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Marystow
Devon

Tree-Ring Analysis of Oak Timbers, Panelling, and Trees

Alison Arnold, Robert Howard, and Cathy Tyers

Discovery, Innovation and Science in the Historic Environment

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Front Cover: Exterior view from the north showing the entrance front and south wing of Sydenham House.
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SUMMARY

Dendrochronological analysis was undertaken on 133 of the 160 samples (or series) obtained from oak structural timbers and wall panelling elements in various areas of Sydenham House, along with the analysis of 26 of the 27 samples derived from recently felled (fallen) or living oak trees on the Sydenham House estate. The dating of 84 of the timbers indicates that the majority of these represent a substantial mid seventeenth-century programme of works, probably in the mid-AD 1650s. A significantly smaller amount of timber, most of which is associated with the cellars, appears to represent works undertaken in the first decade of the seventeenth century, whilst the small amount of sixteenth-century timber identified is scattered through the house, although the cellars are again represented. Thirty of the wall panelling elements were dated, which, whilst it is possible that some were derived from trees felled in the latter-half of the sixteenth century, it is more probable that the majority were felled in early- and mid-seventeenth century. The 26 dated ring series from trees identified death dates in the early AD 2000s for a number of those that had been recently felled or had recently fallen, as well as indicating the year of coring for the living trees.

CONTRIBUTORS

Alison Arnold, Robert Howard, and Cathy Tyers

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INTRODUCTION

The Grade I listed Sydenham House is located on the south-west bank of the River Lyd, just over 1km north-west of the hamlet of Marystow in Devon (Figs 1a–d). It is a seventeenth-century manor house within a landscape of Grade II listed formal gardens and pleasure grounds lying to the east, south and west, and parkland. Sydenham Wood is located across the river on the north-east bank; a steep south-west facing slope of the Lyd valley.

The following information is derived from the listing entries for the house and garden (List Entry Numbers 1164731 and 1000703) and Cherry and Pevsner (1991). The Sydenham estate is the original seat of the de Sydenham family which passed, via various marriages, to the Wise family in the fourteenth century. The extant house is believed to have been built between AD 1600–12, possibly incorporating parts of an earlier, potentially H-shaped, house on the site. This early seventeenth-century construction work was undertaken for Sir Thomas Wise who is thought to have succeeded his brother, William, who died in AD 1600 having only recently inherited Sydenham on the death of their father (also Thomas Wise) in AD 1593. Following the death of Sir Thomas Wise in AD 1630 Sydenham passed to Lady Wise and their son, also Thomas Wise. He died in AD 1641 with Sydenham then passing to his son, Edward Wise.

A programme of substantial alterations was undertaken for Edward Wise in the mid-seventeenth century with documentary evidence dating to AD 1654 for *"ye building of my house at Sydenham"*, referring to cellars, foundations, and timber windows. It is believed that these works were completed by about AD 1656 and it has been suggested that the south end of the west (main) range was rebuilt or completed at this time. Sydenham passed through marriage to the Tremayne family following the death of Edward Wise in AD 1675 and it is thought that some refurbishment was undertaken for Arthur Tremayne in AD 1698–1709. Sydenham remained in the Tremayne family being used in the nineteenth century as a shooting box and dower house, when some refenestration is believed to have occurred in the AD 1840s. Following the death of Miss Tremayne in AD 1937, Sydenham was purchased by Major James Despencer-Robertson. He undertook, potentially quite substantial, repairs including the replacement of some sash windows with stone mullioned cross windows, the addition of a first-floor oriel window on the south-side of the south-east range, the rebuilding of the east wall of the south-east range, and the replacement of an early eighteenth-century doorway to the west porch with a fifteenth century granite doorway introduced from elsewhere. Sydenham was let as a girl's school during the war, and in the immediate aftermath, but was subsequently sold and once again became a private residence in the AD 1950s. In early November 2012 the house was engulfed by a fire. The damage was severe, particularly to the west (main) range, however, a substantial amount of timberwork survived in other parts of the building (Figs 2a–d).

Sydenham House is aligned north-northwest – south-southeast and is an E-plan form (Figs 1d and 3–4c) facing towards Sydenham Bridge. The east-front of the west (main) range has a porch projecting into the courtyard and front projecting wings to the north and south ends (the north-east range and the south-east range), both of which have porches projecting into the courtyard, forming a symmetrical appearance. The west face of the west (main) range also has a porch aligned to that on the east front, and a further wing (the north-west range) to the west. In addition, a kitchen wing (north-east range extension) and dining wing (north range) lie along the north side of the E-plan, the latter having a projecting stair turret on the north side.

Information detailing the roof forms across the building was not available at the time of writing but in very broad terms those roofs still intact after the fire were identified, during sampling for dendrochronological analysis, as principal rafter trusses with tiebeams and collars, the latter of which were quite high-set. Single, staggered butt purlins ran between the trusses, these providing support for two rows of common rafters (approximately 7–10 per bay), which ran from wall plate to purlin and then purlin to ridge. In the rooms still intact at the time of sampling there were collars between the rafters, which were integral to the ceilings.

The house is noted for its substantial oak wall panelling of high quality, some of it of unusual design. It is believed that much of the panelling was installed during the seventeenth century but that some has been adapted, extended, and refurbished during its subsequent history. However, of particular note is the wall panelling in four rooms; the Dining Room on the ground floor (Fig 4a); the King's Bedroom, the Queen's Bedroom, and the State Bedroom on the first floor (Fig 4b), that was considered part of Sir Thomas Wise's rebuilding of Sydenham House in the early seventeenth century (Lamb 2013). That in the Queen's Bedroom (north-east range extension) comprises five rows of plain panels topped with an entablature of double-width short panels (Fig 5a), whereas that in the King's Bedroom (north range) comprises four rows of plain panels topped with a single shorter row, although some adaptations have been noted in this room. The wall panelling to the Dining Room (north range) also consists of four rows of plain panels but these are capped with a torus moulding, above which is a single row of highly decorative panels and frames which may or may not be part of the original panelling scheme. The motifs in the Dining Room suggest a pre-Palladian date. The wall panelling in the State Bedroom (north-east range) comprises three rows of panels topped with an entablature of decorated wider but shorter panels (Fig 5b). However, to confuse matters, whilst it is considered to be a survival from Sir Thomas Wise's rebuilding, it appears to have been adapted to fit this room and has additions from other panelling schemes, furthermore it is thought that the chimneypiece panelling could even be from a different property.

Sydenham Wood, the greater part of the estate woodlands, lies in relative close proximity to the house but is located on the north-east bank of the River Lyd on land rising steeply from the river valley to a ridge above (Figs 1b–c). The ridge is indented eastwards by a slightly more open valley of a tributary to the River Lyd. The trees upslope from the river,

and to the short eastward valley, are a mixture of oak (*Quercus* sp.), sweet chestnut (*Castanea sativa* Mill.) and beech (*Fagus sylvatica* L.), all growing in moderately dense proximity with a hazel (*Corylus avellana* L.) under-storey (Fig 6). There is also an area of trees located relatively close to, but to the west of, the house (Fig 1c), which again comprises oak, chestnut, and beech but includes some ash (*Fraxinus excelsior* L.), willow (*Salix* sp.) and sycamore (*Acer pseudoplantanus* L.). This area provides more open conditions with the trees forming small copses or within field boundaries.

SAMPLING

Following the fire a major scheme of conservation and repair was undertaken involving the stripping out of partition walls, floors, and ceilings and the removal of the most severely damaged timbers. The extant wall panelling, some of which had been damaged by the fire, was considered very vulnerable following water damage due to the potential for deformation during dehydration. It was decided, therefore, that following detailed *in situ* recording the surviving panelling would be lifted in large sections and taken to the Swan Farm Studios where appropriate conservation and repairs could be undertaken, also allowing drying-out under controlled conditions.

A programme of dendrochronological investigation was requested by Francis Kelly to enhance understanding of the historic development of this manor house and hence inform the significance of the areas damaged by the fire. This, along with the programme of recording, would help inform advice, and hence decisions, relating to repair and potential reinstatement works. The opportunity to undertake analysis on modern oak from the estate, some of which had already been felled, was generously offered up by the owner. Following discussions with relevant parties it was decided to include these modern trees in this programme of analysis in order to increase the chances of dating the scant post mid seventeenth-century material potentially present in the house and to provide valuable reference data for an area under-represented in the network of reference chronologies which may subsequently result in the successful dating of material from other buildings analysed in the region thought to be of eighteenth- and nineteenth-century date that are currently undated by dendrochronology.

House

A detailed assessment of dendrochronological potential was undertaken throughout the building in collaboration with Francis Kelly, along with James Edgar and members of the architectural and engineering consultants. This process identified that most areas and phases of interest contained sufficient suitable timbers for tree-ring analysis, although in some instances there were areas, or phases, which contained timbers with relatively low numbers of rings.

Following the assessment, sampling was carried out over a number of months in 2013 as different timbers in different areas became accessible. Samples were obtained either by

the removal of a cross-sectional slice from those timbers that were beyond repair and, therefore, being removed, or by coring those timbers that remained *in situ*, or, in the case of the decorative corbels on the west-range east-porch gable, known as the 'Beasts of Sydenham' and thought to be wyverns, by undertaking direct measurement of the growth rings when they had been removed for conservation (Figs 7a–c). It should be noted that the fire and water damage substantially decreased the success rate of sampling the more friable sapwood.

An attempt was made to obtain samples in some form of logical sequence, progressing from room to room, and from area to area but due to various access restrictions, such as safety issues in relation to both the fire and subsequent building works, this was not always possible. The vast majority of the sampled timbers were from the roofs but timbers from the cellars beneath the north range, a stud partition wall, the main staircase in the west range, ceilings, and a number of window and doorways were also sampled.

The location of each core removed from the *in situ* timbers was labelled at the time of sampling with numbered plastic tags (Figs 8a/b) as requested and the locations of the sampled timbers were then recorded on a combination of plans and annotated photographs (Figs 9a–10u). In general, trusses, bays, frames, beams, and other timbers (Figs 9a–11) have been numbered from north to south, having first been located to the area in the house (ie west range, north-east range, south-east range, etc). Individual timbers are then identified on a north–south or east–west basis, as appropriate. In total 123 samples, plus the direct measurements from the two 'Beasts of Sydenham', were obtained, each sample allocated the code SYD-H (Table 1a).

Wall panelling

The removal of the wall panelling to Swan Farm Studios provided the opportunity to access individual elements during conservation and repair. The assessment of dendrochronlogical potential was undertaken in collaboration with conservators Mr Alan Lamb and Ms Kate Lamb. The assessment aimed to identify panels, or other elements, suitable for dendrochronological analysis, and of most relevance to determine the development of the house, as well as those identified as being of significant interest from an art-historical perspective and the development of wall panelling typology. Following this assessment, the work was conducted over a period of several months in 2013–14, as different sections of panelling were dismantled and became available for examination. The ring series were measured directly on the exposed edges of individual elements, each individual element having been given a unique identifier (eg King's Bedroom - K01, Queen's Bedroom - Q33, State Bedroom - S41 etc) during the *in situ* recording process, prior to the removal of the wall panelling to Swan Farm Studios (Fig 5b).

In this way ring-width series were obtained from a total of 35 elements from the wall panelling of four rooms, with each ring-series being given the tree-ring code SYD-P and

numbered 01–35. The unique room and panel identifier for each measured series was record at the time of measurement and is provided in Table 1b.

Trees

In collaboration with the estate, samples were obtained from seven recently felled, or fallen, trees in the area to the west of the house and 20 trees in Sydenham Wood (Figs 6 and 12; Table 1c), with each ring-series being given the tree-ring code SYD-M and numbered 01–27. The detailed location of the individual felled, or fallen, trees was unknown in the area to the west of the house, but the position of the living trees was plotted approximately on a map (Fig 14) and each tree photographed (Figs 14a–t). It may be seen from Figure 14 that amongst the trees sampled by coring, the maximum, straight-line, distance between any two examples is estimated to be no more than half a mile, and therefore a similar separation being found amongst the fallen tree samples is likely.

ANALYSIS AND RESULTS

House

Each of the 123 samples (cores and cross-sectional slices) was first prepared by sanding and polishing. It was seen at this time that 27 of these had less than the 40 rings considered necessary for reliable cross-matching and dating here, and so these were rejected from this programme of analysis. The annual growth ring widths of the remaining 96 samples were, however, measured. The data of these measurements is given at the end of this report along with the direct measurements from the two 'Beasts of Sydenham'. The data of these 98 measured ring-series were then compared with each other by the Litton/Zainodin grouping procedure (see Appendix), this process identifying a single group of 84 cross-matching samples (Fig 15), which formed at a minimum *t-value* of 3.5.

These 84 cross-matching samples were combined at their indicated offset positions to form SYDHSQ01, a site chronology with an overall length of 261 rings. Site chronology SYDHSQ01 was then compared to an extensive corpus of reference material for oak, matching consistently when the date of its first ring is AD 1394 and the date of its last ring is AD 1654 (Table 2).

Site chronology SYDHSQ01 was then compared with the remaining 14 measured but ungrouped samples, but there was no further satisfactory cross-matching. Each of the 14 ungrouped samples was then compared individually with the full corpus of reference material from both the British Isles and elsewhere in Europe, but again, there was no reliable cross-matching and all of these 14 samples remain undated.

Wall panelling

Each of the 35 wall panelling elements selected for analysis was first prepared by sanding and polishing the exposed edges, and the annual growth ring widths were then measured (the data of these measurements being given at the end of this report). The data of the 35 ring series were then compared with each other by the Litton/Zainodin grouping procedure (see Appendix), this process identifying three separate groups of cross-matching series accounting for 28 series.

The first group comprises 24 series (Fig 16) and formed at a minimum *t-value* of 4.4. These series were combined at their indicated offset positions to form SYDPSQ01, a site chronology with an overall length of 364 rings. Site chronology SYDPSQ01 was then compared to an extensive corpus of reference material for oak, matching consistently when the date of its first ring is AD 1266 and the date of its last ring is AD 1629 (Table 3).

The second group comprises two series (Fig 16) and formed at a minimum *t-value* of 9.7. These series were also combined at their indicated offset positions to form SYDPSQ02, a site chronology with an overall length of 223 rings. Site chronology SYDPSQ02 was then compared to an extensive corpus of reference material for oak, matching consistently when the date of its first ring is AD 1340 and the date of its last ring is AD 1562 (Table 4).

The third group also comprises two series (Fig 16), and formed at a minimum *t-value* of 20.2. These series were likewise combined to form SYDPSQ03, a site chronology with an overall length of 107 rings. Site chronology SYDPSQ03 was similarly compared to an extensive corpus of reference material for oak, matching consistently when the date of its first ring is AD 1455 and the date of its last ring is AD 1561 (Table 5).

Site chronologies SYDPSQ01, SYDPSQ02, and SYDPSQ03 were then compared with the remaining seven ungrouped ring series, but there was no further satisfactory cross-matching. Each of the seven ungrouped samples was then compared individually with the full corpus of reference material. Five of these remain undated but SYD-P13 and SYD-P23 produced consistent matching when the ring series spanned AD 1396–1547 and AD 1438–1609 respectively (Fig 16 and Tables 6 and 7).

Trees

Each of the 27 samples obtained from the estate was prepared by sanding and polishing. It was seen at this time that the ring sequence of sample SYD-M18 showed obvious distortion, as well as clear signs of decay. Thus, as the growth rings could not be measured reliably, it was excluded from further analysis. In addition sample SYD-M19 had a short section of growth towards the middle of the core in which the rings could not be reliably

distinguished, also due to distortion and decay. In this instance, the rings on either side of this unmeasureable section were suitable for measurement.

The annual growth ring widths of the 26 samples considered suitable for analysis were therefore, measured, the data of these measurements being given at the end of this report. These data were then compared with each other by the Litton/Zainodin grouping procedure (see Appendix), allowing a single group comprising all 26 measured samples to be formed (Fig 17) at a minimum *t-value* of 4.5. The 26 samples were combined at their indicated offset positions to form site chronology SYDMSQ01, this having an overall length of 273 rings.

Site chronology SYDMSQ01 was then compared to a corpus of reference material for oak, matching consistently when the date of its first ring is AD 1741 and the date of its last ring is AD 2013 (Table 8).

INTERPRETATION

This section identifies felling dates, felling date ranges, or felled after dates (*termini post quos*) for the dated timbers, the dated wall panels and the seven felled trees, and indicates the year of coring of trees living at the time of sampling. In the absence of bark edge on most of the samples, the estimated felling date is calculated on the basis of the 95% confidence interval for the amount of sapwood the original parent trees are likely to have had which, based on NTRDL datasets, is 15–40 rings for native English oak trees.

House

The 84 dated ring series indicate, not unexpectedly, that these timbers represent a number of different felling episodes ranging from the early sixteenth century through to the late-seventeenth century. To aid interpretation, the results are presented area by area below, and in Figures 18a–19b.

North-east range, roof (SYD-H01 – SYD-H16)

Sixteen samples were obtained from this roof (Table 1a; Figs 3, 4c, and 9a–g) of which one was rejected prior to measurement. The fifteen measured ring series were dated and appear to be coeval (Figs 18a and 19a), these representing four principal rafters, four common rafters, three sprokets, a wall plate, a post, a tiebeam, and a purlin. All fifteen samples retained the heartwood/sapwood boundary, the date of which varies by only 13 years. The average boundary date is AD 1631 which produces an estimated felling date in the range AD 1646–71 for these timbers.

North-east range extension, roof (SYD-H17 – SYD-H24)

Eight samples were obtained from this roof (Table 1a; Figs 3, 4c, and 9h–i) of which one was rejected prior to measurement. The seven measured ring series were dated indicating two distinct periods of felling (Figs 18a and 19a). The tiebeam from truss 28 is the earliest dated timber which, with a heartwood/sapwood boundary dating to AD 1562, produces an estimated felling date in the range AD 1577–1602. The remaining six dated timbers, five principal rafters and a purlin, appear to be coeval. The heartwood/sapwood boundary on those five samples with it varies by only 11 years with the average boundary being dated AD 1631. Thus, these timbers have an estimated felling date in the range AD 1646–71.

North-east range, porch roof (SYD-H25 – SYD-H28)

Four samples were obtained from this roof (Table 1a; Figs 3, 4c, and 9j–k). Two of these were rejected prior to measurement. The two measured ring series were dated but clearly represent two distinct felling periods (Figs 18a and 19a). The earlier of the two, SYD-H28, has a heartwood/sapwood boundary dating to AD 1594, indicating that this common rafter has an estimated felling date in the range AD 1609–34. Sample SYD-H25 has a heartwood/sapwood boundary dating to AD 1636, indicating that this common rafter has an estimated felling date in the range AD 1651–76.

South-east range, roof (SYD-H29 – SYD-H38 and SYD-H84 – SYD-H86)

Thirteen samples were obtained from this roof (Table 1a, Figs 3, 4c, 9l–n, 10n). Two samples were rejected prior to measurement. Nine off the 11 measured series were dated indicating three distinct felling periods (Figs 18a and 19b). The earliest timber, SYD-H31, has a heartwood/sapwood boundary date of AD 1562, indicating that this principal rafter from truss 2 has an estimated felling date in the range AD 1577–1602. Sample SYD-H30 has a heartwood/sapwood boundary dating to AD 1594, indicating that this tiebeam from truss 1 has an estimated felling date in the range AD 1609–34. The remaining seven dated series, representing three principal rafters, two tiebeams, and two posts, appear likely to be coeval with the heartwood/boundary dates on the six timbers on which it survives varying by only 10 years. However, one of these samples, SYD-H34, has retained complete sapwood, the outermost ring dating to AD 1654. Thus, it seems likely that this group of seven timbers were all felled in, or around, AD 1654.

South-east range, porch roof (SYD-H39 – SYD-H44)

Six samples were obtained from this roof (Table 1a; Figs 3, 4c, and 9o–p) of which two were rejected prior to measurement. Three of the four measured series were dated and appear likely to be coeval (Figs 18b and 19b). Only one of these has the heartwood/sapwood boundary present, this dating to AD 1626, indicating that these

three timbers, two common rafters and a sprocket, have an estimated felling date in the range AD 1641– 66.

West range, roof (SYD-H45 – SYD-H54 and SYD-H79 – SYD-H83)

Fifteen samples were obtained from this roof (Table 1a; Figs 3, 4c, and 9q–u), the latter (SYD-H79 – SYD-H83), being cross-sectional slices removed from badly charred *ex situ* timbers about to be discarded. The positions in the roof of all but one of these *ex situ* timbers had been removed prior to measurement (Fig 11). One sample was rejected prior to measurement. Thirteen of the 14 measured series, representing eight tiebeams, two principal rafters, two queen posts, and a timber of uncertain location within this roof, were dated and appear likely to be coeval (Figs 18b and 19b). The heartwood/sapwood boundary date on 10 of the dated samples varies by only 13 years producing an average date of AD 1632 which produces an estimated felling date in the range AD 1647–72. The possible exception within this group of dated samples is SYD-H51, a queen post from truss 18, which has a slightly later heartwood/sapwood boundary date of AD 1644 which produces an estimated felling date range of AD 1659–84. However, it is possible that this timber is one of those whose number of sapwood rings lies outside of the 95% interval commonly applied and thus, it could be coeval with the other dated timbers from this roof.

North range, east cellar, ceiling (SYD-H55 – SYD-H60)

Six samples were taken from ceiling joists (Table 1a; Figs 3 and 9v–x). All six samples were measured and five of the measured ring series were dated indicating two distinct felling periods (Figs 18b and 19a). The earliest timber, SYD-H59, has a heartwood/sapwood boundary dating to AD 1526, indicating that this timber has an estimated felling date in the range AD 1541–66. The four other dated samples appear to be coeval, with heartwood/sapwood boundary dates varying by only five years. However, one of these samples, SYD-H55, was derived from a joist with complete sapwood present but unfortunately the outermost sapwood rings were highly friable and did not survive coring. It was estimated that *c* 10 rings were lost in this section and thus, with an outermost measured ring date of AD 1595, a felling date of *c* AD 1605 is obtained for this and the other three dated timbers in this later group.

North range, west cellar, ceiling (SYD-H61 – SYD-H65)

Five samples were taken from ceiling joists (Table 1a; Figs 3 and 9y). All five were measured and four of the measured ring series were dated indicating at least two distinct felling periods (Figs 18b and 19a). The two samples SYD-H61 and SYD-H62 appear likely to be coeval with heartwood/sapwood boundary dates within seven years of each other. The average heartwood/sapwood boundary date for these two samples is AD 1516, which produces an estimated felling date in the range AD 1531–56 for these two joists. A

further sample, SYD-H63, has no trace of sapwood and thus, with a last measured heartwood ring of AD 1532 it was felled sometime after AD 1547, so it could be coeval with the two joists felled in the mid-sixteenth century or it could represent a different felling episode. The latest of these dated joists, SYD-H64, has a heartwood/sapwood boundary dating to AD 1637 and thus, has an estimated felling date in the range AD 1652–77.

North range, west cellar, stair/hallway (SYD-H66 – SYD-H68)

Three samples were obtained from this area (Table 1a; Figs 3, 9y–z and 10a), one of which was rejected prior to measurement. The two measured series both dated with heartwood/sapwood boundary dates of AD 1563 (SYD-H66) and AD 1580 (SYD-H67) (Figs 18b and 19a). Their individual estimated felling dates of AD 1578–1603 and AD 1595–1620, respectively, clearly overlap and thus, they could potentially both be felled in the period AD 1587–1612 but it is also possible that they represent two different felling episodes.

North range, west cellar, entry hall (SYD-H69 – SYD-H72)

Four samples were taken from ceiling joists (Table 1a; Figs 3 and 10b), one of which was rejected prior to measurement. The three measured series were dated and appear likely to be coeval (Figs 18b and 19a). Two of the samples had retained complete sapwood, the outermost rings dating to AD 1604 (SYD-H71) and AD 1605 (SYD-H69). This indicates the felling date of the trees that these two joists were derived from and it seems likely that the third joist in this group, SYD-H70, was also felled in, or around, AD 1604 or AD 1605.

North-east range, stair/State Bedroom partition wall (SYD-H73 – SYD-H78)

Six timbers were obtained from this partition wall (Table 1a; Figs 3, 4b, and 10c–d), one of which was rejected prior to measurement. Four of the five measured series were dated (Figs 18b and 19a), these representing the central main post, two cross-rails, and a landing support beam. They appear to represent at least three distinct periods of felling. The earliest, SYD-H73, with a heartwood/sapwood boundary date of AD 1558, produces an estimated felling date in the range AD 1573–98 for the central main post. Sample SYD-H78, with a heartwood/sapwood boundary date of AD 1583, produces an estimated felling date in the range AD 1598–1623 for the landing support beam. It is, therefore, possible that these two timbers could be coeval if either one of them had outside of the usual number of sapwood rings. The two cross-rails, SYD-H74 and SYD-H75, are later and appear likely to be coeval with their heartwood/sapwood boundaries being only 10 years apart. The average heartwood/sapwood boundary date is AD 1635 which, produces an estimated felling date in the range AD 1650–75.

South-east range, first-floor timbers (SYD-H87 – SYD-H94, SYD-H120 – SYD-H122)

Eleven timbers were obtained from timbers of the first floor in this range (Table 1a; Figs 3, 4b, 10f–g, and 10n). Five samples were rejected prior to measurement. Four of the six measured series were dated indicating two distinct felling periods (Figs 18c and 19b). The earliest, SYD-H91, has a heartwood/sapwood boundary dating to AD 1501, indicating an estimated felling date in the range AD 1516–41 for this lintel. The three other dated series are clearly coeval, with SYD-H87 and SYD-H88 probably being derived from the same-tree (t = 11.5) and SYD-H89 showing a very high level of similarity with both of these series. The heartwood/sapwood boundary dates on these three samples vary by only nine years with an average of AD 1634. This produces, allowing for the extant rings on SYD-H89, an estimated felling date in the range AD 1655–74 for these two intermediate ceiling beams, and a lintel.

West range, main staircase (SYD-H95 – SYD-H102)

Eight samples were taken from timbers forming this staircase (Table 1a; Figs 3, 4a–b, and 10h–k), of which only three were measured, the remaining five being rejected prior to measurement. All three measured series were dated but appear to represent at least two, or possibly three different felling episodes (Figs 18c and 19b). The earliest, SYD-H95, has a heartwood/sapwood boundary date of AD 1587, which produces an estimated felling date in the range AD 1602–27 for this stairway base beam. Sample SYD-H100 has a heartwood/sapwood boundary date of AD 1612 and hence, an estimated felling date in the range AD 1627–52, whereas SYD-H96 has a heartwood/sapwood boundary date of AD 1629 and an estimated felling date in the range AD 1644–69. Clearly, these two timbers, the lower-stair south-runner and the stairway-post, respectively, have overlapping individual felling date ranges and hence could have been felled at the same time which, using the average heartwood/sapwood boundary date of AD 1621, would produce a felling date range of AD 1636–61.

North range, stair doorway (SYD-H103 – SYD-H106)

Four samples were taken from timbers forming this doorway (Table 1a; Figs 3, 4a, and 10l). All four were measured and three ring series were dated indicating two distinct felling periods (Figs 18c and 19a). The earliest, SYD-H105, has a heartwood/sapwood boundary date of AD 1508, producing an estimated felling date in the range AD 1533–48 for this door lintel. The ring series from the left and right hand jambs show a very high level of similarity (t = 9.4) and have heartwood/sapwood boundaries within 11 years of each other. The average heartwood/sapwood boundary is AD 1563 which produces an estimated felling date range of AD 1578–1603 for these two door jambs.

West range, main staircase, top landing ceiling (SYD-H107)

One sample (SYD-H107) was taken from this ceiling (Table 1a; Figs 3, 4b, and 10m), and its measured ring series was dated (Figs 18c and 19b). The heartwood/sapwood boundary dates to AD 1633 which, allowing for the extant 21 sapwood rings, produces an estimated felling date in the range AD 1654–73 for this main ceiling beam.

South-east range, ground floor, studio (SYD-H108 – SYD-H114)

Seven samples were taken from door and window lintels of which three were rejected prior to measurement (Table 1a; Figs 3, 4a, and 10o–r). Two of the four measured ring series were dated (Figs 18c and 19b). Sample SYD-H109 from a lintel to the studio/flower room doorway had no trace of sapwood and thus, has a *terminus post quem* for felling of AD 1532. Sample SYD-H113 from the east window lintel in the studio, with the heartwood/sapwood boundary dating to AD 1555, has an estimated felling date in the range AD 1570–95.

South-east range, ground floor, south hall (SYD-H115, SYD-H116, SYD-H119)

Three samples were taken from window lintels (Table 1a; Figs 3, 4a, 10o and 10t). All three were measured and two of the ring series were dated indicating two distinct felling periods (Figs 18c and 19b). The heartwood/sapwood boundary of the earliest, SYD-H115, dates to AD 1563, which produces an estimated felling date in the range of AD 1578–1603. The second lintel from this same window, SYD-H116, is clearly later and in the absence of any sapwood it has a *terminus post quem* for felling of AD 1623.

South-east range, stair landing (SYD-H117, SYD-H118)

Two samples were taken from lintels to the window on the first landing of these stairs (Table 1a; Figs 3, 4a–b, and 10s). Both were rejected prior to measurement and thus, no dating evidence is obtained for these timbers.

West-range, east porch, inner door to west-range (SYD-H123)

One sample was taken from the innermost door lintel (Table 1a; Figs 3, 4a, and 10u), which was measured but the ring series could not be dated, thus, no dating evidence is obtained for this lintel.

West-range, east porch gable 'Beasts of Sydenham' (SYD-H124, SYD-H125)

Two decorative corbels, known as the 'Beasts of Sydenham', were measured directly during conservation producing two ring series (Table 1a; Figs 3, 4a, and 7a–c). Both dated (Figs 18c and 19b) and are clearly derived from the same-tree (t = 25.7). The heartwood/sapwood boundary was present on SYD-H12. This dates to AD 1639, thus, producing a felling date in the range AD 1654–79 for both of the 'Beasts of Sydenham'.

Wall panelling

Thirty dated ring series represent wall panelling in the following four rooms and appear likely to represent several episodes of felling ranging from the late-sixteenth century to the early/mid-seventeenth century. To aid interpretation, the results are presented room-by-room below and in Figures 20 and 21.

Queen's Bedroom (SYD-P01 – SYD-P06)

The ring series of six panels were measured and all six were dated (Table 1b; Figs 4b and 5a). They appear coeval (Figs 20 and 21) and the high level of similarity (t-values range from 10.0 – 17.2) suggests that they may well be derived from a single tree or at least trees growing in close proximity to each other. One of the panels had retained a small number of sapwood rings which, with the heartwood/sapwood boundary dating to AD 1602, produces an estimated felling date in the range AD 1617–42 for this group of panels.

King's Bedroom (SYD-P07 – SYD-P17)

The ring series of five gilded framing pieces and six panels were measured, of which nine were dated (Table 1b; Fig 4b). Although some of these elements are derived from locally derived timber, including one potential same-tree pair (SYD-P10/SYD-P12, t = 11.8), some are derived from timber imported from at least two different source areas in the Baltic region (see below and Tables 3–6), also including one potential same-tree pair (SYD-P07/SYD-P08, t = 20.0). However, all dated elements appear coeval (Figs 20 and 21) and, using either the 15–40 (95% confidence interval) sapwood estimate for local timber or the 8–24 (95% confidence interval) sapwood estimate appropriate for timber derived from the Baltic region (Tyers 1998) as appropriate, were all probably felled after AD 1570.

State Bedroom (SYD-P18 – SYD-P25)

The ring series of eight panels were measured and all eight were dated (Table 1b; Figs 4b and 5b). These clearly represent at least two distinct felling periods (Figs 20 and 21). The panel from which SYD-P25 was derived had retained a small number of sapwood rings which, with the heartwood/sapwood boundary dating to AD 1565, produces an estimated felling date in the range AD 1580–1605. The ring series from four panels (SYD-P20 – SYD-P22, SYD-P24) appear very similar (*t*-values range from 14.6 – 19.0) suggesting that they may well be derived from a single tree or at least trees growing in close proximity to each other. One of these panels had retained a small number of sapwood rings which, with the heartwood/sapwood boundary dating to AD 1609, produces an estimated felling date in the range AD 1624–49 for this group of four panels. The remaining three panels, SYD-P19, SYD-P23, and SYD-P18, have felled after dates of AD 1556, AD 1624, and AD 1644 respectively and could thus be associated with one or other of the felling episodes identified in this room or alternatively represent different felling episodes in the later sixteenth century or seventeenth century. The level of similarity between these three ring series and the other dated panels from this room is low suggesting that the panels in this room are a rather disparate group.

Dining Room (SYD-P26 – SYD-P35)

The ring series of nine panels and a muntin piece were measured, with seven of them from panels being dated (Table 1b; Fig 4a). These may represent two felling episodes (Figs 20 and 21). The ring series from five panels (SYD-P26, SYD-P27, SYD-P31 – SYD-P33) appear very similar (*t*-values range from 9.7 – 24.1) suggesting that they may well be derived from a single tree or at least trees growing in close proximity to each other. One of these panels had retained a small number of sapwood rings which, with the heartwood/sapwood boundary dating to AD 1576, produces an estimated felling date in the range AD 1591–1616 for this group of five panels. The two other dated panels appear coeval and thus, were both probably felled after AD 1560. Potentially, they could be associated with the AD 1591–1616 identified for the other dated panels from this room or, alternatively, represent a different felling episode, although it seems likely that this would be in the later sixteenth century or early seventeenth century.

Trees

The ring series from the 14 of the 19 measured and dated samples from Sydenham Wood all have a last ring date of AD 2013, this indicating the year that they were sampled by coring. The outermost rings of the remaining five samples either disintegrated on coring or the core fractured but not with a clean break that could be measured across. However, it can be seen that, using the standard sapwood estimate of 15–40 rings (95% confidence interval), all have an estimated end-date in a range compatible with the known coring year (Figs 22 and 23). It is noticeable that two of these trees have numbers of

sapwood rings in excess of the upper limit of the 95% confidence interval. The heartwood/sapwood boundary dates for these two trees are both AD 1964 which is in contrast to the 12-year variation in heartwood/sapwood boundary date for the remaining trees ranging from AD 1981 to AD 1993.

The felling (death) dates for the seven trees to the west of the house are identified precisely for five of these, one in AD 2004, three in AD 2010, and one in AD 2012 (Figs 22 and 23). Two of the others with bark edge no longer present have estimated felling dates compatible with having been felled, or having fallen, at a similar time. However, one, SYD-M21, has an estimated felling date slightly earlier than the other trees from this area, although if it had more than the usual number of sapwood rings as two of the Sydenham Wood trees actually have, then its felling (death) could also be coeval with the other trees in this area. The overall variation in heartwood/sapwood boundary date is similar to those trees from Sydenham Wood and ranges from AD 1963 to AD 1997.

DISCUSSION

Dating

House

The successful dating of 84 timbers has identified several different episodes of felling from the early sixteenth century to the mid-seventeenth century (Fig 24). These can be related to various periods of construction/modification, and highlights the possible reuse of timber from buildings that predate the extant Sydenham House. Whilst the extant house is thought to have been built between AD 1600–12, it is believed to potentially incorporate parts of an earlier house, and to have undergone a programme of substantial alterations in the mid-seventeenth century. Hence, the possibility of timbers being incorporated from the earlier building, along with timbers from the early seventeenth century being reset or reused during the mid seventeenth-century alterations, leads to complexities with respect to the overall interpretation of the dendrochronological evidence in some areas with dated timbers, some of which may be resolved by detailed survey. There is clear evidence of a small number of timbers felled in the early, mid-, and late-sixteenth century, pre-dating the documented rebuilding of Sydenham House by Sir Thomas Wise and hence, representing timbers incorporated from an earlier building on this site or other earlier buildings in the vicinity. There are remarkably few dated timbers that appear to be associated with the apparent rebuilding in the early seventeenth century and most of these are associated with the cellars. The majority of the dated timbers were felled in the mid-seventeenth century, probably the AD 1650s and hence, appear to be associated with the substantial alterations undertaken for Edward Wise, perhaps suggesting that these alterations were even more substantial than previously thought.

Early and mid-sixteenth century

The six earliest dated timbers scattered through the extant building are; a lintel above the stair doorway in the north range; three joists from the north range, east and west cellar ceilings; and a window lintel and a door lintel on the first floor of the south-east range (Figs 19a–b and 24). They clearly represent more than one episode of felling as the earliest felling date range is AD 1516–41 (SYD-H91), whilst the latest is AD 1541–66 (SYD-H59). Several of the felling date ranges for the individual samples overlap and thus, at least some of these timbers could represent a single episode of felling. These timbers clearly pre-date the early seventeenth-century construction work and hence could represent timbers from the earlier building believed to have been on this site, although it is clearly possible that they may be reused from other buildings in the vicinity.

A seventh timber (SYD-H63), also a joist from the north range west-cellar ceiling, with a felled after date of AD 1547 (Figs 19a and 24) could be associated with a mid sixteenth-century felling episode but, based on the level of similarity it shows with timbers dating to the late-sixteenth and early seventeenth centuries (see below), it appears more likely (although unproven) to be associated with one or other of these later felling episodes or, alternatively, it could represent a separate felling episode represented by only one timber. If it is associated with the later felling episodes identified, this would imply that the joist has been fairly heavily trimmed during conversion from the original tree.

Late-sixteenth century

These seven dated timbers are again scattered through the extant building with three timbers (a principal rafter SYD-H31, a window lintel in the ground-floor studio SYD-H113, and a lintel in the ground-floor south hall SYD-H115) being located in the south-east range, two timbers (a door jamb to the stair doorway SYD-H103 and a main ceiling beam in the west cellar stair/hallway SYD-H66) being located in the north range, a single timber (the central post to the State Bedroom/stair partition wall SYD-H73) being located in the north-east range, and a single timber (a tiebeam) being located in the north-east extension range (Figs 19a–b and 24). These timbers are most probably coeval and all felled in the latter decades of the sixteenth century, although it is just possible that some were felled as late as the first few years of the seventeenth century. It therefore seems most likely that these timbers are associated with the ownership of Sydenham by Sir Thomas Wise's father (died AD 1593) or older brother William (died AD 1600) and are reused in the seventeenth-century Sydenham House, unless they are again, potentially, reused from other buildings in the vicinity.

An eighth timber (SYD-H104) with a felling date range of AD 1583–1608 could be very slightly later than these other seven timbers (Fig 24). However, this is the other door jamb to the stair doorway in the north range and shows very strong similarity with SYD-H103 ($t = 9.4$) which suggests that it is most likely to be coeval with the felling episode in the latter decades of the sixteenth century identified above (Figs 19a and 24).

Early seventeenth century

Ten timbers appear likely to be coeval and hence, all likely to have been felled during the first decade of the seventeenth century with one timber having a precise felling date of AD 1604 and two timbers a precise felling date of AD 1605. Eight of these timbers are associated with the north range cellars, but in addition there is a landing support beam from the stair partition wall in the north-east range and a stairway base beam from the main staircase in the west range (Figs 19a–b and 24). These , therefore, appear to be associated with, what is generally thought to be, the initial construction of the seventeenth century Sydenham House by Sir Thomas Wise.

Two additional timbers, a common rafter from the north-east range porch roof (SYD-H28) and a tiebeam from the south-east range roof (SYD-H30), both have slightly later felling date ranges of AD 1609–34 (Figs 19a–b and 24). These could also be associated with the major construction works thought to have been undertaken during AD 1600–12 by Sir Thomas Wise and could, if they both had fewer than the usual number of sapwood rings, be associated with the AD 1604 or AD 1605 fellings. However, they could potentially represent minor works at a slightly later date but prior to the substantial alterations undertaken by Sir Thomas Wise's grandson, Edward Wise, in the mid-seventeenth century.

Mid-seventeenth century

The remaining 57 dated timbers all appear coeval having probably mostly been felled over period of several years around the AD 1650s, with one timber having a precise felling date of AD 1654 (Figs 19a–b and 24). Although it appears that a handful of timbers could, in principal, marginally pre-date the majority of these mid-seventeenth century timbers (Fig 24) these are usually timbers with no heartwood/sapwood boundary but are part of groups of timbers from a single area that are felled in the mid seventeenth-century (Figs 19a–b). The exception to this is a runner from the main staircase in the west range (SYD-H100), which has an individual felling date range of AD 1627–52. It could have been felled in advance of the planned works and stockpiled or alternatively it could be one of the timbers that have more than the usual number of sapwood rings and hence, felled at the same time as the rest of these mid seventeenth-century timbers. In addition there is a single timber (SYD-H51), a queen post from the west-range roof, that could have been felled marginally later but again it is part of a group of timbers from this roof that were all felled in the mid-seventeenth century and thus, could be one of the timbers that have less than the usual number of sapwood rings.

These mid seventeenth-century timbers are present throughout Sydenham House and appear to be associated with the substantial alterations carried out for Edward Wise. They comprise (Figs 19a–b):

- north-east range roof – fifteen timbers
- north-east range stair partition wall – two timbers
- north-east range porch roof – one timber
- north-east range extension roof – six timbers
- north range west cellar ceiling – one timber

- south-east range roof – seven timbers
- south-east range first floor – three timbers
- south-east range south hall – one timber
- south-east range porch roof – three timbers

- west range roof – thirteen timbers
- west range main staircase – three timbers
- west range east porch gable – two timbers (the Beasts of Sydenham)

Wall panelling

The successful dating of 30 wall panelling elements has identified at least three distinct episodes of felling, ranging from the late-sixteenth century through to the early/mid-seventeenth century with at least one of the four rooms containing panelling representing more than one episode of felling (Fig 21). Not unexpectedly, the wall panelling elements analysed only rarely retained any trace of sapwood as, when constructing wall panelling, the softer more friable sapwood rings are generally trimmed off, this usually resulting in the loss of heartwood rings as well. However, elements such as the panels themselves are usually only relatively lightly trimmed with respect to the loss of heartwood rings (eg Groves 2004), thus reducing wastage of a valuable timber resource. This often results in such groups of panels or boards with a relatively narrow range of dates for the outermost extant heartwood rings present (eg Groves 2004; Tyers and Tyers 2015).

Late-sixteenth/early seventeenth century

The eighteen panels in this group comprise all the dated panels from the King's Bedroom and Dining Room as well as two dated panels from the State Bedroom (Fig 21). Five of those from the Dining Room and one from the State Bedroom have overlapping felling date ranges of AD 1591–1616 and AD 1580–1605 respectively. Two further panels from the Dining Room, a further panel from the State Bedroom, and all nine panels from the King's Bedroom have *terminus post quem* dates for felling ranging from AD 1555 (SYD-P13) to AD 1570. Although these 12 panels could be felled significantly later than the *terminus post quem* dates obtained, bearing in mind the similarity of these end dates and the likely conversion techniques, this seems unlikely and thus, it appears most likely that they are coeval with the felling date ranges obtained spanning the late-sixteenth/early seventeenth centuries. All eighteen of these panels, therefore, appear to be associated

with Sir Thomas Wise's early seventeenth-century rebuilding of Sydenham House, although it remains a possibility that they could just pre-date this and have been reused from another building(s), and hence, inserted at a later date. However, the wall panelling in the King's Bedroom and Dining Room appear to be coherent groups, in spite of the King's Room containing panels of both local and imported origin (see below), suggesting that the extant panelling in both of these individual rooms is an articulated group.

Early/mid-seventeenth century

The twelve panels in this group comprise all the dated panels from the Queen's Bedroom and the six remaining panels from the State Room (Fig 21). All six from the Queen's Bedroom and four from the State Bedroom have overlapping felling date ranges of AD 1617–42 and AD1624–49 respectively. These could, therefore, be associated with Sir Thomas Wise, although post-dating what is considered to be the rebuilding of Sydenham House, but they could potentially represent works undertaken during the incumbency of Lady Wise and their son Thomas Wise or, the early incumbency of Edward Wise. The remaining two panels from the State Bedroom have *terminus post quem* dates for felling of AD 1624 and AD 1644. Although the earlier of these two panels (SYD-P23) could well be coeval with the two felling date ranges obtained, it is noticeable that this ring series was dated individually rather than as part of SYDPSQ01, suggesting the possibility that it is from a slightly different source to much of the dated native oak panelling and, hence, potentially originally from a different scheme of panelling. The latest of these panels (SYD-P18) could just be coeval with the two felling date ranges but is perhaps more likely to represent a later felling episode, potentially associated with the substantial alterations undertaken in the mid-seventeenth century by Edward Wise. Thus, although the wall panelling in the Queen's Bedroom appears to be a coherent group suggesting that the extant panelling in here is an articulated group, the evidence for the State Bedroom panelling suggests that this comprises panelling of different dates and, hence, potential multiple panelling schemes.

Trees

The production of a single well-replicated chronology spanning the period AD 1741–2013 from recently felled and living trees on the estate is a useful temporal and geographical addition to the surprisingly sparse network of chronologies spanning the most recent centuries. The year of coring is clearly demonstrated by those samples from Sydenham Wood that retained their outermost rings and the death date is identified for several of the recently felled or fallen trees from the area to the west of the house (Fig 22). Information is also derived in relation to heartwood/sapwood boundary date variation for a coeval group of trees.

Woodland source

House

The overall cross-matching between the majority of the 84 dated samples in site chronology SYDHSQ01 suggests that the timbers were derived from a single, albeit potentially extensive, woodland source. As well as some groups of timbers from areas having strong overall intra-group cross-matching with many *t*-values in excess of 6.0 (eg the 15 dated timbers from the north-east range roof), suggesting that they are derived from a discrete area of woodland, it also seems likely that there are a number of pairs of timbers potentially derived from the same tree or, at least, trees growing fairly close together within an area of woodland. These latter include:

- SYD-H03 / SYD-H05 (*t* = 11.0) – north-east range roof
- SYD-H16 / SYD-H25 (*t* = 10.7) – north-east range roof & north-east range porch roof
- SYD-H24 / SYD-H31 (*t* = 10.8) – north-east range extension roof & south-east range roof
- SYD-H47 / SYD-H79 (*t* = 10.8) – west range roof
- SYD-H49 / SYD-H80 (*t* = 10.2) – west range roof
- SYD-H87 / SYD-H88 (*t* = 11.5) – south-east range intermediate ceiling beams
- SYD-H124 / SYD-H125 (*t* = 25.7) – west range, east porch gable ('Beasts of Sydenham')

The 'Beasts of Sydenham' appear likely to have been derived from adjacent blocks of timber from the same-tree. It also seems possible that the SYD-H49 / SYD-H80 pair and the SYD-H87 / SYD-H88 pair are potentially all derived from the same-tree with a *t*-value of 11.0 produced between the pairs.

With respect to the location of this probable extensive woodland source then it appears to have been relatively local, possibly even from what was then, and might be now, parts of the Sydenham estate lands. Although site chronology SYDHSQ01 was compared with reference material from all parts of the British Isles, the highest levels of similarity between it and the reference chronologies are found with other sites in Devon and south-west England (Table 2). This also proves to be the case when SYDHSQ01 is also broken down into the different felling date groups.

Wall panelling

The overall cross-matching between the 24 wall panelling elements included in site chronology SYDPSQ01 plus, the individually dated panel (SYD-P23), suggests that they were probably derived from somewhat more widely dispersed woodlands than the building timbers. Within this group of elements there are, however, a number clearly

derived from the same tree or at least trees growing fairly close together within an area of woodland (see above) within three of the rooms. The highest levels of similarity for both SYDPSQ01 and SYD-P23 (Tables 3 and 6) are with reference chronologies slightly further away in the south-west and mid-western regions than those that the structural timber chronology, SYDHSQ01, matches so well with (Table 2), although these two long and well-replicated site chronologies do show a good level of similarity (t = 8.3). This highlights the possibility that these wall panelling elements were derived from woodlands outside of the immediate vicinity of Sydenham House. This diversity of source could possibly be a reflection of the difficulty in obtaining mature trees with a straighter grain better suited to the manufacture of high quality oak panelling, resistant to warping or splitting. It is notable that the basic characteristics of the dated panel series show a tendancy towards longer lived trees when compared to the dated building timbers (Fig 25) with at least one of the trees from which panels were derived being in the order of approximately 350 years old when felled. Trees of such longevity are relatively uncommon in this period in the dendrochronological data set.

The remaining four dated wall panelling elements included in site chronologies SYDPSQ02 and SYDPSQ03, plus the individual panel SYD-P13, have been shown to be derived from timber imported from the Baltic region (Tables 4–6) and thus, are part of a large quantity of material imported primarily through the Hanseatic merchants. Those comprising SYDPSQ02 (SYD-P14, SYD-P15) and the individually dated panel, SYD-P13, are derived from a different source within the Baltic region to those comprising SYDPSQ03 (SYD-P07, SYD-P08). The location of these sources within the Baltic region is uncertain due to the relatively sparse nature of the network of local reference chronologies in the region but the dendrochronological evidence points to systematic changes through the period of importation during the thirteenth to seventeenth centuries (eg Tyers 2010).

Trees

The production of a single, well-replicated chronology spanning the period AD 1741–2013 from recently felled and living trees on the estate is a useful temporal and geographical addition to the surprisingly sparse network chronologies spanning the most recent centuries. It also provides valuable information relating to the levels of similarity observed between the ring series of samples taken from trees a known distance apart. There are clearly a number of ring series that show a very strong level of similarity with t-values in excess of 10.0, including SYD-M17 from Sydenham Wood and SYD-M24 from the area to the west of the house (Table 9). Samples SYD-M10, SYD-M11, SYD-M14, SYD-M15, and SYD-M16 all match very strongly with each other, these trees all being in close proximity on the valley slope and their samples having long overlaps with each other. This is in stark contrast to the levels of similarity between SYD-M01 – SYD-M05, trees located either side of a track nearer the top of the ridge and in very close proximity to each other. The overall mean t-value for each individual ring series within this group of 26 trees highlights the variation between samples with SYD-M20 having a mean t-value of

2.0 and SYD-M15 having a mean *t*-value of 7.0. Eight of the nine samples (SYD-M06, SYD-M10, SYD-M11, SYD-M13 – SYD-M17), with mean *t*-values in excess of 5.0 are from a relatively discrete area in Sydenham Wood, although there are other trees within this area that match less well overall. The other sample (SYD-M24) with a mean *t*-value in excess of 5.0 is from the area to the west of the house. Such information gives some insight into the possible distribution within the source woodland(s) of trees used in the construction of historic timber-framed buildings, there usually being no idea of how far and wide the original carpenters cast their net to obtain their raw material.

The analysis of these trees also highlights the fact that two of the trees from Sydenham Wood have 49 sapwood rings, which is outside of the 15–40 (95% confidence interval) standardly applied. However, it should be noted that the standard sapwood estimate employed is based predominantly on trees from the medieval and post-medieval periods rather than on modern trees. Using the 18 tree series with complete sapwood produces a sapwood estimate of 15–47 (95% confidence interval), so these two trees remain outliers with respect to numbers of sapwood rings.

Undated timbers

House

Fourteen of the 98 measured samples remain ungrouped and undated. Whilst some of these undated samples have sufficient rings for reliable dating, the ring numbers are towards the lower end of the usual acceptable limits. Other undated samples, however, have higher ring numbers, the longest undated samples (SYD-H76, SYD-H106, SYD-H108) having in excess of 100 rings, although these are noticeably very slow grown. None of these undated samples show any particular problems such as compression or distortion, which would adversely affect the chances of their ring series being cross-matched and dated, although if they represent various later minor alterations then as individuals they do have a significantly reduced chance of dating. It is, however, a common feature in tree-ring analysis to find that some samples remain undated for no apparent reason. In this respect, the analysis of these structural timbers from Sydenham House has been successful in achieving in excess of the broadly expected success rate of 70–80% of measured samples for historic standing buildings.

Wall panelling

Five of the 35 measured ring series from wall panelling elements remain ungrouped and undated. Again, none of these undated series show any particular growth anomalies but it has been suggested that some of these could be from different original panelling schemes, as found in the State Bedroom, reused from either elsewhere in Sydenham House or brought on to site from other buildings.

Trees

The only undated sample from the Sydenham estate trees is SYD-M18, which had a distorted ring sequence and was badly decayed and thus, precluded reliable measurement.

CONCLUSION

Dendrochronology has successfully provided dating evidence for the documented rebuilding of Sydenham House and the subsequent substantial alterations undertaken for Sir Thomas Wise and subsequently Edward Wise in the early and mid-seventeenth century respectively. The mid seventeenth-century material predominates with respect to the dated structural timbers, perhaps suggesting that this programme of works was more substantial than previously thought, although overall the sampling programme was somewhat more restricted than would normally be implemented if the house had not suffered the devastating fire resulting in the loss of a substantial part of the fabric of the house. The majority of the dated panelling appears most likely to be associated with Sir Thomas Wise, or perhaps his immediate successors Lady Wise and their son Thomas Wise but some dated panelling could be associated with Edward Wise. A small amount of timber pre-dates the documented rebuilding of Sydenham House, which could support the suggestion of an earlier house on the site, although this material is scattered within the house and clearly could potentially represent timbers reused from another building, or buildings, on this site or in the vicinity. None of the analysed timbers proved to be later than the mid-seventeenth century, thus, no dating evidence was obtained for any later minor alterations.

From a purely dendrochronological perspective the analysis has resulted in the production of two substantial historic chronologies, one comprising 84 timbers, being 261-rings long, spanning AD 1394–1654 and thought likely to represent trees derived from relatively local woodlands, potentially part of the estate, and the second comprising 24 panels, being 364-rings long, spanning AD 1266–1629 and thought likely to represent trees derived from a more diverse and distant woodland source. Although the site chronology from recently felled or fallen trees and live trees did not extend far enough back to link up with the historic chronologies, it is again a well-replicated long chronology comprising 26 trees, being 273-rings long, and spanning AD 1741–2013 and, thus, adds to the relatively sparse network of reference data for the last few centuries. This latter chronology has also provided information relating to a level of similarity between ring series and spatial distribution with a source woodland area, and represents this most recent major scheme of conservation and repair necessitated by the fire.

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TABLES

Table 1a: Details of tree-ring samples from building timbers at Sydenham House, Marystow, Devon

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
	North-east range, roof					
SYD-H01	South wall plate, truss 24 – 25	76	h/s	1554	1629	1629
SYD-H02	North post, truss 24	65	h/s	1573	1637	1637
SYD-H03	North principal rafter, truss 24	58	h/s	1575	1632	1632
SYD-H04	Tiebeam, truss 24	101	h/s	1536	1636	1636
SYD-H05	North principal rafter, truss 22	55	h/s	1570	1624	1624
SYD-H06	North principal rafter, truss 21	55	h/s	1575	1629	1629
SYD-H07	North purlin, truss 21 – 22	108	h/s	1519	1626	1626
SYD-H08	South principal rafter, truss 21	54	h/s	1578	1631	1631
SYD-H09	South common rafter 1 (from west), truss 21 – 22	54	h/s	1578	1631	1631
SYD-H10	South common rafter 2, truss 21 – 22	60	h/s	1572	1631	1631
SYD-H11	South common rafter 6, truss 21 – 22	56	h/s	1578	1633	1633
SYD-H12	South common rafter 4, west end – 21	65	h/s	1565	1629	1629
SYD-H13	South common rafter 7, west end – 21	nm	---	------	------	------
SYD-H14	South sprocket 1 (from west), truss 21 – 22	57	h/s	1573	1629	1629
SYD-H15	South sprocket 3, truss 21 – 22	54	h/s	1574	1627	1627
SYD-H16	South sprocket 4, truss 21 – 22	89	h/s	1547	1635	1635
	North-east range extension, roof					
SYD-H17	East principal rafter, truss 26	62	2	1576	1635	1637
SYD-H18	West principal rafter, truss 26	75	h/s	1559	1633	1633
SYD-H19	Tiebeam, truss 26	nm	---	------	------	------
SYD-H20	East principal rafter, truss 27	77	h/s	1555	1631	1631
SYD-H21	West principal rafter, truss 27	55	3	1582	1633	1636
SYD-H22	West purlin, truss 27 – 28	50	3	1578	1624	1627

Table 1a: (continued)

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
	North-east range extension, roof					
SYD-H23	West principal rafter, truss 28	62	no h/s	1550	------	1611
SYD-H24	Tiebeam, truss 28	152	h/s	1411	1562	1562
	North-east range porch to courtyard, roof					
SYD-H25	East common rafter 9 (from north end)	77	h/s	1560	1636	1636
SYD-H26	West common rafter 10	nm	---	------	------	------
SYD-H27	West common rafter 11	nm	---	------	------	------
SYD-H28	West common rafter 13	55	h/s	1540	1594	1594
	South-east range roof					
SYD-H29	North principal rafter, truss 1	74	h/s	------	------	------
SYD-H30	Tiebeam, truss1	59	h/s	1536	1594	1594
SYD-H31	South principal rafter, truss 2	116	h/s	1447	1562	1562
SYD-H32	Common rafter, frame 34 (north)	nm	---	------	------	------
SYD-H33	Common rafter, frame 18 (north)	61	h/s	------	------	------
SYD-H34	North principal rafter, truss 3	105	20C	1550	1634	1654
SYD-H35	South principal rafter, truss 3	98	h/s	1530	1627	1627
SYD-H36	South post, truss 3	80	h/s	1550	1629	1629
SYD-H37	South principal rafter, truss 4	44	h/s	1594	1637	1637
SYD-H38	South post, truss 4	66	no h/s	1557	------	1622
	South-east range porch to courtyard, roof					
SYD-H39	Sprocket, frame 95 (east)	59	no h/s	1563	------	1621
SYD-H40	Common rafter, frame 91 (east)	nm	---	------	------	------
SYD-H41	Common rafter, frame 97 (east)	nm	---	------	------	------
SYD-H42	Common rafter, frame 86 (west)	80	no h/s	1532	------	1611
SYD-H43	Eaves beam, frame 88 – 90 (west)	54	2	------	------	------
SYD-H44	Common rafter, frame 90 (west)	71	h/s	1556	1626	1626

Table 1a: (continued)

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
	West range roof					
SYD-H45	South wall plate	nm	---	------	------	------
SYD-H46	Tiebeam, truss 8	104	no h/s	1517	------	1620
SYD-H47	Tiebeam, truss 11	87	h/s	1545	1631	1631
SYD-H48	West principal rafter, truss 11	62	h/s	1568	1629	1629
SYD-H49	Tiebeam, truss 12	41	h/s	1593	1633	1633
SYD-H50	West principal rafter, truss 18	61	h/s	1578	1638	1638
SYD-H51	West queen post, truss 18	91	h/s	1554	1644	1644
SYD-H52	East queen post, truss 17	84	h/s	1542	1625	1625
SYD-H53	East principal rafter, truss 17	69	h/s	------	------	------
SYD-H54	Tiebeam, truss 10	59	h/s	1578	1636	1636
	North range, east cellar, ceiling					
SYD-H55	Joist 2 (from east)	144	12+ *(10nmC)*	1452	1583	1595
SYD-H56	Joist 3	163	h/s	1419	1581	1581
SYD-H57	Joist 6	52	h/s	1534	1585	1585
SYD-H58	Joist 8	187	h/s	1394	1580	1580
SYD-H59	Joist 9	101	h/s	1426	1526	1526
SYD-H60	Joist 5	40	no h/s	------	------	------
	North range, west cellar, ceiling					
SYD-H61	Joist 2 (from east)	71	8	1457	1519	1527
SYD-H62	Joist 4	93	5	1425	1512	1517
SYD-H63	Joist 5	75	no h/s	1458	------	1532
SYD-H64	Joist 6	60	2	1580	1637	1639
SYD-H65	Joist 1	80	h/s	------	------	------

Table 1a: (continued)

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
	North range, west cellar, stair/hallway					
SYD-H66	West stair, main ceiling beam	157	h/s	1407	1563	1563
SYD-H67	Hallway cut-off beam	144	7	1444	1580	1587
SYD-H68	West stair, common ceiling joist	nm	---	------	------	------
	North range, west cellar, entry hall					
SYD-H69	Joist 2 (from north)	58	21C	1548	1584	1605
SYD-H70	Joist 4	43	no h/s	1535	------	1577
SYD-H71	Joist 5	67	25C	1538	1579	1604
SYD-H72	Joist 6	nm	---	------	------	------
	North-east range stair/State Bedroom partition wall					
SYD-H73	Central main post	102	h/s	1457	1558	1558
SYD-H74	North cross-rail	56	5	1590	1640	1645
SYD-H75	South cross-rail	40	h/s	1591	1630	1630
SYD-H76	North upper stud post 1	148	20C	------	------	------
SYD-H77	North upper stud post 2	nm	---	------	------	------
SYD-H78	Landing support beam	133	8	1459	1583	1591
	West range, roof					
SYD-H79	Tiebeam, truss 9	82	h/s	1550	1631	1631
SYD-H80	Tiebeam, truss 13	66	h/s	1570	1635	1635
SYD-H81	Tiebeam, truss 14	*(15nm)* +40	no h/s	1576	------	1615
SYD-H82	Tiebeam, truss 15	*(30nm)* +52	h/s	1576	1627	1627
SYD-H83	Uncertain location	81	h/s	1550	1630	1630
	South-east range, roof					
SYD-H84	North principal rafter, truss 2	nm	---	------	------	------
SYD-H85	Tiebeam, truss 2	117	h/s	1513	1629	1629
SYD-H86	Tiebeam, truss 3	105	h/s	1532	1636	1636

Table 1a: (continued)

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
	South-east range, first-floor timbers					
SYD-H87	East intermediate ceiling beam	67	h/s	1565	1631	1631
SYD-H88	West intermediate ceiling beam	70	h/s	1563	1632	1632
SYD-H89	Lintel to south main window	98	14	1557	1640	1654
SYD-H90	Inner lintel to east window	nm	---	------	------	------
SYD-H91	Middle lintel to east window	54	h/s	1448	1501	1501
SYD-H92	Outer lintel to east window	54	no h/s	------	------	------
SYD-H93	Inner lintel to south secondary window	nm	---	------	------	------
SYD-H94	Middle lintel to south secondary window	nm	---	------	------	------
	West range, main staircase					
SYD-H95	Stairway base beam	79	h/s	1509	1587	1587
SYD-H96	Stairway post	64	h/s	1566	1629	1629
SYD-H97	Understair, middle runner	nm	---	------	------	------
SYD-H98	Understair, south runner	nm	---	------	------	------
SYD-H99	Lower stair, north middle runner	nm	---	------	------	------
SYD-H100	Lower stair, south runner	45	h/s	1568	1612	1612
SYD-H101	Second flight, base beam	nm	---	------	------	------
SYD-H102	Second flight, south runner	nm	---	------	------	------
	North range, stair doorway					
SYD-H103	Newel stair door, right hand jamb	130	h/s	1428	1557	1557
SYD-H104	Newel stair door, left hand jamb	135	h/s	1434	1568	1568
SYD-H105	Newel stair door, lintel	121	25	1413	1508	1533
SYD-H106	Newel stair door, wall beam over	121	h/s	------	------	------
	West range, main staircase top landing					
SYD-H107	Main ceiling beam	91	21	1564	1633	1654

Table 1a: (continued)

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
	South-east range, ground floor, studio					
SYD-H108	Studio/flower room door, lintel 1	140	h/s	------	------	------
SYD-H109	Studio/flower room door, lintel 2	80	no h/s	1438	------	1517
SYD-H110	Studio/flower room door, lintel 3	nm	---	------	------	------
SYD-H111	Studio/flower room door, lintel 4	nm	---	------	------	------
SYD-H112	Studio, north window, inner lintel	nm	---	------	------	------
SYD-H113	Studio, east window lintel	62	h/s	1494	1555	1555
SYD-H114	Studio/south hall doorway lintel	67	h/s	------	------	------
	South-east range, ground floor, south hall					
SYD-H115	South hall north window lintel 1	59	h/s	1505	1563	1563
SYD-H116	South hall north window lintel 2	40	no h/s	1569	------	1608
	South-east range, stair landing					
SYD-H117	South stair, first landing window, inner lintel	nm	---	------	------	------
SYD-H118	South stair, first landing window, inner lintel	nm	---	------	------	------
	South-east range, ground floor, south hall					
SYD-H119	Toilet, south window lintel	83	h/s	------	------	------
	South-east range, first-floor ceiling					
SYD-H120	First-floor ceiling, common joist 7	nm	---	------	------	------
SYD-H121	First-floor ceiling, common joist 17	44	no h/s	------	------	------
SYD-H122	First-floor ceiling, common joist E4B2	nm	---	------	------	------
	West range, east porch, inner door to west range					
SYD-H123	Inner lintel	50	h/s	------	------	------
	West range, east porch gable, 'Beasts of Sydenham'					
SYD-H124	South 'Beast'	88	no h/s	1546	------	1633
SYD-H125	North 'Beast'	97	3	1546	1639	1642

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

C = complete sapwood is retained on the sample; the last measured ring date is the felling date of the tree represented

nm = rings not measured

Table 1b: Details of tree-ring samples from oak panels at Sydenham House, Marystow, Devon.

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
	Queen's Bedroom					
SYD-P01	Q14a	132	04	1475	1602	1606
SYD-P02	Q13a	118	no h/s	1465	------	1582
SYD-P03	Q16b	131	no h/s	1457	------	1587
SYD-P04	Q12b	134	no h/s	1456	------	1589
SYD-P05	Q11d	120	no h/s	1454	------	1573
SYD-P06	Q15e	125	no h/s	1451	------	1575
	King's Bedroom					
SYD-P07	K23ai (guilded framing piece)	107	no h/s	1455	------	1561
SYD-P08	K23aii (guilded framing piece)	83	no h/s	1479	------	1561
SYD-P09	K36b (guilded framing piece)	263	no h/s	1266	------	1528
SYD-P10	K36c (guilded framing piece)	201	no h/s	1319	------	1519
SYD-P11	K36d (guilded framing piece)	269	no h/s	1283	------	1551
SYD-P12	K23d	221	no h/s	1297	------	1517
SYD-P13	K24a	152	no h/s	1396	------	1547
SYD-P14	K15b	223	no h/s	1340	------	1562
SYD-P15	K83a	110	no h/s	1342	------	1451
SYD-P16	K24d (wallpapered)	73	no h/s	------	------	------
SYD-P17	K26d (wallpapered)	157	no h/s	------	------	------
	State Bedroom					
SYD-P18	S43B	196	no h/s	1434	------	1629
SYD-P19	S47B	107	no h/s	1435	------	1541
SYD-P20	S26b	194	no h/s	1399	------	1592
SYD-P21	S27c	191	no h/s	1398	------	1588

Table 1b: continued

Sample number	Sample location	Total rings	Sapwood rings*	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
	State bedroom					
SYD-P22	S26c	190	no h/s	1401	------	1590
SYD-P23	S15d	172	no h/s	1438	------	1609
SYD-P24	S103c	173	4	1441	1609	1613
SYD-P25	S33a	203	6	1369	1565	1571
	Dining room					
SYD-P26	D61a	107	7	1477	1576	1583
SYD-P27	D65a	99	no h/s	1467	------	1565
SYD-P28	D52b	146	no h/s	1400	------	1545
SYD-P29	D52a	131	no h/s	1381	------	1511
SYD-P30	D52 muntin piece	80	no h/s	------	------	------
SYD-P31	D191a	115	no h/s	1455	------	1569
SYD-P32	D191b	122	no h/s	1448	------	1569
SYD-P33	D64a	106	no h/s	1468	------	1573
SYD-P34	D101F(2)	91	no h/s	------	------	------
SYD-P35	D101F(1)	61	no h/s	------	------	------

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

Table 1c: Details of tree-ring samples from the Sydenham House estate woodlands, Marystow, Devon

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
SYD-M01	Tree (live)	157	28C	1857	1985	2013
SYD-M02	Tree (live)	167	49C	1847	1964	2013
SYD-M03	Tree (live)	80	23	1933	1989	2012
SYD-M04	Tree (live)	202	49C	1812	1964	2013
SYD-M05	Tree (live)	82	25C	1932	1988	2013
SYD-M06	Tree (live)	199	32C	1815	1981	2013
SYD-M07	Tree (live)	166	h/s	1819	1984	1984
SYD-M08	Tree (live)	179	27C	1835	1986	2013
SYD-M09	Tree (live)	140	20C	1874	1993	2013
SYD-M10	Tree (live)	198	27C	1816	1986	2013
SYD-M11	Tree (live)	199	23C	1815	1990	2013
SYD-M12	Tree (live)	191	21C	1823	1992	2013
SYD-M13	Tree (live)	173	27C	1841	1986	2013
SYD-M14	Tree (live)	191	10	1811	1991	2001
SYD-M15	Tree (live)	200	25C	1814	1988	2013
SYD-M16	Tree (live)	153	23C	1861	1990	2013
SYD-M17	Tree (live)	162	9	1836	1988	1997
SYD-M18	Tree (live)	nm	---	------	------	------
SYD-M19i	Tree (live)	64	no h/s	1855	------	1918
SYD-M19ii	Tree (live)	76	24C	1938	1989	2013
SYD-M20	Tree (live)	270	22	1741	1988	2010
SYD-M21	Tree (fallen/felled)	120	12	1856	1963	1975
SYD-M22	Tree (fallen/felled)	263	29C	1742	1975	2004
SYD-M23	Tree (fallen/felled)	170	13C	1841	1997	2010

Table 1c: continued

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date AD	Last heartwood ring date AD	Last measured ring date AD
SYD-M24	Tree (fallen/felled)	111	h/s	1872	1982	1982
SYD-M25	Tree (fallen/felled)	125	15C	1886	1995	2010
SYD-M26	Tree (fallen/felled)	107	27C	1904	1983	2010
SYD-M27	Tree (fallen/felled)	182	29C	1831	1983	2012

C = complete sapwood is retained on the sample,
h/s = the heartwood/sapwood ring is the last ring on the sample;
nm = not measured

Table 2: Results of the cross-matching of site chronology SYDHSQ01 and relevant reference chronologies when the first-ring date is AD 1394 and the last-ring date is AD 1654

Reference chronology	Span of chronology	*t*-value	Reference
Treludick House, Egloskerry, Cornwall	AD 1516–1630	9.9	Arnold and Howard 2007a
Church of St Nectan (pews) Hartland, Devon	AD 1410–1576	9.5	Arnold and Howard 2013
Trerithick House, Polyphant, Cornwall	AD 1503–1673	8.9	Arnold and Howard 2007b
Oak House, West Bromwich, West Midlands	AD 1405–1590	8.4	Arnold and Howard 2009
Welltown Manor, nr Boscastle, Cornwall	AD 1454–1576	8.1	Tyers 2004
Great Gutton, Shobrooke, Devon	AD 1403–1591	8.1	Tyers *et al* forthcoming
Chaffcombe, Down St Mary, Devon	AD 1531–1667	8.0	Groves 2005
1–5 Bridge Street, Bideford, Devon	AD 1484–1706	7.6	Arnold and Howard 2012a unpubl

Table 3: Results of the cross-matching of sample SYDPSQ01 and relevant reference chronologies when the first-ring date is AD 1266 and the last-ring date is AD 1629

Reference chronology	Span of chronology	*t*-value	Reference
St John's Walk, Hereford Cathedral, Herefordshire	AD 1356–1504	12.3	Arnold and Howard 2015 unpubl
Sinai Park, Burton on Trent, Staffordshire	AD 1227–1750	11.7	Tyers 1997
Warleigh House, Tamerton Foliot, Devon	AD 1366–1539	11.3	Howard *et al* 2006
Hereford Cathedral barn, Herefordshire	AD 1359–1491	11.3	Tyers 1996a
Mercer's Hall, Mercer's Lane, Gloucester, Gloucestershire	AD 1289–1541	11.2	Howard *et al* 1996
Docton Court, Appledore, Devon	AD 1359–1457	11.2	Arnold and Howard 2012b unpubl
The Commandery, Worcester, Worcestershire	AD 1284–1473	9.9	Arnold and Howard 2006
Manor Farm Barn, Halesowen, Dudley, West Midlands	AD 1310–1535	9.6	Arnold and Howard 2008

Table 4: Results of the cross-matching of sample SYDPSQ02 and relevant reference chronologies when the first-ring date is AD 1340 and the last-ring date is AD 1562

Reference chronology	Span of chronology	t-value	Reference
Imported: Baltic 1 panel paintings	AD 1156–1597	7.5	Hillam and Tyers 1995
Imported: Knole House ballroom panelling, Kent	AD 1347–1588	7.4	Tyers 2017
Imported: Otley Hall panelling (type 1), Suffolk	AD 1296–1519	6.7	Tyers 2000
Imported: Fulham Palace gate leaves, Fulham, London	AD 1319–1484	6.4	Bridge and Miles 2004
Imported: Brooke House panelling, Hackney, London	AD 1369–1544	6.4	Tyers 2015
Imported: Winchester College panels, Hampshire	AD 1207–1495	6.0	Miles *et al* 1996
Imported: Bowhill ceiling boards, Exeter, Devon	AD 1161–1483	5.9	Groves 2004
Imported: Sutton House panelling (type 1), Hackney, London	AD 1259–1516	5.6	Tyers 1991

Table 5: Results of the cross-matching of sample SYDPSQ03 and relevant reference chronologies when the first-ring date is AD 1455 and the last-ring date is AD 1561

Reference chronology	Span of chronology	*t*-value	Reference
Poland: Malopolska	AD 1215–1589	6.0	Krapiec pers comm
Imported: Baltic 2 panel paintings	AD 1257–1615	6.9	Hillam and Tyers 1995
Imported: Otley Hall panelling (type 2), Suffolk	AD 1374–1584	6.4	Tyers 2000
Imported: William Cecil, Baron Burghley (NPG OS749) panel painting	AD 1381–1582	6.2	I Tyers pers comm
Imported: Knole House ballroom pilaster, Kent	AD 1491–1578	6.1	Tyers 2017
Imported: Sir Walter Ralegh (NPG OS7) panel painting	AD 1450–1564	6.0	I Tyers pers comm
Imported: barrel staves, BHD90, London	AD 1394–1533	4.9	I Tyers pers comm
Imported: Sutton House panelling (type 2), Hackney, London	AD 1349–1595	4.6	Tyers 1991

Table 6: Results of the cross-matching of sample SYD-P13 and relevant reference chronologies when the first-ring date is AD 1396 and the last-ring date is AD 1547

Reference chronology	Span of chronology	t-value	Reference
Imported: Baltic 1 panel paintings	AD 1156–1597	8.8	Hillam and Tyers 1995
Imported: Knole House ballroom panelling, Kent	AD 1347–1588	8.4	Tyers 2017
Imported: Brooke House panelling, Hackney, London	AD 1369–1544	7.1	Tyers 2015
Imported: Bowhill ceiling boards, Exeter, Devon	AD 1161–1483	6.3	Groves 2004
Imported: Sutton House panelling (type 1), Hackney, London	AD 1259–1516	6.2	Tyers 1991
Imported: Fulham Palace gate leaves, Fulham, London	AD 1319–1484	6.1	Bridge and Miles 2004
Imported: Sandford Orleigh panelling, Newton Abbot, Devon	AD 1326–1517	5.6	Tyers 2012
Imported: Winchester College panels, Hampshire	AD 1207–1495	5.4	Miles *et al* 1996

Table 7: Results of the cross-matching of sample SYD-P23 and relevant reference chronologies when the first-ring date is AD 1438 and the last-ring date is AD 1609

Reference chronology	Span of chronology	*t*-value	Reference
White House, Vowchurch, Herefordshire	AD 1364–1602	7.0	Nayling 1999
Porch House, High Street, Bishops Castle, Shropshire	AD 1416–1564	6.7	Worthington and Miles 2000
26 Westgate Street, Gloucester, Gloucestershire	AD 1399–1622	6.1	Howard *et al* 1998
Dore Abbey Church, Abbey Dore, Herefordshire	AD 1363–1612	6.0	Tyers and Boswijk 1998
St John the Baptist Church, Mamble, Worcestershire	AD 1348–1582	5.7	Tyers 1996b
Welsh Borders	AD 1341–1636	5.7	Siebenlist-Kerner 1978
St Nicholas Church, Bringhurst, Leicestershire	AD 1502–1687	5.6	Arnold *et al* 2005
Parkers Field', North Petherton Somerset	AD 1529–1640	5.8	Arnold and Howard 2011 unpubl

Table 8: Results of the cross-matching of sample SYDMSQ01 and relevant reference chronologies when the first-ring date is AD 1741 and the last-ring date is AD 2013

Reference chronology	Span of chronology	*t*-value	Reference
Gloucestershire modern trees	AD1724–1998	11.9	Howard 1999 unpubl
Fairfield House, Stogursey, Somerset	AD1786–2013	10.9	Arnold and Howard 2015
Clovelly, Devon	AD1750–1981	10.5	Loader pers comm
Exeter Cathedral, Exeter, Devon	AD1780–1921	9.9	Arnold *et al* 2003
Abbeyford wood, Devon	AD1845–1985	9.8	Loader pers comm
Enniscorthy, County Wexford, Ireland	AD1811–1978	9.6	Pilcher and Baillie 1980
Winchester, Hampshire	AD1635–1972	9.5	Barefoot 1975
Bradgate Park, Leicestershire	AD1595–1975	9.3	Laxton and Litton 1988

*Table 9: Matrix of the t-values produced between all the cross-matched and dated samples from modern trees. \ = overlap < 30 years; - = t-values less than 3.00; * = empty triangle*

Filenames	syd-m01	syd-m02	syd-m03	syd-m04	syd-m05	syd-m06	syd-m07	syd-m08	syd-m09	syd-m10	syd-m11	syd-m12	syd-m13	syd-m14	syd-m15	syd-m16	syd-m17	syd-m19i	syd-m19o	syd-m20	syd-m21	syd-m22	syd-m23	syd-m24	syd-m25	syd-m26	syd-m27
syd-m01	*	4.50	3.95	-	-	5.45	-	-	-	5.31	4.07	3.29	3.39	4.55	4.86	5.67	5.16	-	3.07	-	5.58	5.86	4.07	3.44	3.11	-	3.83
syd-m02	*	*	4.93	6.80	4.27	5.29	-	-	-	4.78	4.38	3.35	-	4.12	4.04	5.08	4.37	-	-	-	3.53	4.74	-	-	-	-	-
syd-m03	*	*	*	-	4.74	4.59	-	-	-	-	3.02	-	-	-	-	4.11	3.50	\	4.23	-	-	3.98	3.17	-	3.84	-	-
syd-m04	*	*	*	*	-	3.57	4.76	5.32	3.41	7.00	7.80	6.41	5.41	6.10	6.73	5.33	5.20	-	-	-	-	6.23	-	4.93	-	-	5.24
syd-m05	*	*	*	*	*	4.16	-	-	4.00	7.07	6.36	-	4.56	5.93	5.84	7.04	5.89	\	-	-	-	4.73	-	3.92	3.26	-	3.06
syd-m06	*	*	*	*	*	*	5.63	3.17	3.91	7.41	7.28	4.44	6.94	8.23	7.78	7.00	6.38	3.03	5.26	-	4.13	5.76	5.15	4.17	5.80	-	6.72
syd-m07	*	*	*	*	*	*	*	3.00	-	6.36	5.82	4.53	4.38	7.08	6.93	4.37	4.08	-	-	-	-	5.27	3.97	4.35	7.32	-	5.05
syd-m08	*	*	*	*	*	*	*	*	-	4.22	4.50	5.62	3.62	4.58	4.34	4.39	-	-	-	-	-	3.75	-	5.02	-	-	4.17
syd-m09	*	*	*	*	*	*	*	*	*	5.57	5.78	-	6.32	6.65	7.32	4.70	9.40	-	3.31	-	-	3.73	-	7.41	-	-	4.36
syd-m10	*	*	*	*	*	*	*	*	*	*	13.40	6.70	9.42	11.26	15.15	9.97	9.52	4.49	3.38	-	3.74	8.69	3.17	7.63	-	3.77	5.23
syd-m11	*	*	*	*	*	*	*	*	*	*	*	7.02	9.16	9.94	13.15	10.28	9.48	4.30	-	-	-	7.25	-	7.17	-	3.44	6.76
syd-m12	*	*	*	*	*	*	*	*	*	*	*	*	6.76	7.93	7.66	5.12	5.51	-	-	-	3.60	6.31	-	3.13	3.73	-	4.96
syd-m13	*	*	*	*	*	*	*	*	*	*	*	*	*	9.85	9.37	6.35	7.89	4.37	-	-	-	4.56	-	6.64	-	3.05	6.81
syd-m14	*	*	*	*	*	*	*	*	*	*	*	*	*	*	12.66	9.83	7.69	4.20	-	-	4.82	7.28	4.16	7.29	4.77	-	8.89
syd-m15	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	9.50	10.91	6.37	3.33	-	4.72	9.78	4.92	6.30	4.81	3.31	7.47
syd-m16	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	10.21	4.12	3.52	-	4.35	7.24	4.15	6.75	4.72	3.93	5.84
syd-m17	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	4.64	6.11	-	5.21	7.16	-	11.31	3.19	4.98	5.20
syd-m19i	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	\	-	3.37	3.71	-	-	-	\	3.63
syd-m19o	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-	4.28	3.54	-	3.38	3.53	-	-
syd-m20	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	5.08	7.31	-	-	-	-	-
syd-m21	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	7.78	3.40	3.89	3.41	3.88	5.77
syd-m22	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	6.49	3.82	4.29	3.72	5.03
syd-m23	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	3.18	11.16	-	4.50
syd-m24	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-	5.20	6.33
syd-m25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-	4.45
syd-m26	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-
syd-m27	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

FIGURES

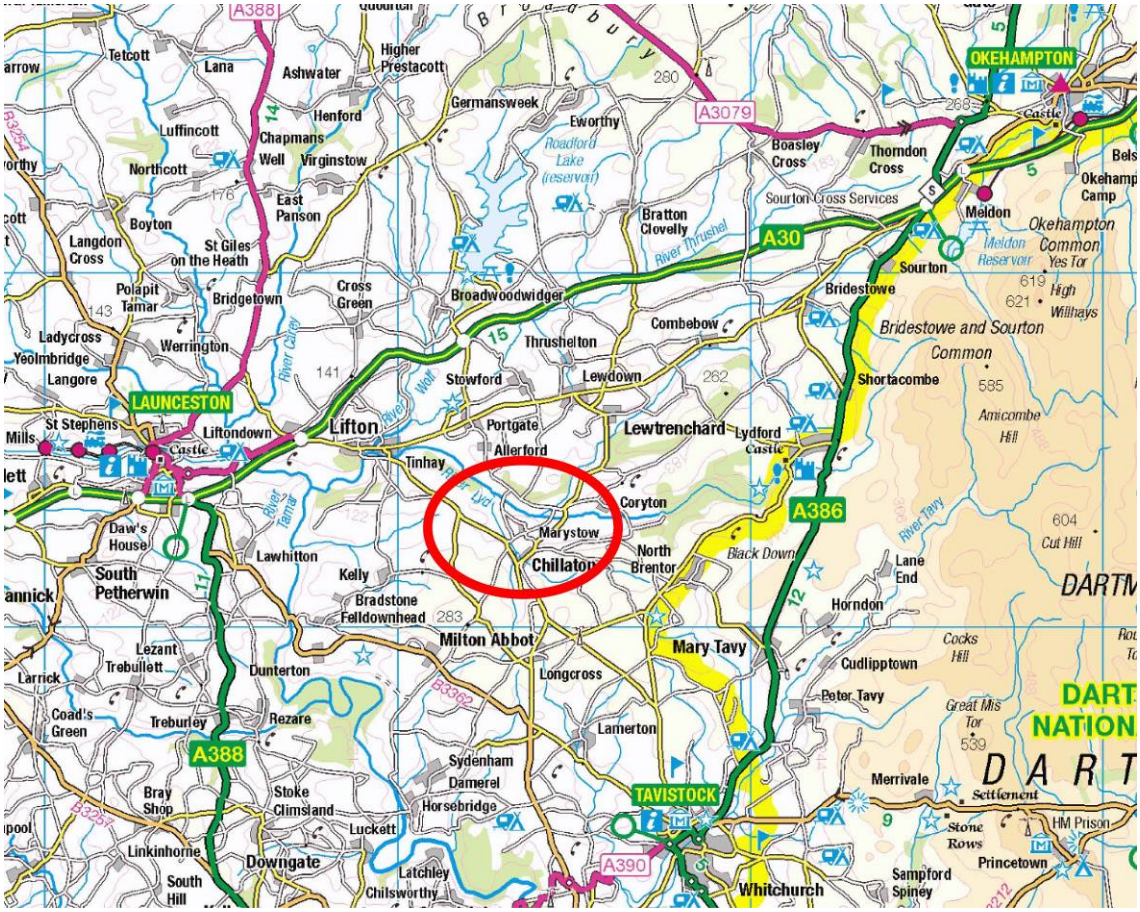

Figure 1a: Map to show the general location of hamlet of Marystow. © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100024900

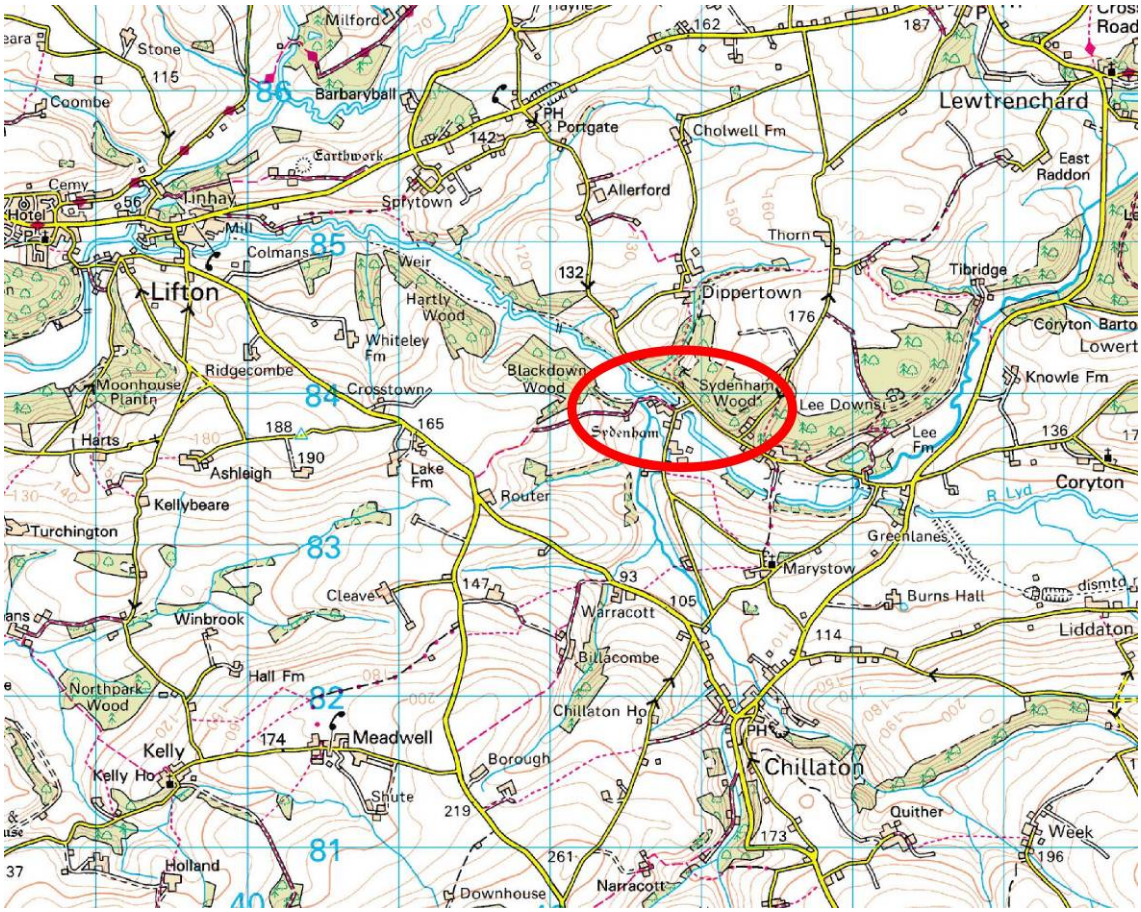

Figure 1b: Map to show the general location of Sydenham House in relation to the hamlet of Marystow. © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100024900

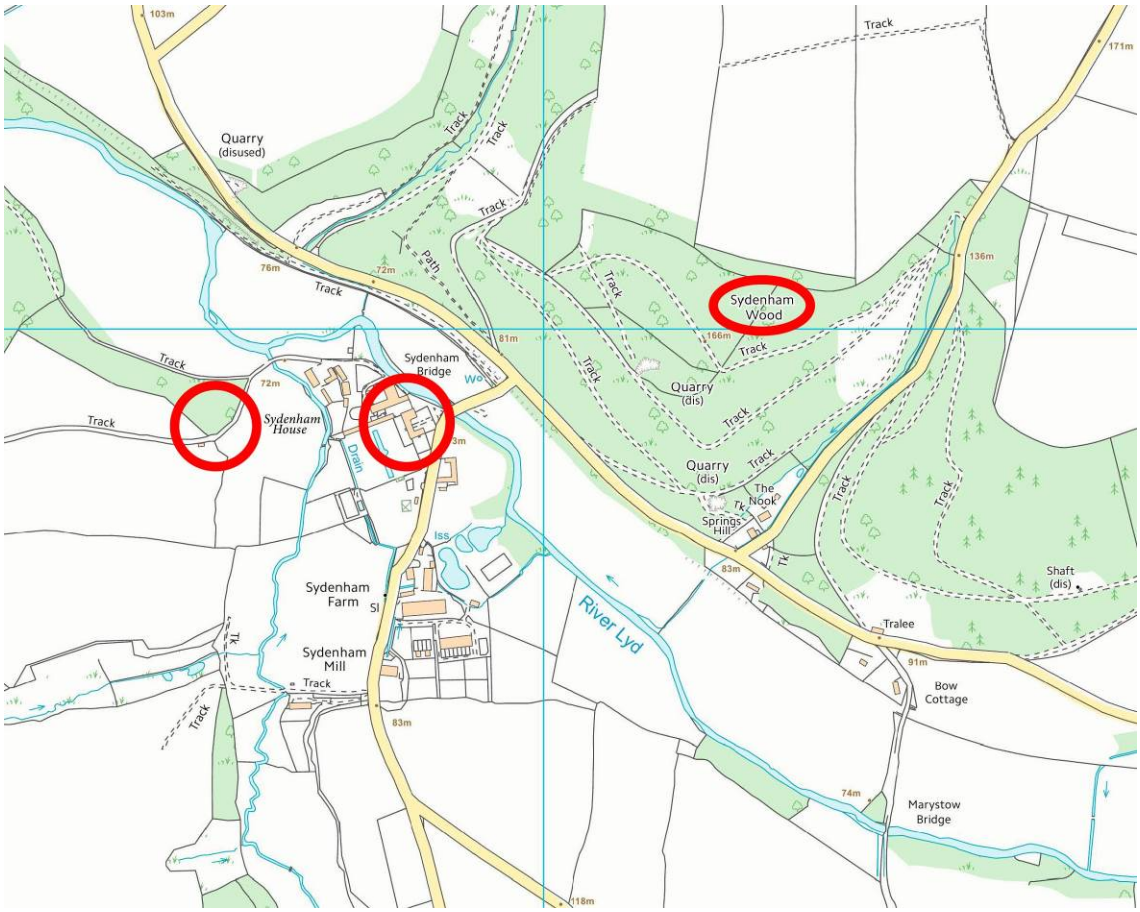

Figure 1c: Map to show the location of Sydenham House and Sydenham Wood. © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100024900

Figure 1d: Map to show the detailed location of Sydenham House. © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100024900

Figure 2a/b: Views showing the extent of the fire to the roofs (photographs Robert Howard)

Figure 2c/d: Views showing the extent of the fire to the lower floors (photographs Robert Howard)

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Figure 3: Ground-floor plan, showing the layout and arrangement of the areas investigated (after Cherry and Pevsner 1991)

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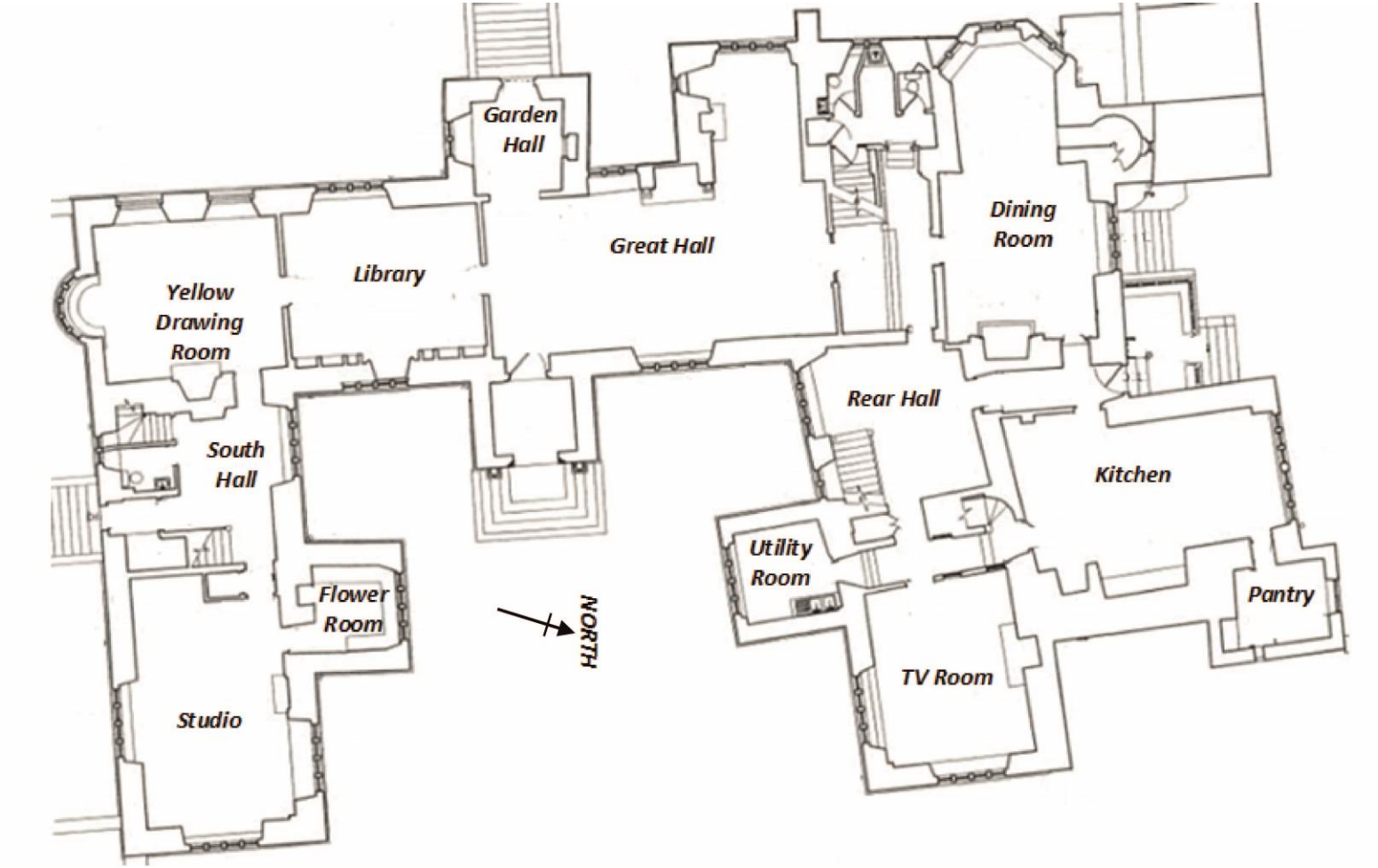

Figure 4a: Plan at ground-floor level with named rooms/areas (after Rodney Melville & Partners)

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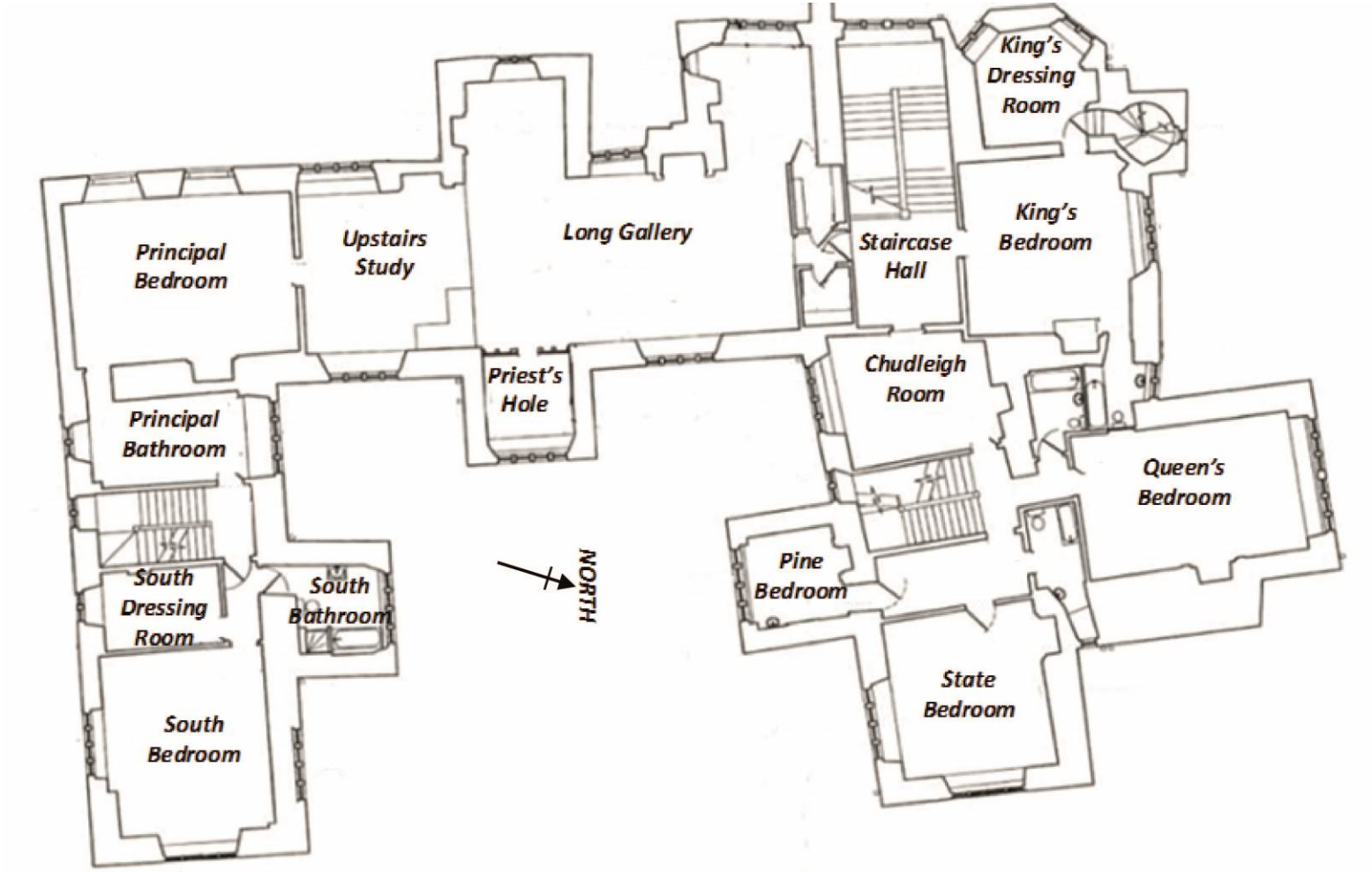

Figure 4b: Plan at first-floor level with named rooms/areas (after Rodney Melville & Partners)

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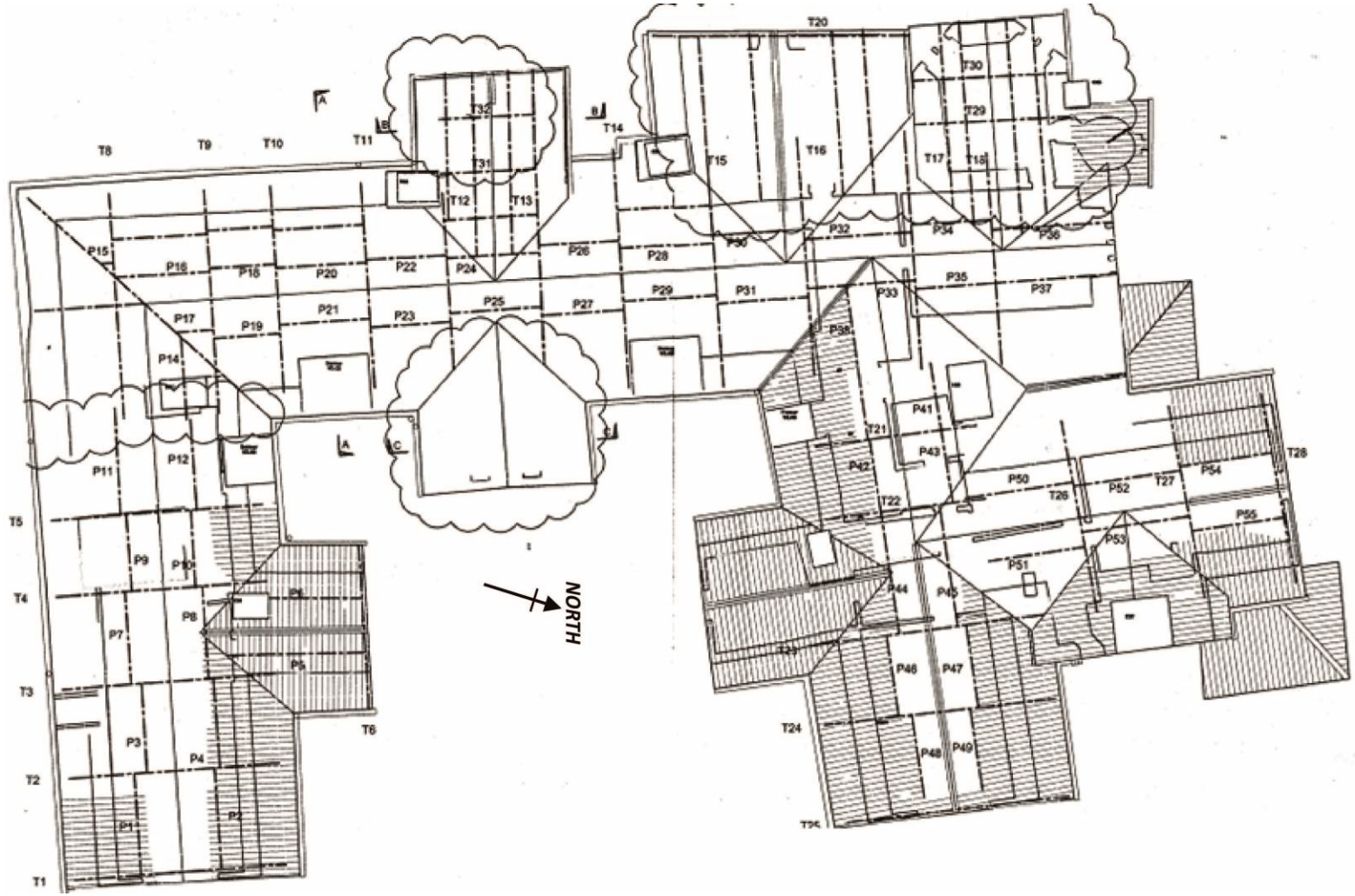


Figure 4c: Plan at attic level (after Rodney Melville & Partners)

Figure 5a: View of the panelling to the Queen's Bedroom before removal for conservation (photograph Alan Lamb)

Figure 5b: View of a section of panelling from the State Bedroom stored at Swan Studios, with each panel labelled with its own unique identifier code (photograph Robert Howard)

Figure 6: Sydenham Wood, showing the density of growth and the under-storey (photograph Robert Howard)

Figure 7a-c: Views of the 'Beast of Sydenham' in-situ (top) at Swan Studios during conservation (middle), and of the rings to its base prepared for measuring (bottom) (photographs Robert Howard)

Figure 8a/b: Views to show the labelling of sampled timbers (photographs Robert Howard)

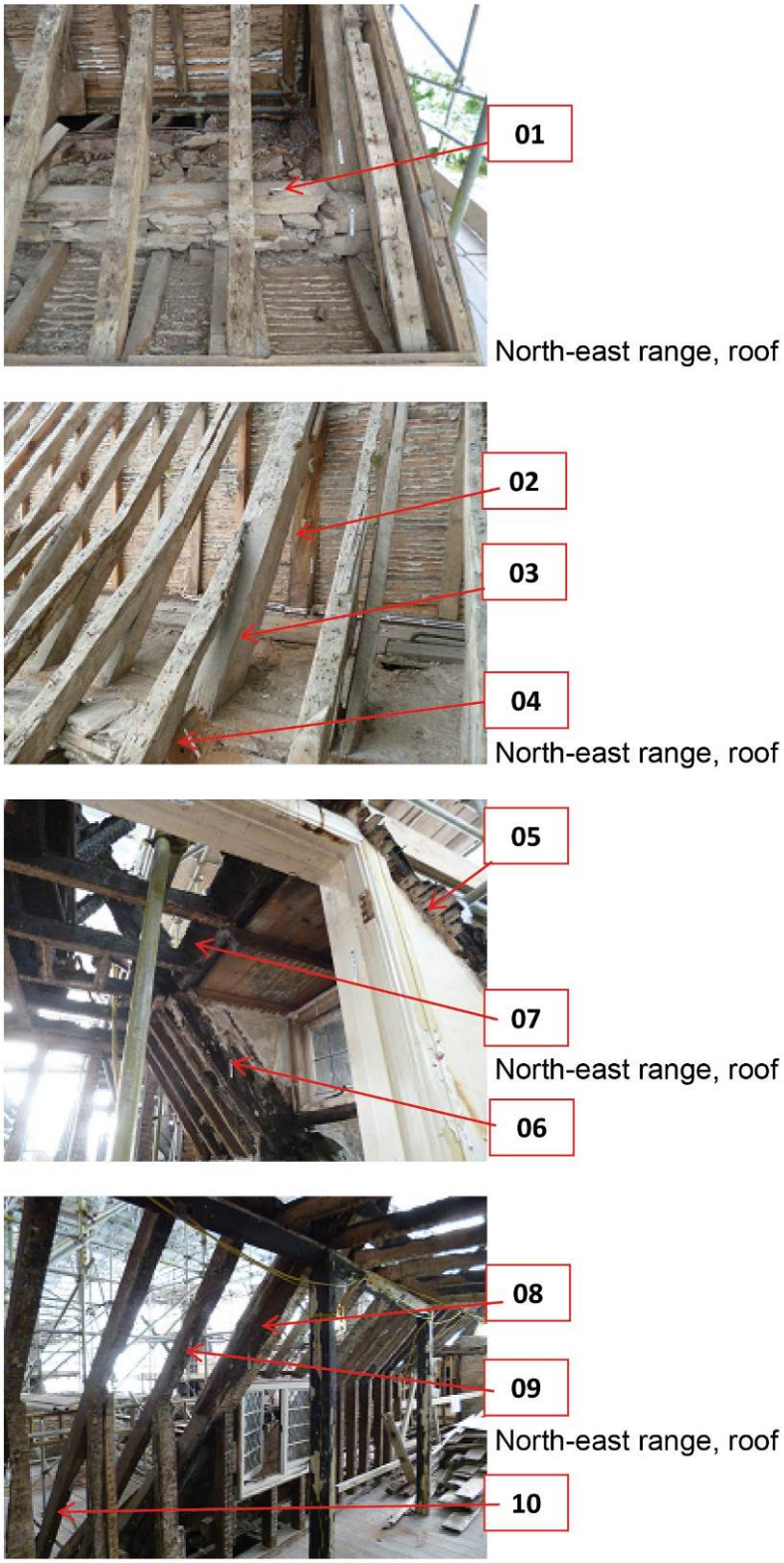


Figure 9a-d: Annotated photographs to help locate the sampled timbers (photographs Robert Howard)

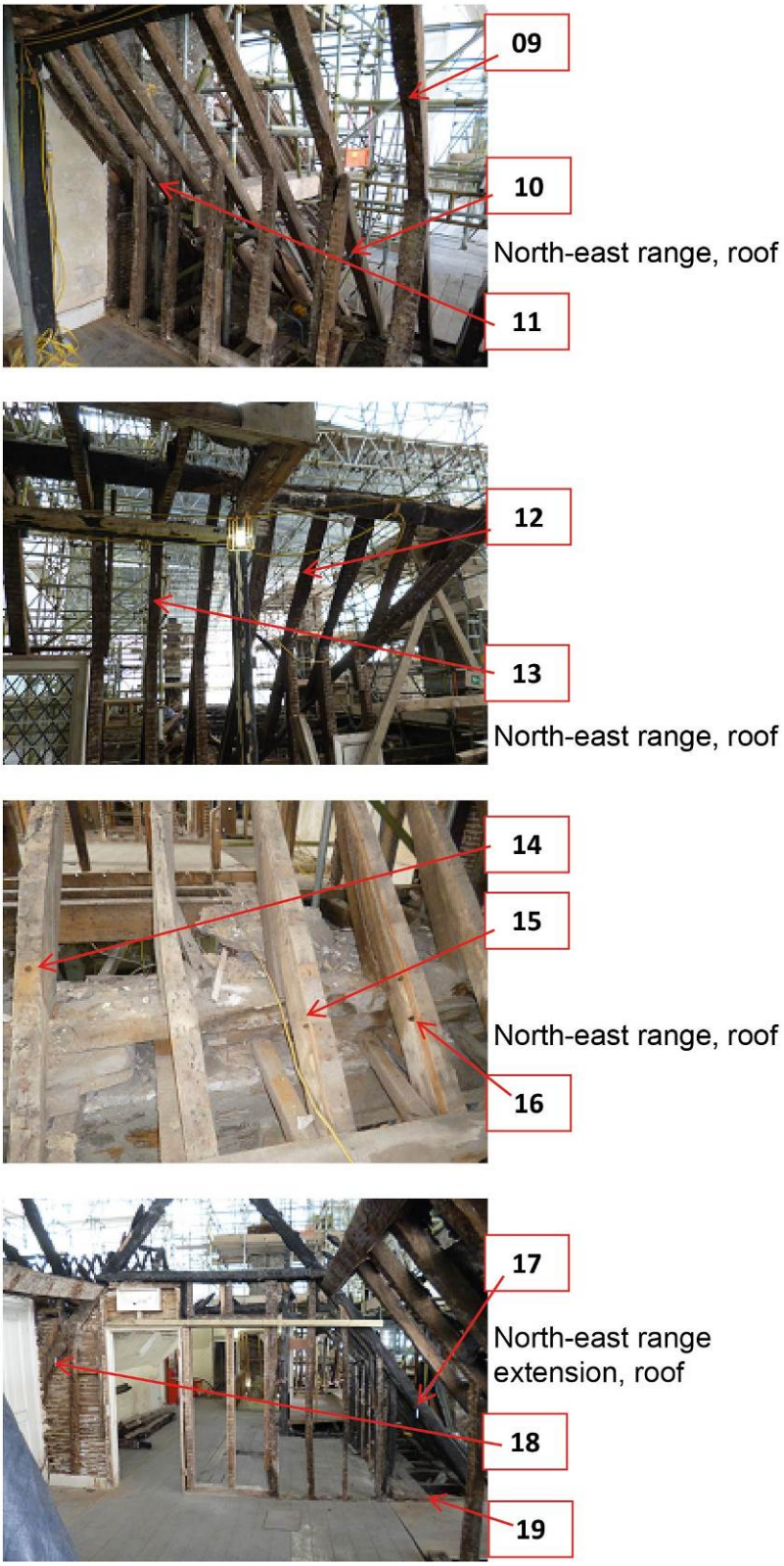


Figure 9e-h: Annotated photographs to help locate the sampled timbers (photographs Robert Howard)

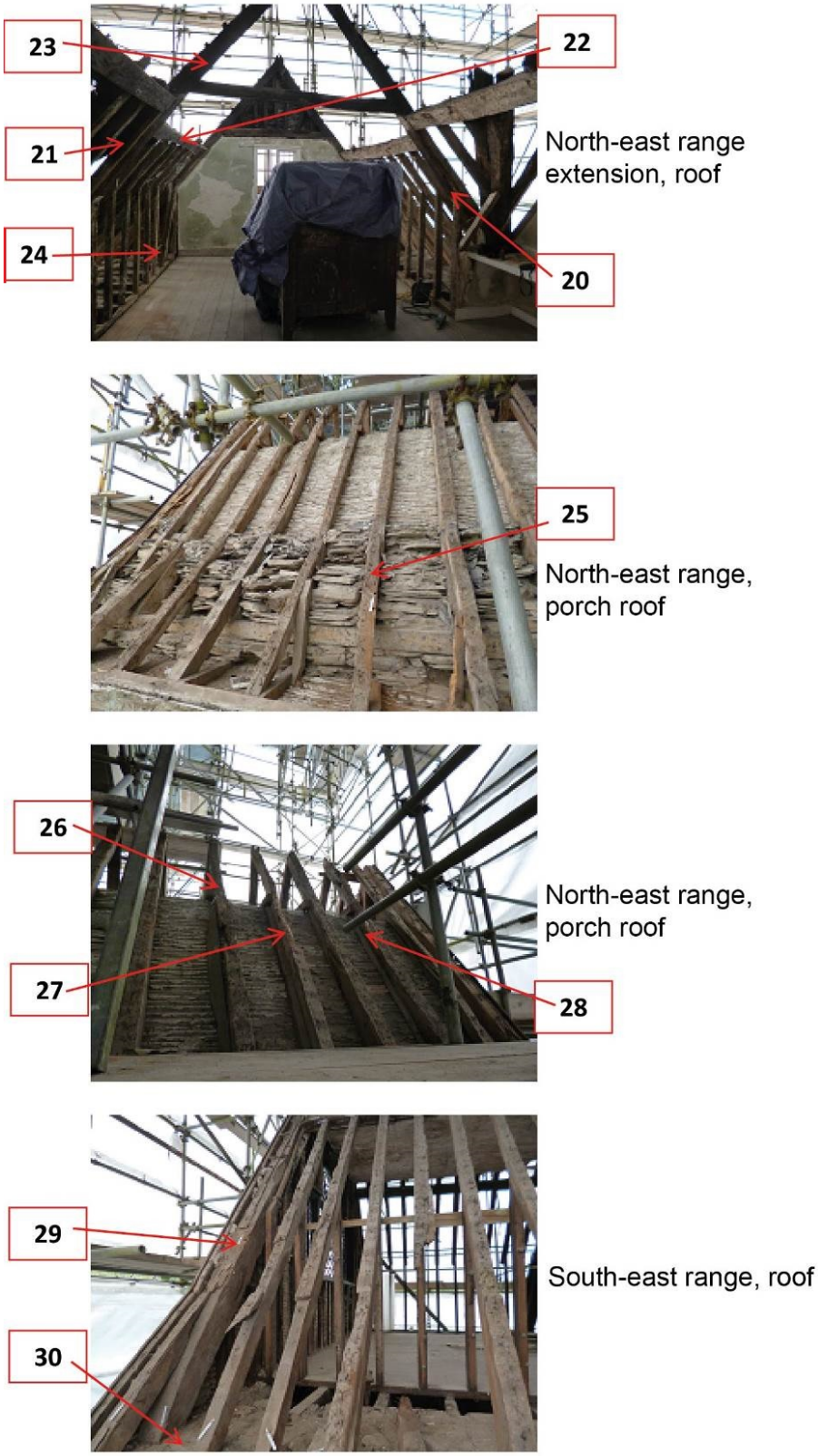


Figure 9i-l: Annotated photographs to help locate the sampled timbers (photographs Robert Howard)

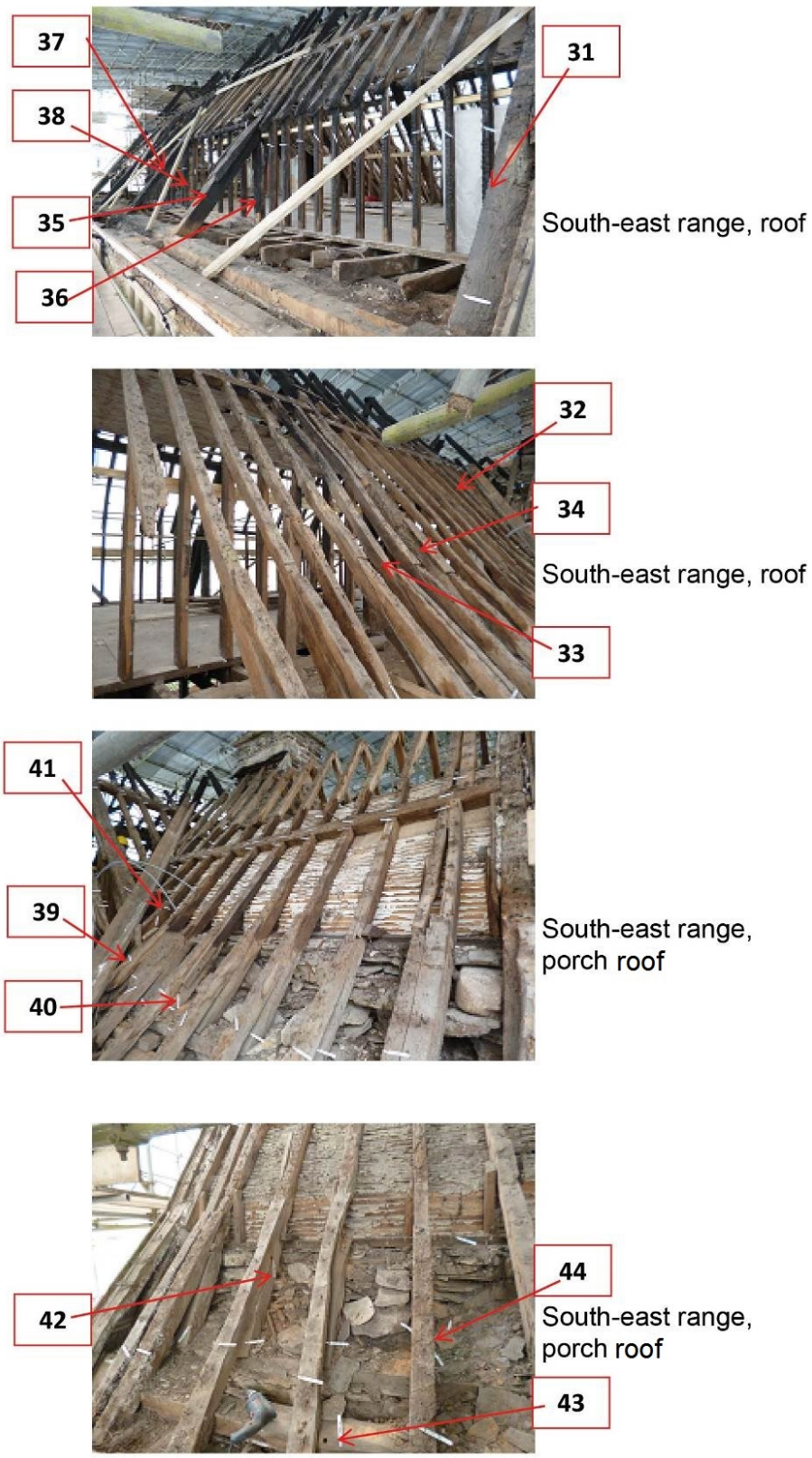


Figure 9m-p: Annotated photographs to help locate the sampled timbers (photographs Robert Howard)

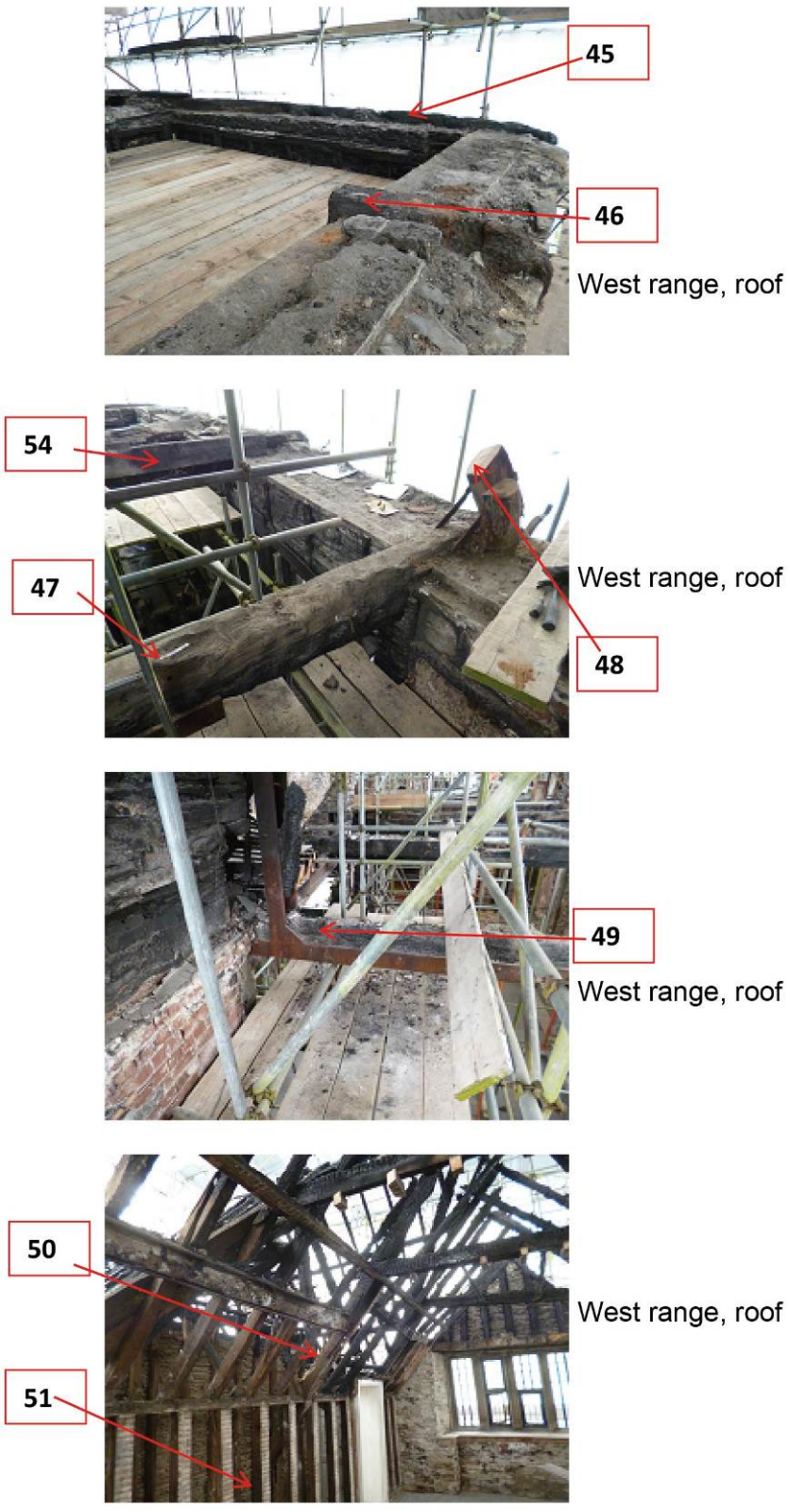
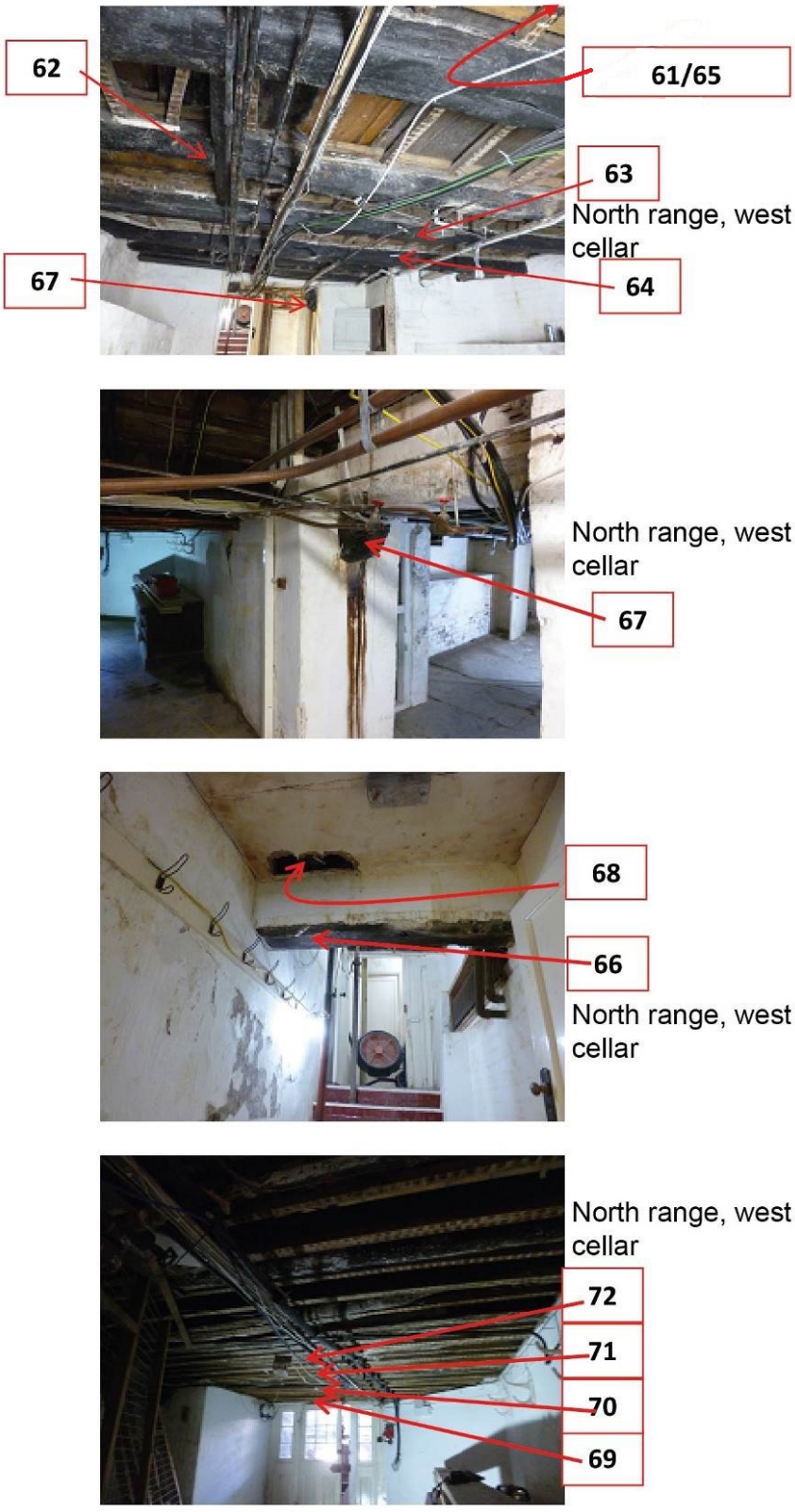


Figure 9q-t: Annotated photographs to help locate the sampled timbers (photographs Robert Howard)

Figure 9u-x: Annotated photographs to help locate the sampled timbers (photographs Robert Howard)



Figures 9y-z and 10a-b: Annotated photographs to help locate the sampled timbers (photographs Robert Howard)

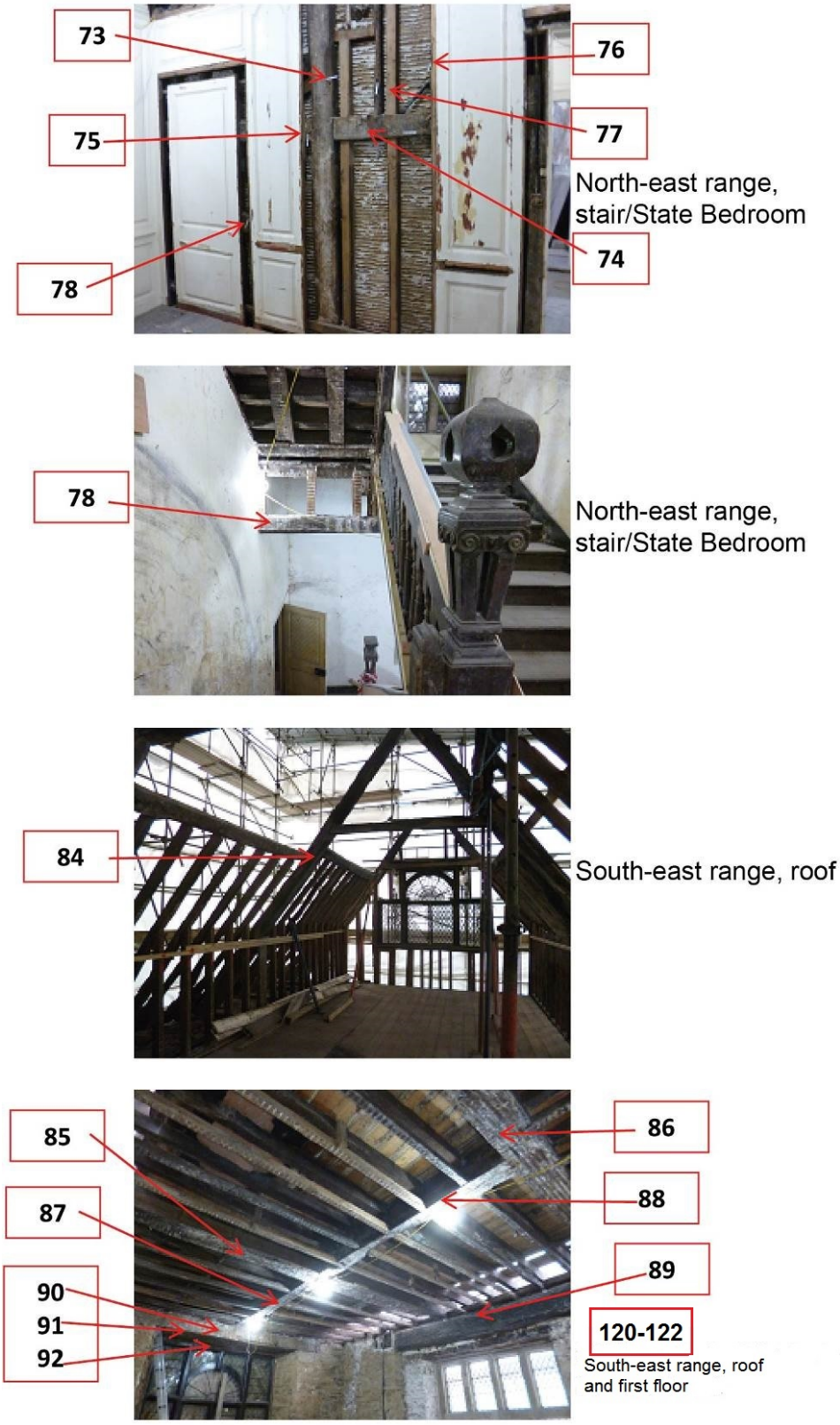


Figure 10c-f: Annotated photographs to help locate the sampled timbers (photographs Robert Howard)

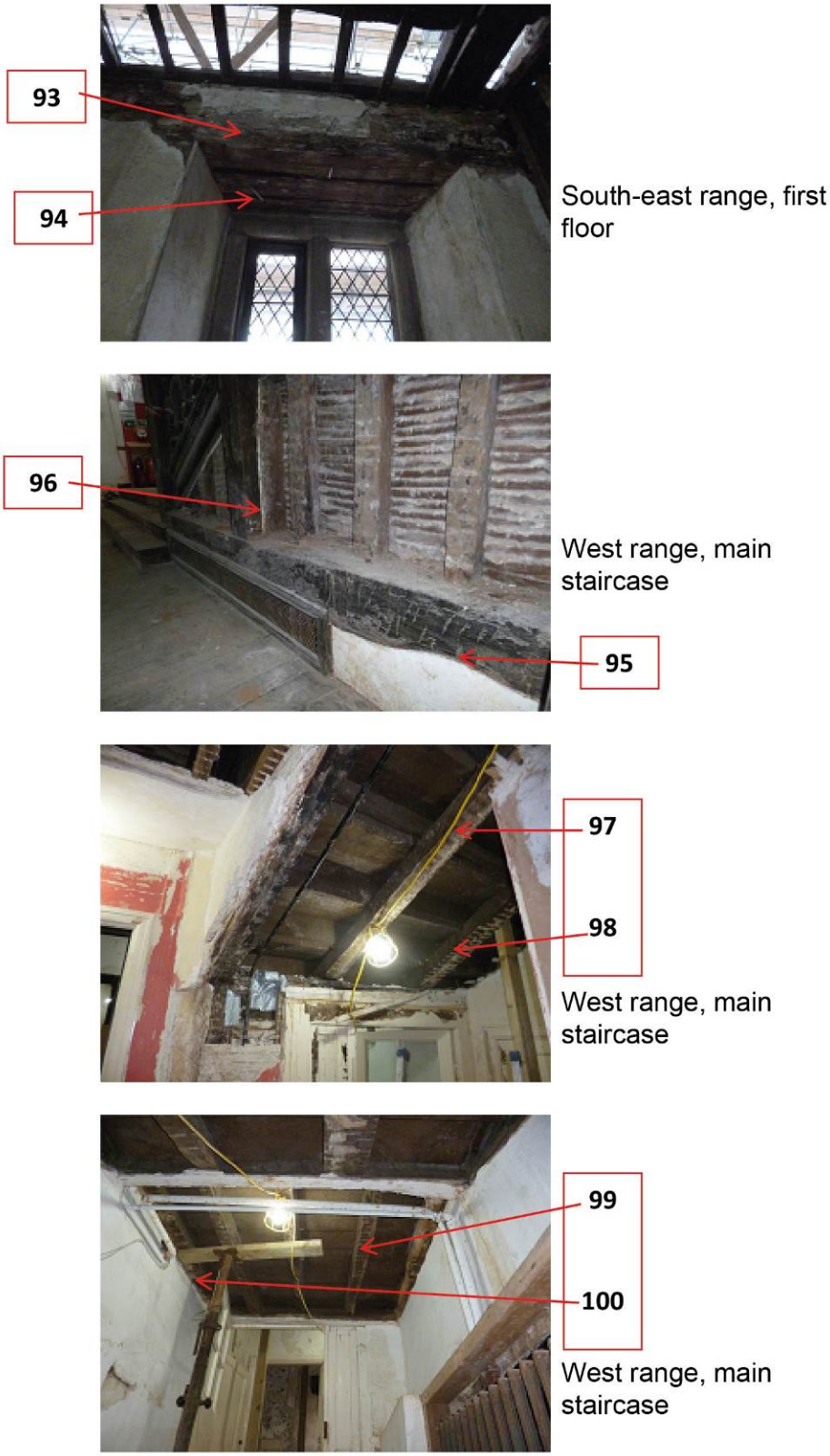


Figure 10g-j: Annotated photographs to help locate the sampled timbers (photographs Robert Howard)

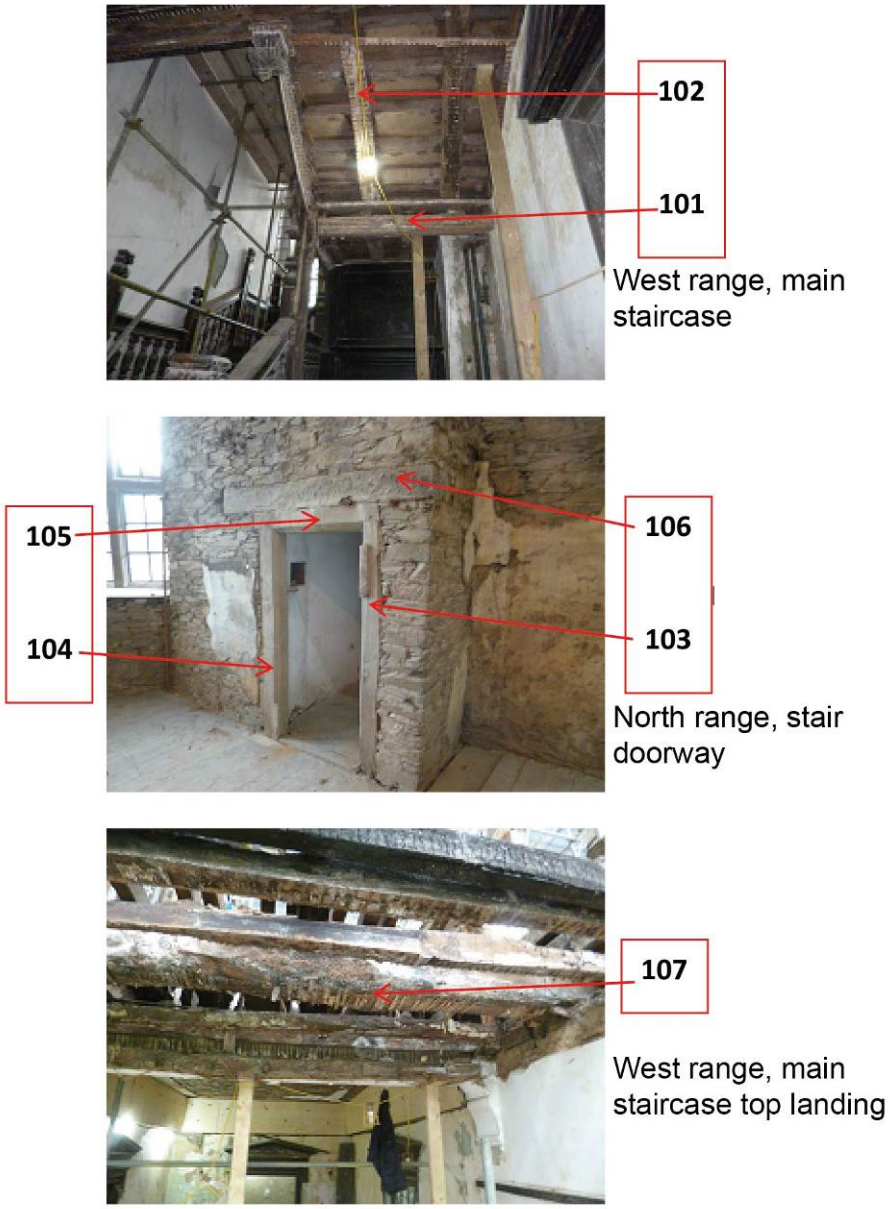


Figure 10k-m: Annotated photographs to help locate the sampled timbers (photographs Robert Howard)

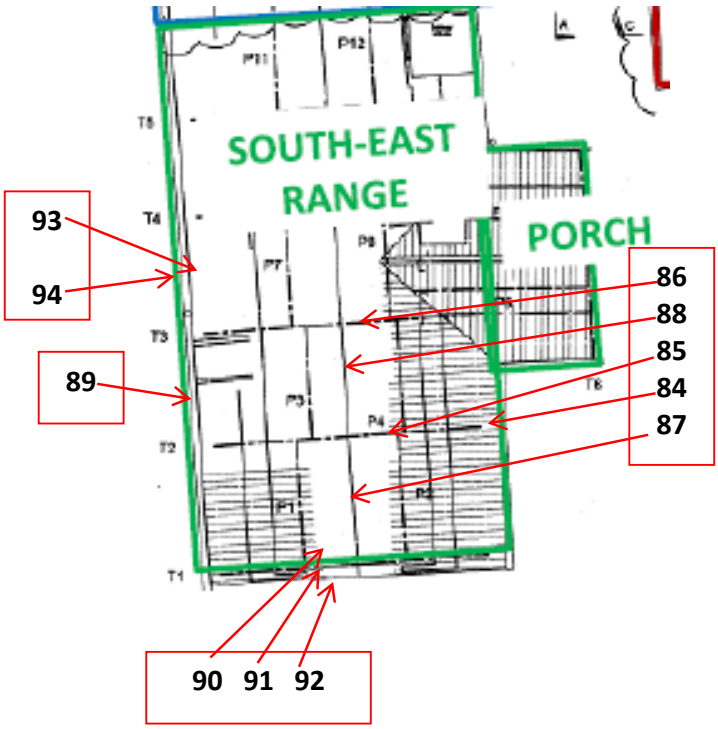


Figure 10n: Annotated plan to help locate the sampled timbers

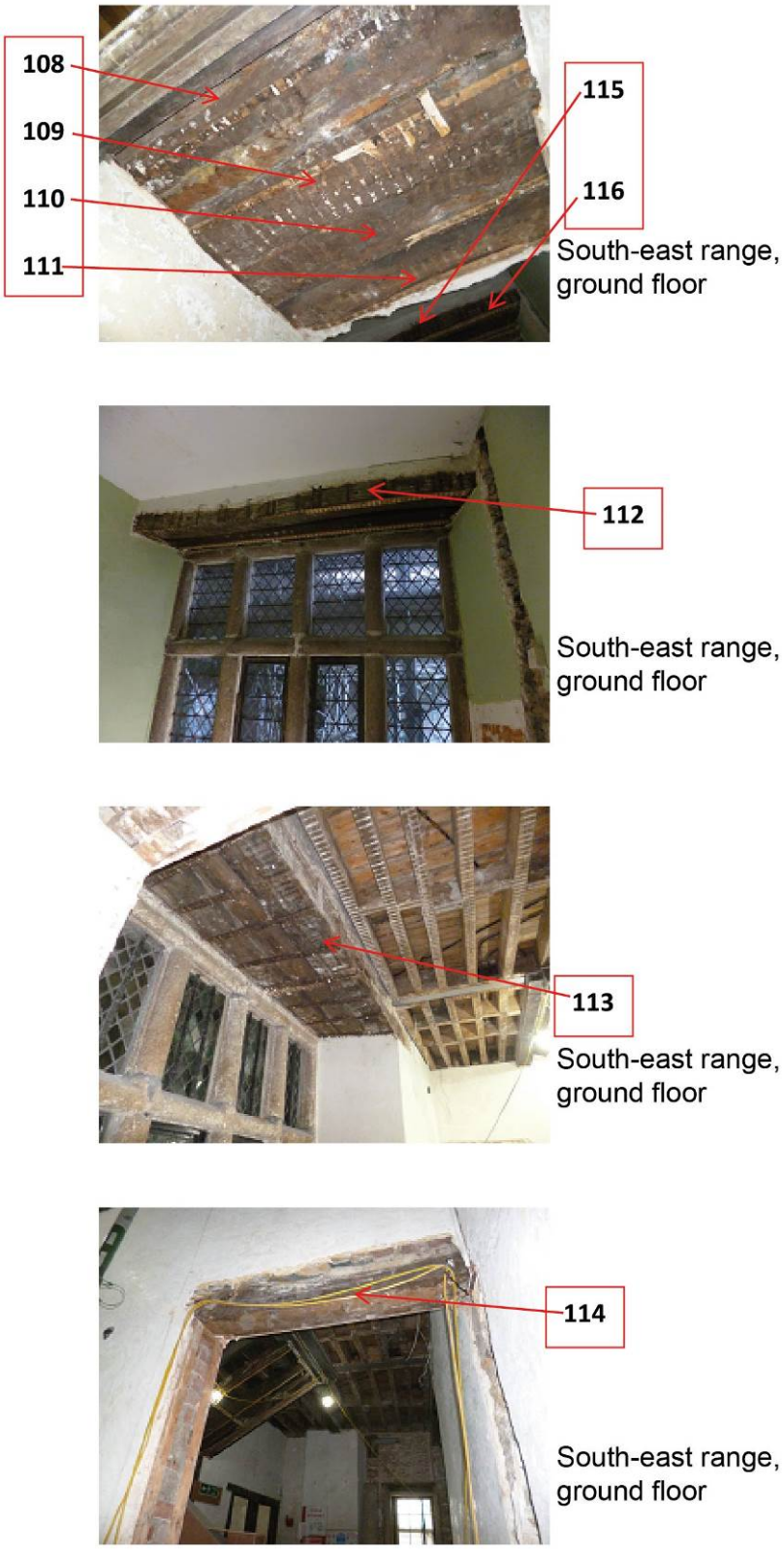


Figure 10o-r: Annotated photographs to help locate the sampled timbers (photographs Robert Howard)

Figure 10s-u: Annotated photographs to help locate the sampled timbers (photographs Robert Howard)

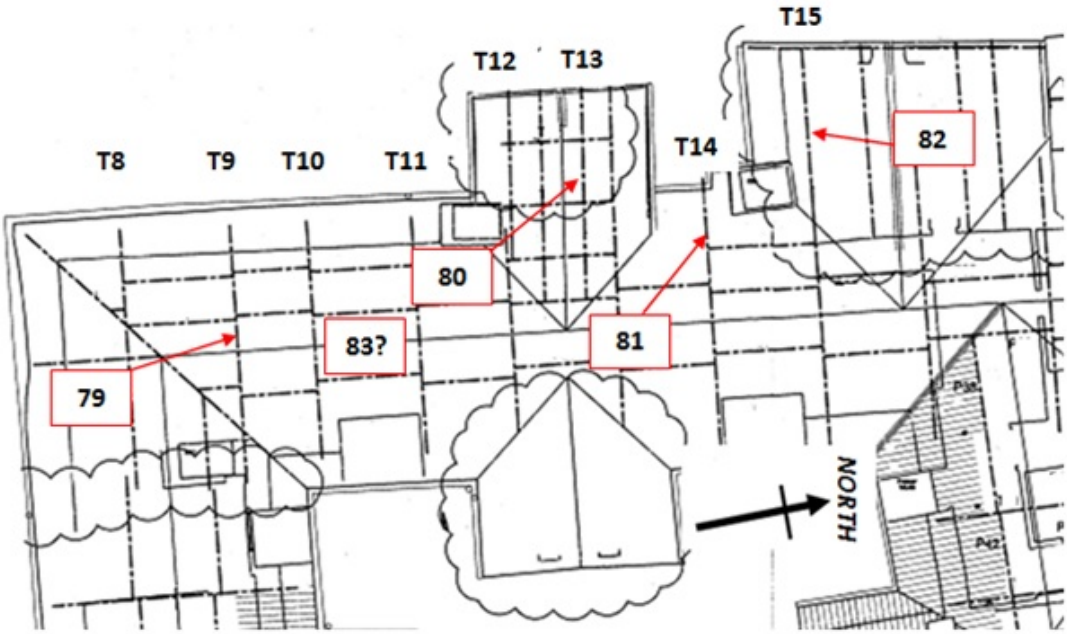


Figure 11: Annotated plan to show locations of sliced samples SYD-H79 – H83 from the ex situ timbers of the West Range roof (after Rodney Melville & Partners)

Figure 12: Illustrative example of a recently felled (fallen) tree from the area to the west of the house with a wedge shaped sample removed for dendrochronological analysis (photograph Robert Howard)

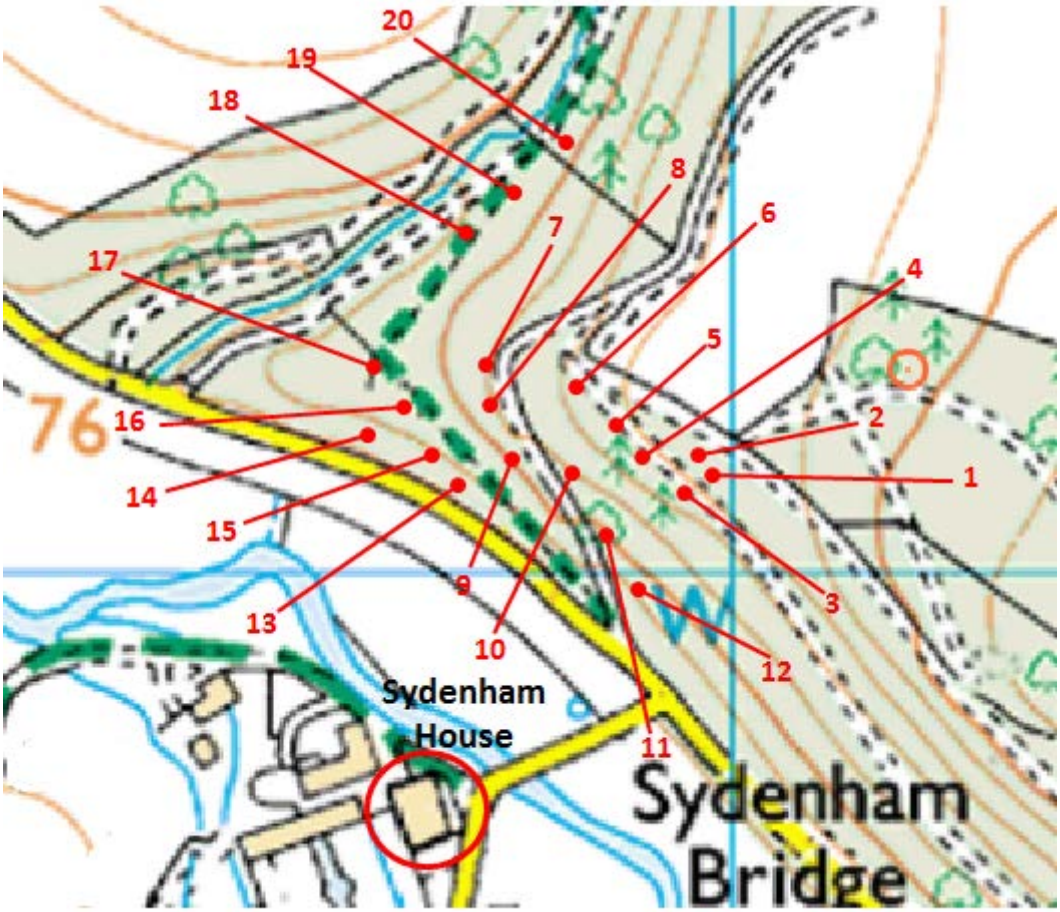


Figure 13: Map to show the approximate location of the 20 core-sampled living trees © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100024900

SYD-M01

SYD-M03

SYD-M02

SYD-M04

Figure 14a-d: Photographs to aid identification of the living trees (photographs Robert Howard)

SYD-M05

SYD-M07

SYD-M06

SYD-M08

Figure 14e-h: Photographs to aid identification of the living trees (photographs Robert Howard)

SYD-M09

SYD-M11

SYD-M10

SYD-M12

Figure 14i-l: Photographs to aid identification of the living trees (photographs Robert Howard)

SYD-M13

SYD-M15

SYD-M14

SYD-M16

Figure 14m-p: Photographs to aid identification of the living trees (photographs Robert Howard)

SYD-M17

SYD-M19

SYD-M18

SYD-M20

Figure 14q-t: Photographs to aid identification of the living trees (photographs Robert Howard)

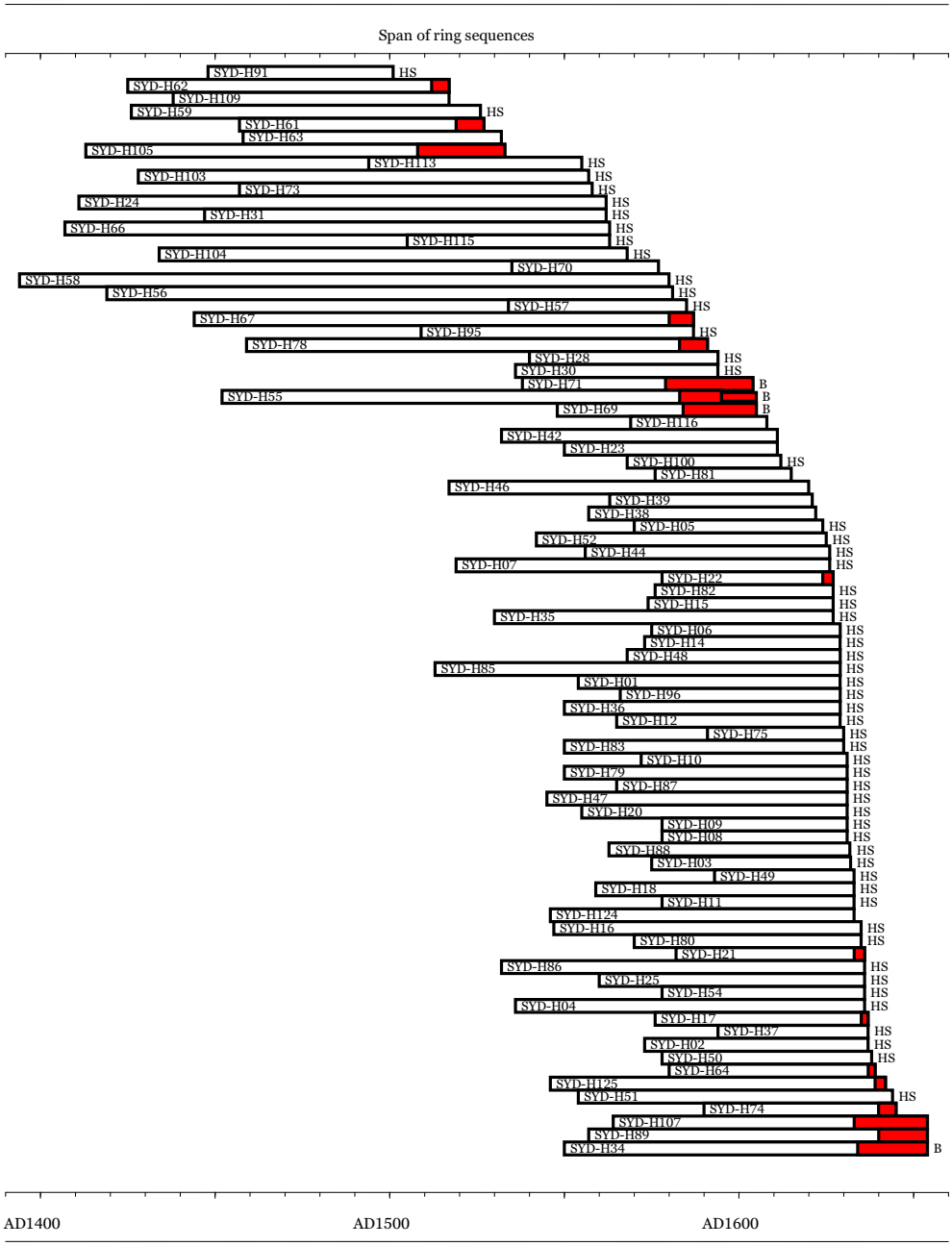


Figure 15: Bar diagram of cross-matched and dated samples in site chronology SYDHSQ01, sorted by end date. White bars = measured heartwood rings; red bars = measured sapwood rings; narrow red bars = unmeasured sapwood rings; HS = heartwood/sapwood boundary, B = bark edge, complete sapwood is retained on the sample, the last measured ring date is the felling of the tree represented

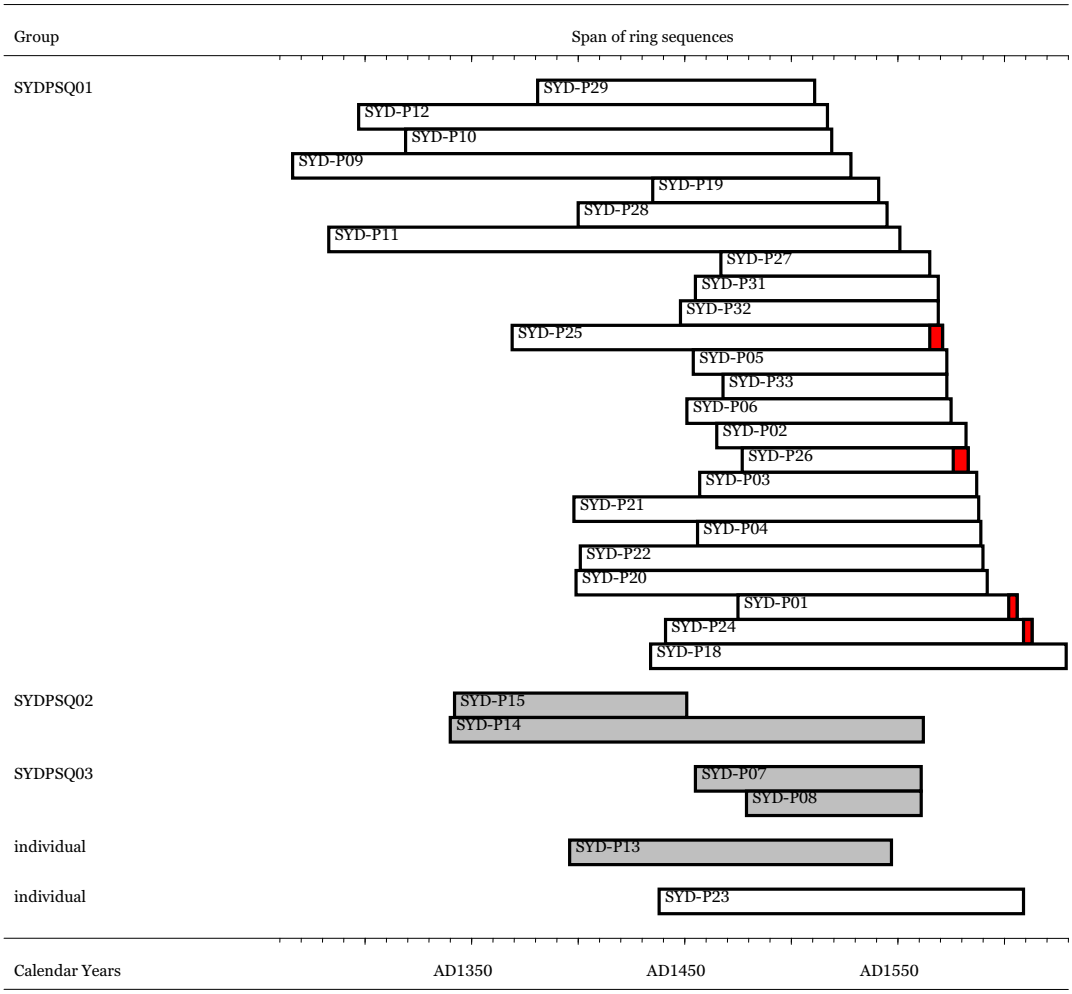


Figure 16: Bar diagram of cross-matched and dated samples in site chronologies SYDPSQ01, SYDPSQ02, and SYDPSQ03 sorted by end date and the two series dated individually. White bars = measured heartwood rings (native oak); grey bars = measured heartwood rings (imported oak); red bars = measured sapwood rings

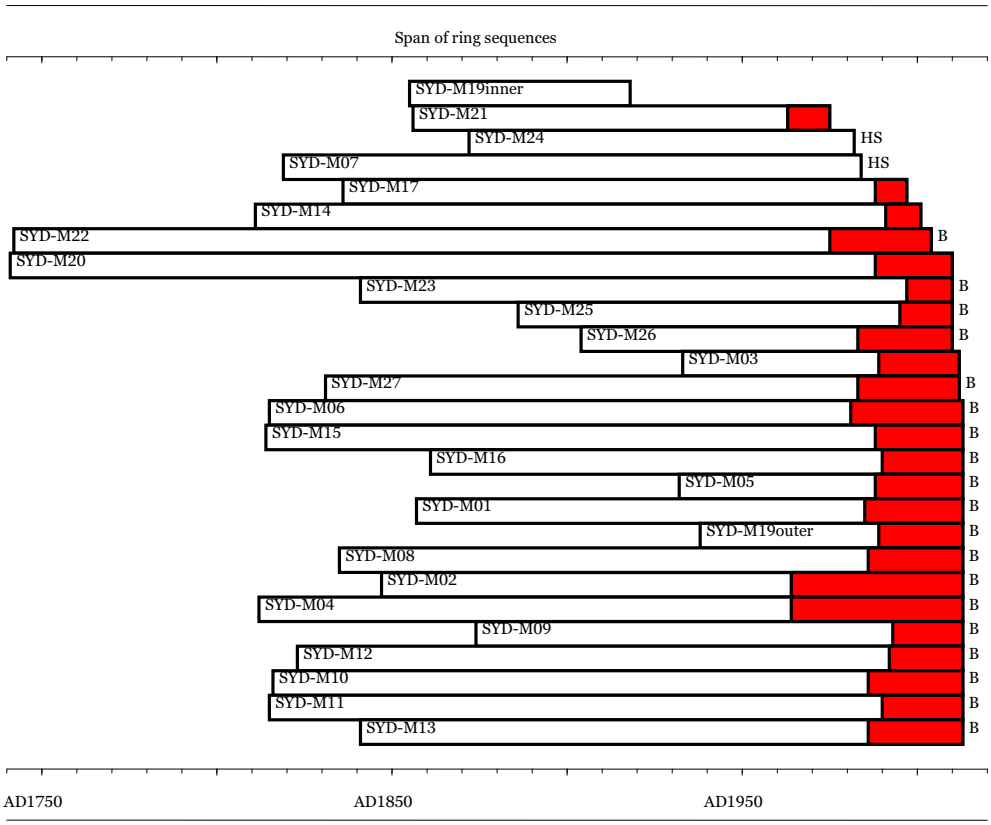


Figure 17: Bar diagram of cross-matched and dated samples in site chronology SYDMSQ01, sorted by end date. White bars = measured heartwood rings; red bars = measured sapwood rings; HS = heartwood/sapwood boundary, B = bark edge, complete sapwood is retained on the sample, the last measured ring date is the felling (death) or coring year of the tree represented

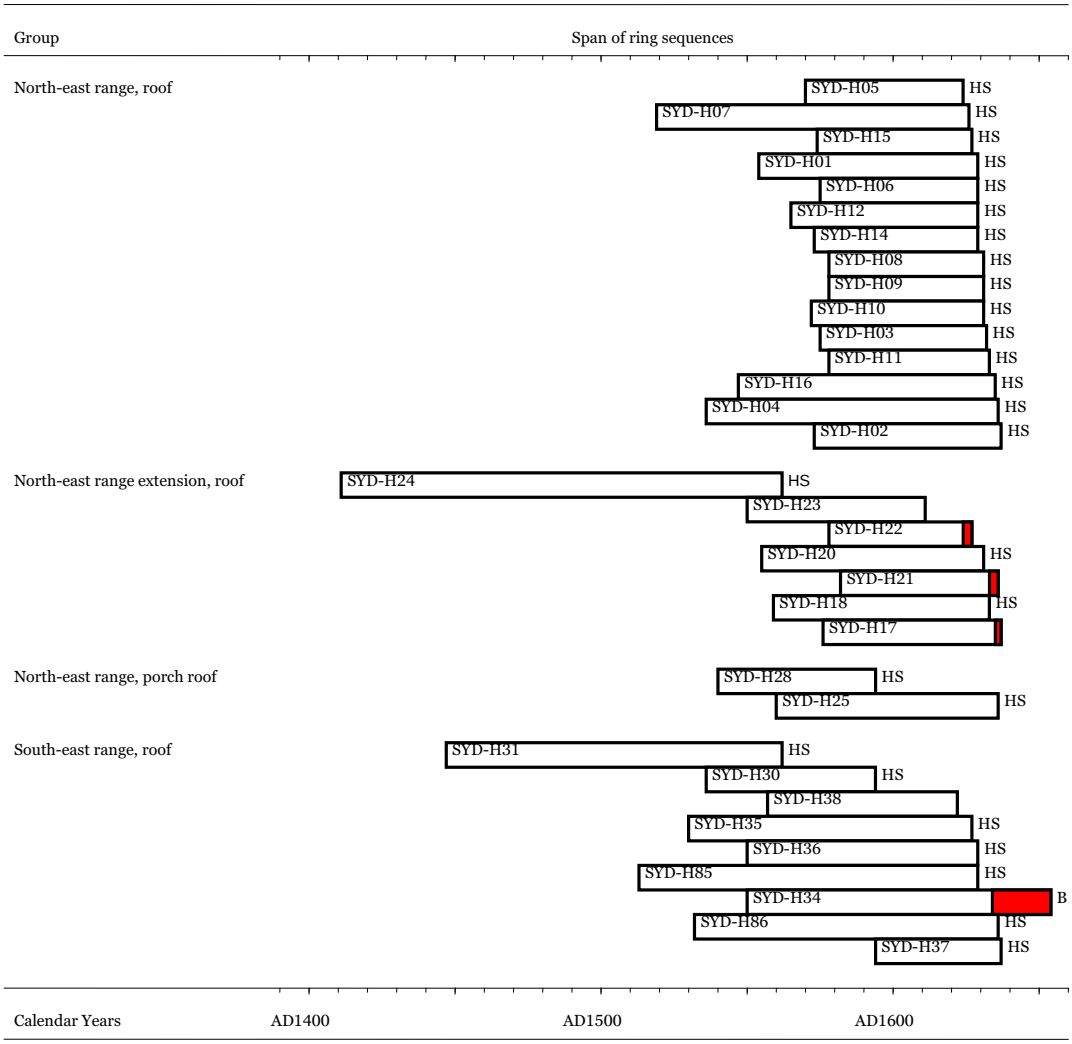


Figure 18a: Bar diagram of cross-matched and dated samples sorted by area and heartwood/sapwood boundary date. White bars = measured heartwood rings; red bars = measured sapwood rings; HS = heartwood/sapwood boundary, B = bark edge, complete sapwood is retained on the sample, the last measured ring date is the felling of the tree represented

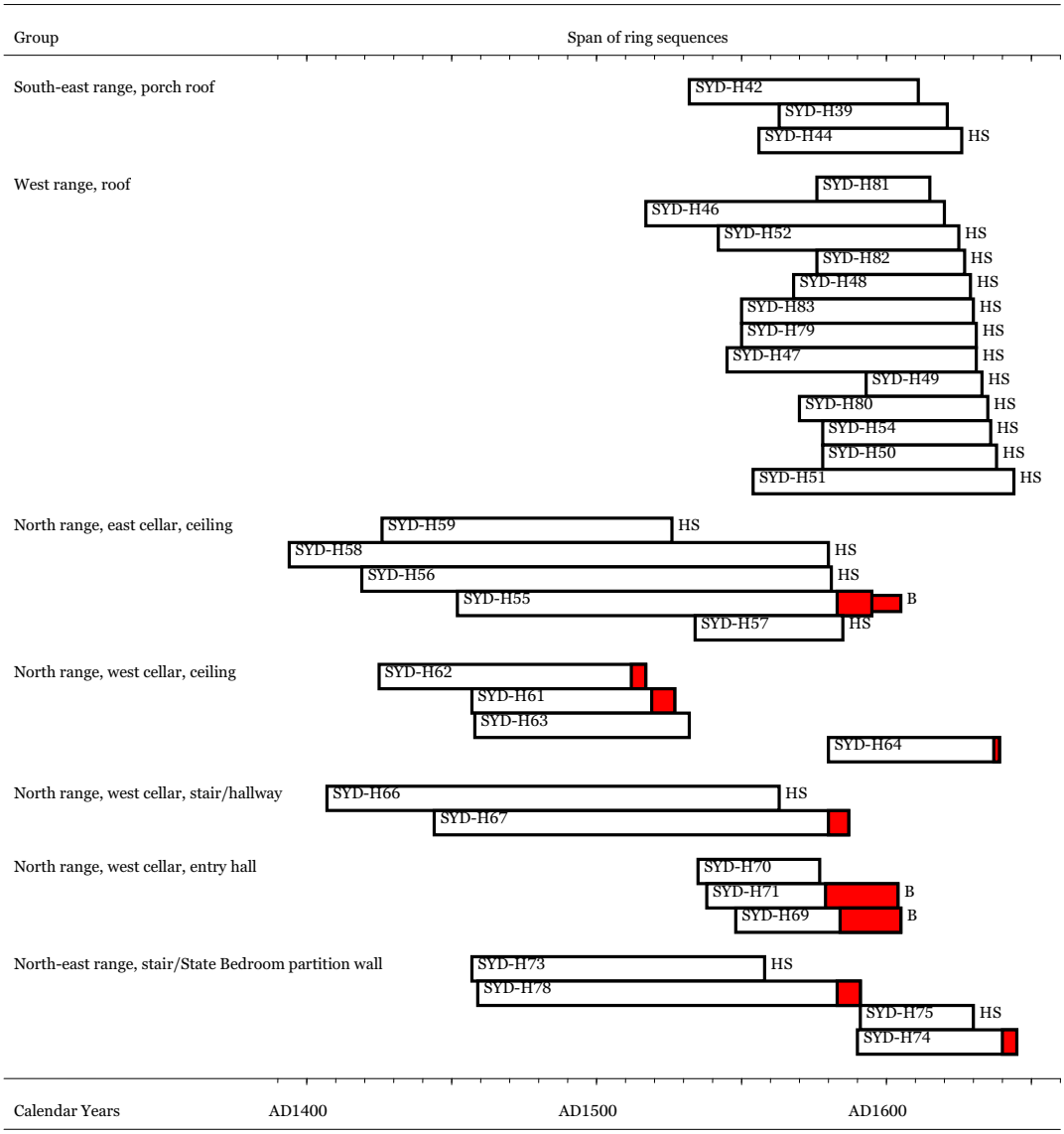


Figure 18b: Bar diagram of cross-matched and dated samples sorted by area and heartwood/sapwood boundary date. White bars = measured heartwood rings; red bars = measured sapwood rings; narrow red bars = unmeasured sapwood rings; HS = heartwood/sapwood boundary, B = bark edge, complete sapwood is retained on the sample, the last measured ring date is the felling of the tree represented

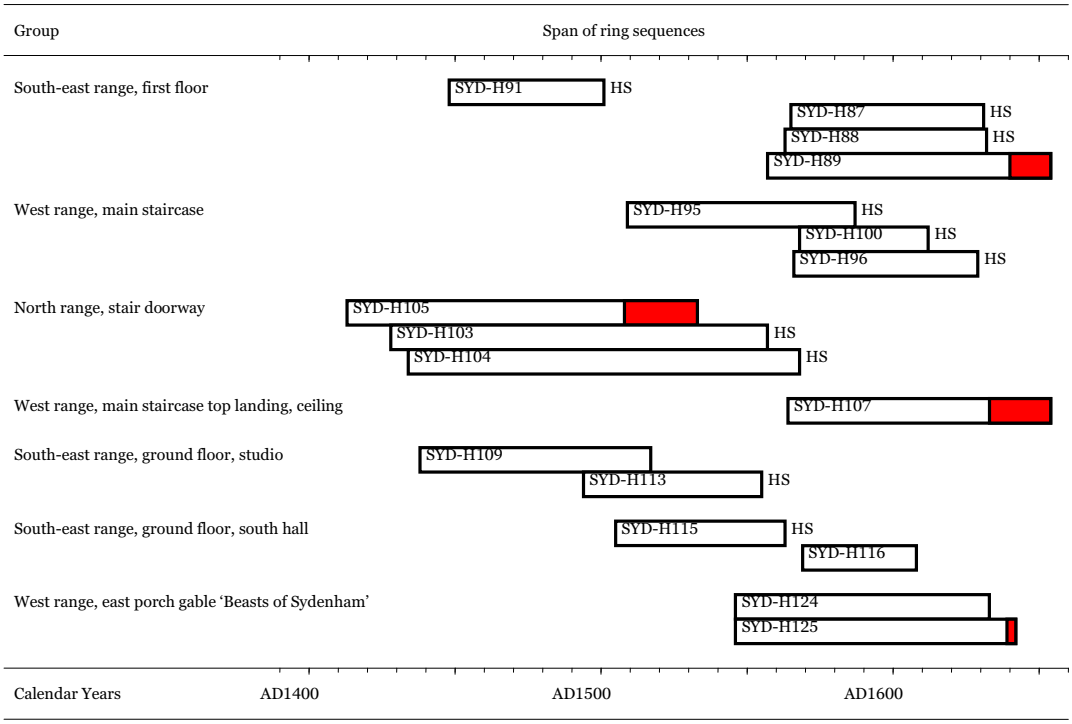


Figure 18c: Bar diagram of cross-matched and dated samples sorted by area and heartwood/sapwood boundary date. White bars = measured heartwood rings; red bars = measured sapwood rings; HS = heartwood/sapwood boundary

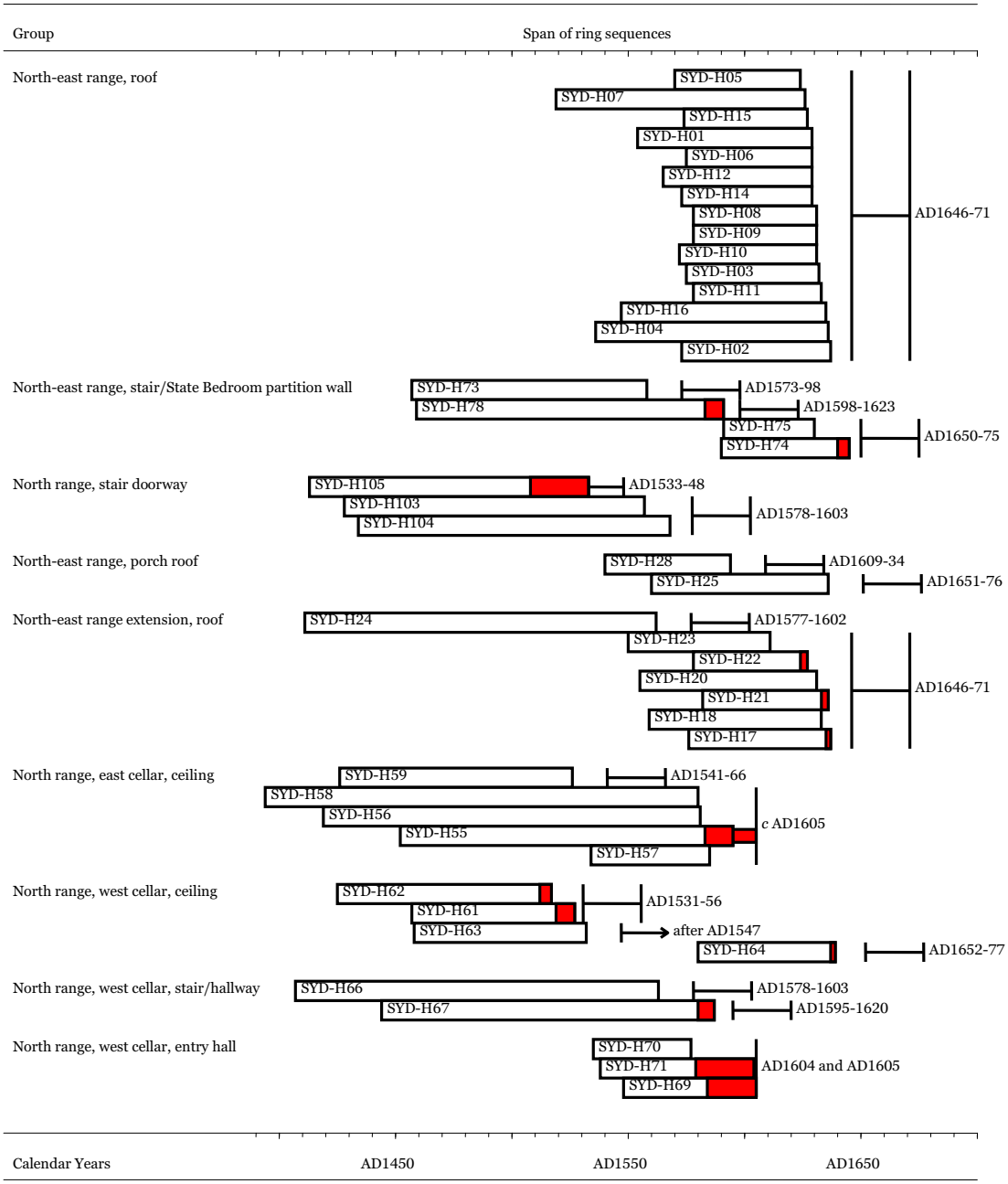


Figure 19a: Bar diagram of cross-matched and dated samples sorted by range and area with area felling dates. White bars = measured heartwood rings; red bars = measured sapwood rings; narrow red bars = unmeasured sapwood rings; HS = heartwood/sapwood boundary, B = bark edge, complete sapwood is retained on the sample, the last measured ring date is the felling of the tree represented

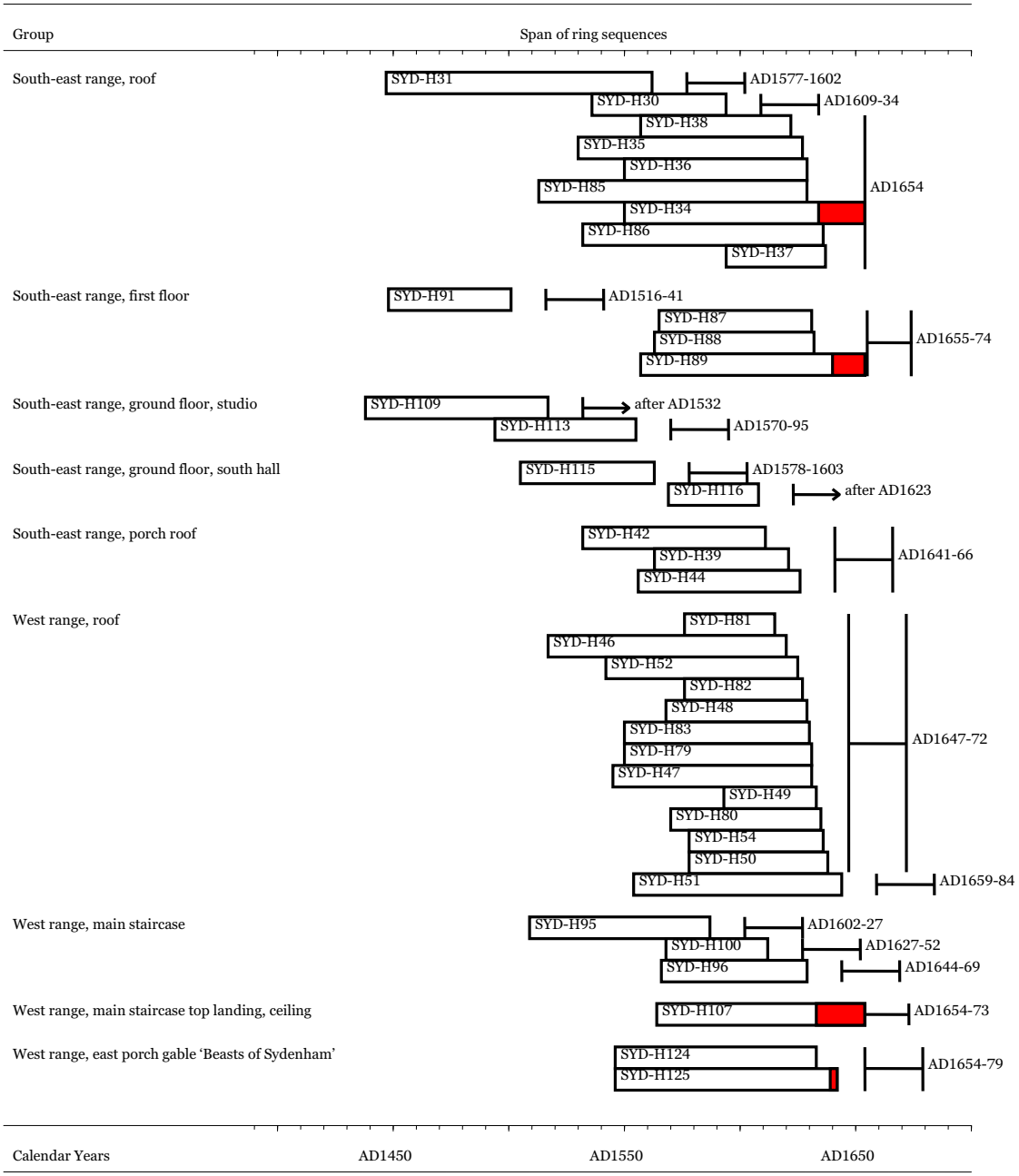


Figure 19b: Bar diagram of cross-matched and dated samples sorted by range and area with area felling dates. White bars = measured heartwood rings; red bars = measured sapwood rings; narrow red bars = unmeasured sapwood rings; HS = heartwood/sapwood boundary, B = bark edge, complete sapwood is retained on the sample, the last measured ring date is the felling of the tree represented

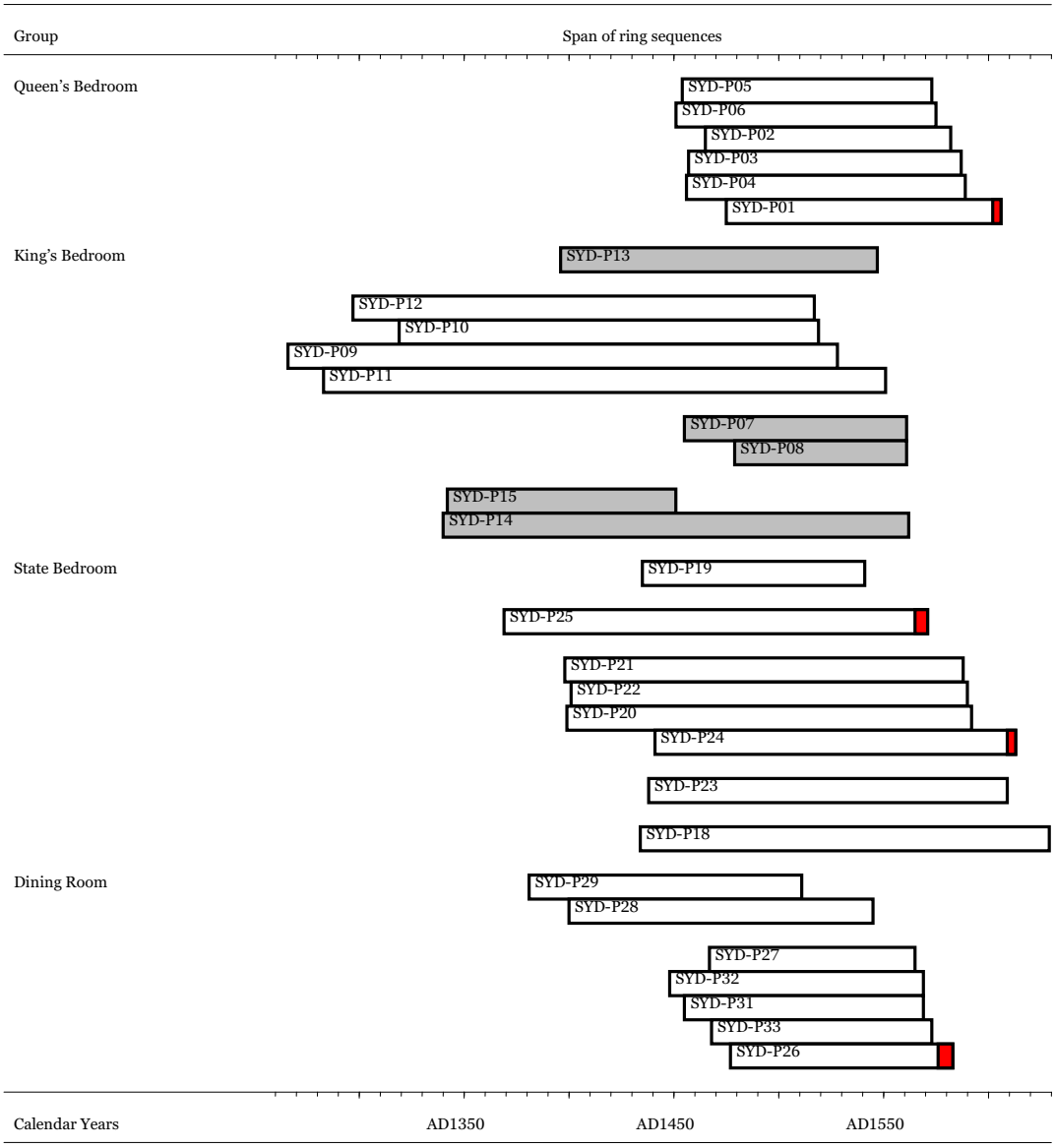


Figure 20: Bar diagram of cross-matched and dated panels sorted by room and heartwood/sapwood boundary date. White bars = measured heartwood rings (native oak); grey bars = measured heartwood rings (imported oak); red bars = measured sapwood rings

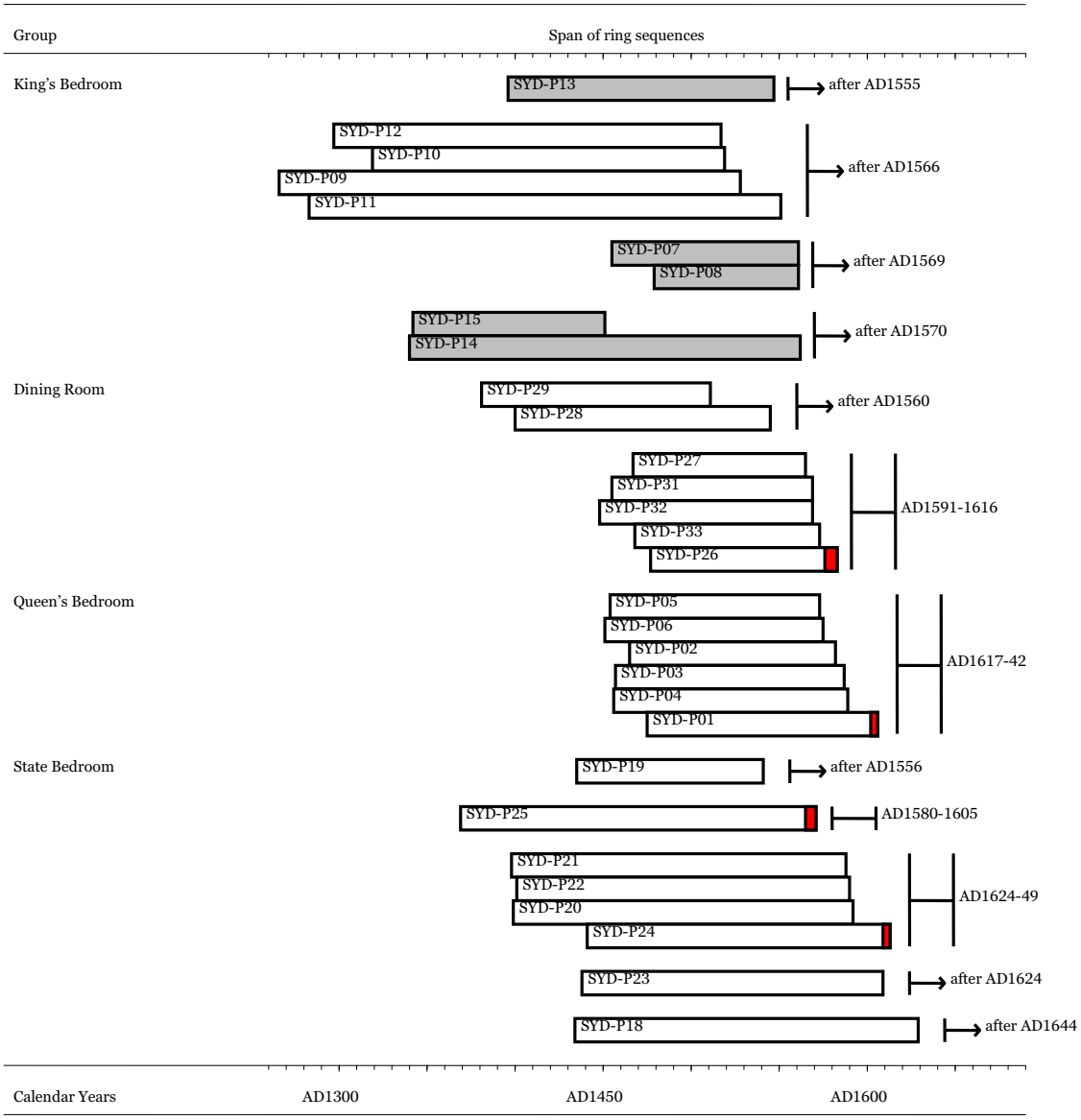


Figure 21: Bar diagram of cross-matched and dated panels sorted by room in overall date order with room felling dates. White bars = measured heartwood rings (native oak); grey bars = measured heartwood rings (imported oak); red bars = measured sapwood

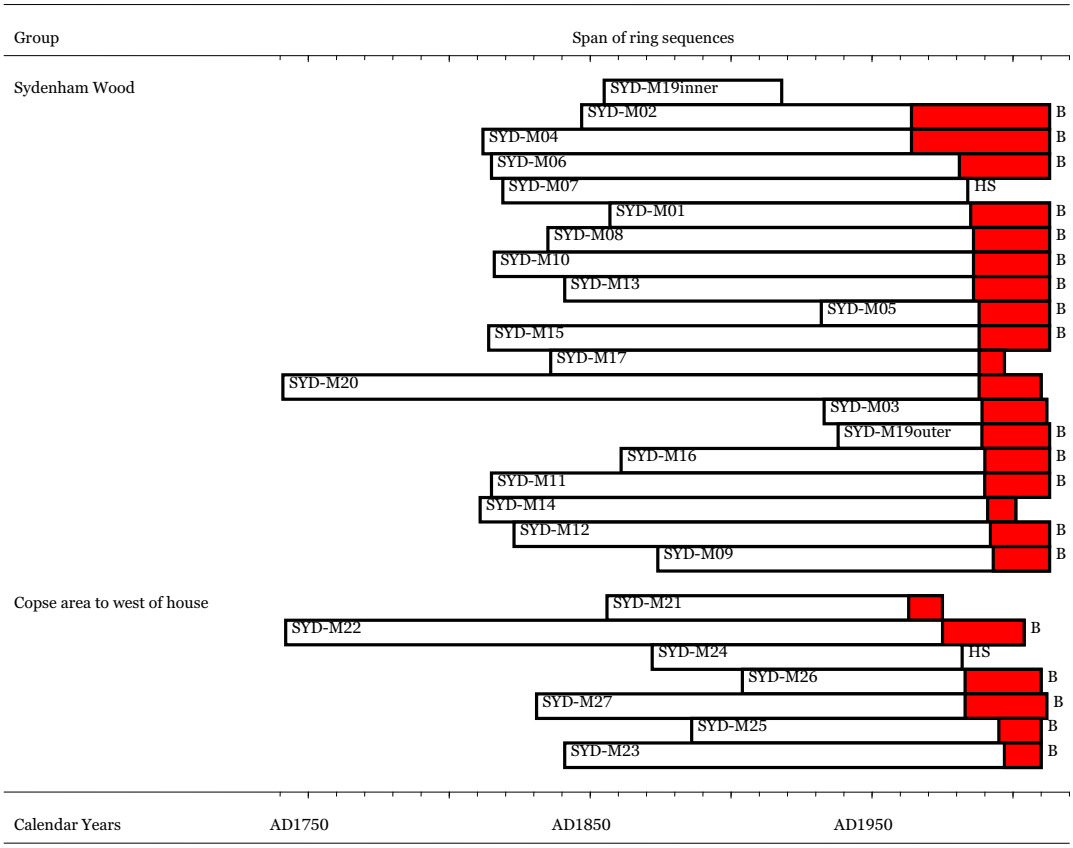


Figure 22: Bar diagram of cross-matched and dated samples sorted by area and heartwood/sapwood boundary date. White bars = measured heartwood rings; red bars = measured sapwood rings; HS = heartwood/sapwood boundary, B = bark edge, complete sapwood is retained on the sample, the last measured ring date is the felling (death) or coring year of the tree represented

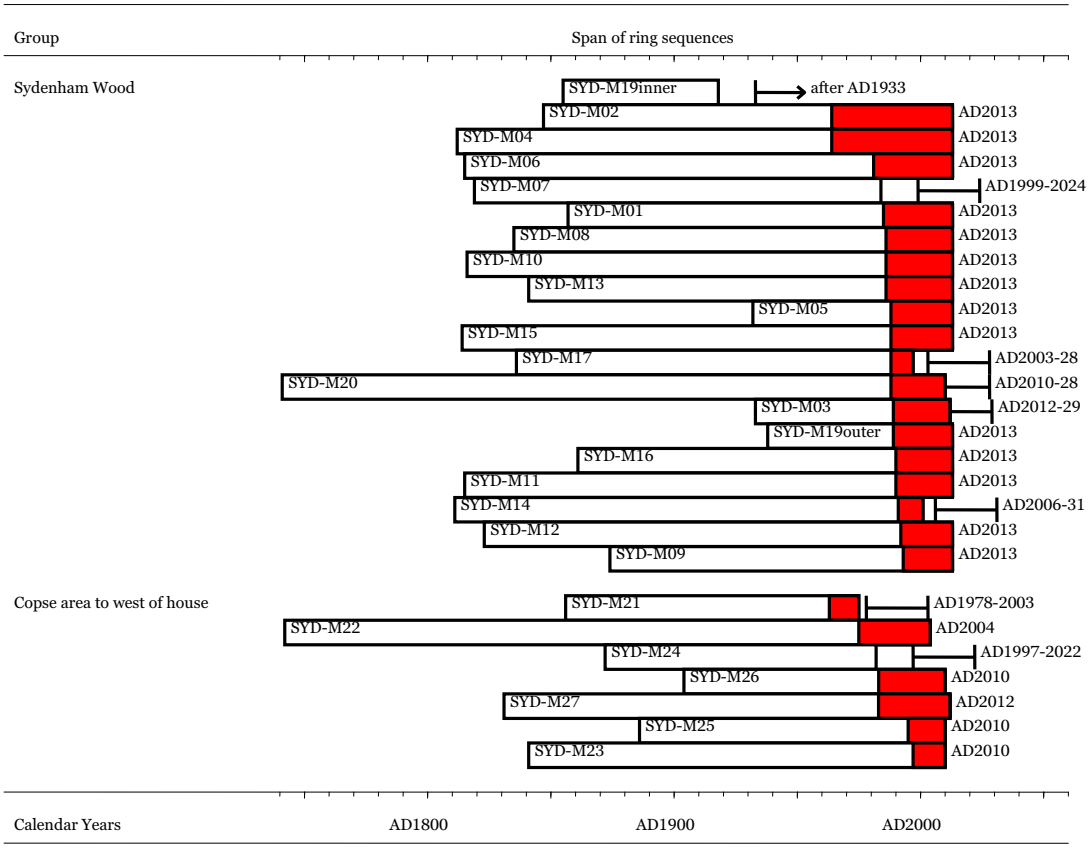


Figure 23: Bar diagram of cross-matched and dated samples sorted by area with individual felling (death) or coring year dates or date ranges calculated using the 15-40 (95% confidence interval) sapwood ring estimate usually applied to historic timber. White bars = measured heartwood rings; red bars = measured sapwood rings

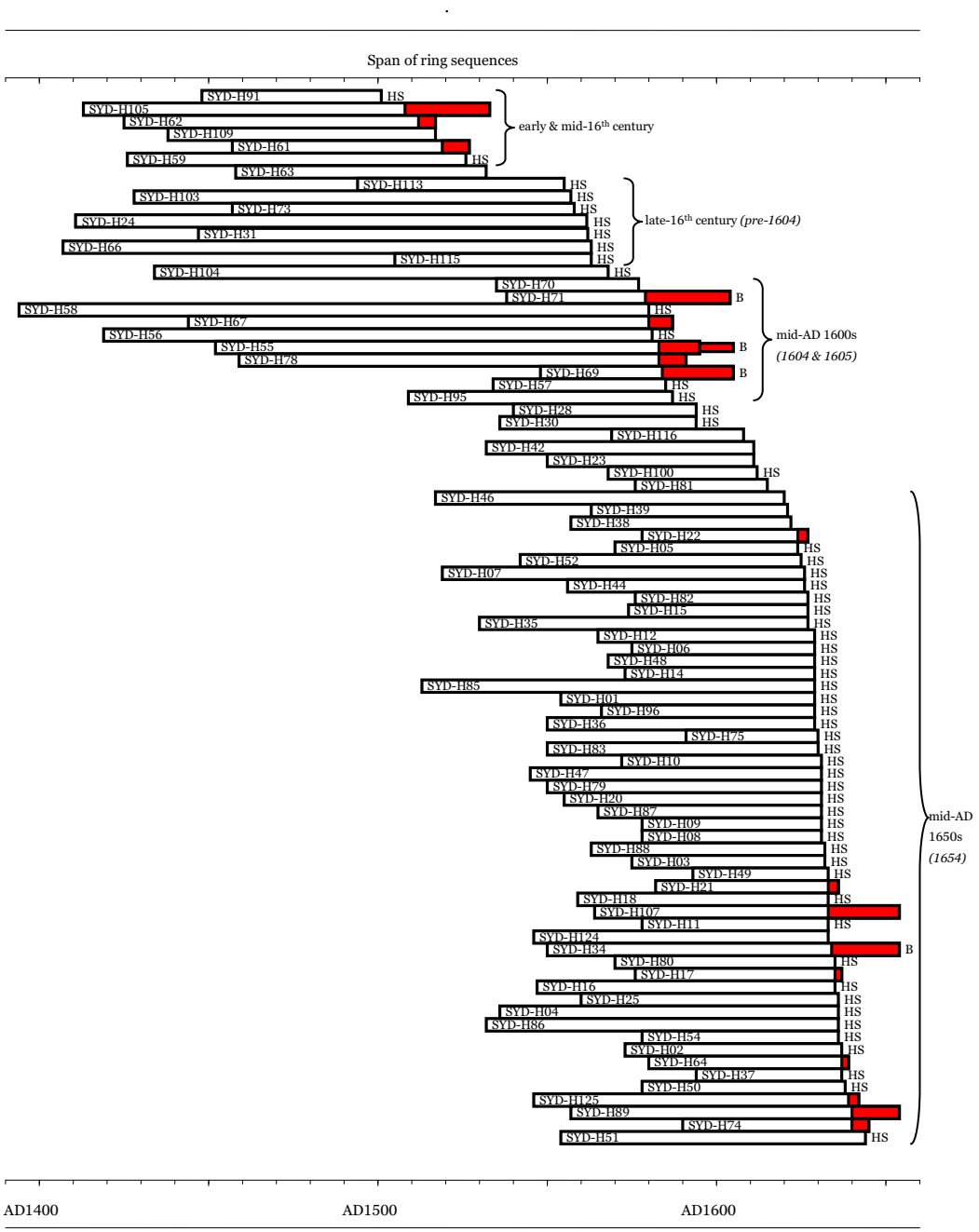


Figure 24: Bar diagram of cross-matched and dated samples in site chronology SYDHSQ01, sorted by heartwood/sapwood boundary, with felling periods summarised. White bars = measured heartwood rings; red bars = measured sapwood rings; narrow red bars = unmeasured sapwood rings; HS = heartwood/sapwood boundary, B = bark edge, complete sapwood is retained on the sample, the last measured ring date is the felling of the tree represented

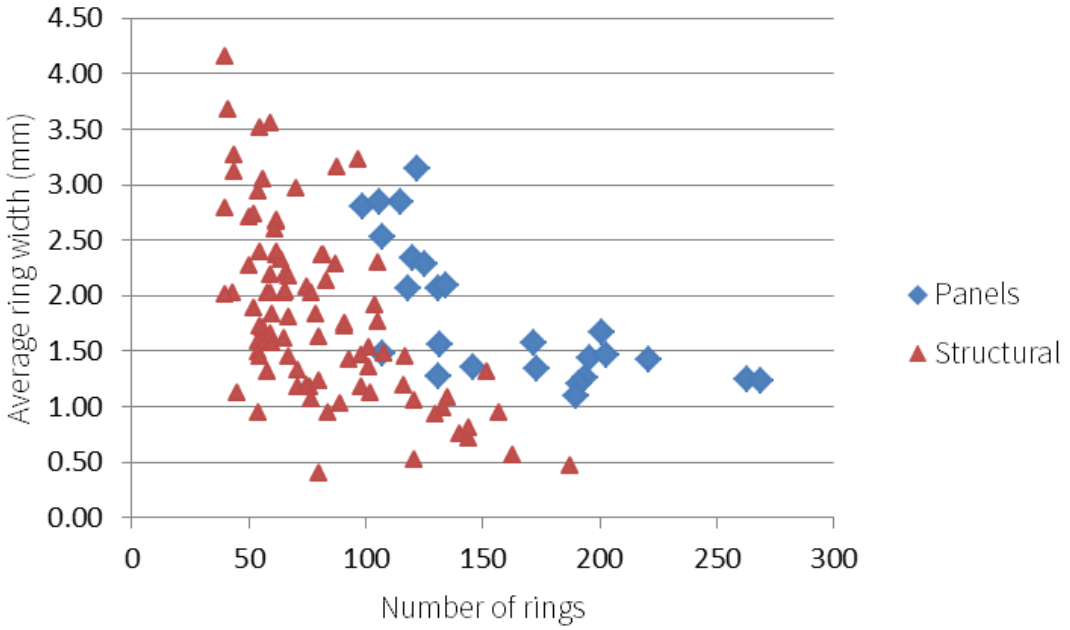


Figure 25: Diagram to comparing measured ring sequence length and average ring width for the dated building timbers and the dated native oak panels

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

SYD-H01A 76
270 305 188 196 149 122 245 148 202 164 135 128 137 128 132 110 171 157 116 132
158 144 117 78 69 110 89 102 93 96 96 89 87 88 103 146 96 122 144 150
117 144 146 107 128 172 123 131 100 147 171 103 110 141 107 87 103 81 67 69
92 75 51 42 92 57 81 48 76 59 60 62 82 68 89 103
SYD-H01B 76
300 301 194 193 136 117 272 143 209 155 136 123 141 134 121 111 153 153 117 139
156 133 131 92 64 105 98 78 78 91 101 84 84 92 103 146 97 130 157 143
127 146 150 99 110 162 121 143 92 140 167 96 117 110 121 89 103 75 74 75
89 77 57 45 82 68 59 65 70 57 51 67 82 75 80 99
SYD-H02A 65
316 293 260 201 129 196 235 235 162 157 254 282 173 203 194 175 232 157 203 203
222 176 221 211 164 176 225 290 210 157 215 284 162 200 212 206 131 262 270 254
250 201 258 145 70 165 126 218 87 140 179 252 145 201 206 226 298 217 209 290
168 112 184 142 229
SYD-H02B 65
294 281 260 200 145 192 231 241 147 153 239 282 185 198 192 190 215 164 190 202
212 171 225 210 164 185 231 280 214 154 234 278 165 207 217 212 121 262 253 252
251 192 243 137 104 148 148 221 103 117 195 253 143 197 203 228 307 217 215 270
165 131 183 143 223
SYD-H03A 58
417 246 278 266 352 328 264 266 233 379 326 250 225 245 346 226 360 229 205 236
232 278 199 132 195 195 171 139 196 268 114 146 167 145 104 192 341 154 123 104
173 114 88 150 184 254 139 182 100 104 57 157 112 117 204 90 153 176
SYD-H03B 58
373 244 256 276 331 332 303 264 241 370 350 249 232 257 362 207 336 220 207 239
236 275 192 136 196 197 173 137 197 267 112 158 173 140 104 187 356 167 100 96
170 114 71 136 199 250 147 175 84 104 76 150 103 120 206 103 151 176
SYD-H04A 101
844 574 548 419 341 285 267 287 228 249 184 178 134 142 131 185 174 125 139 132
69 108 128 134 137 117 200 147 166 125 82 110 107 129 195 173 185 189 160 174
140 118 100 132 134 107 111 85 137 162 146 136 130 178 101 159 138 106 117 143
168 110 117 137 104 93 125 171 165 100 177 267 179 90 135 148 88 92 110 103
68 61 107 81 111 97 140 118 109 91 125 109 86 93 103 75 80 50 68 72
79
SYD-H04B 101
800 567 529 422 341 287 262 285 219 260 150 153 134 152 117 199 175 121 135 141
73 110 150 132 136 116 198 155 154 145 82 95 107 140 201 173 181 189 168 166
125 121 97 126 154 110 114 89 129 167 152 139 139 175 97 152 130 123 115 142
175 112 132 128 104 84 131 156 167 90 198 265 175 97 133 140 82 112 93 98
65 71 92 75 118 96 140 117 108 103 132 104 82 105 96 100 61 50 61 91
81
SYD-H05A 55
463 581 547 452 650 554 521 343 400 407 640 535 450 371 496 506 357 443 441 597
300 378 388 380 416 459 376 335 254 293 306 285 237 237 325 192 244 293 278 175
301 363 230 176 153 240 160 109 208 280 305 192 218 228 225
SYD-H05B 55
473 596 532 453 648 575 514 334 382 422 585 521 451 367 504 525 348 443 406 645

296 389 393 357 437 468 384 333 276 298 328 273 234 246 324 203 231 299 282 173
300 353 215 180 156 247 162 103 200 277 287 199 231 235 229
SYD-H06A 55
139 171 81 70 109 91 327 402 406 350 436 394 380 337 473 258 393 391 325 335
336 379 347 349 404 343 298 260 308 296 190 210 207 281 166 195 231 156 160 175
228 135 67 92 131 151 138 150 156 159 112 123 104 100 159
SYD-H06B 55
133 161 89 69 108 92 336 406 415 393 419 378 357 355 470 250 382 390 309 325
315 390 356 334 412 340 302 257 304 290 187 214 206 262 171 190 235 175 145 187
237 120 67 87 135 154 134 153 160 150 116 122 121 120 167
SYD-H07A 108
354 238 281 191 246 208 354 303 338 307 299 281 283 117 169 169 229 185 192 185
175 149 134 154 249 82 103 111 92 117 121 138 139 132 121 125 130 117 167 117
148 123 114 131 124 123 121 81 73 101 75 84 157 130 154 140 129 98 101 98
107 106 96 59 98 114 123 101 104 89 156 95 153 182 145 114 179 204 178 162
149 143 137 121 141 178 120 159 135 146 94 121 165 158 100 134 143 117 68 146
82 146 96 121 110 87 96 121
SYD-H07B 108
311 219 267 196 253 202 365 307 337 332 280 301 300 160 178 171 232 192 186 180
167 157 128 150 278 84 105 107 83 124 121 137 139 131 118 129 128 113 164 131
139 128 104 139 127 123 126 82 78 89 75 90 156 132 155 132 125 99 90 110
117 106 110 63 103 115 117 107 109 83 150 98 150 184 135 118 190 192 182 160
151 138 147 116 146 174 109 162 125 155 93 119 175 140 109 131 137 112 80 129
83 143 97 130 119 81 100 125
SYD-H08A 54
73 113 92 109 97 786 517 443 405 446 413 536 288 444 378 364 462 390 482 390
360 481 408 357 257 326 310 171 193 242 293 198 293 485 242 243 248 278 159 115
170 203 235 149 206 336 233 184 178 173 195 281 221 253
SYD-H08B 54
69 115 98 110 98 786 527 422 407 448 387 550 284 448 385 360 455 389 475 390
373 439 410 367 250 330 315 178 193 226 300 187 317 476 248 242 254 276 145 128
171 195 229 170 196 328 246 182 152 205 204 281 222 250
SYD-H09A 54
71 116 94 139 134 156 132 121 133 123 125 172 145 229 229 222 195 205 228 216
226 294 257 252 196 249 305 160 234 222 185 146 180 182 125 133 131 151 103 96
129 140 120 100 89 106 103 84 92 103 140 153 72 114
SYD-H09B 54
76 119 84 134 138 148 146 106 132 128 118 180 142 228 226 219 203 212 219 260
246 314 249 244 189 256 306 160 241 216 199 140 171 167 129 138 126 145 102 88
135 137 117 98 96 104 95 91 90 109 134 156 79 119
SYD-H10A 60
100 120 136 159 117 79 76 94 115 98 92 98 146 157 170 142 207 318 226 326
300 275 257 229 270 211 203 263 271 267 179 291 405 225 267 298 206 171 229 191
142 212 167 210 138 106 173 135 153 93 129 156 130 138 139 135 171 181 188 144
SYD-H10B 60
118 122 144 152 131 78 72 100 127 86 105 125 155 148 160 173 192 307 220 355
284 272 258 228 274 214 206 253 270 268 182 282 396 221 265 273 210 178 209 198
135 215 176 203 137 92 171 152 150 101 132 162 131 123 142 128 174 186 160 146
SYD-H11A 56
101 134 146 122 119 144 139 99 115 85 98 154 103 179 192 200 166 237 237 226
238 275 235 186 172 260 312 164 223 240 222 181 217 198 149 152 171 178 142 121
196 159 165 107 153 195 131 118 175 154 190 220 170 140 140 149
SYD-H11B 56

112 129 144 123 126 141 132 101 102 96 94 142 107 171 211 206 161 210 231 217
239 281 220 210 159 270 312 157 235 239 207 185 206 187 150 145 171 188 142 119
206 152 170 106 167 198 129 148 155 167 187 200 184 125 153 141
SYD-H12A 65
274 216 188 158 150 172 192 150 151 157 124 129 83 64 85 92 82 73 101 155
178 210 160 133 232 154 233 226 205 178 208 259 258 285 276 198 206 107 198 248
142 198 198 148 123 175 166 114 151 164 145 120 100 132 114 151 104 157 132 96
109 150 131 186 214
SYD-H12B 65
274 224 177 155 161 156 200 165 148 159 122 134 85 64 92 100 70 75 102 147
191 206 166 127 228 142 218 207 207 174 239 257 261 279 275 207 189 106 199 260
154 192 196 162 106 164 149 128 148 159 156 129 83 135 134 144 106 154 129 100
100 150 138 189 193
SYD-H14A 57
135 158 134 127 79 61 112 92 102 200 216 262 284 337 265 230 376 203 274 212
209 212 271 278 275 228 187 176 130 150 166 151 71 135 132 135 131 128 163 103
76 135 182 74 75 91 109 98 89 130 124 109 89 126 76 89 95
SYD-H14B 57
137 160 129 130 89 62 115 94 81 206 211 252 286 337 273 220 373 203 282 212
217 212 276 294 273 214 185 171 163 153 153 153 71 117 139 144 131 139 157 109
77 130 190 60 87 101 101 96 92 132 109 117 68 130 82 84 97
SYD-H15A 54
239 197 131 130 132 163 154 150 126 222 259 200 187 171 166 296 146 246 242 235
214 292 282 252 167 148 154 146 160 163 153 73 124 139 132 103 107 162 87 64
107 157 50 56 72 112 70 56 93 94 68 64 67 98
SYD-H15B 54
225 183 137 120 139 160 159 146 138 223 226 186 174 184 167 299 150 269 218 233
208 313 251 233 169 157 151 143 156 171 150 80 132 137 124 116 120 158 81 67
98 149 62 53 82 84 70 70 85 103 84 65 69 100
SYD-H16A 89
281 169 150 126 201 143 134 159 182 117 144 158 151 132 109 191 98 176 144 160
119 106 107 147 138 118 163 117 100 91 70 68 72 77 81 71 69 78 110 94
96 70 118 92 110 127 100 128 120 101 83 99 123 78 78 90 141 136 54 106
134 103 59 81 90 56 36 51 82 50 36 92 62 82 59 95 82 76 42 88
67 64 50 35 58 57 57 53 81
SYD-H16B 89
295 171 150 137 189 144 140 159 180 132 143 144 158 134 108 189 107 175 149 152
120 103 110 139 135 120 164 128 101 85 67 66 80 75 73 78 60 89 108 92
109 76 119 82 111 120 114 121 121 108 75 91 120 82 81 107 125 127 64 124
126 117 58 79 82 54 42 49 87 46 31 89 60 74 73 87 84 70 42 85
62 57 50 44 51 53 46 39 80
SYD-H17A 62
397 186 212 294 183 99 108 181 255 272 181 130 246 346 377 459 372 360 421 371
395 311 301 236 317 249 189 173 667 475 342 339 231 182 171 93 97 117 124 247
160 87 165 121 165 109 169 179 214 207 207 192 196 265 176 185 171 138 164 219
269 301
SYD-H17B 62
375 188 207 294 174 101 101 176 273 268 181 128 241 369 390 460 385 359 408 384
395 303 296 247 315 245 186 176 659 499 339 331 219 177 167 82 93 117 126 243
143 93 197 183 221 112 129 114 113 101 139 128 206 253 237 245 268 126 156 225
265 190
SYD-H18A 75
490 309 284 268 201 239 259 231 370 280 83 167 145 100 139 192 226 214 139 149

185 164 82 54 53 144 209 165 110 160 291 281 434 391 362 251 222 343 270 268
215 275 209 217 203 276 198 218 212 218 161 149 106 96 152 175 251 168 109 237
144 230 141 213 228 209 197 243 190 193 296 196 156 118 121
SYD-H18B 75
455 298 285 268 205 229 278 227 400 269 96 224 135 104 107 167 218 200 123 147
195 163 80 53 71 144 210 150 97 169 280 290 432 371 373 254 228 357 265 267
215 268 220 210 207 267 210 215 210 214 163 151 106 92 153 187 237 167 104 227
146 218 150 213 214 199 193 242 209 196 302 188 146 128 120
SYD-H20A 77
527 431 548 606 441 421 325 260 249 242 208 221 325 371 100 142 171 121 171 287
291 270 185 173 251 206 98 78 68 168 171 140 106 167 299 295 373 293 307 262
264 259 167 121 179 174 200 135 168 137 118 144 142 169 93 129 68 103 111 88
118 78 65 162 99 168 88 146 140 182 196 106 145 134 165 117 191
SYD-H20B 77
567 425 547 605 469 371 332 264 249 246 217 218 332 368 99 141 165 123 174 285
295 263 189 171 256 206 101 73 78 170 153 128 104 160 307 300 393 301 327 253
275 257 164 126 182 187 184 143 151 150 104 149 158 178 85 140 67 113 102 85
117 75 74 157 101 160 90 150 130 187 187 113 144 132 150 115 196
SYD-H21A 55
190 291 200 228 195 181 230 311 171 179 160 98 150 171 181 148 194 233 226 308
201 201 204 178 180 150 183 106 94 53 71 64 79 106 61 57 101 67 105 77
88 100 104 98 97 92 123 176 124 135 89 66 55 94 144
SYD-H21B 55
199 289 199 221 198 178 226 312 171 182 170 121 154 178 194 151 190 242 230 304
192 200 207 175 184 143 181 107 89 65 65 64 78 114 70 51 98 70 97 77
88 98 106 104 90 100 123 183 103 156 80 61 56 89 146
SYD-H22A 50
318 434 409 360 347 378 469 331 341 374 335 538 343 308 434 346 228 253 254 224
226 278 290 301 283 317 337 236 427 271 223 143 167 215 251 182 237 260 201 128
178 150 209 133 168 182 131 153 105 115
SYD-H22B 50
291 434 400 374 342 370 468 335 330 413 318 524 350 326 457 400 292 264 265 196
231 271 293 316 287 335 345 236 416 229 204 148 168 206 246 196 214 264 178 121
170 171 211 127 160 166 153 150 114 112
SYD-H23A 62
298 409 322 289 462 489 324 411 457 423 393 328 339 279 312 278 307 281 259 353
376 332 297 223 334 303 260 265 225 256 328 284 189 289 198 221 190 173 227 314
166 182 205 176 192 208 218 240 198 253 200 189 192 199 198 172 168 184 171 172
246 128
SYD-H23B 62
292 415 323 279 477 493 320 407 469 411 422 339 338 277 303 278 288 285 256 362
365 342 312 234 325 298 248 280 245 251 346 273 203 279 195 201 198 168 228 332
171 182 215 159 203 200 237 226 201 243 211 184 182 198 195 178 171 178 156 189
235 130
SYD-H24A 152
157 284 268 226 229 185 145 158 150 175 114 190 188 184 209 137 119 132 150 170
182 159 167 137 186 171 126 56 99 139 167 129 164 182 173 114 76 132 110 59
104 126 78 120 100 101 80 89 82 70 104 139 70 76 71 56 78 82 58 75
67 35 54 70 150 135 119 103 154 120 123 114 114 118 134 96 114 106 48 67
51 57 53 75 92 125 115 92 93 77 76 40 65 93 100 76 47 77 94 89
103 106 70 96 43 54 57 53 46 58 83 115 103 132 148 159 259 343 227 222
245 183 187 221 234 160 218 203 253 288 228 233 203 133 156 121 154 165 179 178
186 132 112 95 91 101 117 156 234 210 220 188

SYD-H24B 152
161 321 250 237 222 177 155 162 157 174 118 170 184 178 196 139 121 142 130 175
174 158 163 146 173 185 124 56 97 137 161 131 167 182 164 107 84 112 101 64
103 120 82 120 109 104 88 95 89 75 103 131 73 75 60 65 76 88 61 77
65 39 58 77 154 139 120 95 154 125 137 112 116 118 134 102 110 103 50 67
45 57 50 87 90 129 121 83 92 73 65 50 68 92 98 77 42 82 93 96
109 103 76 93 45 59 50 56 45 60 77 112 96 131 152 154 262 348 210 235
229 193 196 207 230 162 212 209 247 281 237 231 205 128 153 117 158 158 181 180
182 137 121 108 78 102 115 147 239 213 236 198
SYD-H25A 77
145 101 163 123 150 133 114 118 121 121 172 147 134 176 173 139 123 96 77 106
98 76 83 75 108 128 85 108 110 139 71 125 114 100 146 182 167 117 114 125
107 95 130 135 157 76 140 146 125 78 114 106 68 68 82 114 57 67 112 78
89 71 125 112 92 51 107 98 81 65 66 47 51 62 46 59 74
SYD-H25B 77
158 104 166 114 147 138 111 113 126 120 166 145 146 175 162 126 125 100 73 110
103 73 85 82 116 117 97 101 110 134 79 114 107 97 153 185 160 107 114 135
92 93 123 136 153 77 139 150 128 73 119 123 75 68 85 138 46 58 109 79
90 67 118 107 90 56 110 100 78 62 71 48 42 71 50 57 81
SYD-H28A 55
549 581 405 499 245 288 173 229 198 259 230 264 192 160 189 246 108 156 148 164
213 154 174 148 200 203 228 221 165 167 138 153 114 160 157 132 114 75 64 87
71 73 66 78 73 80 65 87 59 93 76 96 94 103 101
SYD-H28B 55
550 578 399 487 248 296 189 219 191 245 215 263 177 163 185 251 107 167 167 166
193 164 164 134 207 196 225 251 157 175 145 153 120 126 149 139 106 75 72 78
78 72 62 87 73 78 65 86 60 98 70 82 104 118 103
SYD-H29A 74
254 167 190 313 316 484 434 301 393 420 301 357 343 364 427 468 328 371 340 352
389 412 389 393 339 465 245 329 304 354 463 280 373 403 354 367 311 266 258 316
238 223 387 300 253 239 246 328 313 310 339 370 327 241 276 192 322 207 212 193
203 262 359 309 196 237 232 219 231 434 289 234 213 286
SYD-H29B 74
238 179 167 322 309 487 446 319 393 427 289 356 351 294 487 468 310 370 345 337
401 371 379 406 353 452 241 322 317 356 446 278 381 395 364 371 319 252 250 312
235 213 387 306 256 231 246 318 312 321 334 368 323 261 264 190 308 223 203 196
209 272 350 308 196 243 217 227 243 428 288 230 225 286
SYD-H30A 59
404 484 427 516 557 573 415 506 406 479 484 431 414 623 661 643 518 448 562 551
240 182 206 215 254 222 276 259 339 375 318 368 225 245 279 300 310 311 380 409
274 320 268 260 275 265 262 288 348 290 251 226 203 260 225 232 204 292 333
SYD-H30B 59
413 486 434 523 560 568 398 527 400 499 482 475 363 625 675 653 536 452 572 568
234 181 209 214 246 237 265 248 338 379 310 376 228 240 279 300 318 302 400 394
271 331 266 268 271 271 252 285 345 291 268 216 205 240 206 244 218 327 340
SYD-A31A 116
144 164 120 67 82 104 84 91 99 125 125 144 121 149 130 158 94 98 100 94
139 205 111 176 146 92 107 133 221 195 182 154 196 165 190 171 200 177 131 128
143 144 60 75 96 70 87 76 131 170 140 98 103 84 85 50 75 95 108 71
45 89 104 84 90 106 70 96 75 57 67 103 46 56 96 119 115 167 202 183
184 158 129 121 137 82 91 83 104 55 101 100 111 134 117 125 117 104 155 116
120 95 107 93 110 89 95 89 107 88 146 203 217 176 127 160
SYD-A31B 116

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SYD-H33A 61
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57
SYD-H33B 61
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SYD-H34B 105
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65 99 57 61 79
SYD-H35A 98
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SYD-H35B 98
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SYD-H36A 80
204 371 225 200 203 335 175 305 255 269 389 194 192 121 128 144 145 83 114 71
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SYD-H36B 80
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153 210 121 140 125 165 82 73 117 93 159 135 143 162 141 136 157 112 135 162
SYD-H37A 44

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220 267 221 126 201 256 278 284 304 459 189 204 321 306 256 300 279 239 319 291
150 164 287 347
SYD-H37B 44
368 545 505 500 461 407 317 409 389 389 366 269 341 494 348 250 421 418 125 224
225 230 221 125 204 257 275 279 303 468 192 196 339 309 251 285 270 243 335 287
142 154 294 345
SYD-H38A 66
236 252 232 394 228 284 241 222 175 189 132 178 166 217 369 346 345 404 389 186
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95 111 140 140 143 168
SYD-H38B 66
241 247 227 393 234 296 241 232 173 169 142 173 189 209 368 329 345 332 335 186
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281 173 145 148 173 159 179 167 139 139 135 150 117 151 190 172 171 136 175 156
100 111 137 139 142 166
SYD-H39A 59
219 171 236 149 146 175 129 184 199 189 196 198 232 165 157 246 201 161 159 149
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162 151 122 144 139 171 144 145 273 164 125 118 161 107 100 89 109 138 151
SYD-H39B 59
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SYD-H42A 80
284 332 255 427 408 274 310 401 306 231 248 262 203 160 168 148 119 141 146 148
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87 54 79 95 90 84 79 76 68 71 86 82 90 54 68 73 87 59 79 98
SYD-H42B 80
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79 59 75 100 82 76 79 71 90 71 85 95 83 128 73 93 86 53 80 94
SYD-H43A 54
449 279 347 341 244 270 209 214 201 132 171 196 151 128 139 139 153 150 100 136
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SYD-H43B 54
448 264 354 361 244 269 205 217 199 137 162 188 148 120 137 144 159 152 99 138
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86 65 94 52 58 69 64 56 58 52 61 39 47 84
SYD-H44A 71
136 180 188 214 145 134 195 149 149 205 96 112 159 119 132 141 119 131 142 150
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87 65 104 92 117 67 93 82 90 67 96
SYD-H44B 71
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SYD-H46B 104
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SYD-H47A 87
150 265 180 138 268 334 365 292 288 337 362 197 258 196 168 376 288 368 225 274
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SYD-H47B 87
231 270 162 176 293 304 318 268 271 355 296 184 278 207 162 453 333 346 212 247
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196 281 171 169 234 145 150
SYD-H48A 62
400 301 521 440 482 493 648 624 346 296 260 371 393 330 333 350 331 248 282 281
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150 144
SYD-H48B 62
379 295 519 444 477 510 646 630 346 294 266 364 410 335 327 352 337 243 273 284
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SYD-H49A 41
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SYD-H49B 41
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SYD-H50A 61
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126
SYD-H51A 91
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SYD-H51B 91
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SYD-H52A 84
259 158 188 195 182 177 133 142 184 207 186 124 153 144 107 114 160 196 212 137
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SYD-H54A 59
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90 95 121 146
SYD-H55B 144

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SYD-H56A 163
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56 71 89
SYD-H56B 163
167 202 156 99 223 126 104 125 129 105 87 95 107 125 96 105 80 57 42 62
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54 76 87
SYD-H57A 52
340 349 152 210 287 350 375 386 298 301 301 267 177 161 148 212 178 228 171 189
143 235 222 252 288 289 211 149 200 187 157 148 150 93 112 99 103 145 103 146
150 137 57 87 86 96 106 96 100 110 125 185
SYD-H57B 52
277 292 157 214 275 318 379 384 334 310 306 257 172 167 150 203 182 217 181 185
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142 135 64 87 100 104 101 89 98 118 128 189
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111 225 206 117 127 180 104 139 73 111 55 42 63 49 46 56 54 41 55 60
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SYD-H58B 187
82 220 240 136 155 187 111 143 67 106 55 38 66 48 44 53 56 41 53 55
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SYD-H59A 101
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162 95 157 145 76 131 132 109 129 81 109 61 75 62 112 115 129 107 121 90
115
SYD-H59B 101
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142 157 160 126 121 126 67 90 93 146 153 142 104 146 100 117 151 134 140 156
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113
SYD-H60A 40
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SYD-H60B 40
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SYD-H61A 71
171 141 111 139 148 190 165 135 146 124 132 134 103 110 126 103 85 121 164 182
165 152 155 152 199 229 274 239 242 206 187 189 107 127 87 87 115 116 135 98
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103 120 95 90 114 159 154 157 143 170 161
SYD-H61B 71
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102 130 98 81 118 167 153 143 150 173 162
SYD-H62A 93
204 181 172 162 204 236 258 259 254 222 214 250 191 159 212 312 360 332 482 475
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SYD-H62B 93
164 175 173 155 222 234 245 275 242 208 232 250 183 166 205 319 291 341 484 463
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SYD-H63A 75
112 82 180 191 138 141 150 163 135 164 242 101 96 76 45 54 62 80 88 80
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SYD-H63B 75

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SYD-H64A 60
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SYD-H64B 60
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SYD-H65B 80
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SYD-H66A 157
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SYD-H66B 157
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133 173 122 130 132 168 137 149 133 92 110 96 119 114 111 66 51 76 77 55
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SYD-H69B 58
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SYD-H70A 43
134 184 315 368 409 426 451 348 409 381 312 227 210 225 233 196 299 192 164 182
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SYD-H70B 43
132 186 307 376 431 425 448 366 417 385 304 219 230 226 239 197 291 192 178 183
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96 73 100
SYD-H71A 67
505 637 334 308 317 338 297 285 171 159 178 245 202 267 168 130 171 212 134 140
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SYD-H71B 67
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SYD-H73A 102
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101 87
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SYD-H74A 56
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SYD-H74B 56
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SYD-H75B 40
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SYD-H76A 148
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SYD-H76B 148
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SYD-H78A 133
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SYD-H82A 52
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SYD-H83A 81
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SYD-H92B 54
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SYD-H95A 79
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SYD-H95B 79
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115 107 114 152
SYDH100A 45
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101 141 105 98 128 71 84 107 121 104 95 86 117 92 97 114 116 78 100 132
105 58 82 82 94
SYDH100B 45
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103 72 79 85 103
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SYDH104B 135
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SYDH107B 91
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66 127
SYDH114A 67
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SYDH114B 67
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SYDH115A 59
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SYDH115B 59

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SYDH116B 40
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193 296 178 314
SYDH121B 44
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SYDH123B 50
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260 280 270 350 320 300 240 340
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SYD-P02A 118
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273 309 306 262 243 259 253 254 271 184 170 195 195 199 200 176 284 273 287 228
234 255 206 151 219 163 194 202 331 243 243 247 234 373 334 363 371 250 249 219
420 246 316 256 232 278 244 232 201 287 239 333 236 192 197 162 203 174 215 234
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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 Nottingham Tree-ring Dating 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 1998). 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 A1 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 A1, 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 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 A2 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 8–10 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.

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 A2; it is about 150mm long and 10mm 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.

Figure A1: 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 be determined by counting back from the outside ring, which grew in 1976

Figure A2: Cross-section of a rafter, showing sapwood rings in the left-hand corner, the arrow points to the heartwood/sapwood boundary (H/S); and a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil

Figure A3: Measuring ring widths under a microscope. The microscope is fixed while the sample is on a moving platform. The total sequence of widths is measured 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

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Figure A4: 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

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 A2. 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 A3).

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 A4). 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 Figure A5 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 Figure A5. 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 A5 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 straightforward 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 (or the last full year before felling, if it was felled in the first three months of the following calendar year, 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 A2, 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 region 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 A2 was taken still had complete sapwood but that some of the soft sapwood rings were lost in coring. By measuring into the timber the depth of sapwood lost, say 20mm, 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 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; Miles 1997, 50–5). Hence, provided that 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, fig 8; 34–5, where 'associated groups of fellings' are discussed in detail). However, if there is any evidence of storage 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 Figure A6 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 Figure A6. 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 Figure A7. 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 phenomenon 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.

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

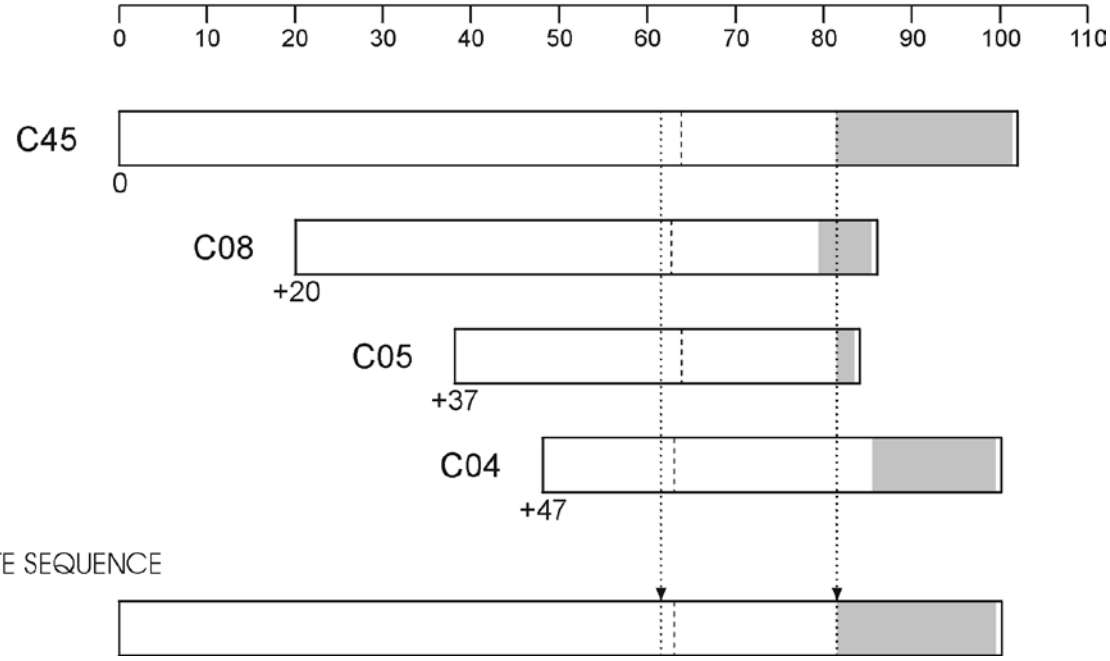

Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

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.

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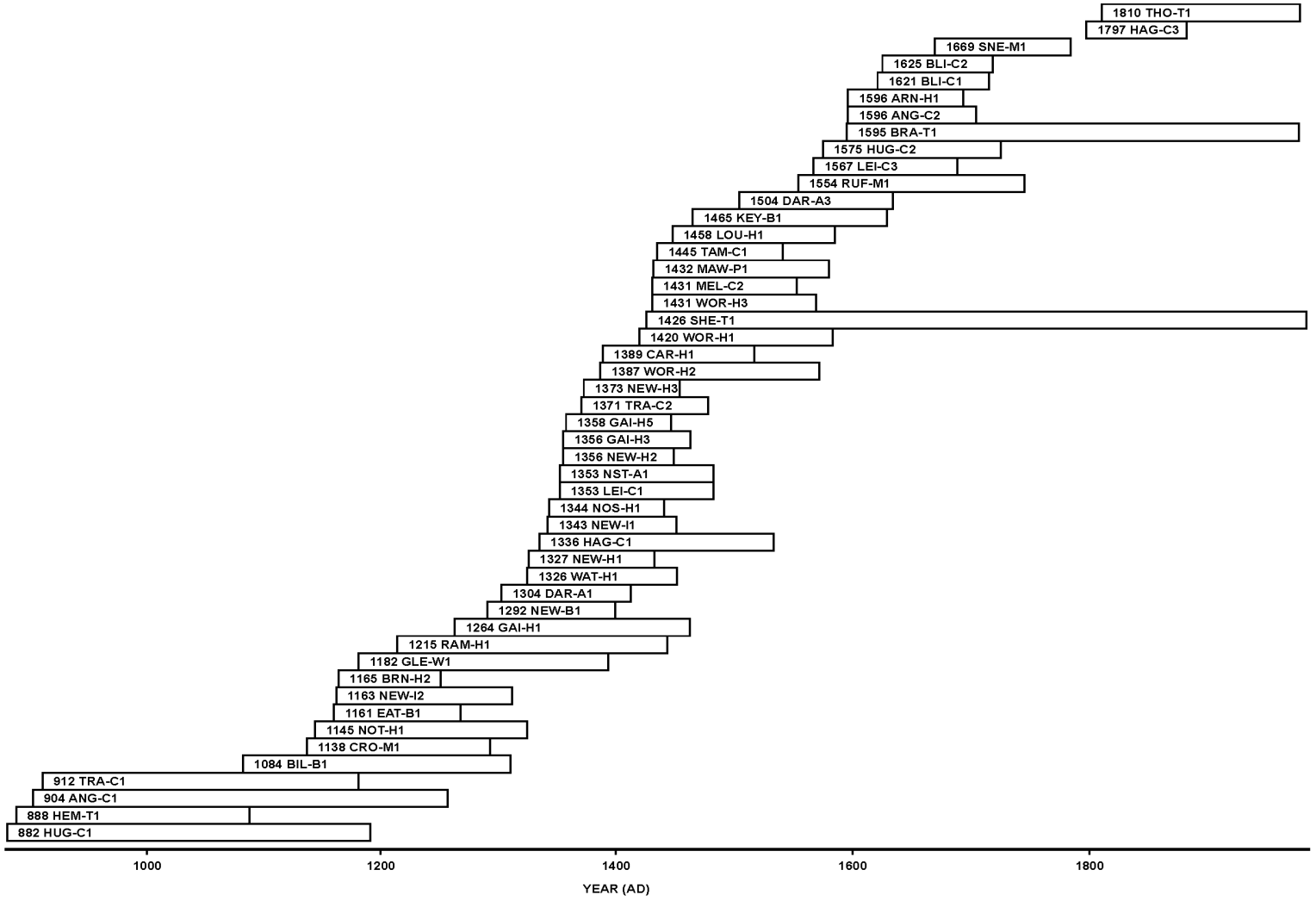
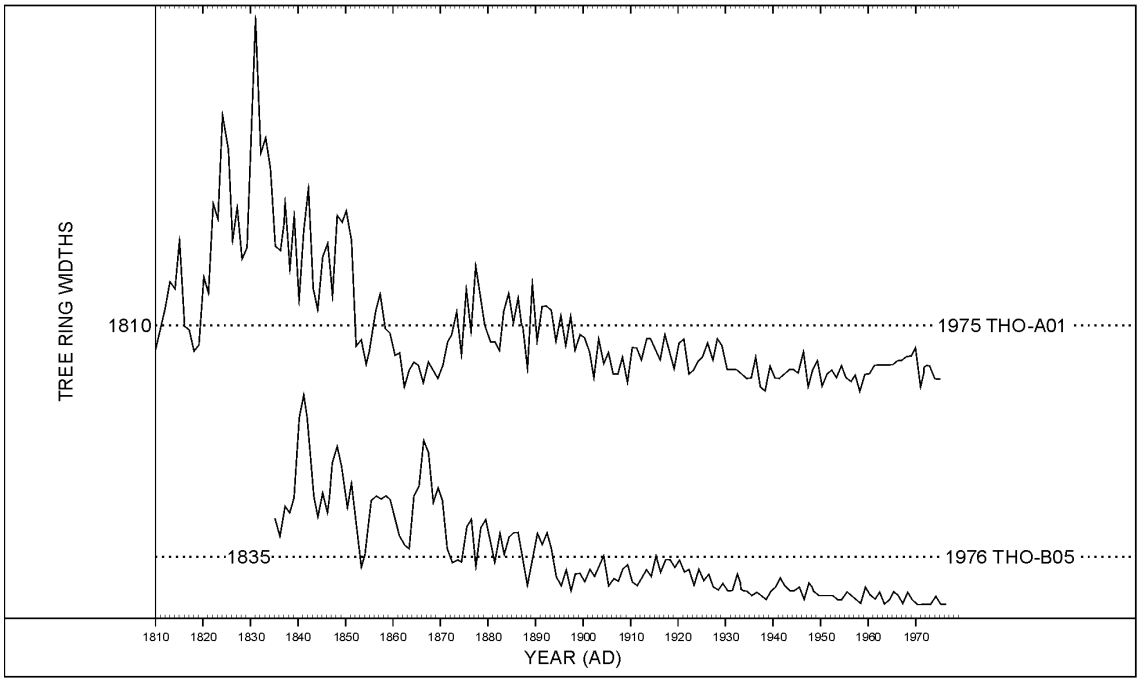


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

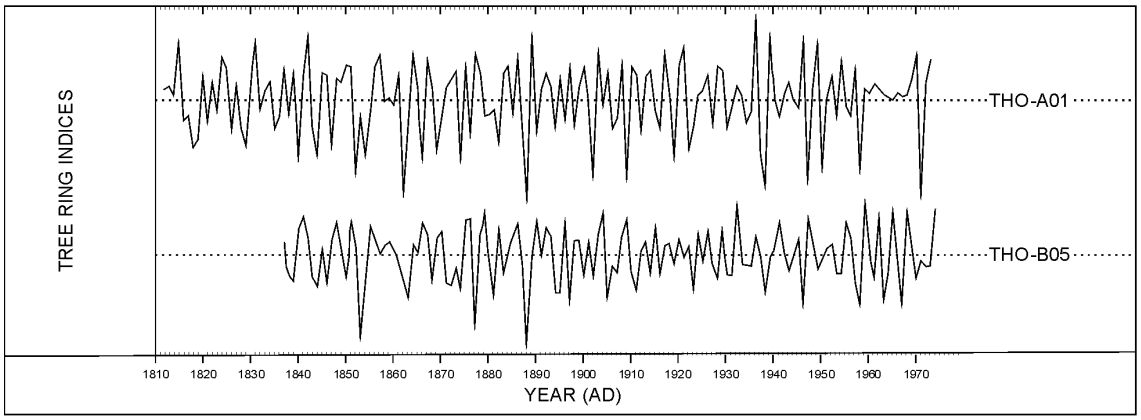


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

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

Figure A7 (b): The Baillie-Pilcher indices of the above widths

The growth trends have been removed completely

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