Oxford Dendrochronology Laboratory
Report 2020/17

THE DENDROCHRONOLOGICAL DATING OF TIMBERS FROM THE CHAPEL PETERHOUSE COLLEGE CAMBRIDGE

(TL 448 579)

Summary
Timbers in the screen and organ loft were assessed, with a variety of species being found. Many timbers had too few rings to be useful for dendrochronology, and/or no sapwood. Samples were taken from eight timbers. A stud in the rear wall of the candle store had complete sapwood, and was found to have come from an oak tree felled in very early spring 1581. It seems likely this was a re-used or stock-piled timber. A large upper beam on the south side of the loft retained complete sapwood, but the outermost rings were lost on coring, meaning only a limited felling date range could be derived, this being from an oak felled in the period 1638–42, suggesting that this was inserted early on in the history of the chapel, which is generally thought to have been built between 1628 and 1632. A pine beam at the front (east) of the loft was from a tree felled in 1628–30, and a second pine beam on the south side of the loft floor was from a tree felled in winter 1626/7. Imported pine was usually used within a year or two of felling, so these almost certainly correspond with the original build of the chapel.

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BACKGROUND TO DENDROCHRONOLOGY

The basis of dendrochronological dating is that trees of the same species, growing at the same time, in similar habitats, produce similar ring-width patterns. These patterns of varying ring-widths are unique to the period of growth. Each tree naturally has its own pattern superimposed on the basic 'signal', resulting from genetic variations in the response to external stimuli, the changing competitive regime between trees, damage, disease, management etc.

In much of Britain the major influence on the growth of a species like oak is, however, the weather conditions experienced from season to season. By taking several contemporaneous samples from a building or other timber structure, it is often possible to cross-match the ring-width patterns, and by averaging the values for the sequences, maximise the common signal between trees. The resulting 'site chronology' may then be compared with existing 'master' or 'reference' chronologies. These include chronologies made by colleagues in other countries, most notably areas such as modern Poland, which have proved to be the source of many boards used in the construction of doors and chests, and for oil paintings before the widespread use of canvas.

This process can be done by a trained dendrochronologist using plots of the ring-widths and comparing them visually, which also serves as a check on measuring procedures. It is essentially a statistical process, and therefore requires sufficiently long sequences for one to be confident in the results. There is no defined minimum length of a tree-ring series that can be confidently cross-matched, but as a working hypothesis most dendrochronologists use series longer than at least fifty years.

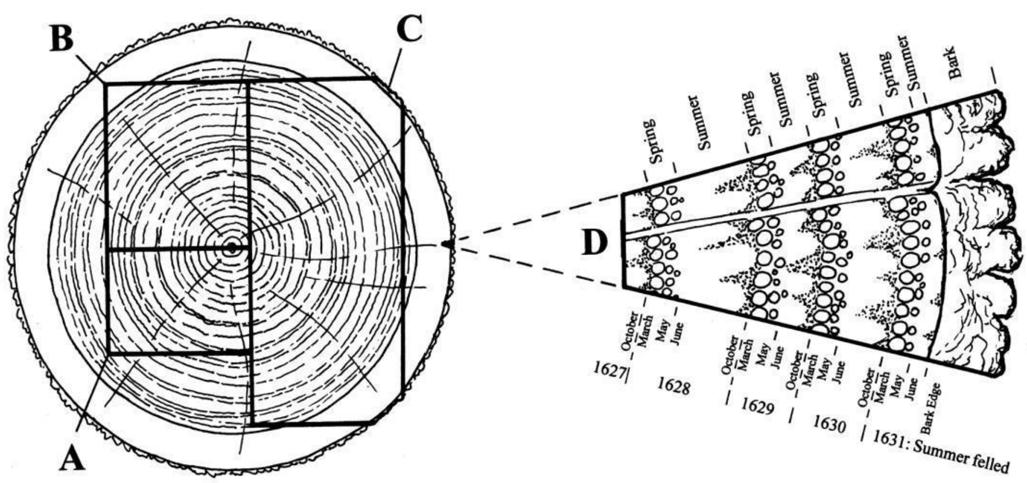
The dendrochronologist also uses objective statistical comparison techniques, these having the same constraints. The statistical comparison is based on programs by Baillie & Pilcher (1973, 1984) and uses the Student's *t*-test. The *t*-test compares the actual difference between two means in relation to the variation in the data, and is an established statistical technique for looking at the significance of matching between two datasets that has been adopted by dendrochronologists. The values of '*t*' which give an acceptable match have been the subject of some debate; originally values above 3.5 being regarded as acceptable (given at least 100 years of overlapping rings) but now 4.0 is often taken as the base value in oak studies. Higher values are usually found with matching pine sequences. It is possible for a random set of numbers to give an apparently acceptable statistical match against a single reference curve – although the visual analysis of plots of the two series usually shows the trained eye the reality of this match. When a series of ring-widths gives strong statistical matches in the same position against a number of independent chronologies the series becomes dated with an extremely high level of confidence.

One can develop long reference chronologies by cross-matching the innermost rings of modern timbers with the outermost rings of older timbers successively back in time, adding data from numerous sites. Data now exist covering many thousands of years and it is, in theory, possible to match a sequence of unknown date to this reference material.

It follows from what has been stated above that the chances of matching a single sequence are not as great as for matching a tree-ring series derived from many individuals, since the process of aggregating individual series will remove variation unique to an individual tree, and reinforce the common signal resulting from widespread influences such as the weather. However, a single sequence can be successfully dated, particularly if it has a long ring sequence.

Growth characteristics vary over space and time, trees in south-eastern England generally growing comparatively quickly and with less year-to-year variation than in many other regions (Bridge, 1988). This means that even comparatively large timbers in this region often exhibit few annual rings and are less useful for dating by this technique.

When interpreting the information derived from the dating exercise it is important to take into account such factors as the presence or absence of sapwood on the sample(s), which indicates the outer margins of the tree. Where no sapwood is present it may not be possible to determine how much wood has been removed, and one can therefore only give a date after which the original tree must have been felled. Where the bark is still present on the timber, the year, and even the time of year of felling can be determined. In the case of incomplete sapwood, one can estimate the number of rings likely to have been on the timber by relating it to populations of living and historical timbers to give a statistically valid range of years within which the tree was felled. For this region the estimate used is that 95% of oaks will have a sapwood ring number in the range 9 – 41 (Miles 1997).



Section of tree with conversion methods showing three types of sapwood retention resulting in **A** *terminus post quem*, **B** a felling date range, and **C** a precise felling date. Enlarged area **D** shows the outermost rings of the sapwood with growing seasons (Miles 1997, 42)

For pine imported from the Baltic, it has been found very difficult to determine sapwood estimates. The sapwood itself is not always clearly distinguishable, or may be evident in some timbers and not others. Sapwood numbers vary considerably. Where the complete sequence is available to the bark edge, it has been found that the timbers were often felled, transported, and incorporated into buildings in this country within just a few years.

<u>The Chapel</u> (from the Listing, list entry number 1087054)

The Chapel 1628-32, George Thompson, Mason; faced with ashlar in 1665. The detailing is part Gothic, part Jocobean and part Classical; the motifs of the last may be of the C18. The interior is lined with C18 bolection moulded panelling. The roof was repaired in 1735, the interior restored in 1821-2. The fittings include an oak door dated 1632, stalls of the same date, C18 communion rails. The East window has C17 Flemish glass. The organ is 1765 by Johann Schnetzler. Early C18 marble paving.

SAMPLING

Sampling took place in July 2020. The complex organ loft floor and the screen were first assessed. The samples were labelled (prefix **pet**) and returned to the Lab, were they were polished with progressively finer grits down to 400 to allow the measurement of ring-widths to the nearest 0.01 mm. The samples were measured under a binocular microscope on a purpose-built moving stage with a linear transducer, attached to a desktop computer. Measurements and subsequent analysis were carried out using DENDRO for WINDOWS, written by Ian Tyers (Tyers 2004). Other programs written by Chris Bridge (RingMaster) were used for dating.

RESULTS AND DISCUSSION

The floor was opened up following temporary removal of the organ and its complex structure was revealed. The development of the structure is far from immediately apparent, with beams at different levels, iron strapping supporting some beams, cut-off joists, and structures that have an unusual relationship with other elements of the building, such as the windows. Dendrochronology had therefore been suggested to see if it could assist in dating timbers and potentially elucidating the sequence of construction.

Many of the timbers seen had too few rings to be useful for dendrochronology, and several had been converted such that there was no sapwood available, so that any dates derived would only be of limited use.

Details of the sample taken are given in Table 1, with the positions of the timbers sampled being illustrated in Figs 1 – 5, and a view of the boards on the east door leaf of the candle store shown in Fig 6. A mix of species was found, with the south-west corner post of the plant room being of elm, and a mix of oak and softwood (assumed to be pine) forming the other major components of the screen and loft floor. Elm sequences are notoriously difficult to date, with only a handful of successes over the last 40 years (Bridge 2020, in press). Samples **pet04**, **pet06** and **pet08** were all relatively short or fractured, and did not date.

Some of the cores fractured on coring (especially common when coring pine) and the individual parts were measured, being labelled i, ii, iii from inside to outside. There was little initial cross-matching between the ring series, so individual series were comparted with dated reference material. This resulted in good matches being found for two oak series (**pet02** and **pet03**) at positions corresponding to the outermost ring having been formed in 1580 and 1637 respectively (Tables 2a and 2b). Although there was little overlap, the two series were combined to form a new oak site series, **pet32m**, which gave stronger matches (Table 2c). Sample **pet02**, a stud in the rear wall of the candle store, had the beginnings of earlywood vessels on the outside bark-edge, showing that the tree used had been felled very-early in the spring of 1581. This is well before construction is thought to have started, so this timber may be re-used from an earlier college structure, or it may have been stock-piled before use. Sample **pet03** was from the uppermost large beam on the south side of the floor structure. This had complete sapwood on the timber, with up to 2mm of the outside being lost on coring. It had 26 sapwood rings, the last measured ring being formed in 1637. To allow for any missing rings, a felling date range of 1638–42 has been given for this timber, strongly suggesting it is original to the loft floor, which it appears may have been constructed shortly after the completion of the main masonry structure.

The outer 73-year ring series of sample **pet07**, a headbeam to the screen and east end of the floor structure, was of softwood, assumed to be pine, and matched a number of imported pine chronologies (Table 2d) from Scandinavia, dating the outermost measured ring to 1626, with another two rings visible but degraded such that they could not be measured. A felling date range of 1628–30 has been applied, in case one or two more rings may have eroded on coring, though the timber itself looked to have complete sapwood. At first the three sections of **pet05** could not be assumed to be continuous, there being the possibility that rings had been lost between the sections. Comparisons of the plots between these sections and the dated sequence **pet07ii** suggested however that the three may indeed be continuous, and when put together as a single 75-year long sequence, this matched **pet07ii** with a value of t = 4.9 (73 years overlap), and it too dated against imported pine chronologies (Table 2e). The two series were combined to form a 75-year site pine chronology (pet75m) which gave overall better matches against the database (Table 2f). The outermost ring of this timber was complete, giving a felling date of winter 1626/7. Previous experience on buildings where the construction date is known has shown that imported pine was incorporated into British buildings very soon after felling. Interestingly, this is amongst the earliest structural imported pine yet found in England. Both these timbers therefore appear to relate to the known date of construction of the chapel, though there is no certainty that they are in their original positions.

The relative positions of overlap of the dated samples are shown in Fig 7.

A sequence was measured from a photograph of the inside panel to the east leaf of the candle store. It is particularly difficult to derive a correct sequence from such a photograph, as not all ring boundaries may be obvious, as compared to an end-grain section. The derived sequence did not match any other pine sequence from the site, nor did it match against the database. Since it is possible that ring boundaries were missed, it has not been investigated further. It is interesting that the oak doors to the plant room and candle store appear identical from the outside, but those to the candle store have had reinforcing pine panels added to the inside, presumably reflecting the value of the contents of the store.

Felling dates (or narrow date ranges) has been derived for two oak and two pine timbers. One oak appears to pre-date the construction present today, the other to be within a decade of the main construction. The two pine timbers date to the time of the main construction. Further fabric analysis may help to determine the sequence of construction and possible alterations to this complex organ loft floor, though at least now many of the timbers do appear to relate to the early history of the chapel, even though it cannot be shown that they are necessarily in their original positions.

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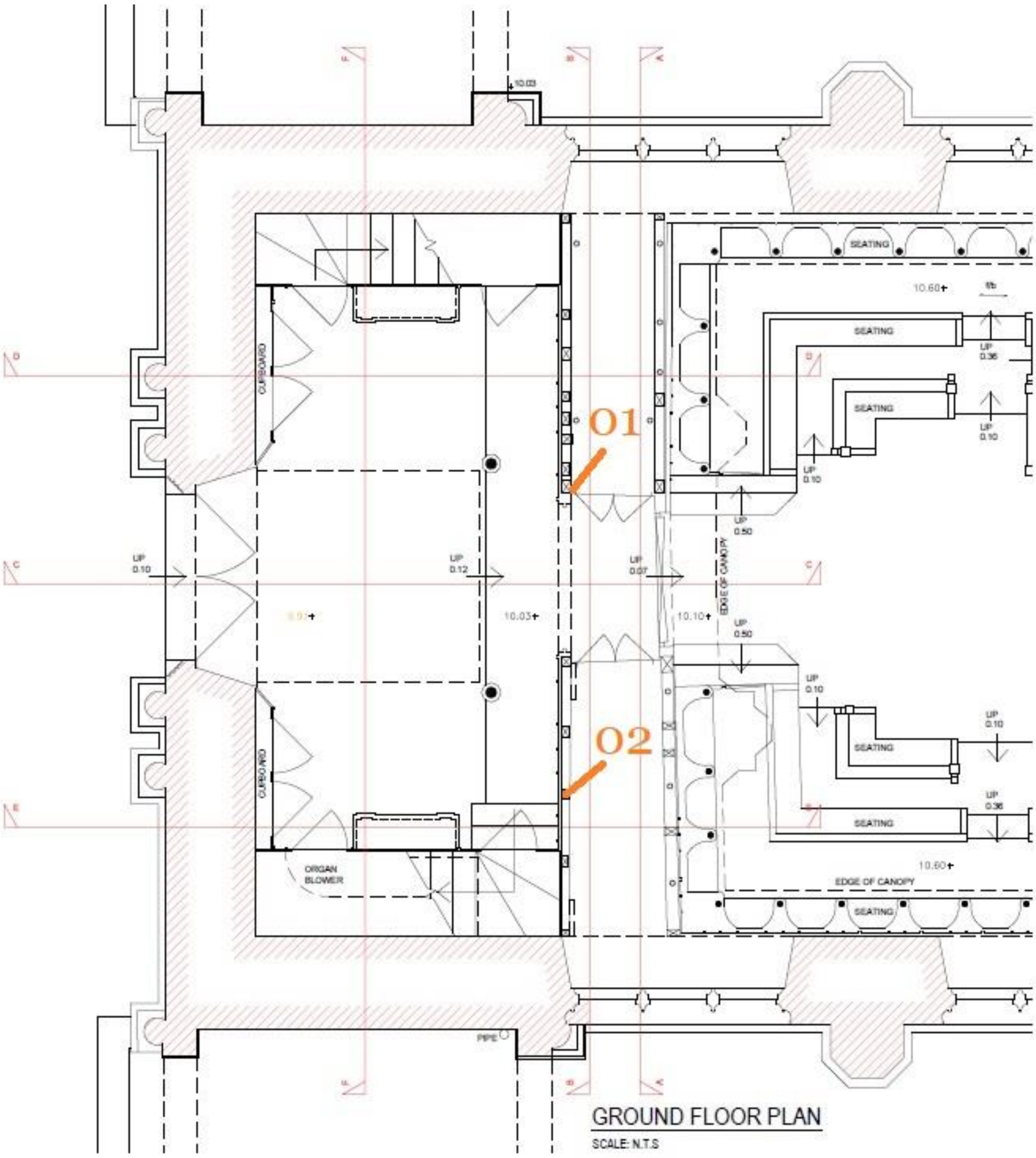

Figure 1: Plan of the ground floor of the west end of the chapel showing the locations of two timbers sampled for dendrochronology (from an original drawing supplied by Alan Wright)

Figure 2: Photo (looking approx. south-east) showing the sampling location of sample **pet03** in the upper beam on the south side of the organ loft.

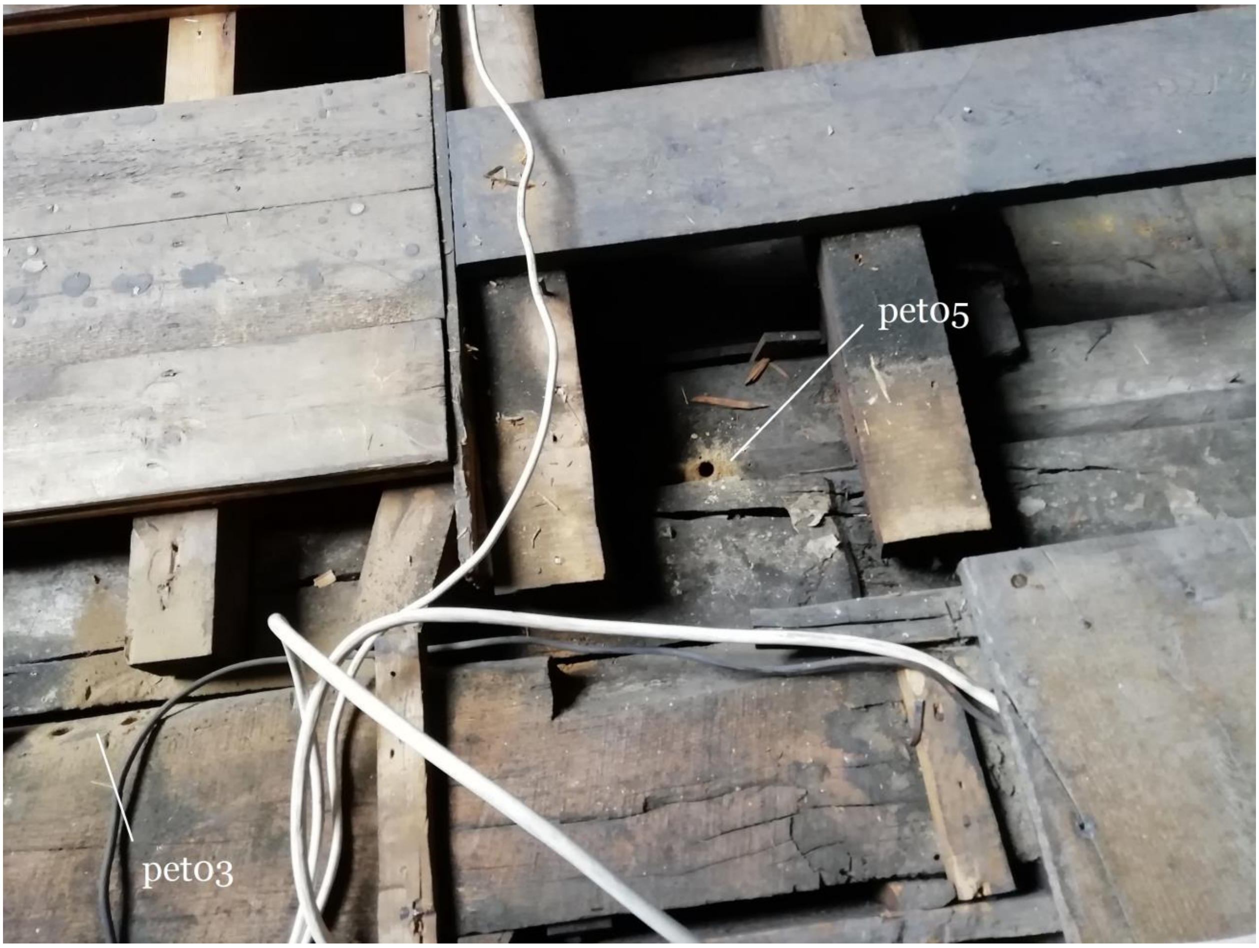

Figure 3: Position of core **pet05** in relation to **pet03**.

Figure 4: Photograph of the north side of the organ loft (looking east) showing various timbers sampled for dendrochronology and other details

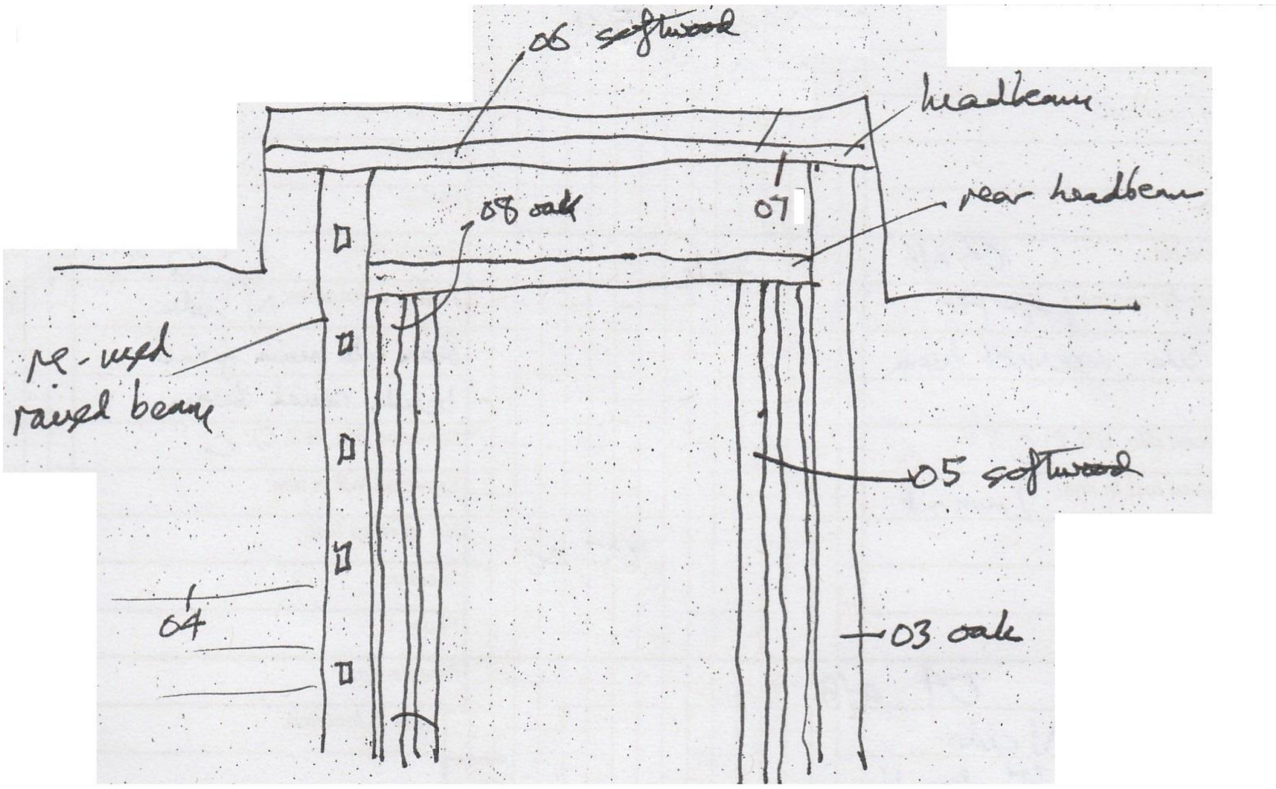

Figure 5: Field sketch of the loft floor (east at the top) showing the timbers sampled

Figure 6: Photograph of the east door leaf of the candle store, showing a pine sequence on the left, and pine with obvious sapwood on the board to the right.

Table 1: Details of samples taken from the Chapel, Peterhouse College

Sample number	Timber and position	Date of series	h/s boundary date	Sapwood complement	No of rings	Mean width (mm)	Mean sens	Felling date range (AD)
Ground floor								
pet01	SWcorner post to plant room (elm)	-	-	C	55	1.73	0.19	-
pet02	Central stud in rear (west) wall of candle store (oak)	1489–1580	1565	15¼C	92	1.16	0.27	Spring 1581
Organ loft floor								
pet03	South side, uppermost beam (oak)	1565–1637	1611	26 (+*c*2mm)	73	1.25	0.24	1638–42
pet04	North side, 3rd N-S joist from west wall (oak)	-	-	14?C	34	2.31	0.24	-
pet05i	*South side, lower softwood beam* (pine)	*1552–1587*	-	-	*36*	*1.58*	*0.24*	
pet05ii	*ditto*	*1588–1605*	-	-	*18*	*0.98*	*0.26*	
pet05iii	*ditto*	*1606–1626*	-	*C*	*21*	*0.97*	*0.21*	*Winter 1626/7*
pet05	South side, lower softwood beam	1552–1626	-	C	75	1.27	0.23	Winter 1626/7
pet06i	Front (east) headbeam of screen, north side (pine)	-	-	-	34	1.00	0.22	
pet06ii	*ditto*	-	-	-	26	0.97	0.23	
pet06iii	*ditto*	-	-	-	20	0.90	0.20	
pet07i	Front (east) headbeam of screen, south side (pine)	-	-	-	23	0.93	0.19	
pet07ii	*ditto*	1554–1626	-	-	73(+2NM)	0.73	0.26	1628–30
pet08i	North side, beam beside raised (re-used) beam (oak)	-	-	-	23	1.89	0.20	
pet08ii	*ditto*	-	-	13¼C	38	1.60	0.21	

Key:

h/s bdry = heartwood/sapwood boundary; ¼C = complete sapwood, felled the following spring; C = complete sapwood, felled the following winter; mean sens = mean sensitivity; NM = not measured.

Table 2a: Dating evidence for the oak series **pet02 1489–1580** against dated reference chronologies

County or region:	***Chronology name:***	***Reference***	***File name:***	***Spanning***	***Overlap (yrs)***	***t-value***
Site Chronologies						
Rutland	Bede House, Lyddington	(Arnold *et al* 2015)	LYBHSQ04	1498–1598	83	7.6
Buckinghamshire	Olney bellframe	(Miles *et al* 2009)	OLNEY	1472–1625	92	7.3
Cambridgeshire	St Andrew's Church, Wimpole	(Bridge 1998)	WIMPOLE1	1469–1615	92	7.1
Cambridgeshire	Forehill, Ely	(NTRDL* pers comm)	ELY-A	1480–1611	92	6.2
Suffolk	12 Aspall Rd, Debenham	(Miles *et al* 2009)	DEBNHM3	1433–1574	86	6.8
Essex	Hill Hall, Theydon Mount	(Bridge 1999)	HILLHAL1	1425–1564	76	6.8

*= Nottingham Tree Ring Dating Laboratory

Table 2b: Dating evidence for the oak series **pet03 1565–1637** against dated reference chronologies

County or region:	***Chronology name:***	***Reference***	***File name:***	***Spanning***	***Overlap (yrs)***	***t-value***
Site/Regional Chronologies						
Oxfordshire	Bodleian Library	(Miles and Worthington 1999)	BDLEIAN3	1395–1610	46	6.4
Wiltshire	Ramsbury Manor stables	(Bridge unpublished)	RAMSBRYS	1560–1636	72	6.0
Cambridgeshire	Soham Church	(Bridge 2008)	shm01	1484–1626	62	5.8
Shropshire	Brookgate Farm	(Miles and Haddon-Reece 1993)	BROOKGT	1362–1611	47	5.7
Shropshire	Old Hall Farm, All Stretton	(Miles and Haddon-Reece 1996)	OLDHLLFM	1379–1630	66	5.7
Buckinghamshire	Olney bellframe	(Miles *et al* 2009)	OLNEY	1472–1625	61	5.6

Table 2c: Dating evidence for the oak combined series **pet32m 1489–1637** against dated reference chronologies

County or region:	*Chronology name:*	*Reference*	*File name:*	*Spanning*	*Overlap (yrs)*	*t-value*
Site/Regional Chronologies						
Buckinghamshire	Olney bellframe	(Miles *et al* 2009)	OLNEY	1472–1625	137	8.9
Cambridgeshire	St Andrew's Church, Wimpole	(Bridge 1998)	WIMPOLE1	1469–1615	127	8.2
Cambridgeshire	Powchers Hall, Ely	(Arnold *et al* 2004)	ELYDSQ01	1457–1609	121	7.5
Rutland	Bede House, Lyddington	(Arnold *et al* 2015)	LYBHSQ04	1498–1598	101	7.4
Oxfordshire	Wadham College	(Miles and Bridge 2010)	WADHAM	1426–1610	122	7.4
Suffolk	Ballingdon Bridge	(Cooper *et al* 2012)	BALLNGDN	1484–1790	149	7.2
Oxfordshire	Bodleian Library	(Miles and Worthington 1999)	BDLEIAN3	1395–1610	122	7.2
London	White Tower, Tower of London	(Miles 2007)	WHTOWR7	1463–1616	128	7.0
Bedfordshire	De Grey Mausoleum, Flitton	(Howard *et al* 2003)	FLTASQ01	1510–1726	128	6.9
Suffolk	Bedfield Hall	(Miles *et al* 2007)	BEDFLD2	1473–1627	139	6.8
Essex	Hill Hall, Theydon Mount	(Bridge 1999)	HILLHAL1	1425–1564	76	6.8

Table 2d: Dating evidence for the pine series **pet07ii 1554–1626** against dated reference chronologies

County or region:	*Chronology name:*	*Reference*	*File name:*	*Spanning*	*Overlap (yrs)*	*t-value*
Site/Regional Chronologies						
Baltic	Queen's House, Greenwich	(Bridge and Miles 2016)	GRNWICH2	1516–1631	73	8.6
Scandinavia	Bledlow Manor, Bucks	(Bridge and Miles 2020)	bled175m	1535–1669	73	6.8
Baltic	Kirkleatham Hall Stables	(Arnold and Howard 2013)	KRKLSQ02	1550–1701	73	6.4
Norway	Oslo	(Daly 2008 pers comm)	N007m005	1471–1622	69	6.0
E Baltic	Joists, Sterling Castle	(Crone 2008)	SPpineX15	1476–1671	73	6.0
Baltic	Wren front, Hampton Court Palace	(Bridge and Miles 2017)	HMPTN12	1516–1700	73	6.0
Baltic	Queen's House, Tower of London	(Bridge and Miles 2016)	TOLQHS2	1497–1677	73	6.0
Baltic	Danson House, Bexley	(Groves 2002)	DANSON1	1489–1758	73	5.7
Baltic	Bromley Hall, London	(Bridge 2015)	BRMHLLR3	1376–1686	73	5.4

Table 2e: Dating evidence for the pine series **pet05 1552–1626** against dated reference chronologies

County or region:	***Chronology name:***	***Reference***	***File name:***	***Spanning***	***Overlap (yrs)***	***t-value***
Site/Regional Chronologies						
E Baltic	Joists, Sterling Castle	(Crone 2008)	SPpineX15	1476–1671	75	6.6
Baltic	Queen's House, Tower of London	(Bridge and Miles 2016)	TOLQHS2	1497–1677	75	5.9
Scandinavia	Bledlow Manor, Bucks	(Bridge and Miles 2020)	bled175m	1535–1669	75	5.7
Norway	Oslo	(Daly 2008 pers comm)	N007m005	1471–1622	71	5.5

Table 2f: Dating evidence for the pine series **pet75m 1552–1626** against dated reference chronologies

County or region:	***Chronology name:***	***Reference***	***File name:***	***Spanning***	***Overlap (yrs)***	***t-value***
Site/Regional Chronologies						
Scandinavia	Bledlow Manor, Bucks	(Bridge and Miles 2020)	bled175m	1535–1669	75	7.6
E Baltic	Joists, Sterling Castle	(Crone 2008)	SPpineX15	1476–1671	75	7.5
Baltic	Queen's House, Tower of London	(Bridge and Miles 2016)	TOLQHS2	1497–1677	75	7.4
Norway	Oslo	(Daly 2008 pers comm)	N007m005	1471–1622	71	7.4
Baltic	Queen's House, Greenwich	(Bridge and Miles 2016)	GRNWICH2	1516–1631	75	6.6
Baltic	Wren front, Hampton Court Palace	(Bridge and Miles 2017)	HMPTN12	1516–1700	75	6.0
Scandinavia	Deal Castle	(Arnold and Howard 2015)	DELCSQ07	1520–1689	75	5.8
Baltic	107 Jermyn Street, Westminster	(Groves and Locatelli 2005)	JemGrp03	1367–1710	75	5.4
Baltic	Kirkleatham Hall Stables	(Arnold and Howard 2013)	KRKLSQ02	1550–1701	75	5.3
Baltic	Bromley Hall, London	(Bridge 2015)	BRMHLLR3	1376–1686	75	5.2

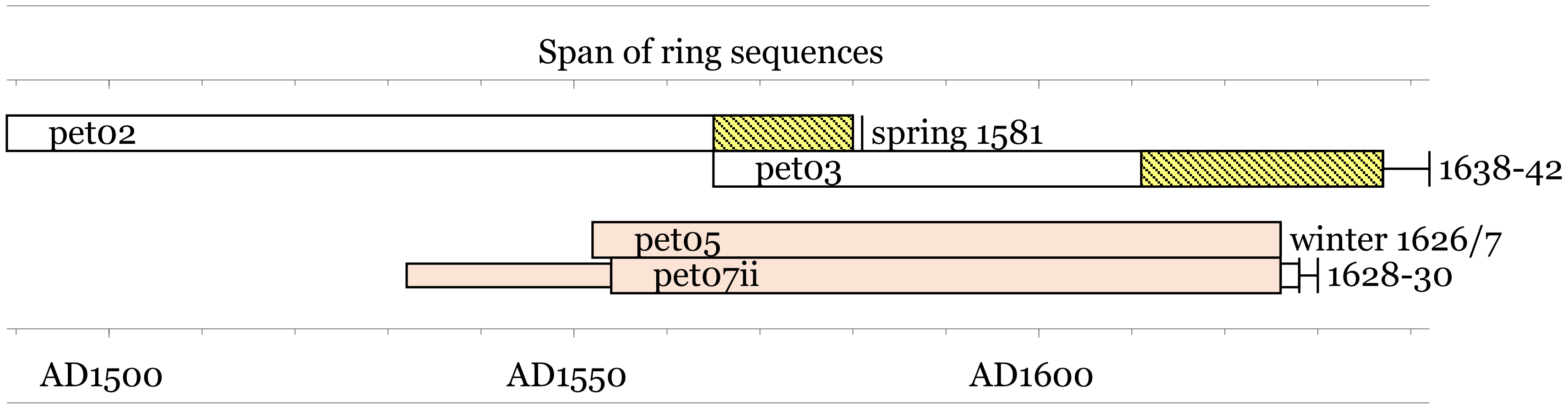

Figure 7: Bar diagram showing the relative positions of overlap of the dated sequences, along with their likely felling date ranges, white bars represent oak heartwood, yellow hatched bars – oak sapwood, narrow coloured bar – additional unmeasured rings, coloured bar – pine rings