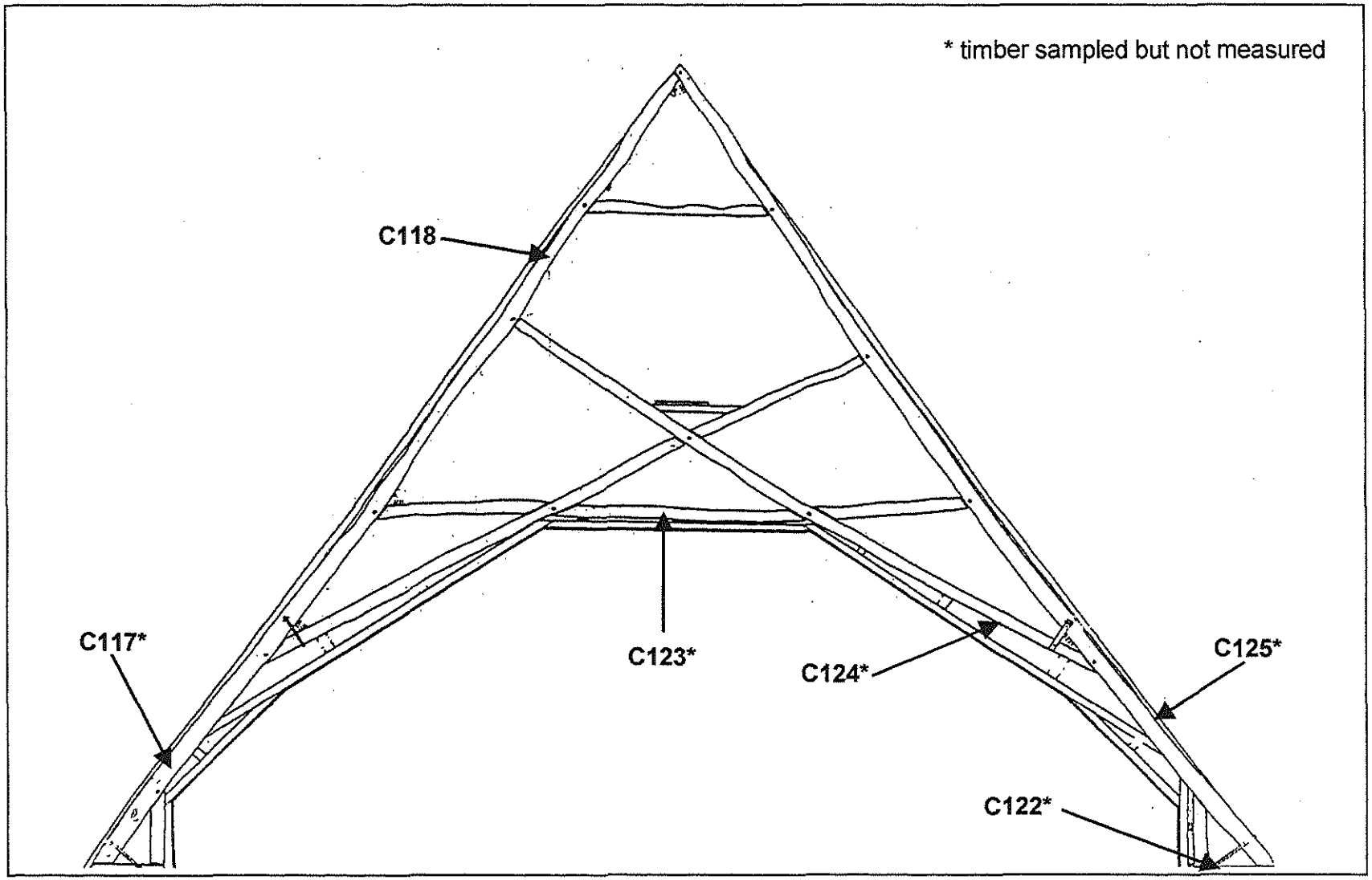


Figure 33d: Nave roof, frame 66 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

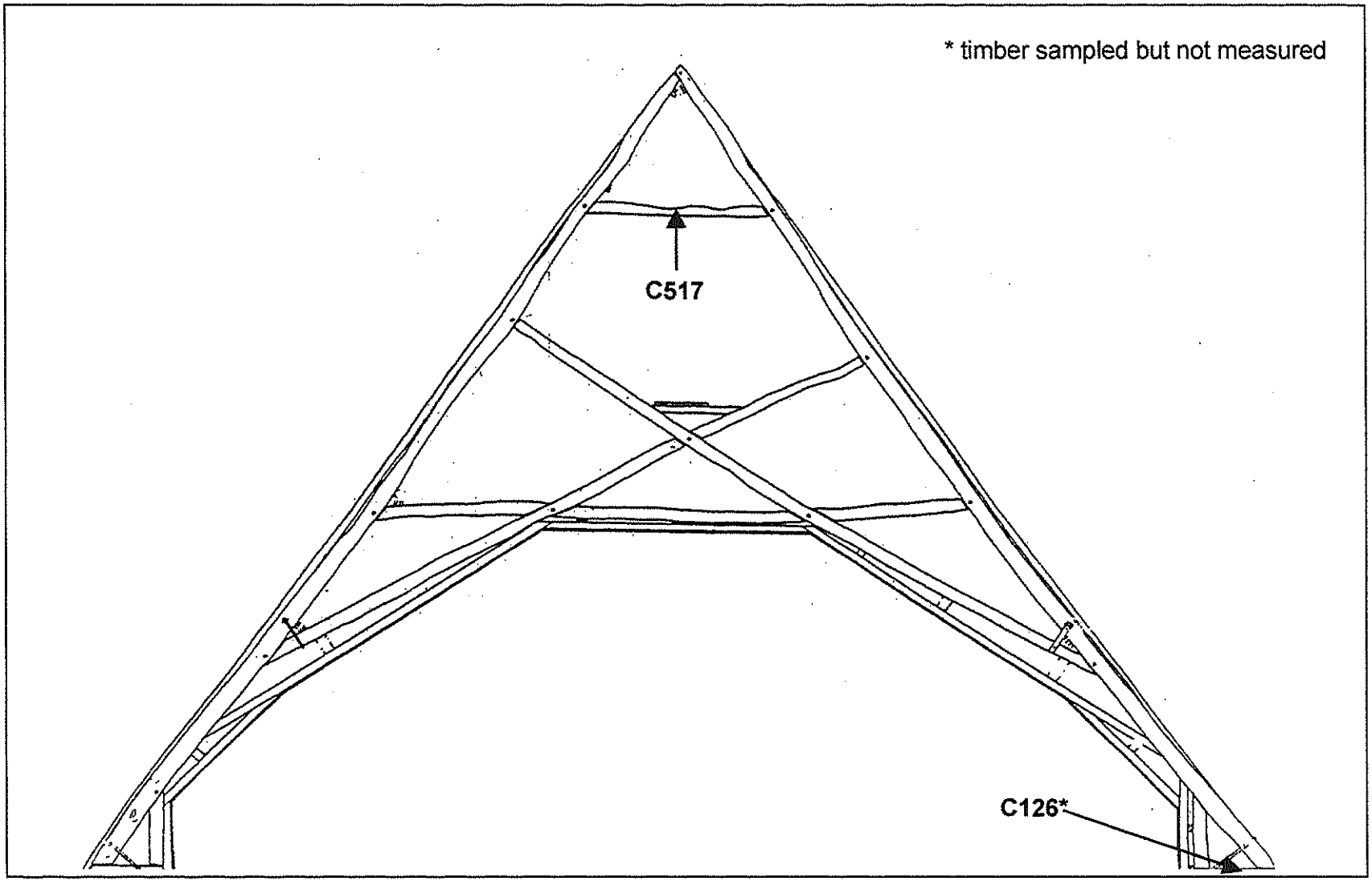


Figure 33e: Nave roof, frame 67 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

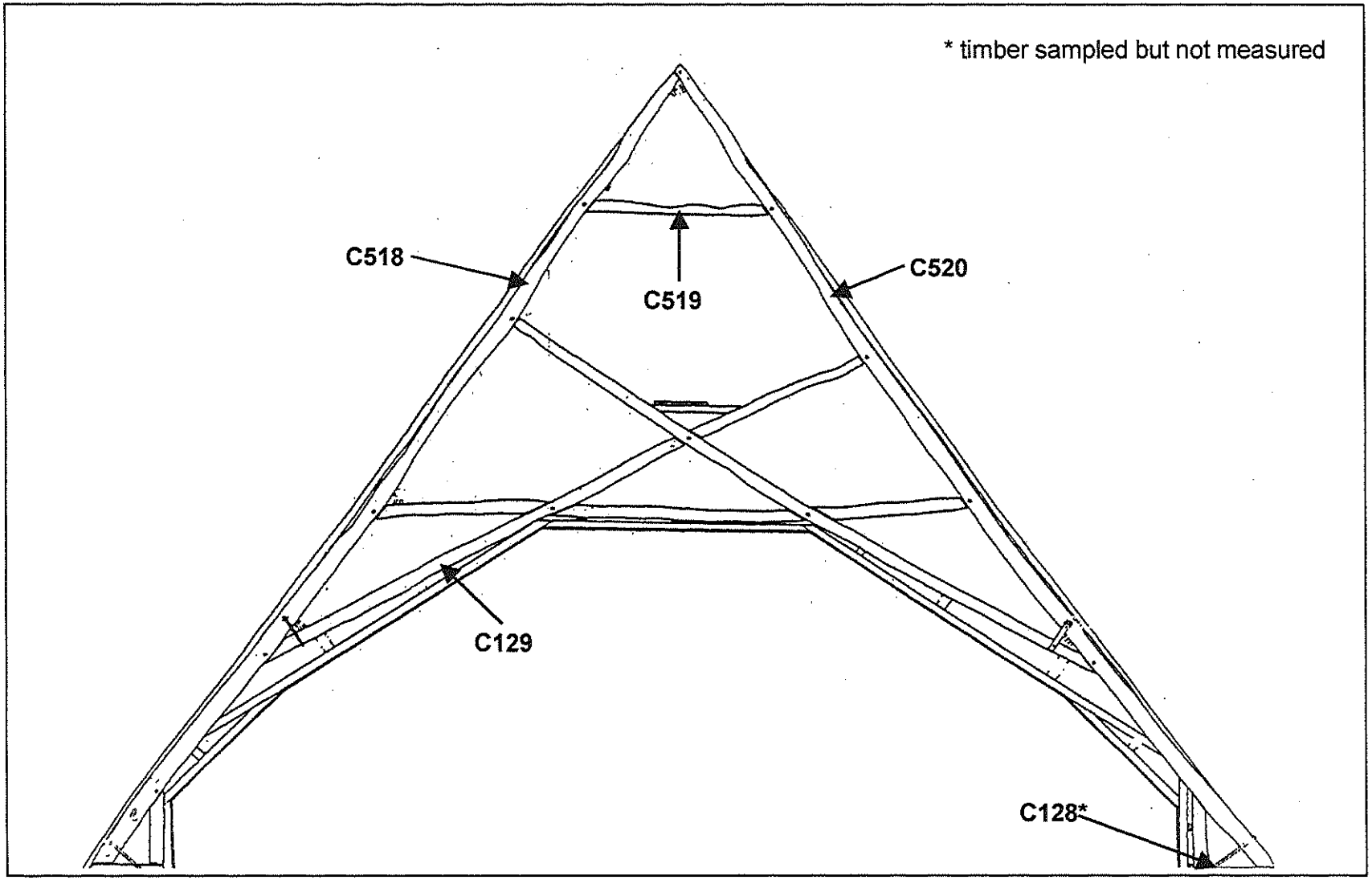


Figure 33f: Nave roof, frame 68 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

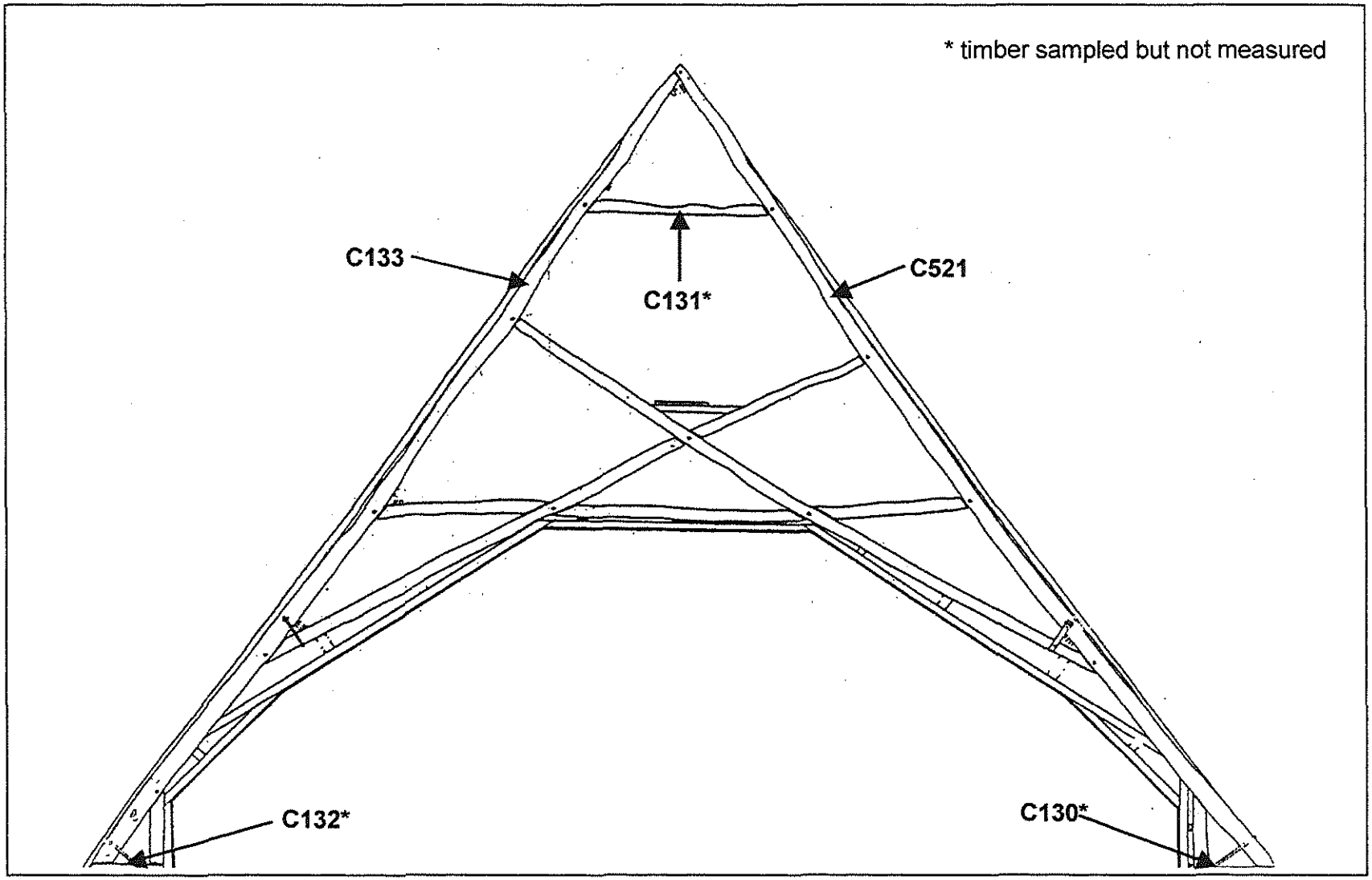


Figure 33g: Nave roof, frame 69 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

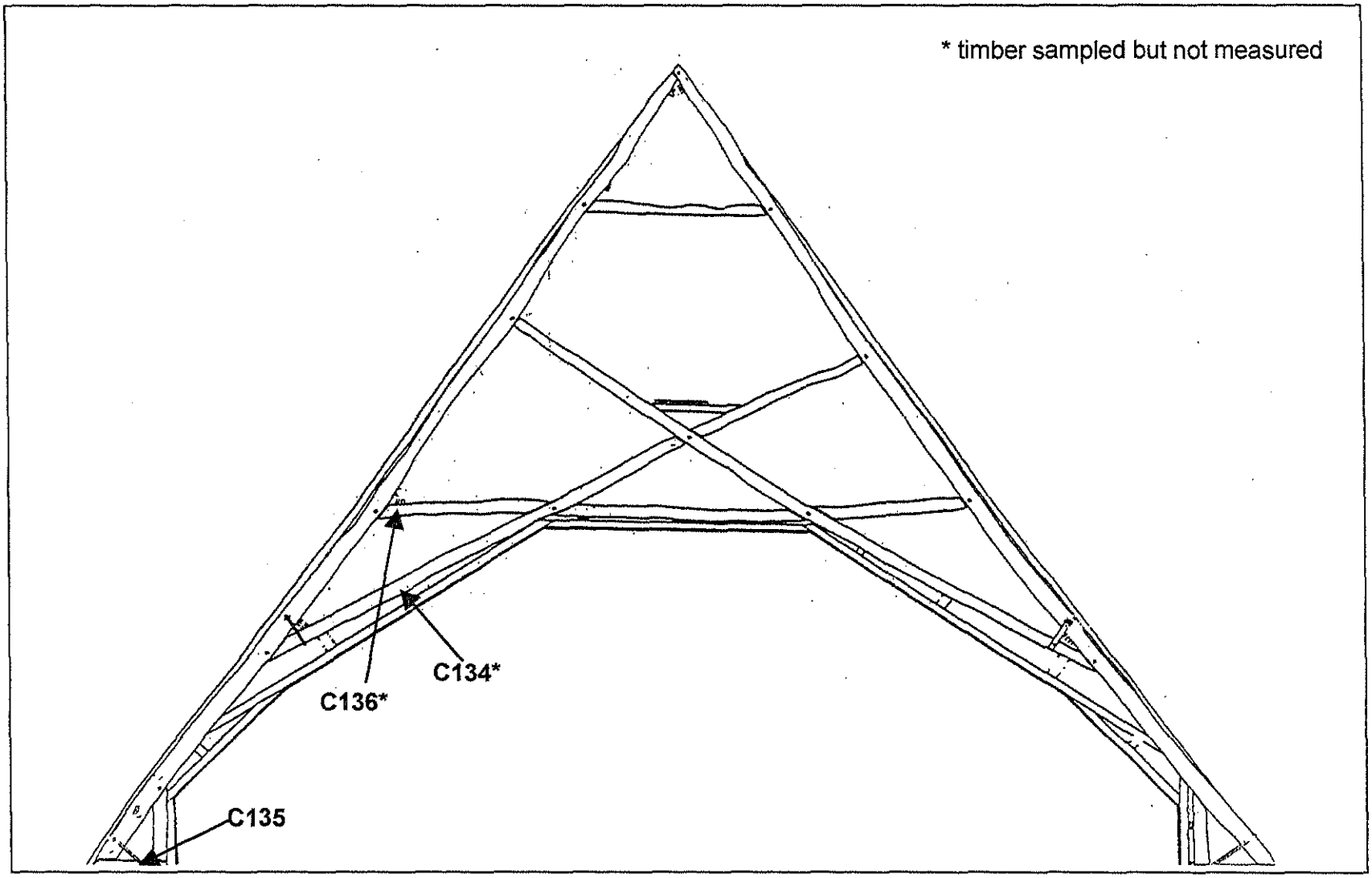


Figure 33h: Nave roof, frame 71 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

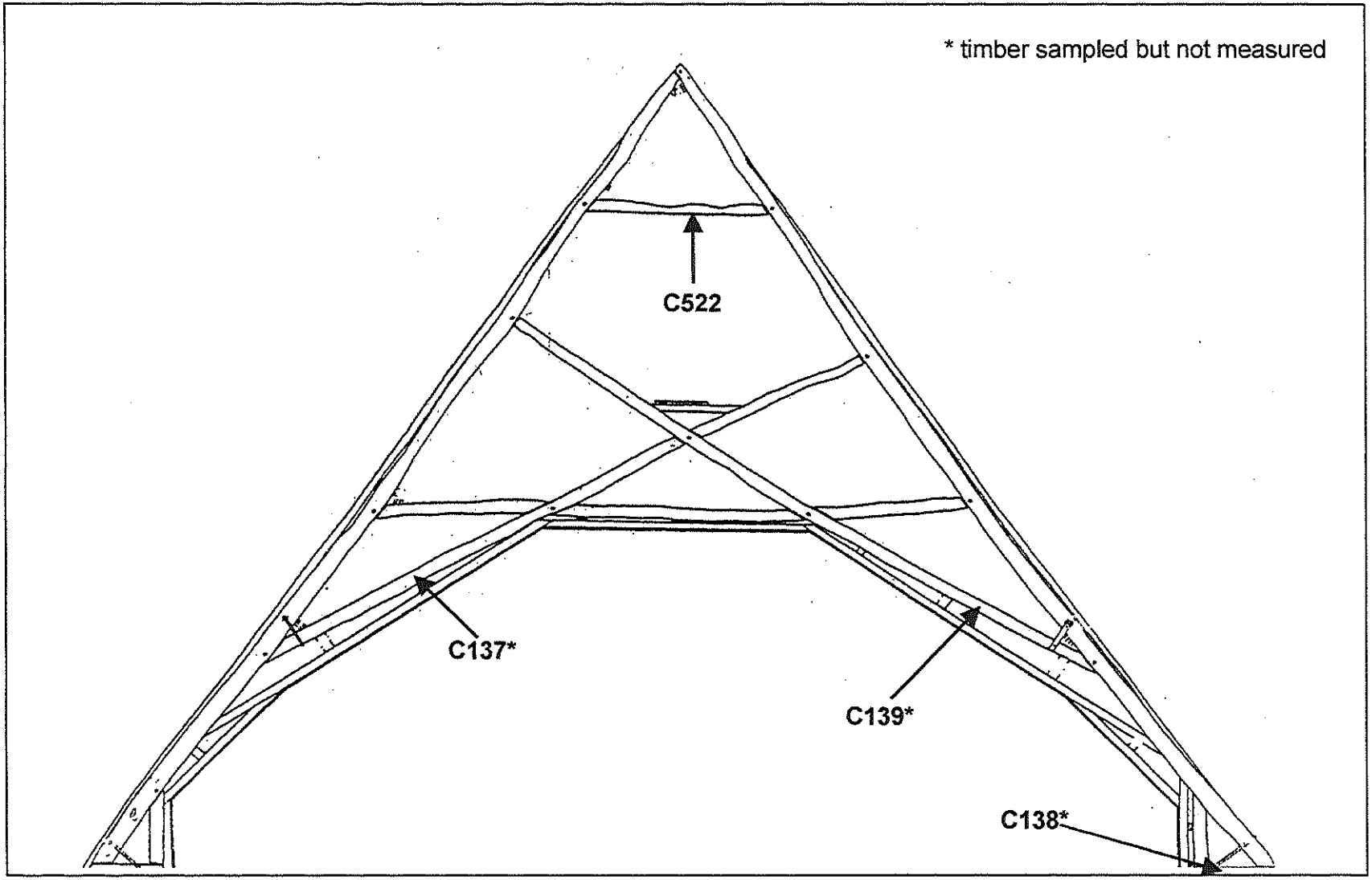


Figure 33i: Nave roof, frame 72 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

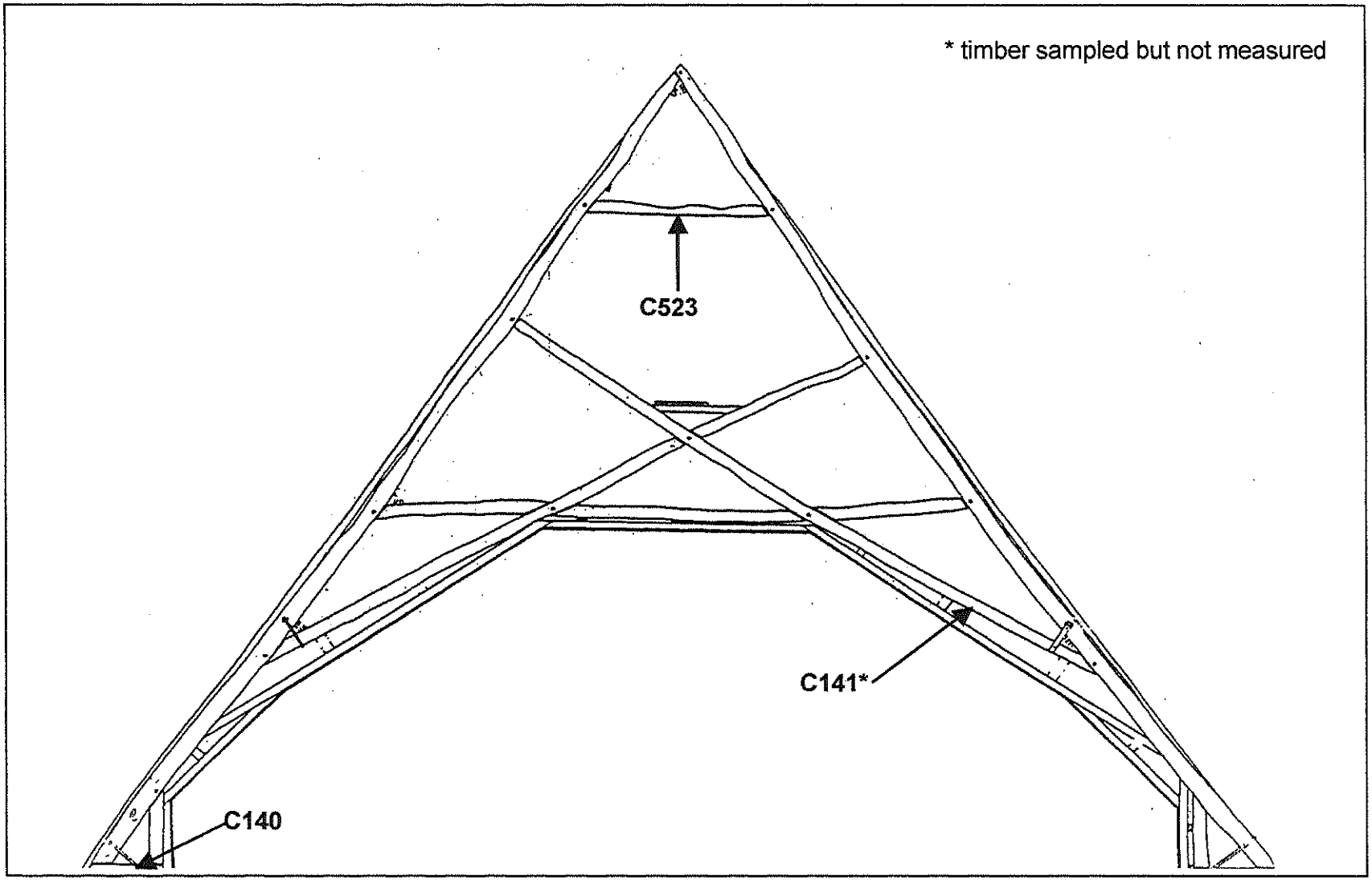


Figure 33j: Nave roof, frame 73 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

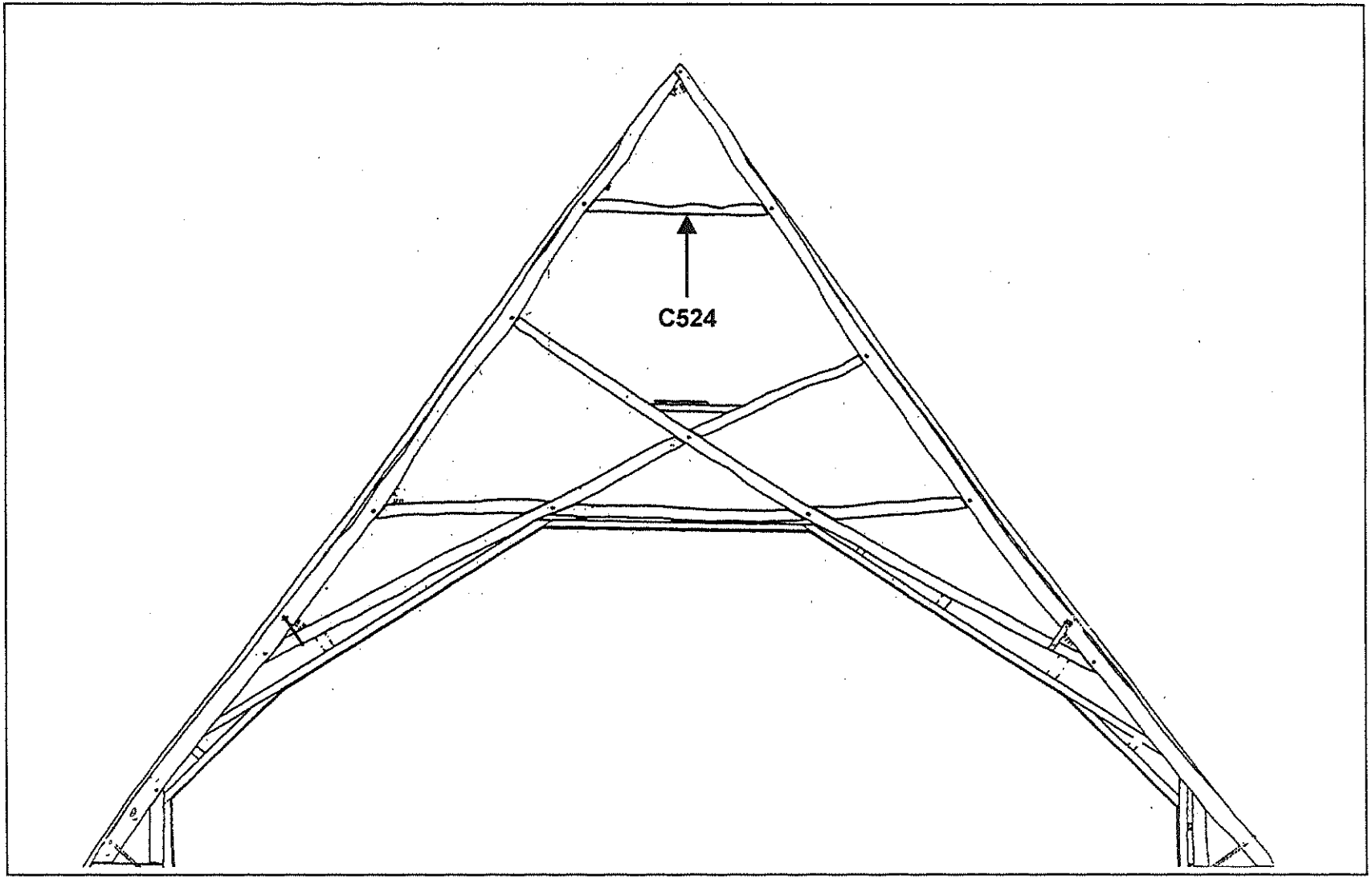


Figure 33k: Nave roof, frame 74 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

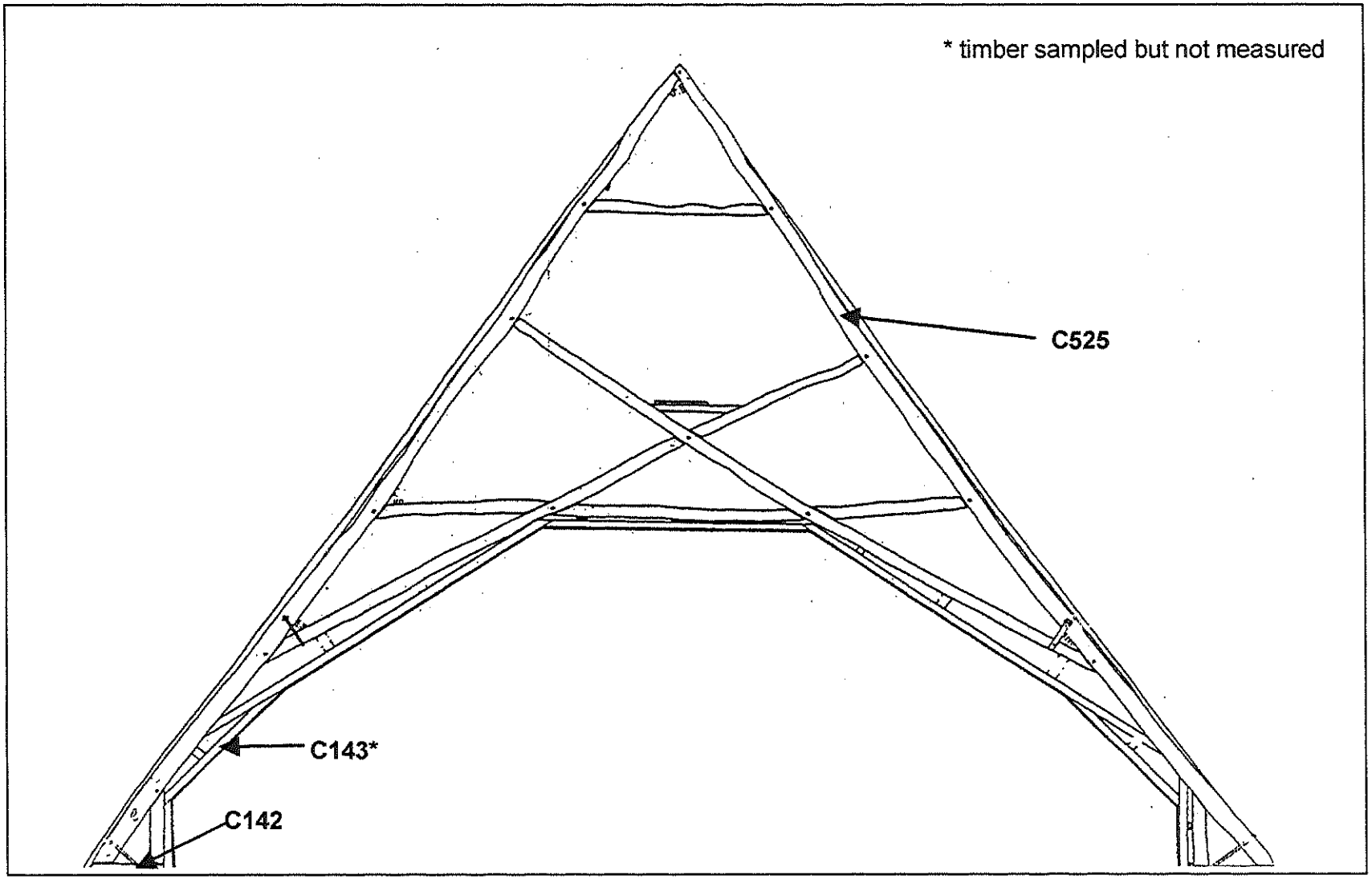


Figure 33l: Nave roof, frame 75 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

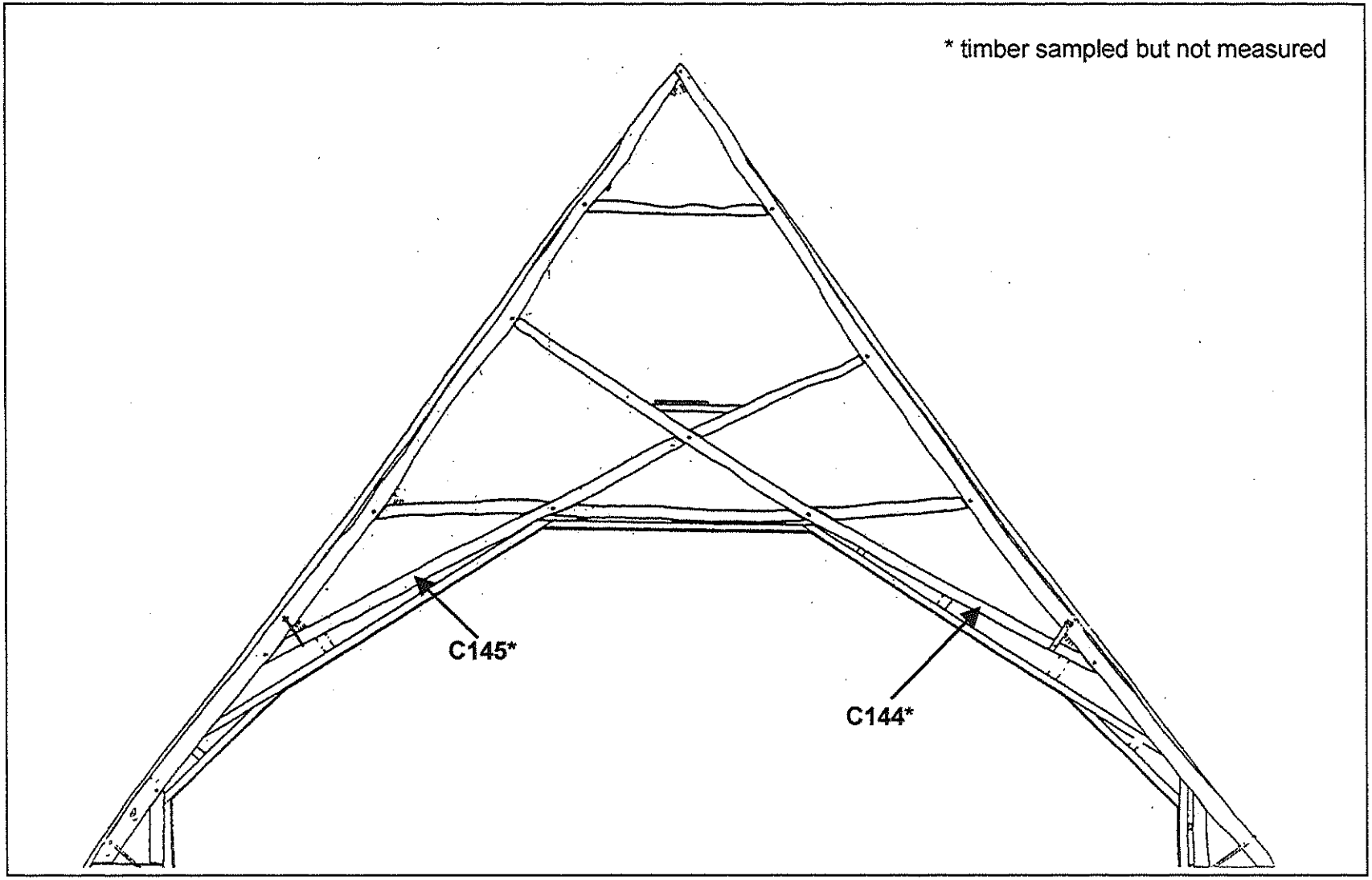


Figure 33m: Nave roof, frame 76 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

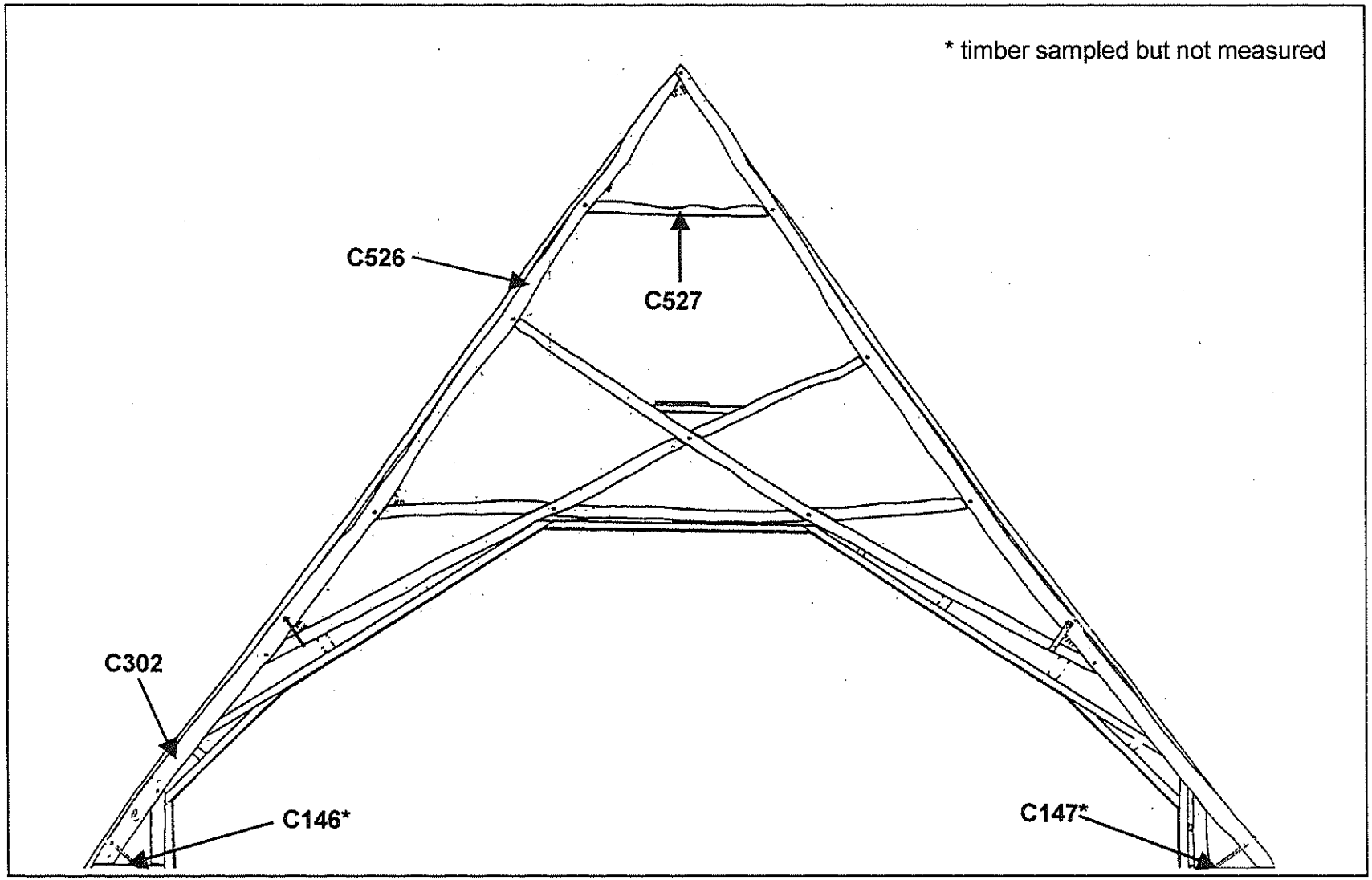


Figure 33n: Nave roof, frame 77 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

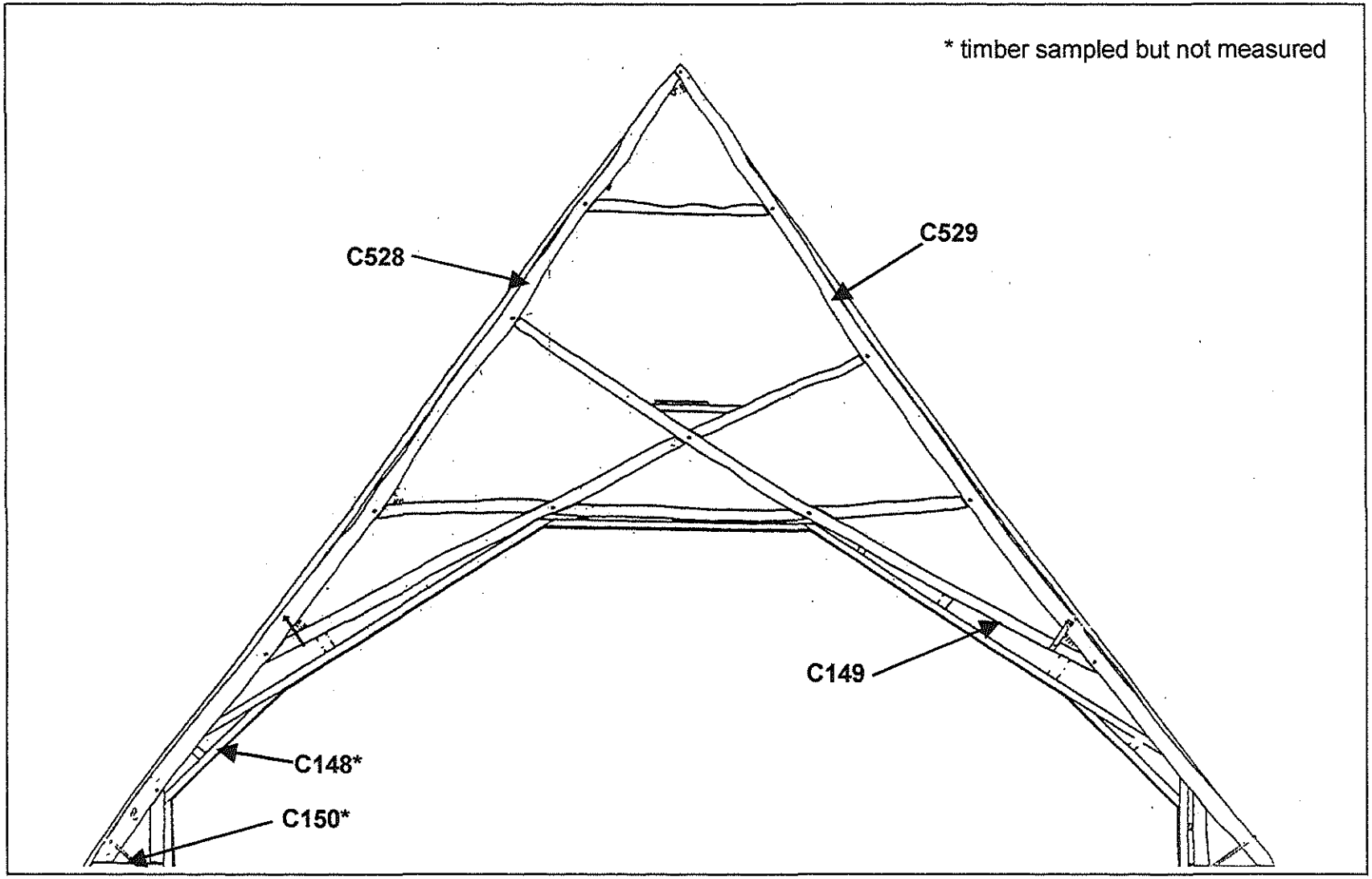


Figure 33o: Nave roof, frame 78 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

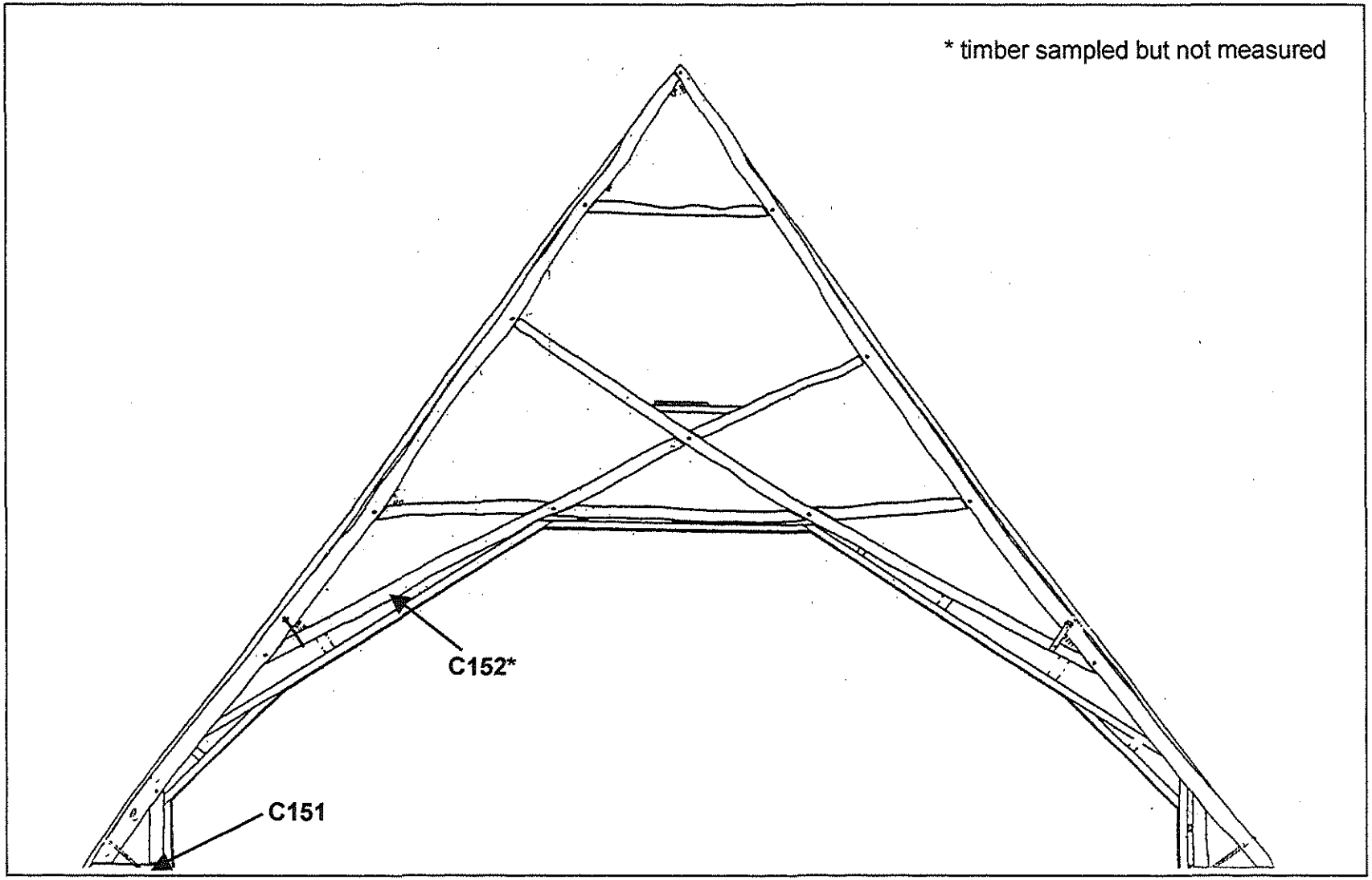


Figure 33p: Nave roof, frame 79 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)

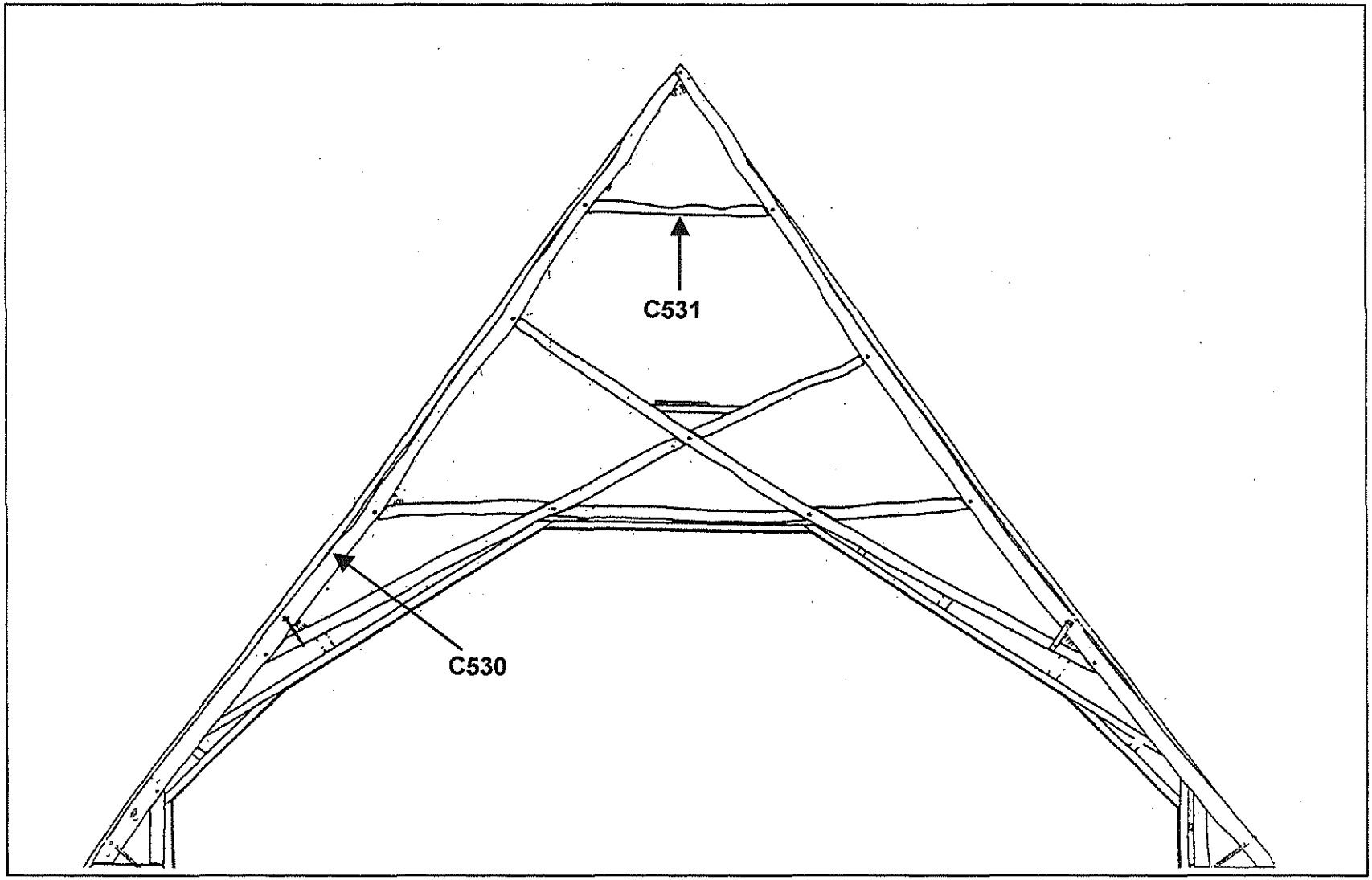
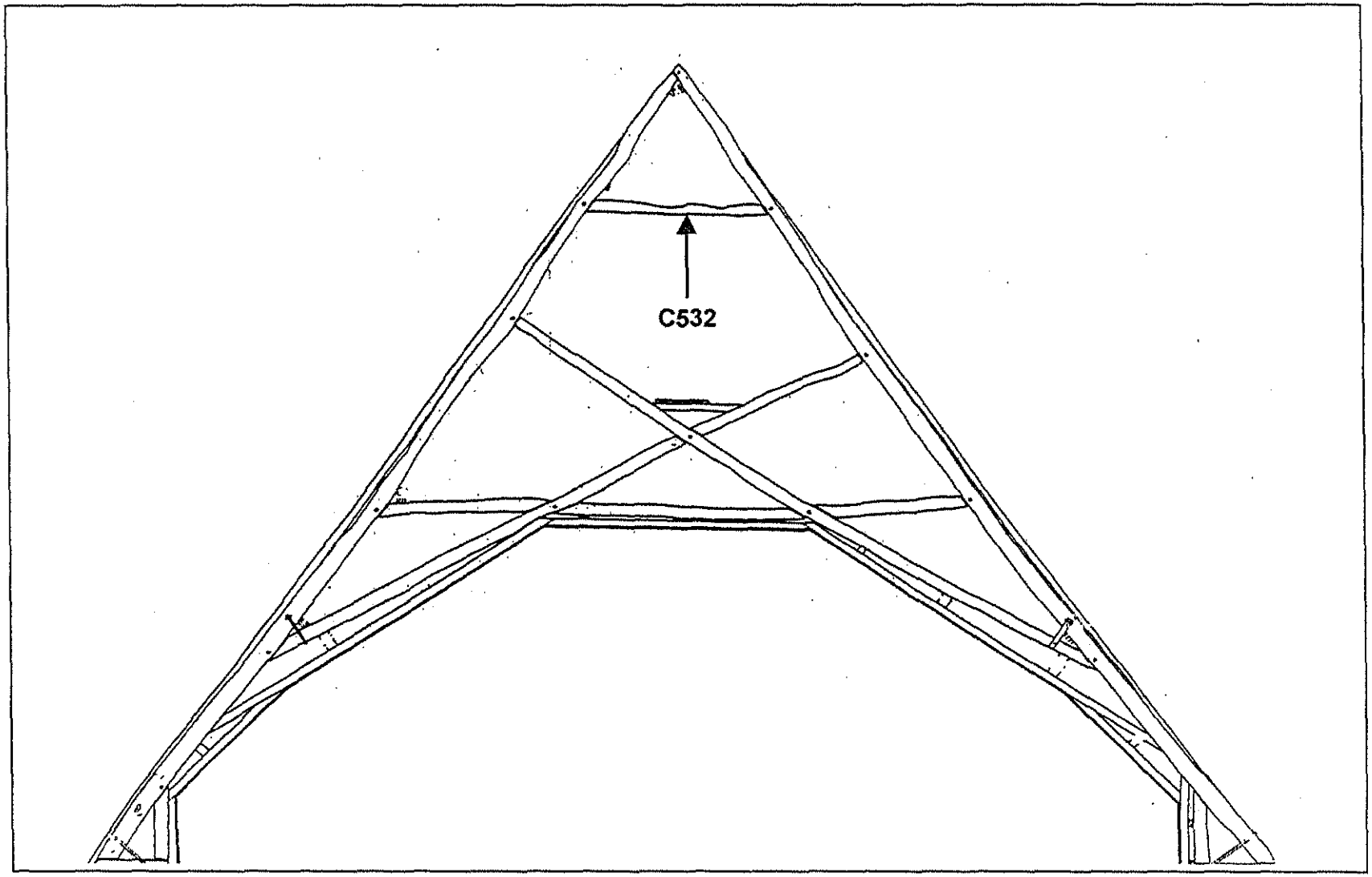


Figure 33q: Nave roof, frame 80 showing sampled timbers
(after Elaine Guilding)
(viewed from the west looking east)



Data of measured samples - measurements in 0.01 mm units

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130 74 239 207 176 130 162 200 118 67 124 145 74 170 202 144 92 127 141 108
152 105 125 106 88 128 135 154 116 87 95 62 77 88 96 82 68 84 88 108
84 68 113 101 84 100 72 114 85 93 103 57 73 105 74 72 73 45 52 34
44 73 82 91 128 118 100 106 106 176 148 178 169 137 198 191 169 122 151 280
213
ELY-C01B 101
149 67 105 171 155 169 127 122 98 66 68 55 131 66 90 128 181 139 137 133
134 84 234 215 185 138 170 203 108 67 127 146 75 179 204 142 89 123 135 112
170 119 130 105 91 132 127 155 124 93 80 67 98 89 92 80 63 101 94 111
83 72 105 101 86 96 82 109 87 87 114 56 82 99 80 70 69 52 46 44
40 79 81 86 138 116 83 119 102 185 178 188 180 132 186 176 169 114 161 262
210
ELY-C03A 97
246 228 247 227 147 121 119 190 186 195 217 204 161 173 225 174 189 177 165 287
183 168 169 182 203 382 283 220 173 221 251 186 188 211 234 221 166 145 132 213
371 326 196 125 150 118 145 134 90 101 80 80 110 125 115 141 159 154 179 159
225 152 191 160 206 239 207 156 138 174 197 368 287 131 180 167 163 69 74 174
122 124 102 74 74 128 131 112 110 135 120 79 114 115 133 131 98
ELY-C03B 98
194 178 129 135 119 224 201 206 189 232 171 206 255 143 192 229 191 297 213 168
199 179 227 211 220 217 196 189 133 158 202 223 195 195 224 221 186 182 273 210
238 175 180 142 156 124 126 143 68 88 122 144 164 168 190 201 207 174 215 195
226 155 241 283 367 294 268 273 175 263 200 130 217 175 175 82 80 90 114 145
117 106 111 171 194 259 297 437 389 229 364 293 283 257 221 199 157 278
ELY-C04A 230
268 186 87 125 135 169 133 107 154 110 101 146 149 169 151 64 83 114 116 122
156 113 133 165 118 121 121 103 104 100 88 97 94 82 97 68 114 158 122 154
86 109 75 98 107 83 74 77 99 85 79 129 102 135 115 83 97 105 124 88
134 70 113 125 117 122 103 101 113 102 113 102 111 60 66 54 56 61 67 92
112 99 79 64 81 78 77 68 84 70 70 76 68 109 127 90 68 71 65 70
40 80 79 70 62 65 59 70 53 70 72 79 81 71 71 49 49 62 54 62
68 45 51 42 47 37 41 51 48 49 47 54 50 42 50 28 38 26 42 32
29 45 22 38 44 44 31 36 29 38 37 37 32 32 38 33 41 46 42 38
34 52 49 35 48 40 41 50 35 43 37 34 42 29 54 55 45 49 35 49
46 49 41 38 51 46 40 40 36 39 46 38 38 36 38 41 42 52 48 45
64 41 42 40 29 36 33 32 35 41 44 39 47 38 47 45 58 49 74 44
66 52 49 44 45 46 71 64 60 67
ELY-C04B 230
274 186 96 118 147 162 138 115 142 112 112 137 154 172 158 79 92 113 125 135
167 124 142 168 117 122 117 110 106 96 86 96 81 83 98 74 111 161 123 157
83 107 81 89 102 80 81 74 94 82 79 121 79 134 126 80 87 99 114 70
138 69 113 130 125 113 102 97 115 100 104 82 107 51 63 57 60 66 61 93
103 95 76 70 79 77 74 68 90 81 63 74 71 99 112 91 71 62 73 76
51 71 80 72 56 65 60 66 51 62 80 73 86 68 72 45 55 63 53 60
58 52 44 41 49 44 49 39 50 50 46 45 50 47 56 37 29 24 34 40
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37 51 38 33 46 43 45 48 34 40 36 33 49 36 49 51 44 44 40 43
43 55 37 44 49 35 49 36 33 33 48 35 41 33 46 50 41 46 44 46
66 50 35 43 33 34 35 24 30 40 44 49 34 47 48 43 59 59 67 42
64 57 49 43 51 47 73 59 55 49

ELY-C05A 82
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137 122 85 128 70 109 92 77 134 138 106 99 78 103 127 151 173 233 164 310
146 147 76 69 37 61 58 179 125 130 200 108 150 173 97 136 160 138 128 94
127 109 91 87 98 125 117 101 67 92 190 185 201 83 92 133 175 165 165 121
169 162
ELY-C05B 82
222 233 254 345 246 178 308 209 228 228 222 232 269 307 166 158 134 55 172 195
149 160 112 141 93 111 110 89 150 147 100 93 94 98 131 180 187 239 181 322
159 156 96 77 44 65 63 170 145 140 196 99 146 229 122 171 164 145 134 105
133 108 90 91 98 125 126 124 70 99 209 196 197 98 83 131 200 176 177 137
177 156
ELY-C07A 98
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164 207 176 206 154 213 211 193 162 148 209 183 230 213 210 196 180 193 155 132
104 86 111 157 159 151 142 103 123 122 83 111 113 122 106 113 135 143 144 111
139 104 111 106 119 129 101 102 109 94 93 102 102 82 90 101 104 98 105 100
82 86 62 88 103 100 93 114 100 105 83 146 131 147 139 106 86 121
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167 203 167 196 140 226 202 177 165 166 210 185 218 219 207 203 165 197 151 124
100 80 115 151 165 144 158 101 111 117 97 108 96 137 97 109 132 144 146 108
137 105 114 110 102 121 95 105 95 92 96 105 98 83 92 95 109 87 114 69
79 75 64 84 113 106 89 106 104 110 80 148 128 154 128 93 125 126
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240 250 160 230 310 180 220 125 150 130 120 115 75 95 170 160 110 90 120 180
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80 80 70
ELY-C11B 120
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145 140 120 125 100 100 185 280 225 205 290 215 190 240 215 255 155 160 170 220
255 170 220 315 180 220 130 150 130 125 120 80 80 170 165 100 90 105 170 195
180 145 130 100 130 200 115 130 95 75 100 95 95 100 90 70 80 85 85 130
75 80 80 80 85 95 120 150 105 90 85 80 95 85 65 90 95 75 80 130
155 130 170 125 110 150 115 90 95 130 140 140 105 95 85 105 100 110 120 50
ELY-C12A 82
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205 169 169 161 176 206 217 152 203 132 167 147 192 229 229 162 129 90 57 54
52 54 92 120 99 182 174 154 84 101 131 213 250 156 100 90 119 128 111 198
164 153 116 50 63 71 126 120 113 132 74 81 60 61 89 90 109 193 115 142
135 110
ELY-C12B 78
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110 129 129 219 220 142 77 153 197 273 278 170 147 109 122 168 187 271 214 154
144 75 112 100 191 220 179 133 110 111 89 82 56 109 113 164 134 79

ELY-C13A 81
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126 119 19 140 260 209 229 215 140 137 133 136 140 154 83 115 104 100 123 180
163 266 437 312 256 285 236 231 217 134 199 174 112 165 178 197 156 128 153 137
200
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151 195 158 116 158 160 171 158 127 150 170 215
ELY-C14A 133
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139 14 127 14 142 178 159 155 156 104 112 132 64 141 150 109 164 142 156 145
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ELY-C16B 66
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131 121 74 90 106 134
ELY-C22A 136
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264 275 150 152 203 246 179 129 168 207 253 212 198 135 135 197 320 176 141 130
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ELY-C24A 207
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ELY-C24B 207
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137 211 116
ELY-C33B 70
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ELY-C34A 83
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242 187 209 159 191 176 120 254 246 238 154 125 96 88 86 92 107 158 150 132
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209 232 134 111
ELY-C36B 84
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225 228 147 77
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46 83 54 52 47 78 59 82 88 68 47 44 49 73 101 130 126 134 100 109
104
ELY-C37B 81
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169 88 40 42 82 81 80 63 33 57 39 45 60 76 104 72 75 75 66 54
50 79 58 50 46 79 58 84 91 75 42 39 56 71 98 130 139 121 107 98
135
ELY-C38A 83
241 216 200 314 271 246 298 239 297 291 272 214 282 222 219 165 200 211 230 265
219 309 286 143 116 114 201 252 266 192 134 108 184 189 247 238 283 185 212 256
115 67 62 196 124 98 118 172 188 131 174 92 155 159 180 241 156 109 103 90
154 182 138 83 83 82 88 58 73 73 126 119 161 118 128 150 169 185 134 76
84 58 99
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236 224 194 311 272 250 299 242 310 296 288 208 284 214 209 173 206 192 232 254
215 324 274 134 104 119 180 232 252 209 152 107 175 191 245 239 292 194 205 272
102 62 74 181 141 87 128 162 180 142 159 90 156 153 188 248 146 105 101 82
161 168 123 86 96 84 86 63 71 75 125 120 157 129 129 144 162 139 147 100
72 71 90
ELY-C40A 70
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68 128 100 123 131 91 45 72 102 115 76 46 55 85 66 40 46 48 50 91
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86 84 105 139 97 117 166 153 145 147

ELY-C40B 70
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84 91 87 124 110 114 132 165 169 164
ELY-C42A 62
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266 281 282 218 127 165 261 297 269 271 210 196 214 328 182 162 401 395 347
405 349
ELY-C42B 56
121 83 52 66 69 71 251 126 152 143 199 188 227 208 316 93 203 137 144 348
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ELY-C44A 74
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160 172 192 128 118 148 149 157 135 159 114 174 260 277
ELY-C44B 74
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158 175 196 113 117 149 157 153 138 145 113 168 289 264
ELY-C45A 83
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86 65 55 41 41 45 58 75 86 122 101 87 88 84 113 102 111 88 97 133
109 117 80 104 125 144 137 122 156 161 78 95 81 93 108 168 133 158 154 165
256 161 202
ELY-C45B 83
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112 111 80 98 134 129 147 130 147 157 82 82 75 92 105 165 124 152 150 161
250 182 168
ELY-C47A 98
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87 64 85 55 101 134 86 91 101 113 108 82 110 97 169 169 150 84 86 81
67 93 81 109 108 119 101 109 115 138 93 134 146 159 139 102 125 123 92 111
139 113 125 120 86 123 90 94 127 94 95 115 89 104 84 94 89 84 104 87
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ELY-C47B 98
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205 311 245 178 210

ELY-C49B 60
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279 278 184 103 83 81 121 172 134 182 139 123 110 114 112 211 314 264 193 256
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52 46
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107 141 113 112 122 118 99 116 88 54 92 96 99 111 150 110 138 175 141 160
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64
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ELY-C51B 68
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79 76 84 75 122 116 75 78
ELY-C52A 85
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ELY-C52B 85
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255 248 268 249 300
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ELY-C53B 133
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ELY-C54A 78
171 282 268 273 251 355 229 394 331 353 588 328 326 182 161 181 154 175 179 139
175 189 203 200 241 257 118 264 251 194 366 225 196 246 176 113 136 167 147 127
106 152 96 102 82 76 54 79 78 81 88 136 70 70 84 109 109 222 238 259
265 271 151 71 117 206 231 98 89 99 88 59 113 156 134 160 125 127
ELY-C54B 78
189 268 263 253 260 344 237 390 334 355 599 329 335 180 157 181 151 170 174 145
166 199 200 191 235 265 125 261 248 200 355 224 202 257 161 123 123 172 159 112
104 136 106 91 90 70 58 73 82 85 98 121 68 75 90 115 99 227 234 266
260 269 142 89 110 207 225 109 90 108 87 62 102 174 123 163 121 150
ELY-C55A 66
124 163 186 186 139 173 185 191 232 229 195 188 148 162 153 174 129 150 144 90
107 113 84 81 167 104 59 61 68 88 98 89 94 97 85 52 59 63 51 54
71 43 55 86 122 69 115 85 64 66 108 79 107 95 118 108 153 129 185 250
138 174 165 221 216 174
ELY-C55B 66
112 171 182 195 135 172 181 195 228 219 190 195 167 153 158 172 126 151 140 87
111 109 90 102 155 108 63 65 70 88 99 81 96 87 89 55 55 66 52 58
62 56 44 94 112 63 103 86 64 71 99 69 116 101 116 111 131 137 179 244
133 173 162 226 216 177
ELY-C58A 82
175 503 488 605 418 254 479 501 467 515 421 289 312 155 310 177 182 234 226 246
264 201 281 244 235 326 310 295 174 279 215 215 289 167 198 270 216 146 160 208
132 129 150 298 204 202 201 208 183 220 142 198 252 258 164 220 171 215 195 237
258 351 283 255 193 205 197 198 268 181 254 171 186 141 148 180 142 226 163 167
206 220
ELY-C58B 82
181 500 485 601 376 231 440 506 489 527 414 276 297 163 317 192 170 224 246 232
263 195 290 256 237 324 306 299 176 270 232 209 289 162 200 269 208 170 148 205
122 150 140 297 205 195 194 199 184 205 144 190 252 267 158 233 173 211 174 238
259 351 273 256 194 198 232 187 250 191 250 158 179 141 147 189 136 240 144 167
203 243
ELY-C65A 81
138 185 54 44 52 29 42 35 68 69 82 110 161 181 324 84 62 57 131 154
202 202 179 179 165 112 95 181 255 271 495 320 286 163 200 100 134 379 314 271
220 199 126 86 100 145 191 190 154 177 163 85 174 141 314 220 146 146 167 116
133 402 207 169 128 127 237 355 335 200 119 131 179 259 484 377 195 96 120 159
226
ELY-C65B 81
135 170 52 49 61 32 55 35 74 77 100 116 159 175 323 81 69 54 97 150
198 187 191 169 150 88 92 159 243 232 457 324 294 183 215 111 136 399 275 255
237 173 127 96 107 193 169 181 154 179 194 92 189 130 350 223 132 130 130 108
121 330 191 180 123 124 314 382 303 210 120 124 160 303 473 364 174 138 96 144
222

ELY-C67A 66
114 228 280 228 307 411 357 447 441 428 304 265 240 292 328 397 371 330 190 104
224 249 255 229 301 242 281 269 308 184 223 211 294 159 289 183 182 144 171 108
165 220 234 287 150 63 56 47 48 64 83 127 130 133 53 46 57 58 145 33
61 61 68 77 100 117
ELY-C67B 66
142 115 227 266 225 312 411 361 413 440 443 299 265 247 271 329 393 365 322 191
115 213 245 247 228 301 244 272 268 309 194 224 204 282 163 289 196 165 144 186
110 165 242 220 291 143 69 41 49 71 67 109 140 146 149 52 53 59 56 152
66 55 48 65 90 114
ELY-C70A 55
407 447 327 322 398 291 125 125 179 262 167 231 183 191 94 161 237 276 337 163
73 89 164 200 171 217 235 185 236 135 310 456 310 214 237 163 122 212 128 102
75 190 242 267 258 171 195 184 218 225 431 310 286 286 250
ELY-C70B 55
407 447 327 322 398 291 125 125 261 194 364 305 291 210 184 192 287 316 158 100
108 143 232 174 246 260 193 233 90 178 232 215 170 220 135 97 187 100 58 51
125 185 202 246 192 222 196 222 257 479 330 358 306 281 259
ELY-C71A 87
264 271 151 311 320 416 337 276 247 203 218 201 204 205 155 133 223 176 186 121
195 203 166 316 196 186 213 168 166 162 231 214 162 165 304 195 180 155 157 135
175 124 160 188 216 116 141 144 158 160 193 255 336 304 317 203 137 208 304 198
157 166 165 160 125 155 191 157 229 163 249 204 225 195 363 279 283 337 353 466
303 266 229 287 179 186 201
ELY-C71B 87
253 276 154 323 310 401 318 265 241 202 228 222 213 192 174 136 213 168 171 116
209 187 167 277 187 181 217 154 143 159 239 208 160 178 279 190 177 156 160 130
182 114 164 182 201 111 103 140 167 165 191 274 338 311 298 216 127 224 289 206
158 157 163 149 125 160 182 157 221 167 246 205 257 178 351 291 271 353 324 472
294 281 243 288 181 216 162
ELY-C72A 153
185 99 78 88 103 109 117 135 119 85 146 116 98 101 113 91 110 117 132 63
78 85 90 99 113 102 87 85 68 69 89 94 101 77 89 76 58 74 61 104
94 127 94 131 110 95 104 123 93 75 116 95 122 115 139 191 79 111 62 116
119 122 146 129 121 97 97 97 108 188 176 146 198 127 184 148 125 119 101 126
109 99 145 132 166 103 114 110 126 98 160 108 109 93 84 128 101 106 136 150
144 102 101 121 96 93 118 96 82 109 103 89 92 82 55 79 65 77 91 142
172 281 238 191 182 250 173 155 124 166 185 149 185 140 158 137 114 107 142 163
168 93 137 191 159 193 141 147 162 176 183 129 207
ELY-C72B 148
157 88 144 152 108 188 105 117 135 156 129 157 121 129 60 79 51 73 96 104
97 88 89 58 87 77 111 90 78 101 88 74 97 93 117 84 138 96 118 88
91 75 114 77 94 78 105 100 113 97 97 95 123 102 76 109 66 71 108 87
73 80 65 84 113 99 87 90 71 79 83 85 79 87 92 101 82 104 168 143
101 85 104 107 91 92 91 98 80 56 104 101 105 90 80 101 72 69 87 87
79 78 88 77 105 75 91 57 90 52 61 68 77 66 101 91 98 129 126 110
162 118 134 132 120 152 144 148 128 125 125 66 120 135 104 129 97 108 177 141
142 156 152 112 125 189 130 150
ELY-C74A 70
61 129 146 239 210 279 246 235 157 177 176 120 102 130 170 172 215 158 100 97
57 53 52 43 79 84 118 158 96 60 54 114 121 59 95 145 136 99 79 70
55 113 92 138 84 109 127 108 142 160 66 88 87 87 78 72 80 107 115 110
53 71 58 107 107 87 80 97 80 200

ELY-C74B 70
85 127 147 242 214 289 240 234 158 182 178 119 107 121 168 171 228 152 104 96
54 61 47 39 82 80 117 168 83 59 64 116 126 78 83 156 116 88 79 64
54 102 91 141 74 110 117 111 138 164 81 81 91 88 69 76 94 93 111 115
70 60 68 99 88 109 73 102 80 212
ELY-C80A 69
178 183 147 52 37 28 86 153 144 159 118 130 128 269 299 244 235 471 499 313
290 252 202 232 163 245 264 193 133 152 300 246 129 127 201 300 212 323 212 226
215 143 221 181 175 133 171 135 174 198 118 96 93 57 46 118 107 139 166 125
55 60 62 86 96 83 79 111 147
ELY-C80B 69
212 178 150 52 32 30 93 139 142 162 122 126 125 263 319 249 232 412 468 292
315 254 193 209 157 229 256 210 129 158 286 236 126 129 193 303 201 324 210 219
204 157 227 178 173 134 170 128 178 210 114 80 94 59 50 119 106 135 147 147
54 57 69 75 105 80 75 124 151
ELY-C81A 62
175 261 226 254 269 259 240 277 242 237 193 161 220 128 84 101 123 179 174 135
244 111 118 140 167 167 178 171 250 233 205 112 141 132 183 132 249 225 281 179
181 124 172 235 198 188 176 73 58 67 63 100 136 123 170 137 129 80 71 55
66 75
ELY-C81B 62
167 258 225 247 275 255 267 266 225 229 194 155 241 128 89 99 132 177 170 141
244 103 109 142 169 165 181 153 252 237 205 116 144 125 182 129 259 220 271 195
168 137 154 237 211 185 177 83 60 59 50 108 135 121 167 136 142 65 73 56
88 93
ELY-C84A 76
304 350 271 171 252 270 320 306 292 220 276 258 232 124 226 198 213 257 193 226
191 190 97 117 89 80 127 140 137 100 127 101 139 147 182 141 135 154 104 84
116 77 53 66 63 98 94 142 106 94 134 121 109 106 131 146 97 88 101 93
118 108 100 70 71 61 54 50 73 68 68 77 51 69 63 66
ELY-C84B 76
304 368 265 172 247 282 365 270 303 209 271 257 216 124 236 172 171 240 200 237
206 195 84 99 99 92 134 157 142 91 119 103 128 164 206 152 159 153 87 112
110 80 45 72 70 101 123 140 90 83 136 97 120 107 117 153 122 101 74 104
122 110 119 58 56 66 54 60 83 49 71 77 44 47 64 81
ELY-C85A 63
197 221 170 20 256 327 271 321 233 249 337 342 383 268 264 302 291 113 173 152
150 169 299 171 173 183 191 263 255 186 238 369 302 280 264 292 332 234 194 197
219 251 429 278 206 312 239 239 249 241 267 205 244 322 303 434 430 422 299 367
341 314 357
ELY-C85B 63
191 198 210 239 259 352 301 343 270 265 342 366 389 271 259 316 316 107 173 179
191 223 30 188 230 209 224 237 239 160 247 342 289 315 295 328 367 206 194 225
233 237 477 278 222 317 227 229 296 248 280 208 235 276 326 424 413 398 260 334
330 302 313
ELY-C87A 95
158 188 268 268 130 313 389 274 364 205 113 171 129 283 147 81 135 119 149 125
135 144 169 138 161 185 200 131 199 165 146 268 226 165 253 198 140 148 210 219
176 137 96 131 148 171 188 141 141 108 126 157 229 97 74 170 169 143 199 252
268 242 232 195 167 344 276 316 220 140 242 186 119 234 242 248 287 232 225 182
201 146 284 260 437 249 232 289 165 192 248 258 179 196 320

ELY-C87B 95
170 205 264 275 126 327 387 285 355 206 118 186 117 282 145 95 130 122 148 118
136 138 171 137 155 183 202 128 195 173 132 282 215 170 252 203 134 144 216 222
185 145 100 140 145 184 187 140 129 111 121 160 237 98 77 159 174 144 202 246
276 240 221 197 182 332 285 305 221 139 252 178 131 222 241 248 280 229 250 175
209 142 281 258 419 257 221 292 171 194 253 247 179 209 321
ELY-C88A 116
94 101 96 175 224 163 181 133 133 97 214 241 161 127 160 202 197 158 170 218
222 221 101 108 85 91 150 127 203 159 143 122 102 82 53 52 44 84 109 155
157 101 113 66 71 59 52 52 57 65 77 66 62 85 68 118 117 114 136 163
137 100 94 78 71 59 62 77 86 116 94 96 103 102 83 91 102 117 116 123
138 187 186 183 141 185 121 193 188 225 239 222 212 175 192 251 170 144 136 187
236 239 186 182 193 167 101 116 78 79 75 87 83 88 111 119
ELY-C88B 101
174 194 138 261 249 230 237 131 92 64 51 48 84 88 114 134 135 146 113 84
75 59 71 47 67 93 77 64 78 46 78 107 93 78 89 81 47 49 36 39
52 36 46 47 62 37 64 47 44 67 50 64 80 70 83 66 112 110 88 69
84 68 94 123 141 162 184 164 161 202 174 137 88 127 105 145 165 118 205 189
189 119 151 96 102 124 132 91 145 154 187 173 151 183 137 151 130 165 140 152
90
ELY-C91A 85
494 460 376 384 364 323 286 340 333 292 210 259 277 240 257 169 201 128 94 101
156 148 185 153 243 167 277 128 268 223 252 92 73 99 126 90 191 213 308 156
191 132 168 195 274 316 205 125 87 58 79 138 151 120 202 206 268 171 185 220
300 170 153 175 195 178 185 217 248 229 175 223 281 327 309 323 381 236 237 257
233 203 185 190 201
ELY-C91B 89
493 477 444 456 377 285 288 275 239 249 268 266 214 215 268 303 271 250 179 221
127 86 73 130 133 149 116 176 157 257 134 238 240 237 93 89 108 118 80 200
226 318 136 185 131 179 206 298 380 208 110 66 43 70 100 141 136 192 184 270
203 234 222 342 218 166 205 246 283 261 323 264 307 179 189 253 280 240 231 289
225 183 202 196 218 185 165 186 227
ELY-C92A 68
314 276 333 256 186 208 241 381 448 361 285 328 241 212 141 236 177 124 102 161
137 151 141 204 174 212 90 179 179 191 81 95 89 91 58 155 229 229 195 226
142 198 208 205 282 170 128 90 106 122 148 158 190 245 254 211 144 164 194 336
220 143 145 231 142 208 221 199
ELY-C92B 60
253 300 361 339 416 376 269 350 279 249 176 224 170 139 133 218 182 224 168 219
157 213 97 193 226 249 123 93 144 132 98 167 278 272 188 151 153 174 279 268
242 170 181 72 95 109 142 176 215 261 324 286 210 199 127 369 311 125 180 101
ELY-C93A 80
382 198 231 151 221 159 118 109 128 145 99 112 203 230 151 168 225 249 144 232
178 220 244 205 240 257 156 135 146 177 141 124 115 258 208 190 218 244 193 273
162 237 303 344 146 180 212 239 157 254 269 299 267 264 165 174 178 250 270 177
200 206 213 156 203 360 245 203 161 238 195 133 129 185 188 202 204 230 202 225
ELY-C93B 80
373 201 224 178 228 156 112 116 131 137 102 116 199 234 149 165 232 249 143 230
186 226 238 180 230 267 156 131 143 154 148 120 123 266 202 187 234 241 191 297
159 244 290 373 144 176 215 239 153 252 262 320 286 262 168 159 196 260 275 177
232 203 205 149 226 344 225 210 162 188 197 142 137 162 171 195 207 222 216 244

ELY-C94A 84
124 210 286 220 334 317 331 316 231 234 155 241 239 204 259 198 163 231 201 217
113 252 175 119 277 133 133 246 147 122 143 244 184 150 165 303 140 173 179 180
121 143 78 142 133 125 81 131 91 105 91 64 68 177 202 179 182 97 93 112
108 157 78 94 109 99 50 106 91 104 122 114 84 99 68 63 139 87 116 95
114 133 78 127
ELY-C94B 84
122 201 282 200 298 292 383 307 242 230 159 221 223 211 259 186 164 235 218 208
102 262 160 136 267 135 135 247 127 116 126 240 185 146 161 309 140 184 173 195
109 161 82 131 115 151 71 126 113 100 80 61 71 179 198 187 175 115 94 114
93 151 88 92 120 84 56 112 87 102 123 106 99 96 62 60 139 93 112 98
115 126 77 108
ELY-C95A 85
334 441 483 354 407 396 252 197 219 181 266 318 313 276 240 141 160 182 200 208
216 140 141 232 190 190 156 150 207 184 226 176 229 218 250 236 182 291 284 320
245 234 368 376 291 322 443 383 336 306 233 192 269 214 242 242 217 127 136 139
175 152 187 141 149 139 109 104 117 100 53 83 87 76 76 93 114 78 92 89
111 86 84 85 111
ELY-C95B 85
326 447 484 336 425 374 240 202 227 188 226 315 321 260 248 129 162 191 183 213
222 147 135 235 182 201 155 155 186 204 217 172 237 230 236 241 181 289 295 324
243 232 368 374 300 315 449 367 337 303 256 200 260 221 241 234 210 128 130 129
163 204 153 157 154 121 132 92 78 105 71 69 90 91 77 76 100 79 97 79
91 76 93 82 122
ELY-C96A 62
407 470 509 511 354 420 409 386 393 321 341 247 241 251 190 181 223 292 341 359
381 692 421 472 103 102 207 309 229 238 236 271 256 301 149 240 105 139 139 114
81 53 57 116 79 112 148 161 105 231 60 107 156 178 198 184 147 143 125 279
360 337
ELY-C96B 62
420 510 489 490 304 422 396 360 385 405 374 268 245 258 190 179 221 277 331 353
393 694 420 482 94 111 195 317 228 252 228 265 259 310 155 247 89 147 114 128
108 77 73 81 72 114 151 158 125 211 57 89 163 226 203 172 165 122 124 290
352 323
ELY-C102A 75
186 303 236 326 267 215 346 229 279 282 239 217 240 255 252 207 216 172 286 188
156 281 153 178 225 138 110 130 131 101 122 155 253 119 159 177 206 157 253 111
153 194 247 109 190 182 165 165 135 265 258 255 267 156 114 113 142 119 112 128
142 144 76 88 142 122 157 117 173 101 81 58 99 106 127
ELY-C102B 70
182 321 244 379 258 186 344 235 302 277 251 278 287 266 271 256 190 146 250 162
142 275 139 177 221 138 114 126 141 105 127 157 264 97 186 194 192 141 264 105
174 170 215 105 174 184 173 146 104 264 235 201 259 163 133 125 146 134 132 164
152 128 71 98 138 113 162 117 184 125
ELY-C104A 95
475 449 419 352 342 307 284 245 324 184 241 194 162 270 238 183 181 213 205 139
126 108 132 142 122 209 172 193 134 119 193 162 177 115 219 265 192 234 156 151
231 160 121 121 170 166 149 121 156 170 146 90 104 87 99 131 128 124 100 78
101 106 128 110 153 115 122 76 114 151 133 99 85 111 142 100 78 102 166 133
120 103 74 89 101 131 97 112 143 72 108 94 112 89 84

ELY-C104B 86
137 127 107 134 146 123 207 178 196 134 117 195 163 175 119 215 261 194 235 156
139 192 119 144 95 185 193 139 137 216 216 145 122 74 84 110 183 165 175 159
89 84 155 168 102 154 123 164 172 116 146 126 169 112 191 227 172 160 161 238
186 152 129 94 118 111 127 124 147 141 117 112 108 110 101 105 87 70 84 100
109 103 86 98 78 138
ELY-C105A 86
187 278 202 333 239 226 296 244 379 203 167 229 217 213 240 195 239 259 224 196
156 164 134 286 185 163 350 208 225 270 213 170 147 216 198 209 190 424 208 219
227 261 163 253 137 165 238 254 125 203 161 214 172 223 427 440 321 279 173 99
170 263 257 161 208 258 196 88 124 202 145 176 117 216 130 104 90 177 128 149
140 159 131 131 57 156
ELY-C105B 86
202 280 207 346 239 219 298 247 374 196 167 228 225 222 235 200 240 268 223 198
164 168 140 296 179 161 344 209 221 254 224 162 146 216 196 200 187 416 204 232
227 250 167 263 132 151 247 264 116 207 155 219 167 226 425 439 317 280 177 109
160 252 258 164 213 264 190 97 124 195 132 182 114 222 121 110 93 174 152 159
151 159 143 103 79 117
ELY-C106A 91
288 147 143 90 130 115 140 210 281 222 241 213 252 270 173 211 219 218 278 170
260 337 266 168 137 70 95 138 172 113 106 152 145 152 125 98 146 193 219 173
179 155 234 205 217 273 327 315 191 154 192 251 231 251 356 289 293 276 301 174
219 244 300 342 464 254 261 199 301 217 166 152 160 149 104 89 116 96 64 88
58 82 88 82 85 85 134 72 129 135 134
ELY-C106B 91
275 156 132 100 126 114 140 210 269 214 265 254 272 252 209 214 236 197 292 193
277 341 271 131 137 79 83 137 183 118 109 155 131 142 133 96 141 200 222 166
166 160 213 204 205 273 331 309 193 151 189 257 234 257 345 293 284 280 297 178
206 248 292 346 474 264 271 194 295 226 170 171 168 145 114 94 132 97 69 59
59 95 85 86 110 43 131 80 115 144 139
ELY-C108A 86
306 407 524 419 350 300 285 344 357 319 440 398 318 286 195 60 108 181 233 315
121 131 72 129 185 202 245 382 297 231 336 193 103 66 94 162 99 174 203 95
83 76 50 85 139 160 133 103 99 91 80 159 202 122 77 85 115 70 64 52
101 137 143 107 123 114 85 147 220 118 74 88 87 120 136 140 161 133 71 137
129 86 102 130 98 95
ELY-C108B 86
324 415 503 424 339 344 290 358 344 330 444 402 316 282 198 75 97 178 236 318
122 134 67 120 192 202 242 384 297 235 337 223 87 72 83 149 101 170 191 109
57 68 53 76 114 149 119 93 104 75 101 162 194 133 104 81 105 68 55 76
100 153 115 122 100 109 75 168 211 120 100 120 88 116 138 136 156 143 80 98
155 97 136 98 95 77
ELY-C109A 156
166 172 186 104 124 135 137 140 144 120 83 113 102 92 74 73 54 79 166 149
120 173 99 101 107 221 161 159 171 200 146 62 59 105 186 203 251 208 177 201
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135 111 181 151 173 167 155 97 208 357 317 297 232 168 270 118 122 161 124 163
168 230 267 205 218 164 235 240 235 226 192 182 148 128 101 118 156 118 131 135
107 132 168 104 105 64 101 75 120 119 131 122 138 148 136 146 135 126 165 142
187 129 110 135 179 123 134 120 82 118 95 107 78 65 74 100 74 61 70 63
71 90 93 96 116 100 79 116 115 112 86 89 91 91 113 135

ELY-C109B 116
141 153 177 176 153 141 81 114 125 175 182 130 135 89 166 102 196 189 218 221
252 141 55 57 79 141 179 253 229 183 192 110 168 87 64 40 42 70 152 167
226 238 151 142 146 173 198 198 214 241 245 105 187 190 145 142 146 165 82 139
134 146 108 108 117 195 125 80 102 81 115 123 205 210 185 191 117 143 131 191
190 198 166 134 112 111 157 233 165 151 170 104 153 159 115 113 72 86 86 148
94 147 131 130 114 152 108 97 138 145 150 183 120 93 115 124
ELY-C110A 80
232 250 205 166 218 195 173 118 155 155 173 114 118 121 126 129 138 140 128 172
143 169 168 195 198 219 204 172 127 124 111 150 159 194 257 263 225 233 207 384
364 257 166 171 167 122 99 146 122 168 113 171 180 162 158 176 159 139 125 114
118 126 149 135 154 176 172 133 141 137 160 97 140 105 124 126 149 132 135 107
ELY-C110B 100
294 124 84 74 54 82 118 164 199 172 216 192 200 331 314 236 228 159 216 233
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150 205 167 178 184 357 338 347 347 246 153 162 131 174 159 223 276 258 205 184
217 360 408 315 200 196 168 159 141 169 159 209 145 218 279 227 271 241 197 174
156 134 137 170 166 169 177 232 201 125 129 148 176 113 134 123 113 176 178 158
ELY-C111A 113
277 166 206 354 404 227 282 493 376 702 477 386 176 307 491 249 321 265 178 96
81 194 105 101 226 215 133 252 240 170 326 244 137 91 106 85 67 113 168 146
135 280 267 148 188 108 112 346 270 266 212 196 166 354 434 216 127 170 220 186
305 134 208 376 190 195 120 366 212 116 112 351 133 149 143 58 72 114 63 110
122 120 82 127 135 97 136 144 155 312 119 182 111 118 96 118 228 148 182 109
127 139 114 118 64 103 74 93 91 128 76 67 129
ELY-C111B 113
274 158 214 365 391 228 279 483 391 691 502 371 179 288 500 222 291 293 214 92
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153 283 262 143 197 123 105 403 278 258 197 190 186 347 435 236 112 166 222 195
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126 127 90 129 136 102 135 143 160 326 133 180 102 119 102 126 224 165 157 121
133 127 133 100 77 99 88 81 86 119 65 83 114
ELY-C115A 165
67 58 78 38 35 38 38 75 108 66 68 36 78 68 101 74 103 90 146 117
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50 52 49 50 58 40 57 41 53 63 53 37 41 63 65 93 53 42 36 56
73 67 57 49 44 79 70 82 76 83 81 95 64 60 46 27 41 38 63 61
52 52 50 53 74
ELY-C115B 165
22 40 84 22 29 24 34 66 96 70 42 35 81 66 89 75 104 92 145 131
142 123 155 125 107 196 130 115 114 104 79 59 78 77 84 86 112 130 82 101
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53 45 57 60 52 44 60 32 53 63 66 37 44 56 67 76 58 49 31 49
74 67 61 43 43 80 68 87 83 79 74 83 74 60 49 39 27 46 70 53
51 49 53 57 55

ELY-C118A 77
168 236 302 370 380 256 255 314 266 210 227 212 216 221 147 245 134 152 102 193
163 170 236 194 194 268 135 145 153 234 237 185 193 282 176 173 159 154 91 110
93 134 148 249 128 178 135 113 109 157 190 274 347 282 145 145 140 178 139 104
105 84 89 91 94 121 112 125 148 143 172 144 103 170 135 167 166
ELY-C118B 77
217 208 289 374 387 224 226 342 262 190 212 194 210 215 158 274 136 151 96 202
151 167 214 174 195 289 134 150 162 228 227 199 194 262 180 166 164 156 96 114
82 134 154 244 106 176 138 108 116 153 199 273 348 285 136 148 130 161 160 111
123 82 77 94 95 116 111 132 138 144 184 122 108 176 127 173 158
ELY-C121A 63
193 131 222 206 265 237 193 223 232 358 365 330 208 455 446 411 416 336 364 368
375 359 385 372 227 222 280 372 344 262 296 277 201 122 66 79 144 144 197 213
187 164 99 102 102 91 67 68 86 82 71 56 57 80 76 75 78 53 78 43
70 54 59
ELY-C121B 63
200 132 236 212 271 241 185 216 223 334 375 336 201 418 420 394 402 336 388 387
369 350 395 361 234 215 267 346 341 251 305 291 206 119 74 71 148 142 229 231
210 175 104 92 109 95 63 67 79 95 70 47 58 89 75 69 83 55 68 55
60 55 63
ELY-C129A 61
150 250 335 274 339 381 437 255 252 318 354 268 198 172 157 161 126 173 210 219
225 83 120 140 103 86 125 132 113 126 101 82 103 82 82 76 114 109 88 87
131 97 158 163 132 132 105 102 134 141 119 117 160 131 151 180 184 69 96 107
141
ELY-C129B 61
161 231 363 295 311 423 454 257 259 309 358 259 191 188 162 144 131 161 234 210
234 98 113 127 92 88 114 140 126 116 116 96 83 97 94 80 122 104 94 74
132 98 144 178 154 141 105 103 135 145 113 104 171 147 151 169 216 77 91 110
121
ELY-C133A 185
165 160 92 84 104 128 147 153 165 161 152 106 99 100 105 141 279 241 228 185
110 113 91 160 83 70 131 136 184 158 173 194 154 179 92 54 36 48 67 101
123 192 163 114 146 89 94 42 49 50 62 98 145 108 89 102 97 100 101 106
101 118 136 102 76 80 117 104 95 111 98 130 91 106 129 105 100 122 98 97
109 113 121 167 89 94 93 106 109 106 111 94 157 148 116 148 124 124 126 146
92 127 194 134 135 115 114 114 79 105 77 49 54 99 77 93 113 96 125 134
165 114 104 88 89 88 146 123 158 129 167 112 102 79 102 90 60 72 60 79
95 84 68 62 48 42 56 73 58 80 79 52 69 72 72 61 50 61 74 57
65 73 59 72 56 53 46 65 79 59 71 65 56 57 52 52 67 61 56 78
54 49 41 57 56
ELY-C133B 131
194 184 144 134 129 110 104 79 107 130 150 213 188 191 151 86 109 84 178 94
78 97 108 142 145 138 159 139 149 132 97 65 68 118 144 124 242 205 181 204
142 139 77 62 60 61 119 196 121 110 122 130 146 107 109 112 125 133 124 85
100 114 114 101 116 89 149 126 137 152 157 174 182 111 124 105 98 104 192 114
147 104 173 125 115 108 74 137 138 105 130 104 100 129 108 79 86 240 126 125
113 108 96 83 80 50 51 54 69 58 76 79 79 80 98 118 104 102 78 78
102 146 136 163 170 143 148 136 118 137 84

ELY-C135A 116
95 222 195 169 135 161 212 186 199 173 177 151 198 160 145 126 160 148 168 144
147 111 100 112 102 117 111 156 147 169 152 177 115 106 129 178 120 100 124 75
93 76 104 136 128 130 94 101 92 69 70 102 135 137 115 113 119 101 97 92
74 68 75 119 104 103 89 104 119 119 117 74 92 108 122 110 74 64 87 103
77 102 91 132 99 105 94 102 114 97 106 110 97 85 84 117 91 105 154 121
99 105 98 117 115 149 110 114 121 139 116 114 102 92 140 157
ELY-C135B 116
134 212 195 167 137 158 212 189 193 175 175 150 194 158 146 129 164 143 164 145
151 110 104 110 101 121 102 157 152 166 157 167 123 99 135 175 124 105 119 82
89 79 98 144 127 126 90 104 91 72 67 106 136 144 114 118 118 102 93 94
78 63 69 116 114 95 90 109 120 114 118 73 91 113 124 102 80 62 85 103
81 103 91 126 100 103 98 95 116 99 104 114 91 89 85 114 93 109 142 121
112 98 88 122 108 160 108 120 116 144 105 115 119 86 132 158
ELY-C140A 81
272 271 152 179 195 288 300 382 231 334 368 354 293 332 446 408 394 401 627 567
496 491 389 521 370 276 220 172 165 352 140 212 199 166 232 260 334 176 138 138
142 103 58 57 90 90 97 141 203 180 99 88 74 100 143 154 154 163 158 139
105 131 141 115 81 113 125 171 116 103 118 134 107 115 128 127 149 130 100 132
133
ELY-C140B 81
255 265 156 171 204 286 219 351 234 350 371 358 292 334 436 432 426 392 639 581
520 397 341 457 349 289 218 184 161 345 139 214 190 180 238 258 319 164 134 124
144 108 48 62 87 89 97 137 201 177 117 90 71 98 138 156 160 166 155 126
113 133 131 120 88 108 134 167 113 101 115 137 114 117 128 134 144 130 99 129
130
ELY-C142A 83
80 45 30 28 26 198 134 162 64 37 20 21 36 24 48 15 21 26 19 18
29 26 28 30 38 39 23 30 101 165 58 32 70 74 66 71 81 217 191 155
129 245 215 230 234 202 159 126 187 172 111 129 71 145 122 288 234 280 226 270
156 160 108 153 217 266 299 227 214 180 252 148 167 146 164 193 110 136 118 142
123 219 184
ELY-C142B 83
64 49 29 28 31 190 134 159 68 34 21 28 31 28 46 17 28 19 21 20
29 27 29 37 33 42 17 30 103 167 64 40 75 79 78 73 76 227 198 159
137 270 210 238 242 197 169 146 186 163 101 121 58 127 120 244 230 273 231 279
153 155 117 152 198 277 274 221 201 177 228 148 175 137 162 189 122 135 114 130
127 215 224
ELY-C149A 100
248 188 188 136 162 230 134 184 286 191 238 187 180 132 272 114 260 248 251 106
176 138 184 167 234 162 212 149 179 124 163 173 185 170 132 122 138 112 84 114
155 170 184 125 121 142 156 114 194 147 147 164 172 181 135 165 130 125 108 127
142 165 136 213 189 164 102 116 93 108 116 146 156 179 130 133 90 180 165 118
171 163 98 114 99 119 149 87 108 104 115 99 114 134 120 87 73 50 41 58
ELY-C149B 100
247 182 190 122 164 217 132 179 298 187 260 176 181 141 267 119 267 244 230 127
179 147 146 180 276 149 240 191 193 125 150 178 167 178 127 114 129 102 91 95
89 124 192 114 121 142 139 133 189 141 123 129 152 190 121 158 135 156 150 133
199 193 125 196 178 174 104 77 114 83 134 136 155 162 124 108 90 184 178 130
161 168 95 110 106 113 151 102 102 104 131 96 132 117 113 88 65 65 50 48
ELY-C151A 73
203 141 156 115 153 222 161 93 119 101 165 237 234 233 179 215 100 110 97 116
172 134 215 264 197 250 166 133 148 132 199 178 134 182 161 191 164 206 174 211
151 103 133 164 175 99 115 124 138 138 141 138 129 178 247 205 212 194 165 171
233 193 89 93 82 79 69 96 125 129 111 60 63

ELY-C151B 55
71 113 84 151 167 200 221 196 195 76 72 86 86 114 88 113 204 143 206 152
99 141 112 159 142 93 153 121 132 109 122 114 154 151 121 141 198 169 93 108
114 142 126 138 130 96 137 172 170 121 151 97 115 164 172
ELY-C153A 80
277 126 138 73 107 288 302 268 289 394 219 270 254 234 296 236 655 560 416 261
400 284 383 512 530 489 467 387 228 287 380 359 409 189 407 432 188 97 69 70
161 188 362 150 115 102 152 268 220 149 128 277 259 190 66 132 118 151 85 168
204 87 121 97 156 125 75 85 94 114 188 120 113 147 175 62 89 55 65 73
ELY-C153B 80
260 126 141 98 116 274 314 264 291 391 212 256 276 260 321 236 656 562 455 283
404 304 461 500 560 501 484 414 269 277 365 335 384 197 408 442 220 97 67 78
154 202 383 190 171 110 153 260 238 147 128 265 262 180 59 140 90 156 93 149
194 102 123 93 163 142 98 90 124 125 185 151 141 158 146 41 90 49 73 91
ELY-C154A 54
234 216 122 100 204 235 120 206 140 158 169 187 174 157 183 106 152 157 117 168
156 180 151 203 128 114 145 179 133 135 161 151 111 168 177 240 131 198 100 85
110 148 224 180 134 136 117 139 183 103 157 118 163 142
ELY-C154B 54
241 214 123 102 204 240 119 215 143 174 166 192 168 181 150 102 149 168 122 169
146 174 155 188 122 124 152 159 140 141 166 142 116 172 187 219 141 184 105 91
120 162 205 176 125 145 112 141 182 95 140 125 162 167
ELY-C155A 58
196 237 273 267 235 268 173 160 127 150 59 83 160 147 129 217 236 195 151 218
270 286 267 203 125 140 219 229 159 244 193 178 205 176 266 266 283 242 222 167
133 189 119 137 84 162 166 265 194 164 249 178 193 178 245 260 301 154
ELY-C155B 56
240 173 189 199 229 258 225 225 144 122 98 161 71 78 171 159 131 233 205 154
111 157 190 273 280 195 114 121 204 201 135 221 175 188 174 147 232 269 279 202
170 162 140 182 110 119 82 175 156 243 169 155 245 179 189 179
ELY-C156A 100
142 165 170 173 202 165 168 122 119 149 130 80 62 72 78 149 180 163 80 65
94 155 171 136 124 122 90 66 69 92 107 159 125 123 132 113 117 100 154 233
193 170 119 105 201 134 129 108 154 158 182 164 97 145 174 165 131 116 145 205
166 119 135 148 150 132 105 71 131 75 79 83 112 103 135 163 163 182 113 117
123 150 145 194 184 125 93 103 141 143 183 149 154 153 137 165 130 118 112 131
ELY-C156B 102
132 112 172 165 147 173 166 178 215 168 171 138 108 152 138 80 64 67 90 142
163 156 82 67 102 145 164 133 129 103 87 64 62 100 114 150 133 115 138 113
109 93 175 248 222 193 133 114 205 149 114 120 148 166 172 166 109 133 175 156
142 121 165 191 161 112 133 145 152 143 127 76 128 88 82 83 110 96 130 163
158 173 107 119 132 145 147 195 180 138 100 92 138 142 180 148 160 143 141 162
129 97
ELY-C157A 181
135 97 103 183 157 126 196 275 196 211 150 180 73 155 114 161 134 142 146 170
108 85 99 145 103 103 122 184 159 192 123 147 207 114 142 142 142 93 118 69
134 128 134 132 129 139 144 149 124 101 132 133 105 130 130 127 135 128 94 130
89 106 69 89 78 94 80 86 65 105 60 62 65 79 116 108 76 113 95 74
70 84 101 87 80 76 104 97 110 95 128 126 108 68 80 73 68 84 68 94
73 68 64 58 62 78 71 86 62 73 75 84 81 86 68 40 77 77 59 67
65 55 55 65 53 75 70 52 71 78 77 77 73 68 71 71 89 63 84 68
80 92 102 94 95 97 125 105 107 75 91 97 84 79 85 118 99 120 112 70
85 99 91 91 88 92 95 107 110 100 115 113 116 126 134 106 101 103 89 117
96

ELY-C157B 176
141 196 162 129 182 265 204 215 169 187 82 148 117 145 133 150 159 183 120 87
109 142 113 107 111 167 132 170 111 129 179 93 83 148 155 102 123 64 126 129
134 121 131 141 135 143 120 119 129 127 111 132 137 134 119 105 82 142 62 99
63 85 85 93 96 83 78 96 70 62 58 81 109 95 75 110 93 77 61 73
114 82 75 69 98 86 87 101 134 112 118 72 83 79 66 74 64 87 68 65
65 65 56 77 84 96 67 93 90 70 91 99 61 46 70 73 63 58 67 58
48 66 42 69 65 50 63 64 80 71 75 63 76 63 85 67 85 78 71 101
99 88 102 99 116 105 98 85 89 98 104 84 90 120 98 146 112 78 94 84
97 90 93 94 106 109 125 104 115 110 115 127 133 91 128 84
ELY-C158A 119
288 194 137 207 199 210 223 177 193 120 101 63 99 176 134 151 141 93 97 177
143 99 157 204 196 221 231 231 122 93 112 129 102 97 100 162 121 202 200 164
223 211 116 154 103 114 112 96 103 90 92 145 106 94 86 110 94 140 142 248
212 179 147 84 88 149 118 157 184 197 195 121 201 270 281 274 153 150 188 158
182 138 142 119 130 186 170 122 89 198 187 183 111 129 124 267 155 171 108 90
143 232 172 169 196 216 127 164 141 205 161 277 189 157 112 159 110 108 65
ELY-C158B 114
170 170 191 125 104 80 104 193 143 154 148 88 103 202 139 104 156 188 211 201
245 254 140 100 123 145 94 103 111 145 118 200 170 169 202 184 126 145 99 116
115 94 106 90 83 161 97 82 76 107 102 131 134 251 221 181 151 90 95 144
134 147 189 237 211 138 186 244 300 252 157 176 194 168 166 153 142 121 155 190
180 113 89 174 192 200 128 125 138 295 158 179 123 87 150 239 188 170 201 228
154 187 154 207 188 317 213 161 125 173 118 120 78 103
ELY-C159A 146
144 183 165 186 155 211 139 237 190 183 140 97 162 139 176 135 107 93 129 144
183 122 136 130 140 174 155 190 158 153 159 151 99 120 114 147 87 104 150 150
187 112 134 153 103 97 171 96 79 100 123 201 92 159 170 144 120 192 146 156
89 97 115 133 118 131 144 134 110 117 121 118 107 77 87 86 81 109 126 103
105 143 121 137 108 134 254 173 149 171 148 140 136 130 141 227 147 180 193 150
120 156 115 128 192 146 142 191 104 115 101 94 141 166 134 166 113 165 146 122
173 132 148 108 96 98 96 80 66 100 80 90 92 104 84 81 68 65 71 81
79 74 95 88 88 98
ELY-C159B 150
136 248 183 185 139 89 151 139 162 127 107 107 118 153 172 125 126 136 143 161
152 187 150 155 138 125 97 118 109 131 81 93 148 143 155 107 123 135 99 109
156 108 99 107 143 204 109 157 152 155 129 208 154 147 91 96 119 138 129 138
153 155 118 123 128 127 98 83 85 86 87 116 120 115 117 145 121 156 109 143
235 159 149 173 140 147 146 141 143 212 140 194 197 158 130 159 129 143 190 159
150 200 117 115 116 96 146 171 138 177 119 182 162 128 164 133 129 110 92 96
95 98 84 98 96 86 88 112 87 89 67 72 82 65 92 85 100 93 83 74
75 100 115 134 99 86 93 96 71 101
ELY-C160A 136
154 151 129 153 148 171 178 167 158 178 194 172 124 183 168 177 165 173 150 182
186 191 184 208 168 146 122 81 157 133 159 131 164 154 135 102 124 94 111 108
65 58 84 102 98 113 147 129 85 93 118 116 83 90 69 103 103 137 133 107
114 137 79 106 102 72 78 66 90 96 91 58 75 57 83 72 72 73 75 88
72 111 117 80 82 125 139 102 92 92 94 66 96 61 95 67 65 82 71 91
114 84 75 89 84 115 86 85 65 73 108 93 97 120 96 93 99 85 91 74
89 112 90 91 123 94 106 91 112 90 103 103 88 97 122 101

ELY-C160B 146
125 167 130 148 139 126 155 140 158 161 147 144 161 168 166 124 174 168 166 149
157 137 175 188 180 178 188 163 149 129 94 145 140 145 127 147 132 123 107 111
92 104 106 67 49 76 111 84 105 132 129 85 94 108 107 87 86 59 105 91
128 120 127 111 141 84 115 101 69 72 59 83 86 71 77 80 64 79 78 74
68 89 80 95 110 128 90 88 109 122 97 84 85 96 75 94 64 88 72 66
77 74 86 101 88 69 88 68 119 75 76 58 72 109 97 97 113 93 94 77
89 67 71 92 91 76 80 117 85 106 85 89 92 91 107 89 83 110 87 118
63 50 64 74 92 99
ELY-C161A 136
219 304 308 254 211 172 232 129 135 148 220 182 149 156 217 192 162 78 120 121
144 145 169 148 121 124 166 127 171 166 139 113 180 194 144 115 152 214 202 200
261 231 273 259 201 205 226 184 181 120 90 89 103 144 181 125 164 171 105 95
94 174 130 95 96 91 98 95 95 121 120 141 122 173 92 107 102 97 129 169
123 134 104 115 79 90 90 116 130 118 119 132 171 136 166 197 154 146 160 119
116 129 147 125 97 90 153 133 156 133 179 121 116 107 83 102 140 109 88 89
60 96 112 135 106 148 104 109 117 102 107 96 107 52 51 53
ELY-C161B 132
280 274 259 289 197 266 130 143 159 217 169 166 160 199 166 142 81 99 101 116
119 138 127 112 123 148 125 153 160 135 106 151 153 131 106 125 190 170 193 250
211 205 211 170 174 198 162 161 119 88 92 119 126 162 123 140 156 100 89 89
156 129 98 93 88 86 104 89 125 114 141 147 181 101 110 105 109 136 156 135
149 102 107 94 85 94 123 131 117 126 126 162 162 155 189 144 144 165 114 118
131 142 124 113 90 143 132 149 119 165 109 88 103 92 94 113 106 89 84 72
86 104 122 89 132 97 107 121 99 100 83 47
ELY-C162A 134
155 202 176 207 184 214 246 252 210 161 126 92 183 179 170 146 157 149 165 130
147 111 133 116 86 69 97 144 115 119 134 121 98 96 112 128 97 113 104 126
108 114 122 143 122 166 111 119 127 98 106 80 120 91 117 139 112 87 73 89
106 107 91 96 76 96 111 103 124 65 120 100 110 115 102 96 112 81 106 99
83 99 97 101 117 105 106 110 96 124 98 96 80 85 127 120 112 154 99 103
98 83 77 78 100 118 86 96 118 90 118 103 109 104 99 122 85 87 101 106
110 105 107 74 83 89 103 97 101 95 84 88 98 100
ELY-C162B 134
139 185 161 194 180 212 251 236 205 147 124 94 186 162 159 161 149 165 171 118
137 108 126 113 90 76 97 133 116 108 128 132 93 99 110 116 99 107 90 122
117 107 135 154 129 150 105 128 128 97 106 104 116 112 119 129 116 87 99 108
111 105 107 114 100 116 133 116 110 105 123 96 119 118 103 87 112 83 116 99
86 100 85 112 116 100 106 120 82 119 103 83 77 84 118 109 97 143 109 98
93 85 82 94 99 103 86 107 103 94 107 97 118 112 94 117 91 93 88 105
110 97 76 77 104 87 128 78 107 81 86 92 105 86
ELY-C168A 106
346 338 533 572 519 455 415 427 530 456 601 459 684 556 371 515 540 624 604 499
309 481 555 598 337 427 478 515 639 515 494 541 494 310 296 441 347 376 260 375
259 298 242 204 173 266 224 296 286 374 212 299 274 279 276 468 314 267 278 262
173 220 266 375 427 230 213 229 215 177 197 191 141 236 187 258 209 148 138 189
170 156 180 179 228 159 175 179 149 139 163 211 212 194 262 261 226 200 167 164
127 135 192 122 125 143
ELY-C168B 106
334 344 521 572 513 460 458 469 507 440 597 448 665 588 384 510 534 608 588 489
328 472 561 601 326 430 505 531 611 502 516 545 485 315 289 432 340 366 242 371
270 284 247 201 184 255 220 298 303 360 212 295 267 294 269 469 323 268 284 234
170 212 280 354 415 265 190 230 230 155 183 204 149 226 196 258 212 163 143 181
173 147 184 185 228 148 165 187 155 136 165 224 212 196 261 263 220 201 161 165
125 129 176 140 111 165

ELY-C169A 145
226 219 282 170 222 177 117 84 90 125 116 86 131 81 193 127 140 86 120 113
80 115 230 253 238 204 242 132 93 157 213 213 171 155 159 144 170 154 133 135
185 175 93 72 57 62 77 159 201 296 144 195 196 242 285 192 258 170 179 125
81 63 48 127 97 90 118 73 84 90 51 100 86 71 164 253 344 172 119 172
188 261 145 100 91 169 132 100 136 83 159 168 92 87 140 110 248 119 94 120
225 261 148 111 242 286 329 148 130 144 108 141 113 71 102 86 108 99 113 133
127 222 213 309 194 201 166 110 156 168 183 82 96 111 142 130 88 90 73 83
90 73 84 91 86
ELY-C169B 145
240 215 279 176 221 186 112 91 92 112 121 86 130 80 197 127 133 97 118 110
77 125 230 273 236 201 238 130 94 150 215 221 175 161 165 142 179 157 129 143
188 178 91 76 54 56 82 155 201 298 139 191 209 251 271 204 259 182 194 120
83 61 58 124 100 96 114 71 90 77 62 97 95 70 156 263 340 168 124 166
186 260 153 95 85 175 130 108 141 72 151 166 92 83 149 113 244 114 92 122
238 241 144 110 232 268 315 143 111 149 108 138 119 69 102 85 108 102 113 138
108 229 212 302 208 193 166 106 159 177 178 81 104 111 138 127 88 93 69 76
94 83 93 100 81
ELY-C170A 68
319 351 331 255 329 260 259 351 236 274 317 417 354 315 135 369 434 467 357 270
356 236 288 242 386 305 261 328 320 265 251 174 160 224 316 179 153 204 244 134
91 75 73 86 121 76 84 121 159 151 136 138 163 119 134 123 82 106 114 156
108 111 137 133 129 154 203 242
ELY-C170B 68
304 342 322 255 316 280 255 340 259 269 311 427 339 307 133 392 410 468 364 283
351 232 279 241 398 298 249 334 324 255 249 184 151 234 310 190 150 213 234 159
94 74 73 85 115 96 69 127 156 158 130 153 172 110 130 117 87 92 104 127
102 112 146 125 135 161 194 222
ELY-C171A 99
183 219 154 226 108 118 41 81 95 161 120 178 225 166 113 115 51 118 112 174
155 113 238 189 204 183 167 165 140 180 125 152 154 102 72 102 91 106 158 161
122 151 183 205 185 167 159 267 260 246 290 305 294 226 213 195 171 134 148 135
102 66 68 56 82 111 189 108 88 104 129 145 167 198 168 178 142 209 212 226
251 162 112 87 66 93 99 100 71 54 59 52 78 85 75 71 88 95 108
ELY-C171B 99
153 217 168 224 117 125 40 86 84 159 122 177 246 163 111 121 56 111 100 183
150 111 217 203 211 191 172 149 131 165 138 150 136 115 78 108 86 110 151 161
145 132 188 203 184 189 156 273 286 266 267 290 290 232 217 207 167 139 147 127
81 76 71 69 90 122 201 110 96 99 122 138 159 193 182 169 140 191 213 236
241 188 124 100 84 132 87 117 85 53 66 47 79 98 78 66 90 89 99
ELY-C172A 94
378 234 127 83 163 319 411 423 364 402 555 502 483 308 387 343 361 353 245 251
427 469 369 491 395 419 268 342 230 163 248 307 230 228 166 201 246 270 359 329
251 270 136 92 81 102 134 186 144 106 68 113 119 133 104 72 79 61 76 108
110 62 65 79 108 127 117 96 84 79 116 113 95 77 56 78 100 108 108 135
68 47 37 66 60 77 47 58 75 54 84 68 61 91
ELY-C172B 94
371 207 134 82 176 332 427 419 371 418 558 493 501 301 390 344 370 358 242 236
430 460 374 489 409 402 298 321 238 177 241 309 228 234 162 200 254 292 370 334
234 274 130 91 85 113 151 186 150 112 77 104 119 149 96 54 72 62 73 100
88 54 58 76 106 131 111 94 84 79 106 117 100 67 68 72 93 100 112 129
72 46 38 73 53 72 57 53 75 52 81 89 106 112

ELY-C173A 75
234 205 184 139 108 156 174 131 132 270 226 255 178 149 124 248 244 147 199 111
225 158 94 96 145 129 173 209 159 226 244 195 133 216 258 229 273 198 196 200
147 241 224 138 197 188 161 127 100 168 181 257 133 217 196 209 146 120 209 213
187 92 134 149 172 226 170 145 119 77 108 67 89 94 129
ELY-C173B 75
223 204 183 135 98 141 161 151 133 285 237 248 175 154 119 250 246 147 207 106
226 158 89 99 144 127 174 204 169 223 238 194 137 217 258 232 271 213 190 199
148 240 228 135 188 180 160 132 106 191 209 250 152 217 170 220 140 113 193 232
168 90 122 148 179 237 149 172 95 96 69 94 90 102 147
ELY-C174A 54
237 155 217 164 220 184 205 311 323 312 316 244 234 258 240 194 187 182 116 125
148 112 169 205 201 190 188 178 282 269 183 149 168 254 221 260 264 275 248 173
118 215 266 251 166 113 110 121 137 139 125 125 134 127
ELY-C174B 54
200 164 216 185 242 176 217 296 303 294 317 249 229 275 242 205 197 179 124 125
141 116 180 221 205 200 188 188 282 284 189 157 158 251 236 275 288 283 213 191
111 215 246 234 178 114 113 116 127 144 118 125 141 115
ELY-C175A 60
96 110 102 139 99 108 91 97 100 157 160 154 125 125 179 162 142 112 121 95
131 88 125 145 177 99 145 147 153 159 185 138 151 164 189 133 104 143 176 194
169 166 118 115 86 165 164 157 204 149 138 151 141 100 168 161 144 157 198 124
ELY-C175B 60
10 10 10 13 11 12 10 9 12 16 19 16 14 13 18 15 14 15 12 10
14 10 14 15 20 13 19 13 18 15 20 14 19 18 20 15 11 14 25 20
16 15 15 12 10 15 18 16 19 15 15 16 16 12 18 16 15 18 19 12
ELY-C177A 54
733 573 471 448 541 362 414 459 356 425 481 533 352 465 298 288 261 185 144 178
182 209 167 139 133 199 142 176 119 102 118 175 131 139 148 135 161 133 138 121
147 129 147 213 174 154 115 163 166 129 169 117 106 86
ELY-C177B 56
535 356 460 295 284 263 190 139 174 184 210 166 140 134 163 168 150 125 112 120
182 157 150 182 139 142 135 152 122 123 93 125 119 120 115 111 157 148 128 161
124 96 96 133 159 173 165 193 182 173 196 202 124 111 177 202
ELY-C178A 77
208 219 336 187 251 186 141 131 198 144 188 162 100 177 172 155 164 139 124 113
171 163 95 127 94 133 107 80 81 93 106 67 93 59 67 61 86 83 92 66
48 63 42 66 75 63 70 70 68 49 51 51 56 28 42 52 32 35 44 50
41 32 26 35 43 36 51 43 48 42 45 54 75 41 60 49 60
ELY-C178B 96
303 348 227 258 182 172 148 146 238 195 161 163 170 164 224 296 181 194 294 253
220 279 177 173 293 165 220 166 145 132 185 157 191 160 102 178 173 153 160 131
120 107 176 172 88 133 109 155 93 106 89 93 101 81 80 69 69 67 85 89
76 77 53 54 45 64 88 54 70 66 68 50 60 53 46 29 38 56 30 49
37 46 43 31 26 34 48 39 40 45 47 34 54 52 61 49
ELY-C179A 61
431 309 239 269 399 538 561 685 659 371 447 244 192 143 174 213 306 183 217 124
81 85 140 130 63 57 84 86 280 224 222 298 319 333 210 244 241 218 197 201
223 176 178 116 140 135 147 172 142 106 92 118 154 165 156 165 165 155 211 199
157
ELY-C179B 61
428 310 229 263 396 517 535 683 664 356 463 241 188 148 173 215 286 195 222 128
78 85 136 134 66 48 85 91 267 230 213 300 320 329 211 250 213 204 197 188
228 187 173 106 142 134 155 171 144 99 91 119 157 154 153 167 161 163 207 199
154

ELY-C180A 69
310 364 450 455 523 322 379 413 386 340 286 174 151 184 191 194 202 179 160 335
314 257 206 172 252 349 273 298 224 192 195 296 282 281 274 179 185 195 176 127
173 124 128 125 109 107 96 158 131 123 155 115 80 93 98 161 151 138 156 161
141 178 126 150 141 136 117 112 119
ELY-C180B 69
297 378 462 444 515 309 361 402 394 349 299 207 133 161 170 192 202 174 167 340
323 259 219 183 259 339 283 293 216 202 189 303 262 265 265 180 191 195 180 127
172 118 134 123 104 111 104 166 123 136 145 111 99 80 104 161 150 128 157 154
147 175 129 142 143 130 112 105 116
ELY-C181A 112
464 326 314 246 292 197 255 272 405 251 236 160 295 261 380 386 214 305 327 392
475 317 262 202 282 259 155 137 111 179 176 185 205 210 171 146 222 108 111 101
85 71 129 129 136 92 74 116 179 124 98 111 90 88 123 110 73 112 84 92
82 77 93 124 96 115 108 108 95 64 116 93 87 90 76 59 81 67 90 80
81 73 85 82 111 93 111 85 110 117 80 91 96 83 121 112 103 149 171 107
152 106 87 86 86 104 135 89 133 172 112 83
ELY-C181B 112
464 338 315 240 291 199 255 278 414 266 235 160 293 257 371 385 217 304 325 394
464 311 273 214 287 271 159 139 103 183 178 188 212 196 162 158 210 120 114 98
82 81 120 137 132 92 69 112 182 120 132 119 94 98 122 109 67 109 81 86
80 70 94 130 90 111 114 108 92 79 110 96 88 88 71 63 70 63 79 78
77 65 94 84 108 92 105 89 106 115 82 93 95 87 121 106 107 148 143 138
151 102 89 86 88 104 135 85 136 171 112 86
ELY-C182A 76
45 153 154 100 199 257 244 273 378 244 396 342 314 291 285 249 245 319 320 274
219 220 216 320 251 360 273 234 215 282 243 173 185 143 133 179 205 137 180 189
186 232 136 138 171 164 191 127 149 197 105 184 138 194 234 110 158 81 139 218
220 175 325 245 183 289 203 162 150 140 158 120 123 164 112 140
ELY-C182B 76
57 148 159 99 200 278 239 276 381 239 379 337 299 308 270 288 246 315 293 241
215 215 217 315 254 363 270 233 218 276 251 169 187 146 132 181 195 140 180 182
203 230 148 141 170 158 192 133 152 213 102 183 143 191 231 109 159 80 140 217
219 176 324 243 183 304 216 144 168 136 154 139 127 161 118 152
ELY-C183A 56
200 133 135 141 132 141 429 290 255 200 315 396 485 444 411 278 258 440 426 407
398 318 420 419 105 109 108 199 243 252 256 330 271 242 382 269 234 210 219 212
248 237 195 159 119 220 319 230 263 206 195 144 176 156 190 204
ELY-C183B 65
308 250 221 402 415 498 381 336 222 300 434 450 352 325 281 391 367 101 97 103
165 260 258 278 271 217 208 312 214 223 192 202 191 250 234 198 163 121 218 322
228 266 208 193 147 178 158 189 207 166 145 106 108 98 131 144 132 165 125 103
91 130 109 114 148
ELY-C185A 121
432 273 230 267 480 676 471 377 179 120 190 259 461 403 339 241 206 235 215 221
175 199 308 237 137 233 313 247 303 284 415 395 338 151 141 108 137 151 171 148
156 169 97 89 96 137 122 100 89 86 92 129 99 92 69 80 75 72 56 93
86 85 44 53 38 37 35 53 42 46 75 53 40 45 44 65 74 62 66 60
72 54 66 94 76 28 43 43 14 42 51 39 40 31 30 31 48 38 22 28
25 42 42 35 38 46 28 22 29 28 40 30 35 39 37 53 49 34 31 41
28

ELY-C185B 121
439 261 238 253 456 598 484 376 189 114 192 260 466 402 334 245 219 216 215 213
192 199 297 236 157 225 290 247 302 285 421 405 321 157 144 110 126 159 172 161
134 180 91 88 93 143 112 114 82 98 94 131 88 81 78 81 73 70 59 99
77 77 56 55 32 43 31 50 34 54 75 45 45 42 42 59 94 54 62 61
73 48 74 90 74 37 39 27 27 28 50 35 43 36 29 21 53 37 23 29
21 35 43 38 38 42 27 28 25 30 31 29 32 42 45 47 49 47 41 36
55
ELY-C302A 150
174 147 114 113 166 205 230 177 131 55 228 176 108 160 271 187 264 357 224 182
262 162 162 154 129 168 130 185 262 183 148 186 136 216 221 240 195 258 217 184
188 172 209 155 123 65 111 159 119 119 156 175 154 108 81 87 163 156 125 135
172 174 114 129 100 72 72 112 93 120 102 100 95 82 94 100 91 61 78 83
62 62 65 65 62 84 88 96 93 94 46 66 60 56 61 77 68 52 40 54
56 50 39 50 46 44 61 62 74 62 62 65 51 29 46 63 72 87 67 65
76 65 85 106 74 99 111 74 106 100 96 156 164 229 288 196 238 184 160 152
136 165 136 134 93 112 125 104 117 132
ELY-C302B 150
195 152 113 114 159 197 224 156 134 48 236 178 108 185 259 198 269 344 263 191
260 164 160 159 135 165 123 185 263 186 144 185 136 212 228 240 180 242 223 189
182 160 204 155 130 52 119 159 120 138 153 162 154 108 82 86 167 158 139 133
156 167 113 137 102 78 87 110 85 122 94 91 99 71 102 104 87 67 81 84
80 52 63 70 74 81 88 92 110 84 51 67 57 57 65 76 68 57 35 54
54 52 47 49 50 48 53 63 74 58 63 71 45 42 42 62 74 85 65 65
71 62 81 106 86 92 106 77 111 108 104 151 163 230 291 212 244 178 159 145
143 164 136 131 96 106 123 110 116 163
ELY-C303A 90
185 93 84 122 124 160 72 72 87 82 106 77 92 88 113 96 95 52 34 39
41 52 75 111 98 89 121 75 67 72 47 56 79 84 127 120 82 86 79 106
125 100 102 125 121 117 83 90 116 80 72 115 108 108 71 102 104 95 117 153
116 127 170 153 106 146 165 147 139 180 136 195 192 230 240 263 212 234 241 267
193 157 173 198 242 237 179 209 224 262
ELY-C303B 90
183 92 90 113 125 160 72 71 89 78 111 72 91 87 112 102 94 48 34 42
40 52 79 108 100 89 123 81 67 68 52 61 76 73 132 120 85 76 90 112
124 102 102 130 120 116 83 96 104 82 72 117 102 116 73 93 106 97 117 158
112 133 170 147 110 147 164 149 135 182 147 197 190 241 238 259 216 224 230 277
200 141 172 203 240 234 184 208 212 296
ELY-C304A 148
328 357 311 271 293 321 277 250 195 312 402 342 263 314 267 318 318 228 167 268
272 328 282 254 186 177 217 265 249 241 267 244 217 205 236 223 163 194 220 102
136 213 173 149 119 193 154 248 233 104 85 68 55 99 137 143 178 164 108 146
113 120 108 78 65 74 88 97 125 135 108 106 112 104 108 82 84 96 94 104
69 57 53 43 50 56 57 53 42 48 47 53 57 67 112 106 114 108 113 97
106 87 113 108 127 119 139 122 141 106 145 96 157 142 127 125 104 136 116 120
116 136 130 79 60 66 76 65 90 129 113 110 116 120 141 129 139 145 161 201
132 154 115 166 188 170 237 264

ELY-C304B 149
311 226 164 268 387 323 260 320 357 378 303 228 162 242 226 379 337 296 198 205
268 325 322 255 283 273 245 232 246 190 149 160 221 95 142 221 153 179 134 226
170 268 248 114 77 75 50 111 148 163 174 187 121 154 113 125 115 96 83 87
104 104 157 157 122 145 142 110 104 93 95 108 97 108 80 63 50 53 58 62
48 53 54 50 40 54 59 79 120 108 112 106 129 90 123 99 108 120 127 144
143 114 144 127 140 100 147 137 119 123 102 139 122 120 108 153 129 84 81 69
84 77 98 130 124 137 133 146 121 137 118 134 151 200 146 174 100 168 162 178
212 195 137 303 196 161 137 92 122
ELY-C309A 64
191 226 132 162 151 204 152 98 94 73 61 87 147 166 217 193 147 137 100 97
74 63 119 56 51 99 117 98 131 114 145 132 130 132 118 121 98 112 127 127
78 83 125 98 127 100 145 115 108 118 132 118 178 140 136 140 108 108 86 96
120 102 164 184
ELY-C309B 64
197 230 131 162 156 198 151 102 91 72 80 82 156 169 205 200 155 135 99 85
70 66 115 58 50 106 100 106 121 125 132 145 125 132 116 127 90 116 131 129
76 91 111 106 134 96 146 116 99 125 134 123 173 138 142 136 115 95 91 104
111 99 151 141
ELY-C310A 72
171 156 112 120 192 242 307 234 118 129 158 183 257 278 208 98 62 140 160 149
178 129 283 303 164 187 201 187 186 203 184 118 156 104 111 108 127 142 189 165
132 92 116 90 106 139 121 87 110 108 117 132 113 92 76 111 91 67 90 116
114 83 89 61 62 65 56 77 67 88 74 104
ELY-C310B 72
156 161 124 116 174 250 332 234 112 124 143 200 247 293 188 100 67 134 156 146
166 125 283 312 157 199 205 180 198 190 186 144 130 114 102 108 125 147 193 166
129 95 115 97 97 140 100 87 117 108 115 143 112 93 73 108 88 74 96 106
114 96 79 55 67 70 73 67 60 86 87 84
ELY-C311A 96
136 141 159 160 99 135 106 118 131 149 116 144 142 183 148 184 145 156 186 173
213 186 207 197 129 143 141 188 183 144 185 151 106 81 102 173 150 185 164 150
169 161 131 122 89 164 140 120 127 163 164 106 149 145 161 208 209 198 164 165
194 147 156 188 166 165 151 155 201 179 176 118 122 132 106 146 122 120 111 111
97 135 139 124 168 174 139 143 130 133 122 72 114 104 108 157
ELY-C311B 96
139 141 147 157 94 125 106 121 118 157 122 146 137 187 170 187 150 151 187 174
207 193 209 194 136 132 152 198 184 151 200 154 106 86 104 159 153 182 165 160
168 153 130 132 88 161 144 114 125 159 161 106 155 143 162 198 190 201 169 159
211 153 173 187 172 162 147 156 201 180 181 115 127 124 106 151 121 118 111 104
100 146 123 135 164 160 140 139 135 135 117 68 114 102 99 162
ELY-C312A 160
92 81 82 86 90 74 62 53 65 104 85 100 82 73 78 58 47 53 78 75
79 71 80 89 54 70 83 83 89 93 84 62 78 68 54 60 90 74 93 99
70 93 86 87 69 63 65 84 124 102 77 93 66 55 65 51 71 97 73 79
74 100 73 72 77 68 92 66 88 99 135 85 62 48 55 74 125 75 104 116
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72 93 108 99 99 104 108 69 66 66 57 75 66 76 53 69 69 62 50 66
62 76 79 77 71 117 108 80 83 78 84 92 55 66 136 118 95 75 72 94
55 68 38 44 75 62 79 45 55 72 83 70 89 78 117 60 69 60 55 90

ELY-C312B 161
89 71 74 90 85 75 53 62 62 108 80 102 75 74 82 56 44 51 83 74
80 68 82 87 50 72 85 79 95 92 83 72 77 71 49 62 77 76 96 98
65 94 88 81 68 67 73 80 118 106 73 90 68 58 61 52 72 98 68 88
74 100 68 78 77 62 95 67 85 95 139 90 73 49 48 71 119 86 102 110
91 92 62 50 86 93 102 95 75 102 97 81 74 99 97 123 116 104 88 110
73 91 117 93 99 106 104 63 61 70 47 75 61 65 62 68 62 63 58 68
60 77 74 75 79 112 110 80 85 76 80 90 55 77 125 121 97 83 72 94
65 53 40 52 88 67 57 56 40 76 81 66 91 73 115 72 65 63 53 94
68
ELY-C313A 92
275 141 199 154 172 142 158 169 119 102 110 129 127 94 130 82 127 129 117 155
81 102 106 132 108 138 100 176 104 102 108 131 127 133 115 106 102 82 84 148
100 121 82 111 112 78 102 104 85 139 119 89 95 98 83 118 87 95 125 116
98 129 96 129 132 122 127 134 135 111 133 95 125 100 78 80 106 96 70 100
70 95 74 77 89 75 78 72 80 62 60 70
ELY-C313B 92
259 145 188 167 169 132 172 168 134 122 116 151 124 102 125 99 136 148 130 145
76 108 121 127 108 137 104 172 108 94 129 137 129 124 114 106 102 84 80 134
99 110 80 115 110 79 102 100 89 130 117 87 95 100 81 117 91 88 127 117
104 121 94 143 117 129 119 133 140 110 122 108 121 102 83 80 91 104 71 94
73 92 79 70 92 87 78 71 67 69 69 75
ELY-C501A 80
252 325 136 154 117 146 62 133 158 156 79 131 121 100 142 74 95 70 79 104
104 101 106 80 79 73 85 96 88 90 86 105 79 88 66 73 129 114 96 91
79 122 84 90 104 67 57 84 53 70 55 44 35 33 37 53 75 73 89 98
76 98 73 80 96 106 105 83 103 109 129 85 93 101 132 126 116 94 123 133
ELY-C501B 80
204 323 143 157 116 131 67 129 171 157 99 130 140 105 150 62 97 80 75 86
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99 99 68 94 177 153 115 68 69 113 130 148
ELY-C502B 72
149 81 181 254 291 252 305 279 223 175 154 98 144 158 162 163 112 137 87 107
87 81 138 120 111 107 92 122 94 100 104 117 119 212 104 101 82 63 42 59
65 123 77 104 103 75 79 109 84 127 123 102 79 82 88 73 64 60 56 75
92 92 61 98 160 151 120 70 66 128 109 147
ELY-C503A 95
267 279 204 76 46 51 38 106 128 103 184 159 141 158 106 102 73 211 166 162
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95 74 96 96 95 87 82 68 101 69 55 48 48 38 35 37 39 42 40 68
59 57 70 64 86 81 114 98 88 86 81 74 94 70 151
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53 63 77 67 83 76 120 96 84 95 76 81 88 76 124

ELY-C504A 211
81 63 52 44 36 25 24 20 24 46 45 62 71 74 92 109 83 72 53 68
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341 279 213 293 274 259 408 414 315 356 358 293 332 174 114 136 160 168 146 182
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303 281 304 300 323 191 213 219 172 316 156 179 245 132 134 144 144 161 100 73
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108 117 134 175
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230 280 306 303 309 200 206 221 170 320 174 179 240 129 132 149 139 158 102 77
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106 109 125 179
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224 122 270 130 170 288 439 506 598 622 634 281 517 419 202 301 215 340 429 190
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95 203 154 150 164
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192 207 233 184 135 145 124 146 309 270 88 144 133 230 221 240 128 138 112 72
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141 145 157 126 110 131 137 78 58 44 56 61 50 59 67 100 136 136
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ELY-C524B 68
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172 192 210 240 238 269 216 230 350 457 312 370 374 321 268 279 204 154 196 298
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563 560 576 684 470 555 583 548 540 480 425 355 308 239 201 162 183 283 181 316
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ELY-C530 67
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212 203 160 117 381 222 241 236 219 266 180 110 163 141 140 251 262 178 219 178
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ELY-C538B 97
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408 285 340
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107 130 178

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109 120 176
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ELY-C554A 60
221 270 284 175 316 293 405 216 323 383 258 530 348 309 394 279 184 184 292 260
222 178 248 204 181 198 159 89 132 123 176 165 209 112 159 174 208 204 278 259
307 297 458 175 161 221 256 290 138 155 173 169 63 104 142 141 149 95 96 118
ELY-C554B 60
227 234 331 176 331 298 351 274 279 391 283 515 360 301 412 257 196 178 314 247
216 176 243 203 177 209 153 97 133 105 160 163 216 118 154 187 208 206 276 256
293 307 464 198 148 227 231 281 155 157 174 163 66 111 133 146 153 99 87 114
ELY-C555A 58
414 138 111 157 209 218 231 232 312 223 152 126 179 123 106 119 99 100 159 190
188 110 103 132 164 183 227 256 453 409 213 130 103 171 318 279 349 254 319 420
265 129 128 253 342 363 324 373 323 237 269 246 172 167 110 113 72 103
ELY-C555B 58
393 137 115 154 215 200 241 228 309 230 161 143 170 125 115 112 100 100 166 187
195 107 112 125 161 187 213 253 431 435 173 110 101 146 257 281 330 255 312 407
247 136 115 269 359 383 310 360 321 267 271 254 146 158 102 109 75 104
ELY-C556A 60
255 148 98 58 111 142 169 151 173 290 236 407 384 320 115 147 105 280 133 87
213 215 84 236 162 228 335 204 221 154 202 172 162 181 194 179 163 147 179 153
203 159 121 185 163 146 172 169 171 246 266 229 102 135 193 264 314 229 210 187
ELY-C556B 60
280 129 119 56 115 152 181 147 166 283 211 432 391 336 115 160 93 288 144 101
200 222 88 227 163 242 322 198 233 147 198 197 150 190 196 190 177 149 202 151
224 150 109 195 166 150 171 174 176 237 256 247 99 133 159 219 352 237 193 196

APPENDIX

Tree-Ring Dating

The Principles of Tree-Ring Dating

Tree-ring dating, or *dendrochronology* as it is known, is discussed in some detail in the Laboratory's Monograph, '*An East Midlands Master Tree-Ring Chronology and its uses for dating Vernacular Building*' (Laxton and Litton 1988) and, *Dendrochronology; Guidelines on Producing and Interpreting Dendrochronological Dates* (English Heritage 1988). Here we will give the bare outlines. Each year an oak tree grows an extra ring on the outside of its trunk and all its branches just inside its bark. The *width* of this annual ring depends largely on the weather during the growing season, about April to October, and possibly also on the weather during the previous year. Good growing seasons give rise to relatively wide rings, poor ones to very narrow rings and average ones to relatively average ring widths. Since the climate is so variable from year to year, almost random-like, the widths of these rings will also appear random-like in sequence, reflecting the seasons. This is illustrated in Figure 1 where, for example, the widest rings appear at irregular intervals. This is the key to dating by tree rings, or rather, by their widths. Records of the average ring widths for oaks, one for each year for the last 1000 years or more, are available for different areas. These are called master chronologies. Because of the random-like nature of these sequences of widths, there is usually only one position at which a sequence of ring widths from a sample of oak timber with at least 70 rings will match a master. This will date the timber and, in particular, the last ring.

If the bark is still on the sample, as in Figure 1, then the date of the last ring will be the date of felling of the oak from which it was cut. There is much evidence that in medieval times oaks cut down for building purposes were used almost immediately, usually within the year or so (Rackham 1976). Hence if bark is present on several main timbers in a building, none of which appear reused or are later insertions, and if they all have the same date for their last ring, then we can be quite confident that this is the date of construction or soon after. If there is no bark on the sample, then we have to make an estimate of the felling date; how this is done is explained below.

The Practice of Tree-Ring Dating at the University of Nottingham Tree-Ring dating Laboratory

1. ***Inspecting the Building and Sampling the Timbers***. Together with a building historian the timbers in a building are inspected to try to ensure that those sampled are not reused or later insertions. Sampling is almost always done by coring into the timber, which has the great advantage that we can sample *in situ* timbers and those judged best to give the date of construction, or phase of construction if there is more than one in the building. The timbers to be sampled are also inspected to see how many rings they have. We normally look for timbers with at least 70 rings, and preferably more. With fewer rings than this, 50 for example, sequences of widths become difficult to match to a unique position within a master sequence of ring widths and so are difficult to date (Litton and Zainodin 1991). The cross-section of the rafter shown in Figure 2 has about 120 rings; about 20 of which are sapwood rings – the lighter rings on the outside. Similarly the core has just over 100 rings with a few sapwood rings.

   To ensure that we are getting the date of the building as a whole, or the whole of a phase of construction if there is more than one, about 8 to 10 samples per phase are usually taken. Sometimes we take many more, especially if the construction is complicated. One reason for taking so many samples is that, in general, some will fail to give a date. There may be many reasons why a particular sequence of ring widths from a sample of timber fails to give a date even though others from the same building do. For example, a particular tree may have grown in an odd ecological niche, so odd indeed that the widths of its rings were determined by factors other than the local climate! In such circumstances it will be impossible to date a timber from this tree using the master sequence whose widths, we can assume, were predominantly determined by the local climate at the time.

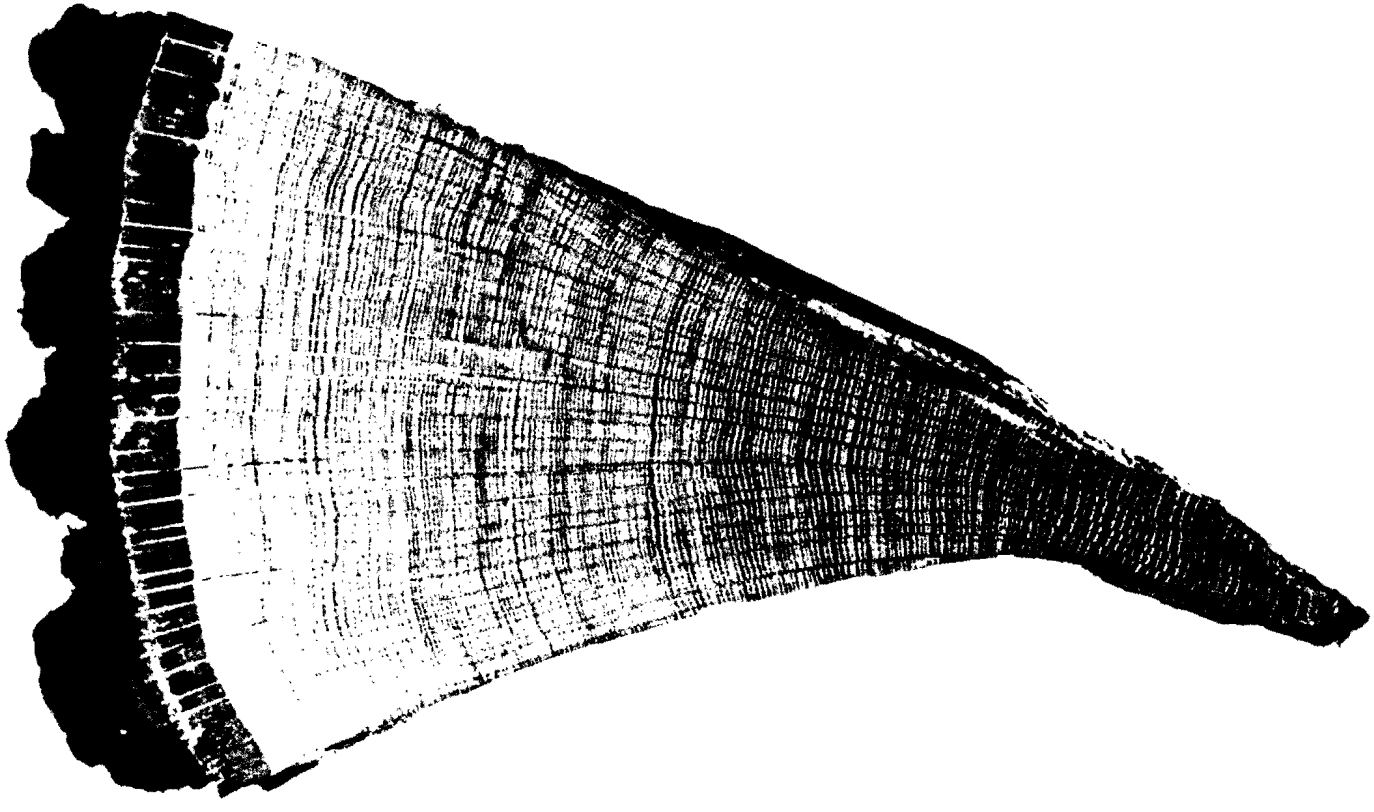


Fig 1. A wedge of oak from a tree felled in 1976. It shows the annual growth rings, one for each year from the innermost ring to the last ring on the outside just inside the bark. The year of each ring can determined by counting back from the outside ring, which grew in 1976.

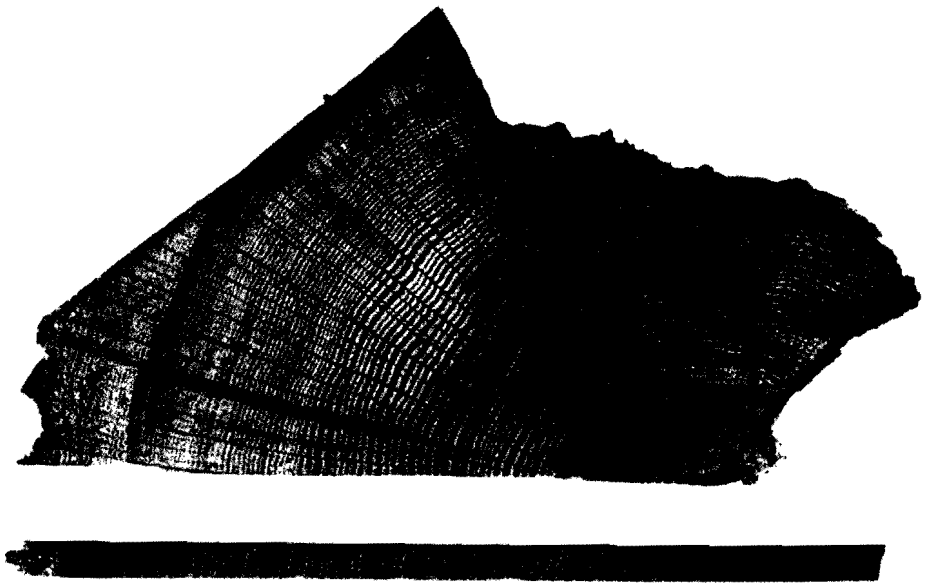


Fig 2. Cross-section of a rafter showing the presence of sapwood rings in the left hand corner, the arrow is pointing to the heartwood/sapwood boundary (H/S). Also a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil.

Fig. 3 Measuring ring widths under a microscope. The microscope is fixed while the sample is on a moving platform. The total sequence of widths is measure twice to ensure that an error has not been made. This type of apparatus is needed to process a large number of samples on a regular basis.

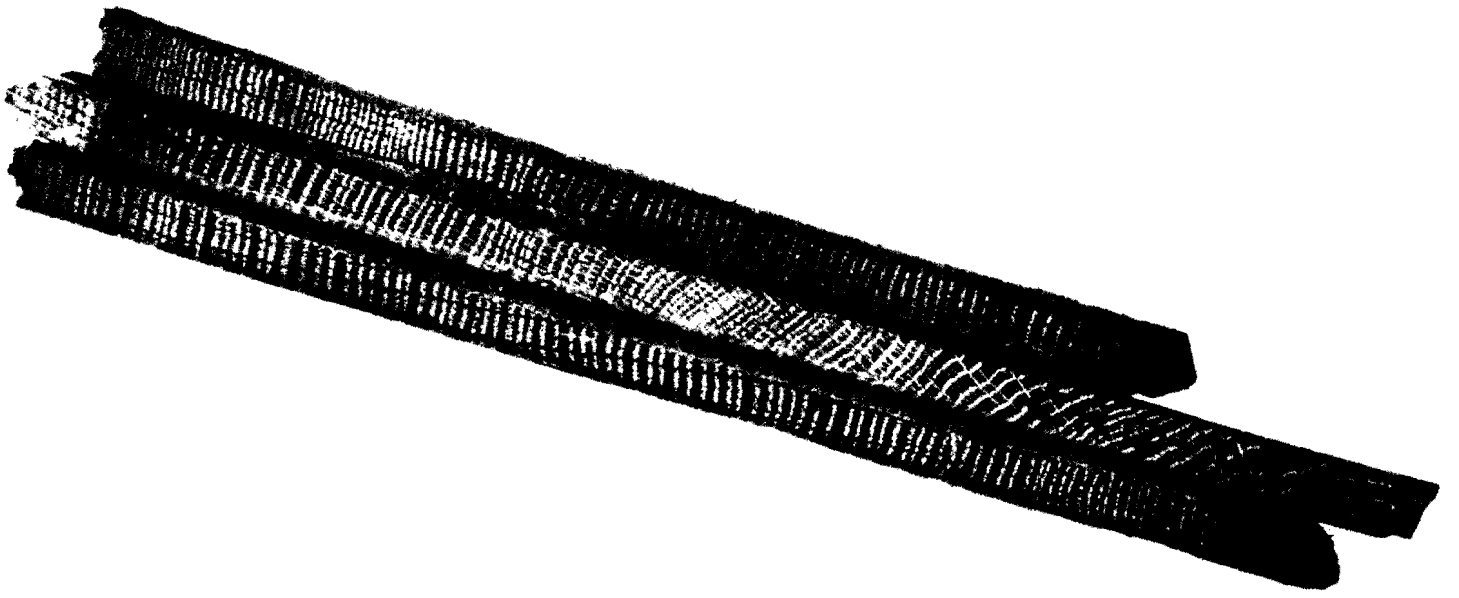


Fig 4. Three cores from timbers in a building. They come from trees growing at the same time. Notice that, although the sequences of widths look similar, they are not identical. This is typical.

Sampling is done by coring into the timber with a hollow corer attached to an electric drill and usually from its outer rings inwards towards where the centre of the tree, the pith, is judged to be. An illustration of a core is shown in Figure 2; it is about 15cm long and 1cm diameter. Great care has to be taken to ensure that as few as possible of the outer rings are lost in coring. This can be difficult as these outer rings are often very soft (see below on sapwood). Each sample is given a code which identifies uniquely which timber it comes from, which building it is from and where the building is located. For example, CRO-A06 is the sixth core taken from the first building (A) sampled by the Laboratory in Cropwell Bishop. Where it came from in that building will be shown in the sampling records and drawings. No structural damage is done to any timbers by coring, nor does it weaken them.

During the initial inspection of the building and its timbers the dendrochronologist may come to the conclusion that, as far as can be judged, none of the timbers have sufficient rings in them for dating purposes and may advise against sampling to save further unwarranted expense.

All sampling by the Laboratory is undertaken according to current Health and Safety Standards. The Laboratory's dendrochronologists are insured.

2. ***Measuring Ring Widths***. Each core is sanded down with a belt sander using medium-grit paper and then finished by hand with flourgrade-grit paper. The rings are then clearly visible and differentiated from each other with a result very much like that shown in Figure 2. The core is then mounted on a movable table below a microscope and the ring-widths measured individually from the innermost ring to the outermost. The widths are automatically recorded in a computer file as they are measured (see Fig 3).

3. ***Cross-matching and Dating the Samples***. Because of the factors besides the local climate which may determine the annual widths of a tree's rings, no two sequences of ring widths from different oaks growing at the same time are exactly alike (Fig 4). Indeed, the sequences may not be exactly alike even when the trees are growing near to each other. Consequently, in the Laboratory we do not attempt to match two sequences of ring widths by eye, or graphically, or by any other subjective method. Instead, it is done objectively (ie statistically) on a computer by a process called cross-matching. The output from the computer tells us the extent of correlation between two sample sequences of widths or, if we are dating, between a sample sequence of widths and the master, at each relative position of one to the other (offsets). The extent of the correlation at an offset is determined by the *t-value* (defined in almost any introductory book on statistics). That offset with the maximum *t*-value among the *t*-values at all the offsets will be the best candidate for dating one sequence relative to the other. If one of these is a master chronology, then this will date the other. Experiments carried out in the past with sequences from oaks of known date suggest that a *t*-value of at least 4.5, and preferably at least 5.0, is usually adequate for the dating to be accepted with reasonable confidence (Laxton and Litton 1988; Laxton *et al* 1988; Howard *et al* 1984-1995).

This is illustrated in Fig 5 with timbers from one of the roofs of Lincoln Cathedral. Here four sequences of ring widths, LIN-C04, 05, 08, and 45, have been cross-matched with each other. The ring widths themselves have been omitted in the *bar-diagram*, as is usual, but the offsets at which they best cross-match each other are shown; eg the sequence of ring widths of C08 matches the sequence of ring widths of C45 best when it is at a position starting 20 rings after the first ring of C45, and similarly for the others. The actual *t*-values between the four at these offsets of best correlations are in the matrix. Thus at the offset of +20 rings, the *t*-value between C45 and C08 is 5.6 and is the maximum found between these two among all the positions of one sequence relative to the other.

It is standard practice in our Laboratory first to cross-match as many as possible of the ring-width sequences of the samples in a building and then to form an average from them. This average is called a *site sequence* of the building being dated and is illustrated in Fig 5. The fifth bar at the bottom is a site sequence for a roof at Lincoln Cathedral and is constructed from the matching sequences of the four timbers. The site sequence width for each year is the average of the widths in each of the sample sequences which has a width for that year. Thus in Fig 5 if the widths shown are 0.8mm for C45, 0.2mm for C08, 0.7mm for C05, and 0.3mm for C04, then the corresponding width of the site sequence is the average of these, 0.55mm. The actual sequence

of widths of this site sequence is stored on the computer. The reason for creating site sequences is that it is usually easier to date an average sequence of ring widths with a master sequence than it is to date the individual component sample sequences separately.

The straightforward method of cross-matching several sample sequences with each other one at a time is called the 'maximal *t*-value' method. The actual method of cross-matching a group of sequences of ring-widths used in the Laboratory involves grouping and averaging the ring-width sequences and is called the 'Litton-Zainodin Grouping Procedure'. It is a modification of the straight forward method and was successfully developed and tested in the Laboratory and has been published (Litton and Zainodin 1991; Laxton *et al* 1988).

4. ***Estimating the Felling Date.*** As mentioned above, if the bark is present on a sample, then the date of its last ring is the date of the felling of its tree. Actually it could be the year after if it had been felled in the first three months before any new growth had started, but this is not too important a consideration in most cases. The actual bark may not be present on a timber in a building, though the dendrochronologist who is sampling can often see from its surface that only the bark is missing. In these cases the date of the last ring is still the date of felling.

Quite often some, though not all, of the original outer rings are missing on a timber. The outer rings on an oak, called *sapwood* rings, are usually lighter than the inner rings, the *heartwood*, and so are relatively easy to identify. For example, sapwood can be seen in the corner of the rafter and at the outer end of the core in Figure 2, both indicated by arrows. More importantly for dendrochronology, the sapwood is relatively soft and so liable to insect attack and wear and tear. The builder, therefore, may remove some of the sapwood for precisely these reasons. Nevertheless, if at least some of the sapwood rings are left on a sample, we will know that not too many rings have been lost since felling so that the date of the last ring on the sample is only a few years before the date of the original last ring on the tree, and so to the date of felling.

Various estimates have been made and used for the average number of sapwood rings in mature oak trees (English Heritage 1998). A fairly conservative range is between 15 and 50 and that this holds for 95% of mature oaks. This means, of course, that in a small number of cases there could be fewer than 15 and more than 50 sapwood rings. For example, the core CRO-A06 has only 9 sapwood rings and some have obviously been lost over time – either they were removed originally by the carpenter and/or they rotted away in the building and/or they were lost in the coring. It is not known exactly how many sapwood rings are missing, but using the above range the Laboratory would estimate between a minimum of 6 (=15-9) and a maximum of 41 (=50-9). If the last ring of CRO-A06 has been dated to 1500, say, then the estimated felling-date range for the tree from which it came originally would be between 1506 and 1541. The Laboratory uses this estimate for sapwood in areas of England where it has no prior information. It also uses it when dealing with samples with very many rings, about 120 to the last heartwood ring. But in other areas of England where the Laboratory has accumulated a number of samples with complete sapwood, that is, no sapwood lost since felling, other estimates in place of the conservative range of 15 to 50 are used. In the East Midlands (Laxton *et al* 2001) and the east to the south down to Kent (Pearson 1995) where it has sampled extensively in the past, the Laboratory uses the shorter estimate of 15 to 35 sapwood rings in 95% of mature oaks growing in these parts. Since the sample CRO-A06 comes from a house in Cropwell Bishop in the East Midlands, a better estimate of sapwood rings lost since felling is between a minimum of 6 (=15-9) and 26 (=35-9) and the felling would be estimated to have taken place between 1506 and 1526, a shorter period than before. (Oak boards quite often come from the Baltic and in these cases the 95% confidence limits for sapwood are 9 to 36 (Howard *et al* 1992, 56)).

Even more precise estimates of the felling date and range can often be obtained using knowledge of a particular case and information gathered at the time of sampling. For example, at the time of sampling the dendrochronologist may have noted that the timber from which the core of Figure 2 was taken still had complete sapwood but that none of the soft sapwood rings were lost in coring. By measuring into the timber the depth of sapwood lost, say 2 cm, a reasonable estimate can be made of the number of sapwood rings lost, say 12 to 15 rings in this case. By adding on 12 to 15 years to the date of the last ring on the sample a good tight estimate for the range of the felling date can be obtained, which is often better than the 15 to 35 years later we would have estimated without this observation. In the example, the felling is now estimated to

t-value/offset Matrix

	C45	C08	C05	C04
C45		+20	+37	+47
C08	5.6		+17	+27
C05	5.2	10.4		+10
C04	5.9	3.7	5.1	

Bar Diagram

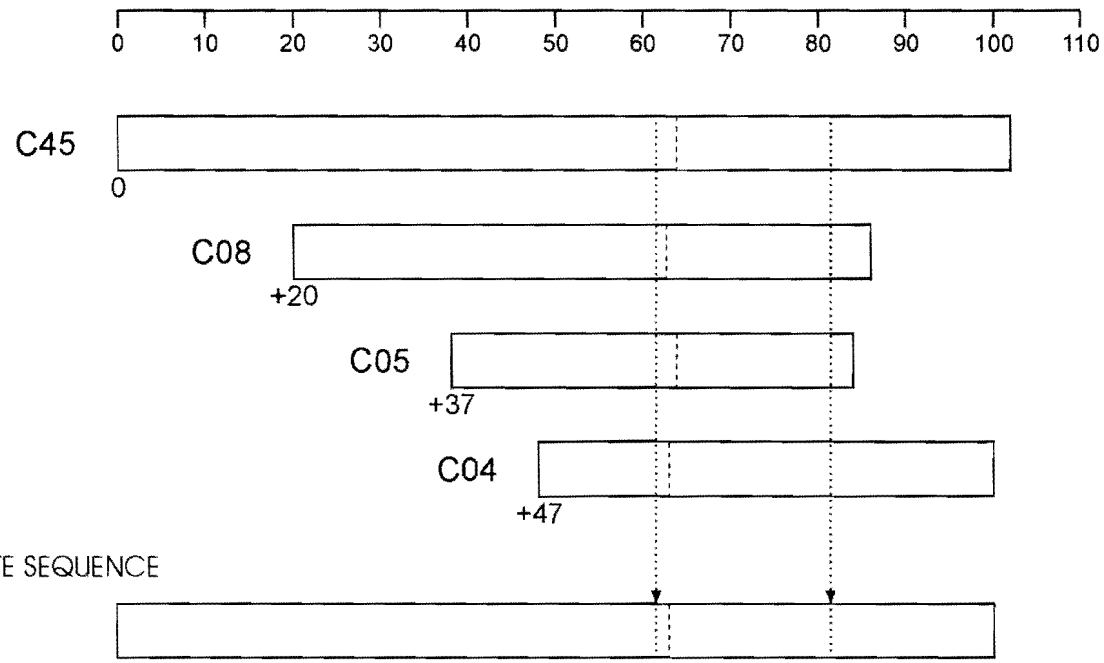


Fig 5. Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them.

The *bar diagram* represents these sequences without the rings themselves. The length of the bar is proportional to the number of rings in the sequence. Here the four sequences are set at relative positions (*offsets*) to each other at which they have maximum correlation as measured by the *t*-values.

The *t*-value/offset matrix contains the maximum *t*-values below the diagonal and the offsets above it. Thus, the maximum *t*-value between C08 and C45 occurs at the offset of +20 rings and the *t*-value is then 5.6.

The *site sequence* is composed of the average of the corresponding widths, as illustrated with one width.

have taken place between AD 1512 and 1515, which is much more precise than without this extra information.

Even if all the sapwood rings are missing on a sample, but none of the heartwood rings are, then an estimate of the felling-date range is possible by adding on the full compliment of, say, 15 to 35 years to the date of the last heartwood ring (called the heartwood/sapwood boundary or transition ring and denoted H/S). Fortunately it is often easy for a trained dendrochronologist to identify this boundary on a timber. If a timber does not have its heartwood/sapwood boundary, then only a *post quem* date for felling is possible.

5. ***Estimating the Date of Construction***. There is a considerable body of evidence collected by dendrochronologists over the years that oak timbers used in buildings were not seasoned in medieval or early modern times (English Heritage 1998 and Miles 1997, 50-55). Hence provided all the samples in a building have estimated felling-date ranges broadly in agreement with each other, so that they appear to have been felled as a group, then this should give an accurate estimate of the period when the structure was built, or soon after (Laxton *et al* 2001, figure 8 and pages 34-5 where 'associated groups of fellings' are discussed in detail). However, if there is any evidence of storing before use or if there is evidence the oak came from abroad (eg Baltic boards), then some allowance has to be made for this.

6. ***Master Chronological Sequences***. Ultimately, to date a sequence of ring widths, or a site sequence, we need a master sequence of dated ring widths with which to cross-match it, a Master Chronology. To construct such a sequence we have to start with a sequence of widths whose dates are known and this means beginning with a sequence from an oak tree whose date of felling is known. In Fig 6 such a sequence is SHE-T, which came from a tree in Sherwood Forest which was blown down in a recent gale. After this other sequences which cross-match with it are added and gradually the sequence is 'pushed back in time' as far as the age of samples will allow. This process is illustrated in Fig 6. We have a master chronological sequence of widths for Nottinghamshire and East Midlands oak for each year from AD 882 to 1981. It is described in great detail in Laxton and Litton (1988), but the components it contains are shown here in the form of a bar diagram. As can be seen, it is well replicated in that for each year in this period there are several sample sequences having widths for that year. The master is the average of these. This master can now be used to date oak from this area and from the surrounding areas where the climate is very similar to that in the East Midlands. The Laboratory has also constructed a master for Kent (Laxton and Litton 1989). The method the Laboratory uses to construct a master sequence, such as the East Midlands and Kent, is completely objective and uses the Litton-Zainodin grouping procedure (Laxton *et al* 1988). Other laboratories and individuals have constructed masters for other areas and have made them available. As well as these masters, local (dated) site chronologies can be used to date other buildings from nearby. The Laboratory has hundreds of these site sequences from many parts of England and Wales covering many short periods.

7. ***Ring-width Indices***. Tree-ring dating can be done by cross-matching the ring widths themselves, as described above. However, it is advantageous to modify the widths first. Because different trees grow at different rates and because a young oak grows in a different way from an older oak, irrespective of the climate, the widths are first standardized before any matching between them is attempted. These standard widths are known as ring-width indices and were first used in dendrochronology by Baillie and Pilcher (1973). The exact form they take is explained in this paper and in the appendix of Laxton and Litton (1988) and is illustrated in the graphs in Fig 7. Here ring-widths are plotted vertically, one for each year of growth. In the upper sequence of (a), the generally large early growth after 1810 is very apparent as is the smaller later growth from about 1900 onwards when the tree is maturing. A similar phenomena can be observed in the lower sequence of (a) starting in 1835. In both the widths are also changing rapidly from year to year. The peaks are the wide rings and the troughs are the narrow rings corresponding to good and poor growing seasons, respectively. The two corresponding sequence of Baillie-Pilcher indices are plotted in (b) where the differences in the immature and mature growths have been removed and only the rapidly changing peaks and troughs remain, that are associated with the common climatic signal. This makes cross-matching easier.

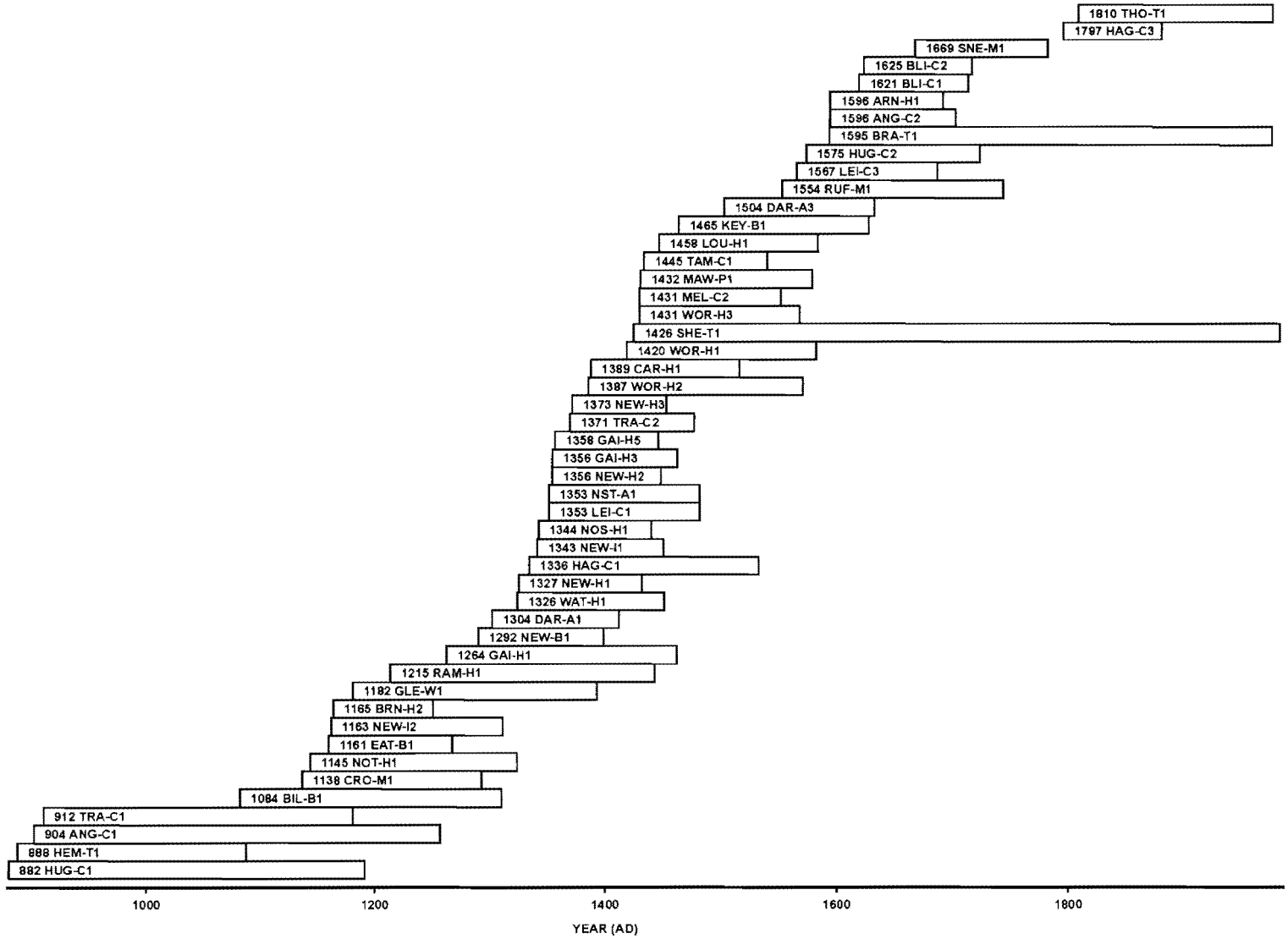
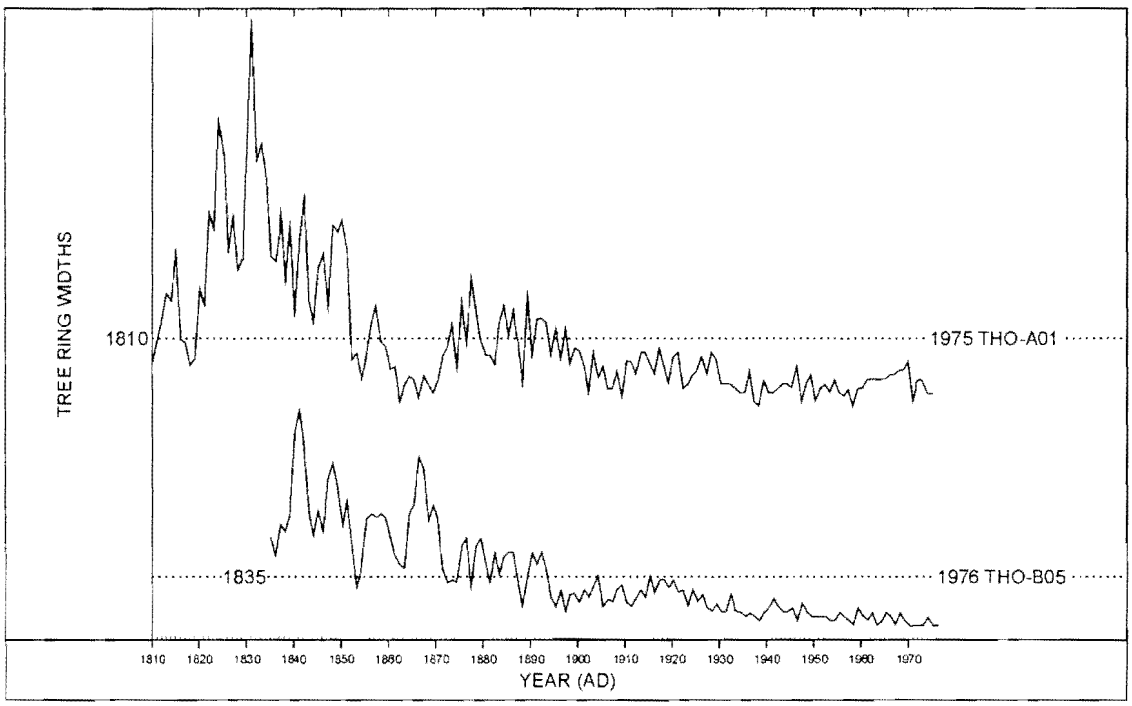


Fig. 6 Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

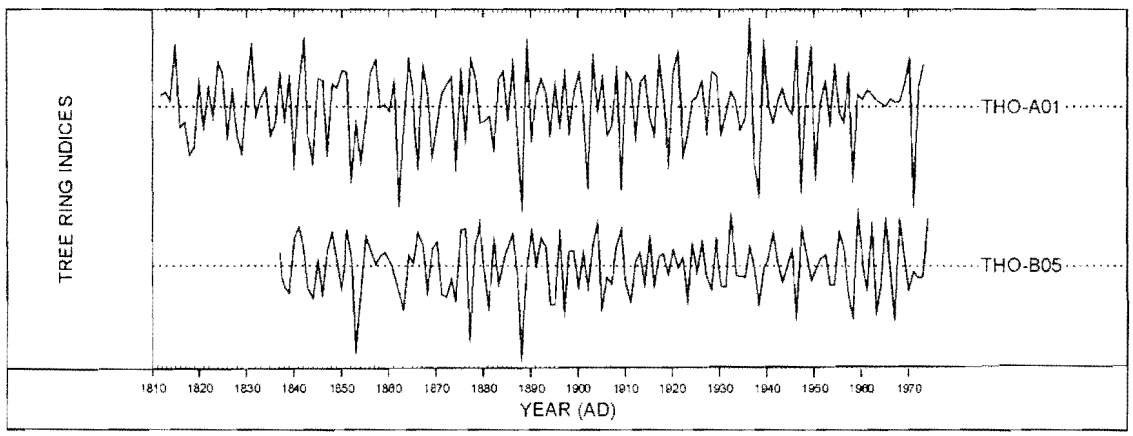


Fig 7. (a) The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known. Here the ring widths are plotted vertically, one for each year, so that peaks represent wide rings and troughs narrow ones. Notice the growth-trends in each; on average the earlier rings of the young tree are wider than the later ones of the older tree in both sequences.

Fig 7. (b) The *Baillie-Pilcher* indices of the above widths. The growth-trends have been removed completely.

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