SLEDDALL HALL
WILDMAN STREET
KENDAL
CUMBRIA

TREE-RING ANALYSIS OF TIMBERS

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SUMMARY

Analysis by dendrochronology of cores from 13 of the 15 different timbers sampled at Sleddall Hall (two samples having too few rings) resulted in the production of two dated site chronologies.

The first site chronology comprises five samples and is 191 rings long, these rings dated as spanning the years 1371–1561. Interpretation of the sapwood on these samples indicates that four timbers from the front range roof were cut as part of a single episode of felling at some point between 1571 at the earliest and 1596 at the latest. The felling date of a fifth timber, a first floor ceiling beam to the rear range, cannot be determined but is unlikely to be before 1543 at the earliest.

The second site chronology comprises three samples and is 119 rings long, these rings spanning the years 1536–1654. Interpretation of the sapwood on these indicates that the dated timbers to the rear range roof were also cut as part of a single episode of felling in, or about, 1660.

Five measured samples remain ungrouped and undated.

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Introduction

The Grade II Sleddall Hall stands just to the south side of Wildman Street towards the north side of the town, close to where the A65 trunk road crosses the River Kent (SD 51937 93033, Fig 1a/b). The building plot reflects the town's distinctive urban form, with a pedestrian access passage to the side of the building and a rear range enclosing a narrow yard (cover photograph). Formed from a former high-status house in the historic centre of Kendal, the site presents a shop range to the street frontage with a workshop/store range running to the rear at a right-angle (Fig 2). Despite later adaptation and exterior remodelling, the interior retains much original detail.

The listing entry describes the building as a shop and pottery studio, formerly a dwelling of seventeenth century date, though incorporating earlier fabric, with dated ornamentation of 1666. It is of rubble stone construction, with ridge chimney stacks, and a slate roof covering laid to diminishing courses. It was altered in the mid- to late-nineteenth century.

The building is of two storeys and five bays, with open passage entrance to right, and doorways to the left in bays 2 and 3. Bay 1 has multi-pane shop window, bay 3 has a doorway with 6-panel part-glazed door, and a multi-pane display window to the right. There is a single ridge chimney to the right-hand end. Five first-floor windows with 6-over-6 pane sash windows. Rear range has its entrance at the junction of the two ranges, with an advanced bay and a recessed bay with paired windows, and a second advanced bay with an external stair to a galleried entrance landing.

Within, the street frontage range is divided into two cells, that to the right with a substantial chamfered spine beam, winder stair, hearth with imported surround and seventeenth century square panelling moved from an upper room. The hearth wall incorporates a spice cupboard. The rear range has back-to-back hearths in the present storage areas, and a further altered hearth to the end bay with a damaged decorative plaster overmantle panel with the inscription '*F/I M/1666*'. Above, a large undivided room or workshop accessed by means of the external stair, with exposed cross-framed spine beams. The roof structure is supported on tiebeam trusses with angle struts, the trusses formed from what appear to be re-used cruck blades. The building has been the subject of extensive survey and recording (Bowd and Basey-Fisher 2015).

Sampling

Sampling and analysis by dendrochronology of the timbers within Sleddall Hall were commissioned by Mr Clive Bowd, consulting buildings archaeologists, with funds generously provided by the Cumberland and Westmorland Antiquarian and Archaeological Society (CWAAS), this work being undertaken out of historic interest in the building and concern for its future wellbeing. It was hoped that tree-ring analysis might more accurately and reliably determine the date of the front and rear ranges of the building, and provide some information on the sequential internal development of the house.

The roof to the front range comprises three principal rafter-with-tiebeam trusses, the principals supporting double purlins to each pitch, the purlins in turn supporting common rafters (Fig 3a/b). Some of the joints to this timbering are slightly ill-fitting and there are also some redundant mortices and peg-holes. Some of the timbers, particularly the purlins, are also of slightly different sizes. However, while it is possible that some older timber has been reused here, and/or that some more recent timber has been introduced as later repairs, it would seem that a substantial number of the roof timbers are original, although there may have been some re-setting of these timbers.

The roof to the rear range also comprises three principal rafter-with-tiebeam trusses, the principals again supporting double purlins, which again support common rafters. In this roof, however, not only are there both slightly curved and straight queen struts to the trusses, but the timbers (apart from some purlins which are clearly modern replacements), all appear to be of similar dimensions and they have a much more consistent appearance than do the timbers of the front range roof (Fig 3c/d).

There are various further timbers to the ground and first floors, these forming lintels to doors and other openings, wall beams, stud posts, and ceiling beams, the main collection of ceiling beams being found to the first floor of the rear range. Prior to sampling it was seen that while several timbers to the roofs of both front and rear ranges had sufficient rings for reliable analysis, all the timbers to the lower floors were either derived from very fast-grown trees and thus had insufficient rings for reliable dating, and/or potentially represented individual-phase timbers, such individual timbers offering little prospect for dating. Such timbers were not sampled.

Thus, from the timbers available to the roof and floor frames of both the front and rear ranges, a total of 15 samples was obtained by coring. Each sample was given the tree-ring code KND-A (for Kendall, site ‘A’), and numbered 01–15. Details of the samples are given in Table 1, including the timber sampled and its location, the total number of rings each sample has, and how many of these, if any, are sapwood rings. The individual date span of each dated sample is also given. The sampled timbers are located either on drawings taken from the Cumbria Vernacular Buildings Group survey report or on annotated photographs, these being shown here as Figures 4a–g. In this report the front of the building is taken to be facing ‘site north’ onto Wildman Street.

The Nottingham Tree-ring Dating Laboratory would like to take this opportunity to firstly thank the owners of Sleddall Hall, Andrew and Robert Aindow, not only for their enthusiastic support for this programme of analysis, but also for their hospitality during sampling. The laboratory would also like to thank Clive Bowd for commissioning this programme of tree-ring analysis, for his help and advice on the interpretation of the building, and for the use of his plans and drawings. Finally we would like to thank the CWAAS for their financial support of this project.

Tree-ring dating

Tree-ring dating relies on a few simple, but quite fundamental, principles. Firstly, as is commonly known, trees (particularly oak trees, the timber most commonly used in building construction until the introduction of pine from the late eighteenth century onwards) grow by adding one, and only one, growth-ring to their circumference each, and every, year. Each new annual growth-ring is added to the outside of the previous year's growth just below the bark. The width of this annual growth-ring is largely, though not exclusively, determined by the weather conditions during the growth period (roughly March–September). In general, good conditions produce wider rings and poor conditions produce narrower rings. Thus, over the lifetime of a tree, the annual growth-rings display a climatically influenced pattern. Furthermore, and importantly, all trees growing in the same area at the same time will be influenced by the same growing conditions and the annual growth-rings of all of them will respond in a similar, though not identical, way (Fig 5).

Secondly, because the weather over a certain number of consecutive years (the statistically reliable minimum calculated as being 54 years) is unique, so too is the growth-ring pattern of the tree. The pattern of a shorter period of growth, 20, 30**,** or even 40 consecutive years, might conceivably be repeated two or even three times in the last one thousand years, and is considered less reliable. A short pattern might also be repeated at different time periods in different parts of the country because of differences in regional micro-climates. It is less likely, however, that such problems would occur with the pattern of a longer period of growth, that is, anything in excess of 45 years or so. In essence, a short period of growth, anything less than 45 rings, is not reliable, and the longer the period of time under comparison the better.

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

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

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

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

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

Analysis & Interpretation

Each of the 15 samples obtained from the various timbers to the front and rear range of Sleddall Hall was prepared by sanding and polishing. It was seen at this time that two samples, KND-A08 and A09, from the roof of the rear range, had fewer than the 40 rings here deemed necessary for reliable dating, and they were rejected from this programme of analysis. The growth ring widths of the remaining 13 samples were, however, measured, these measured data then being compared with each other as described in the notes above. This comparative process indicated that a two separate group of cross-matching samples could be formed.

Site chronology KNDASQ01 (samples KND-A01–A04)

The first group comprises five samples, four of them from the roof to the front range plus one from the single sampled first-floor ceiling beam to the rear range. These five samples cross-match with each other as shown in the bar diagram, Figure 6. The five samples were combined at their indicated cross-matching positions to form KNDASQ01, a site chronology with an overall length of 191 rings. Site chronology KNDASQ01 was then compared to the full corpus of reference material for oak, cross-matching with a number of chronologies with a date span of 1371–1561 (Table 2).

None of the five samples of site chronology KNDASQ01 retain complete sapwood (ie, they do not have the last ring produced by the tree represented before felling), and it is thus not possible to reliable say precisely when any particular tree was cut. However, two samples (KND-A01 and A04) retain some sapwood or at least the heartwood/sapwood boundary (h/s in Table 1 and the bar diagram). This means that although the samples have lost some or all of their sapwood rings, it is *only* the sapwood that has been lost. Furthermore, given that the heartwood/sapwood boundary on the two samples is similar to each other, it is likely that they have lost similar amounts of sapwood and that the source trees are, therefore, likely to have been felled at, or about, the same time as each other.

Given that oak trees generally have numbers of sapwood rings within defined limits (a minimum of 15 sapwood rings and a maximum of 40 – the 95% confidence interval), it is possible to calculate a date range within which the felling is most likely to have occurred. This is done by taking the average date of the heartwood/sapwood boundary on the samples that retain it, in this case 1556, and adding the upper and lower sapwood estimates, 15–40 rings, to it. Here, this would give the timbers represented an estimated felling date of some point between 1571 at the earliest and 1596 at the latest.

In theory, the felling date of the trees represented by the two other front range roof samples in site chronology KNDASQ01 (KND-A05 and A07) cannot be reliably determined. This is because, in not retaining the heartwood/sapwood boundary, the timbers are missing not only all their sapwood rings, but an unknown number of heartwood rings as well; they could have gone on growing for many years after their last extant heartwood ring dates. However, given the high level of cross-matching between all four front-range roof samples, it is likely that the source trees were growing close to each other in the same woodland. As such, it would be something of a coincidence that they should come to be used in the same building if the trees had been felled at different times. It is thus perhaps more likely than not that all the trees were felled at, or about the same time as each other in the period 1571–96.

Site chronology KNDASQ01 (sample KND-A15)

The same argument cannot, however, be applied to the final constituent sample (KND-A15) of site chronology KNDASQ01, which is again without the heartwood/sapwood boundary, and for which a felling date cannot be reliably determined. Not only is the sampled timber from a different part of the building (a ceiling beam to the rear range), but it also cross-matches less well with the other samples from the front range roof, this suggesting that the source tree was growing in a different woodland.

Thus, while it is of course *possible* that this timber was felled at the same time as those used in the front range roof, there is a distinct possibility that it was felled at some other, unknown, time. What may be said is that, with a last extant heartwood ring date of 1527, and allowing that it might be missing just one ring to the heartwood/sapwood boundary plus at least 15 further sapwood rings, it is unlikely to have been felled before 1543 at the earliest.

Site chronology KNDASQ02 (samples KND-A10, A12, and A13)

The second group to form comprises three samples, all of them from the roof to the rear range, these samples again cross-matching with each other as shown in the bar diagram Figure 6. The three cross-matching samples were combined at their indicated offset positions to form KNDASQ02, a site chronology with an overall length of 119 rings. Site chronology KNDASQ02 was then also compared to the full corpus of reference material for oak, cross-matching with a number of chronologies with a date span of 1536–1654 (Table 3).

One of these samples (KND-A12) is from a timber which did have complete sapwood on it. However, due to its soft and fragile nature, a portion of this sapwood, about 5mm, was lost from the sample in coring (this being denoted by lower case 'c' in Table 1 and the bar diagram). It is reckoned that this lost 5mm contained only 5–6 rings. Given that the last extant sapwood ring on sample KND-A12 is dated 1654, this would give the source tree a felling date of, say, 1660.

Of the other two samples of this group, one retains the heartwood/sapwood boundary, the other is without the boundary. However, both the relative position of the boundary on the one sample, and the cross-matching between them all, would suggest that all three dated timbers were cut as part of a single episode of felling, and that all three trees were, therefore, felled in, or about, 1660.

Conclusion

Analysis by dendrochronology has, therefore, clearly demonstrated that as possibly expected on the basis of structural evidence, there are at least two, and possibly more, phases of felling represented by the timbers to the front and rear ranges at Sleddall Hall.

While it is possible that some un-sampled, or sampled but undated, beams may represent reused older timbers, and that there may be repairs and replacements made of more recent timbers, there is certainly a group of probably in-situ construction-phase timbers in the front range roof dating to the later-sixteenth century. Similarly, there is a group of timbers to the rear range roof dating to 1660, with another timber to the first floor ceiling here being no earlier than about the middle of the sixteenth century.

Woodland source

Although both site chronology KNDASQ01 and KNDASQ02 have been compared with reference chronologies from every part of Britain, there is a strong tendency for both chronologies to match best with references made up of material from other sites in northern England rather than anywhere else. As may be seen from Tables 2 and 3, the highest *t*-values, ie, the greatest degrees of similarity are often found with other sites in Cumbria, as well as Northumberland and North Yorkshire. While the exact location of the woodland sources for these reference sites are themselves unknown, the overall cross-matching would suggest, perhaps not unexpectedly, that the timbers used at Sleddall Hall are of regional, and probably relatively local, origin.

Undated samples

Five measured samples remain ungrouped and undated. As may be seen from Table 1, one of these sample, KND-A11, has a very low number of rings, being just above the absolute minimum, while another sample, KND-A14, shows some disturbance to its growth (a number of its outer rings being too distorted to measure). The other three samples show no such problems. It is possible, though not at all certain, that these undated timbers are older reused individuals or later insertions, this in effect making them ‘singletons’. While such timbers can on occasion be dated, it is much more difficult than with groups of replicated timbers. It is, in any case, a common feature of most programmes of tree-ring analysis to have some samples which remain undated, often for no apparent reason.

Bibliography

Baillie, M G L, 1977 The Belfast Oak Chronology, *Tree-ring Bulletin* **37**, 1–12

Bowd, C, and Basey-Fisher, M, 2015 Sleddall Hall, Wildman Street, Kendal; Cumbria Vernacular Buildings Group survey (CVBG)

Bridge, M C, 2003 Tree-ring Analysis of Timbers from Stubley Old Hall, Featherstall Road, Littleborough, Greater Manchester, Centre for Archaeol Rep, **85/2003**

Arnold, A J, Howard, R E, and Litton, C D, 2004 Tree-ring Analysis of Timbers from 17 and 19 St Mary's Chare, Hexham, Northumberland, Centre for Archaeol Rep, **51/2004**

Arnold, A J, and Howard, R E, 2008 Turton Tower, Chapeltown Road, Turton, Blackburn with Darwen, Lancashire: Tree-ring Analysis of Timbers, English Heritage Res Dep Rep Ser, **93/2008**

Arnold, A J and Howard, R E, 2009 List 210 no 3 – Nottingham Tree-Ring Dating Laboratory: results, *Vernacular Architect,* **40**, 111–17

Arnold, A J, Howard, R E, and, Litton, C D, 2008 Additional Dendrochronology Dates from Nottingham Tree-ring Dating Laboratory, no 6, *Vernacular Architect,* **39**, 107–11

Arnold, A J, and Howard R E, 2014 Dandra Garth, Garsdale, Cumbria; Tree-ring Analysis of Timbers, English Heritage Res Rep Ser, **22/2014**

Arnold, A J, Howard, R E, and Tyers, C, 2015 The Great Tythe Barn, Bolton Abbey, North Yorkshire: Tree-ring Analysis of Timbers, Historic England Res Rep Ser, **48/2015**

Arnold, A J, and Howard, R E, 2011 unpubl Row Ridding Farm, Woodland, Broughton-in-Furness, Cumbria; Tree-ring Analysis of Timbers from the House and Outbuildings, – Nottingham Tree-ring Dating Laboratory, unpubl computer file *RRFASQ01*

Arnold, A J, and Howard, R E, 2012 unpubl Tree-ring Analysis of Timbers from The Ship Inn, 14 Market Place, Cockermouth, Cumbria – Nottingham Tree-ring Dating Laboratory unpubl computer file *CKMBSQ01*

Arnold, A J, and Howard, R E, 2013 unpubl Tree-ring Analysis of Timbers from Danby Castle, Danby, Eskdale, North Yorkshire – Nottingham Tree-ring Dating Laboratory unpubl computer file *DBYCSQ01*

Howard, R E, Laxton, R R, Litton, C D, and Simpson, W G, 1991 List 39 no 2a/b/c – Nottingham University Tree-Ring Dating Laboratory: general list, *Vernacular Architect,* **22**, 40–3

Howard, R E, Laxton, R R, Litton, C D, and Simpson, W G, 1994 List 57 no 10a – Nottingham University Tree-Ring Dating Laboratory: results, *Vernacular Architect,* **25**, 36–40

Howard, R E, Laxton, R R, and Litton, C D, 2002 Tree-ring Analysis of Timbers from the Rigging Loft and Chapel Undercroft, Trinity House, Broad Chare, Newcastle upon Tyne, Tyne and Wear, Centre for Archaeol Rep, **63/2002**

Table 1: Details of tree-ring samples from Sleddall Hall, Wildman Street, Kendal, Cumbria						
Sample number	**Sample location**	**Total rings**	**Sapwood rings***	**First measured ring date (AD)**	**Heart/sap boundary (AD)**	**Last measured ring date (AD)**
	Front Range					
KND-A01	North upper purlin, truss 1 – 2	96	6	1466	1555	1561
KND-A02	North principal rafter, truss 2	66	h/s	------	------	------
KND-A03	South principal rafter, truss 2	60	h/s	------	------	------
KND-A04	South upper purlin, truss 1 – 2	109	h/s	1449	1557	1557
KND-A05	South upper purlin, truss 2 – 3	110	no h/s	1431	------	1540
KND-A06	North principal rafter, truss 3	57	h/s			
KND-A07	North upper purlin, truss 3 to west wall	77	no h/s	1456	------	1532
					1556=70-96	
	Rear Range					
KND-A08	East principal rafter, truss 4	nm	---	------	------	------
KND-A09	West principal rafter, truss 4	nm	---	------	------	------
KND-A10	East principal rafter, truss 5	82	no h/s	1536	------	1617
KND-A11	West principal rafter, truss 5	41	h/s	------	------	------
KND-A12	East principal rafter, truss 6	119	23	1536	1633	1654
KND-A13	West principal rafter, truss 6	89	h/s	1537	1625	1625
KND-A14	East upper purlin, truss 6 to end wall	56+	no h/s			
KND-A15	First floor ceiling beam	157	no h/s	1371	------	1527
C = complete sapwood is retained on the sample, the last measured ring date is the felling date of the tree represented						
h/s = heartwood/sapwood boundary, i.e., only the sapwood rings are missing						

Table 2: Results of the cross-matching of site chronology KNDASQ01 and the reference chronologies when the first ring date is 1371 and the last ring date is 1561		
Reference chronology	*t*-value	
Row Ridding Farm, Woodland, Cumbria	6.6	(Arnold and Howard 2011 unpubl)
Dandra Garth, Garsdale, Cumbria	6.6	(Arnold and Howard 2014)
Stubley Hall, Littleborough, Manchester	6.6	(Bridge 2003)
Tithe Barn, Bolton Abbey, West Yorkshire	6.5	(Arnold *et al* 2015)
Danby Castle, Eskdale, North Yorkshire	6.2	(Arnold and Howard 2013 unpubl)
Nether Levens Hall, Kendal, Cumbria	6.1	(Howard *et al* 1991)
The Rigging Loft, Newcastle, Tyne and Wear	6.1	(Howard *et al* 2002)
Seaton Holme, Easington, County Durham	5.9	(Arnold *et al* 2008)

Table 3: Results of the cross-matching of sample KNDASQ02 the reference chronologies when its first ring date is 1536 and the last ring date is 1654		
Reference chronology	*t*-value	
Dandra Garth, Garsdale, Cumbria	6.6	(Arnold and Howard 2014)
Turton Tower, Turton, Lancashire	6.1	(Arnold and Howard 2008)
Church Farm House, Ockbrook, Derbyshire	5.5	(Arnold and Howard 2009)
England Master Chronology	5.4	(Baillie 1977)
St Marys Chare, Hexham, Northumberland	5.2	(Arnold *et al* 2004)
Ship Inn, Cockermouth, Cumbria	5.1	(Arnold and Howard 2012 unpubl)
Nether Levens Hall, Kendal, Cumbria	5.0	(Howard *et al* 1991)
Brewhouse Yard Museum, Nottingham	5.0	(Howard *et al* 1994)

Site chronologies KNDASQ01 and KNDASQ02 are composites of the data of the relevant cross-matching samples as seen in the bar diagram Figure 6 below. These composite data produces ‘average’ tree-ring patterns, where the possible erratic variations of any one individual sample are reduced and the overall climatic signal of the group is enhanced. These ‘average’ site chronologies are then compared with several hundred reference patterns covering every part of Britain for all time periods, cross-matching with a number of these only at the date spans indicated. The Tables give only a small selection of the very best matches as represented by ‘*t*-values’ (ie, degrees of similarity). It may be noticed from this that the resultant *t*-values are well in excess of the *t*=3.5 value usually taken as the minimum acceptable level for satisfactory dating.

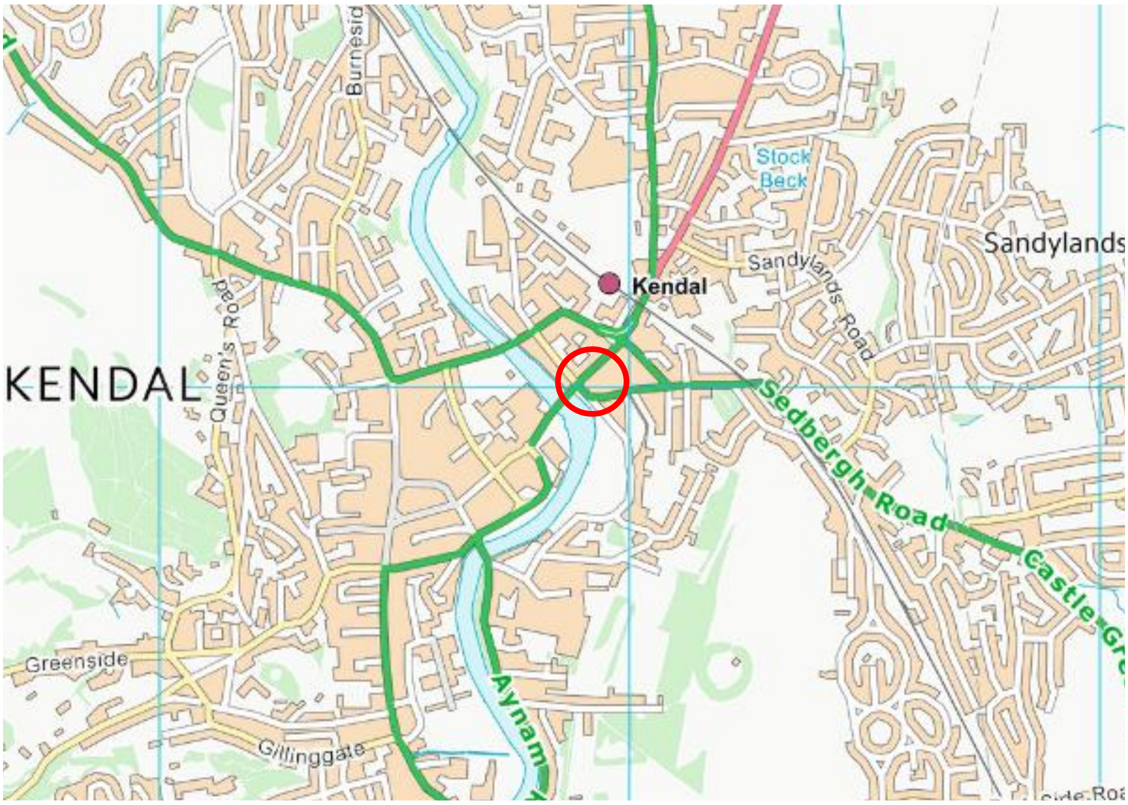


Figure 1a/b: Maps to show location of Kendal (top) and Wildman Street (bottom)

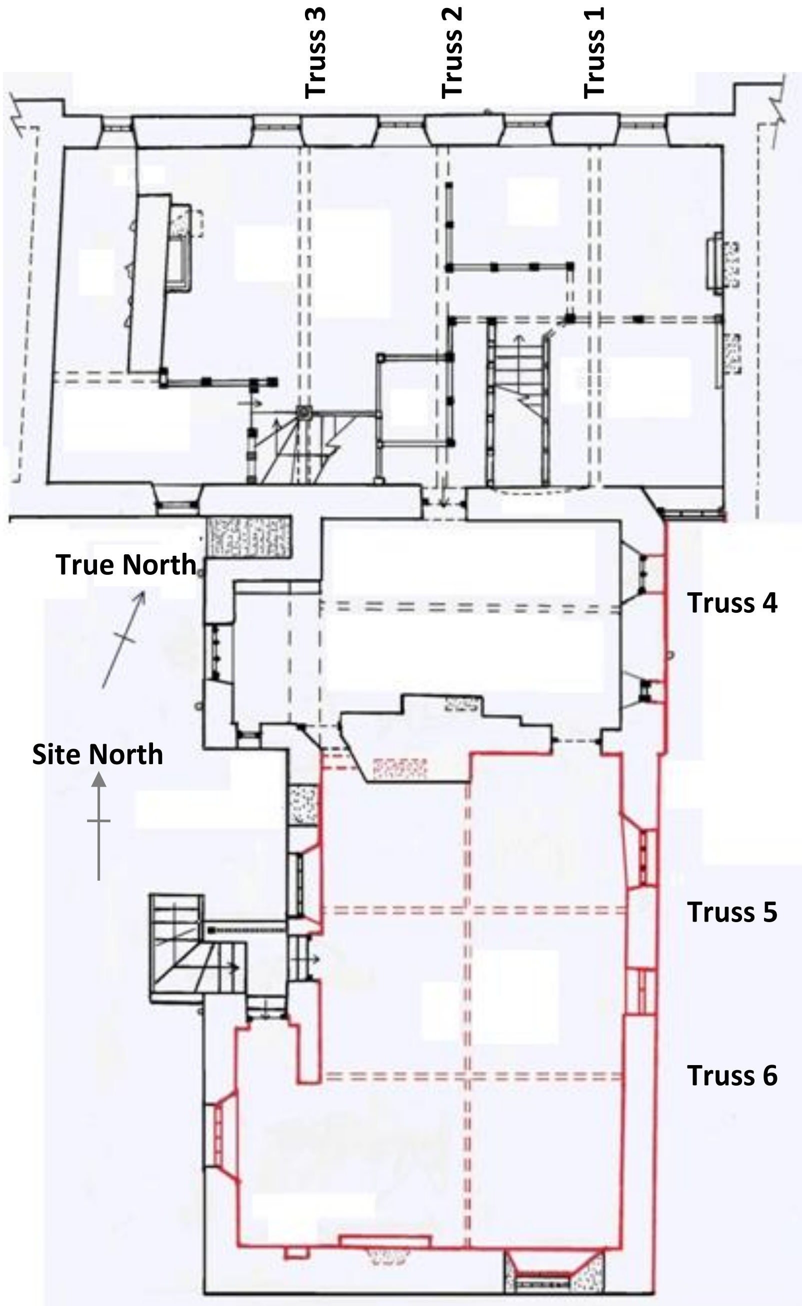


Figure 2: Plan of Sleddall Hall (at first floor level) to show arrangement and layout of the roof trusses (after Cumbria Vernacular Buildings Group survey)

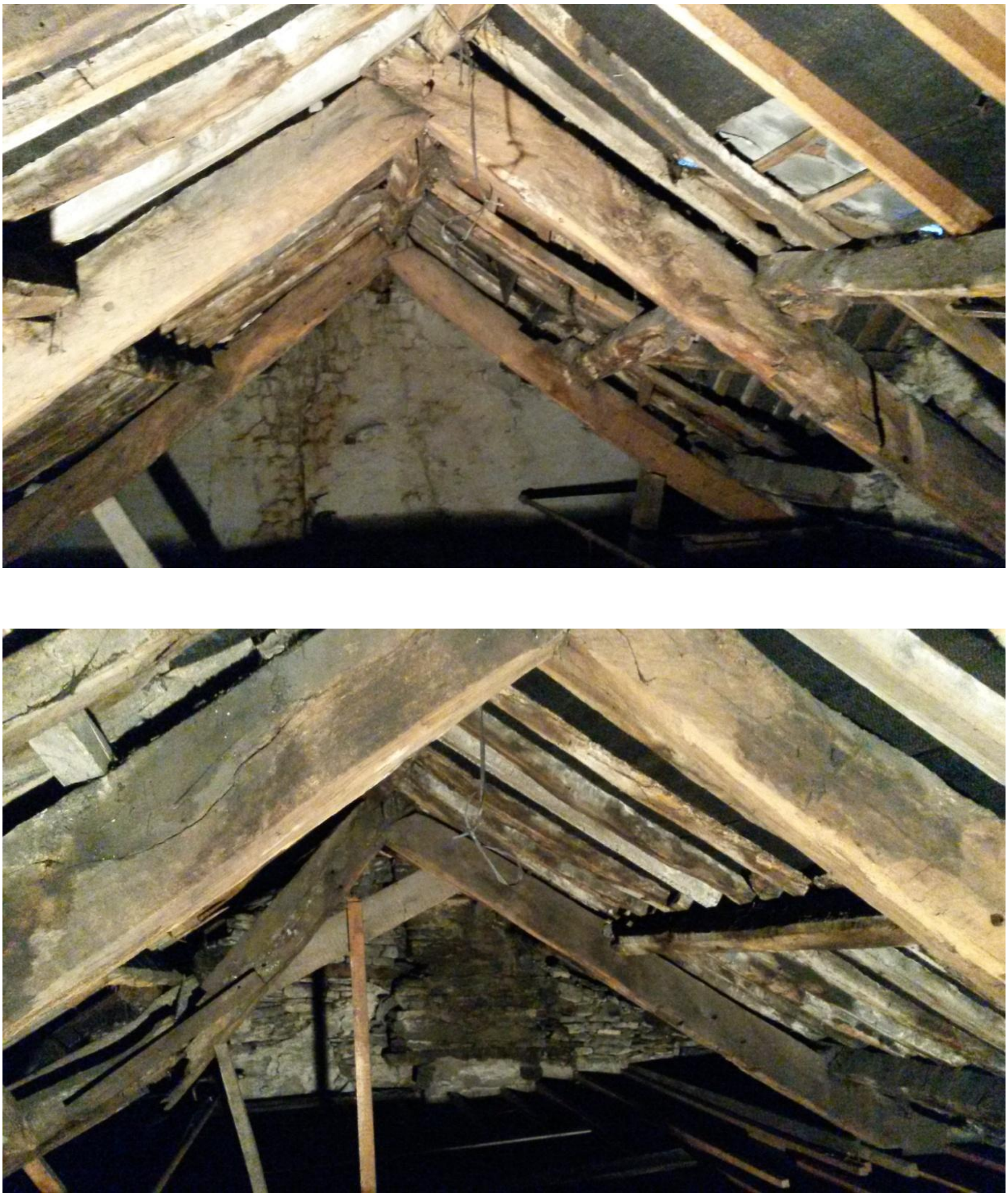


Figure 3a/b: Views of the front range roof, looking west to east (top) with truss 2 in the foreground and truss 1 beyond, and looking east to west (bottom), with truss 3 beyond

Figure 3c/d: Views of the rear range roof, looking north to south (top) with truss 5 in the foreground and truss 6 beyond, and the first floor ceiling to the rear range (bottom)

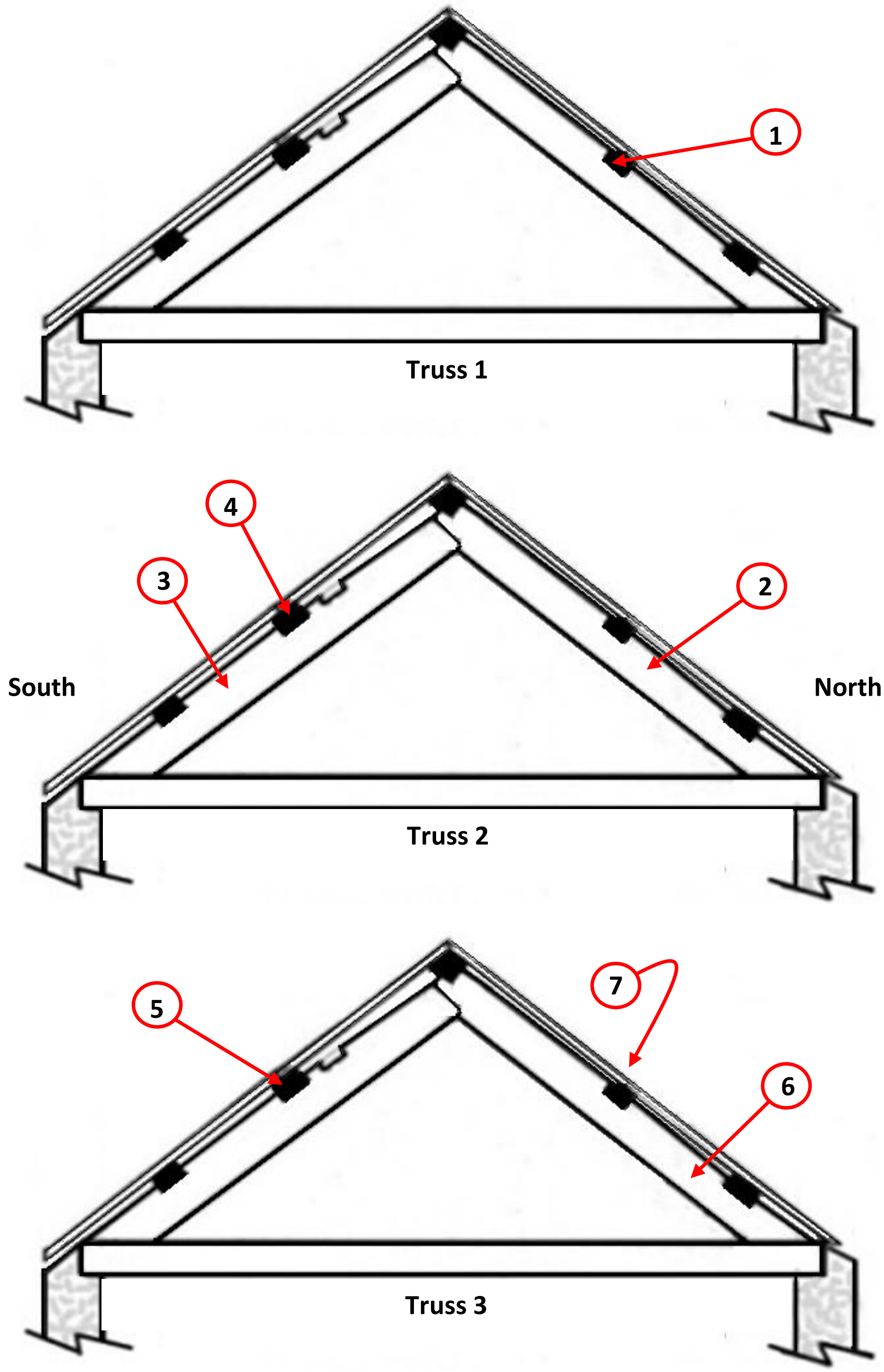


Figure 4a–c: Sections through the front range roof to help locate sampled timbers (see Table 1) (after Cumbria Vernacular Buildings Group survey)

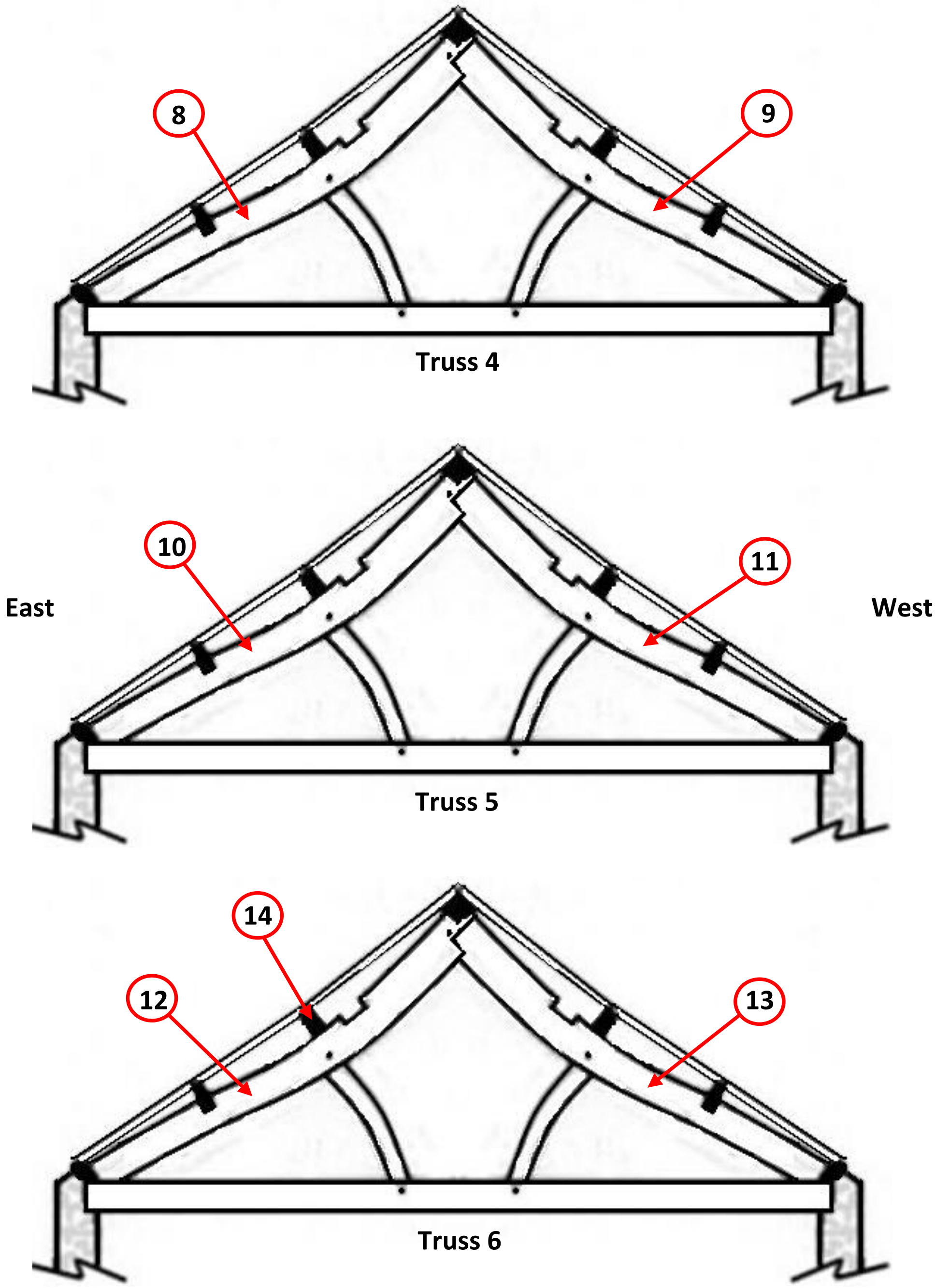


Figure 4d–f: Sections through the rear range roof to help locate sampled timbers (see Table 1) (after Cumbria Vernacular Buildings Group survey)

Figure 4g: Annotated photograph of the first floor ceiling to the rear range to show sampled timber (see Table 1)

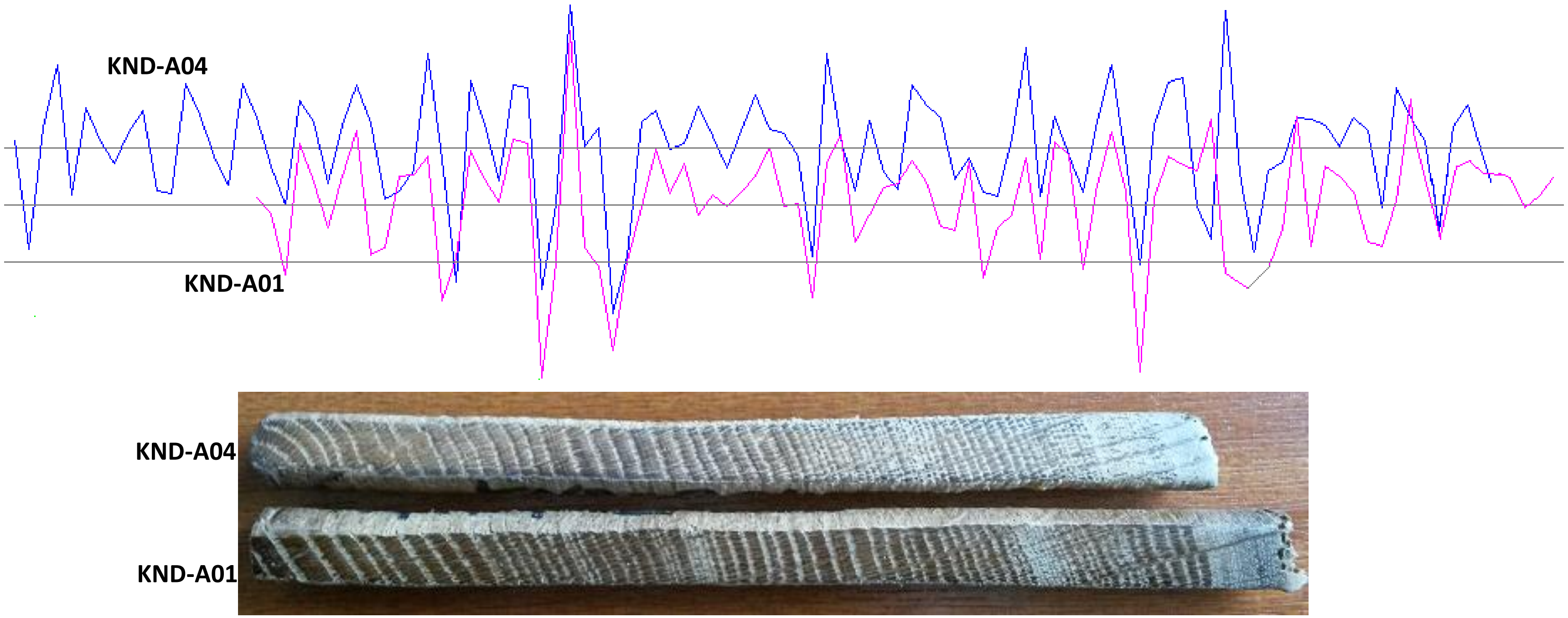
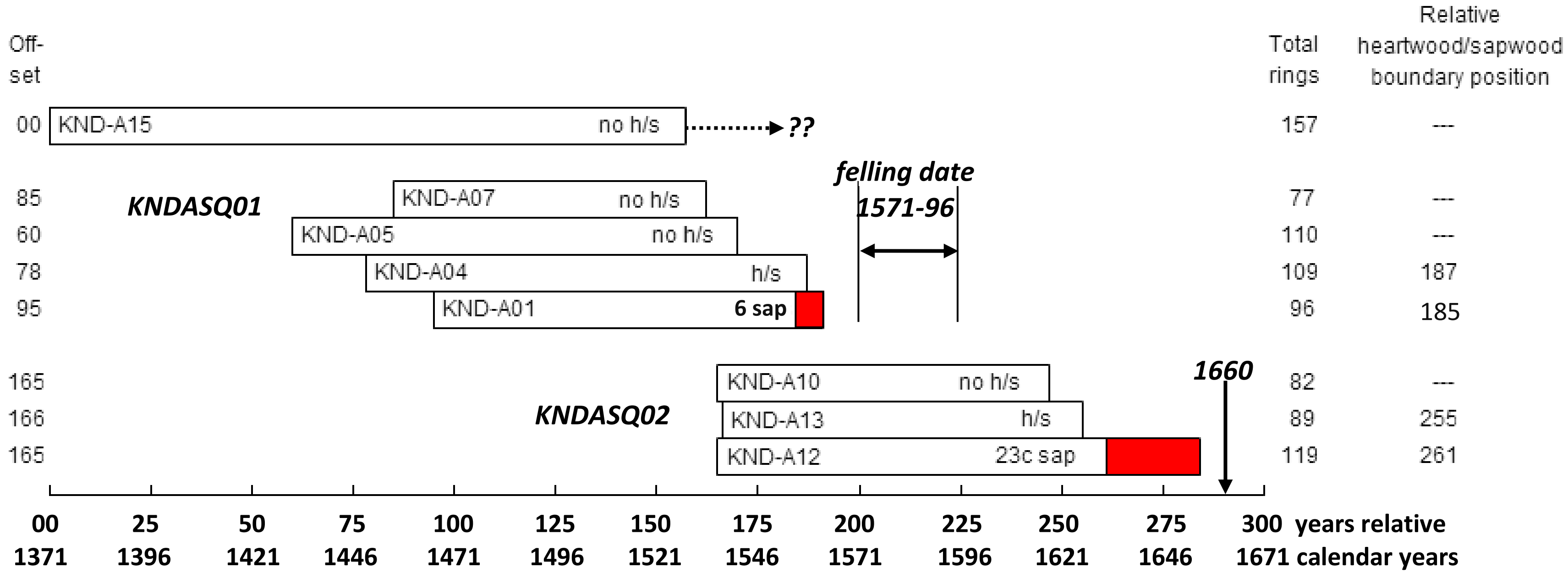


Figure 5: Graphic representation of the cross-matching of two samples, KND-A01 and A04

When cross-matched at the correct positions, as here, the variations in the rings of these two samples (where they overlap) correspond with a high degree of similarity. As the ring widths of one sample increase (represented by peaks in the graph), or decrease (represented by troughs), so too do the annual ring widths of the second sample. This similarity in growth pattern is a result of the two trees represented having grown at the *same time* in the *same place.* The growth ring pattern of two samples from trees grown at different times would never correspond so well.



blank bars = heartwood rings, shaded bars = sapwood rings
c = complete sapwood is found on sampled, but part lost from sample in coring
h/s = heartwood/sapwood boundary, i.e., only the sapwood rings are missing

Figure 6: Bar diagram of the samples in site chronologies KNDASQ01 and KNDASQ02

The five samples of site chronology KNDASQ01 and the three of KNDASQ02 are shown here in the form of bars at positions where the ring-width patterns of the constituent samples cross-match with each other, this similarity being produced by the trees of each respective group growing at the same time as each other in the same place. The site chronologies have been dated by comparison with the 'reference' chronologies (see Tables 2 and 3).